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IEA Renewable Energy Programmes : International Collaboration

Programmes de l'AIE en énergies renouvelables : Collaboration internationale

High-level Expert Meeting
Réunion d'experts de haut niveau

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IEA RENEWABLE ENERGY PROGRAMMES: INTERNATIONAL COLLABORATION

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1.0 SUMMARY AND OVERVIEW

1.1 SUMMARY

This paper will focus on the prospects for renewable energy technologies in the 21st century and an overview of the full range of international collaboration on renewable energy technologies conducted under the auspices of the International Energy Agency. IEA Member countries are committed to the continuing importance of diversity of energy supplies, both fuels and sources, in enhancing overall energy security. They are also committed to environmental protection in concert with energy security and sustainable economic growth. The role of renewable energy in furthering these goals is readily apparent.

The IEA and its Member countries are engaged in a variety of activities with respect to renewable energies, ranging from studies of technology potential and national programmes to actual systems design and materials testing. The paper will outline IEA Member country activities, including: i) active involvement of IEA countries in international research and development collaboration in eleven Implementing Agreements in the renewable energy technology area; ii) ongoing activities of an IEA Renewable Energy Technologies Market Deployment Task Force to examine impediments to early market introduction; iii) prospective Programme of Work for the IEA Working Party on Renewable Energy Technologies; iv) studies of the role of renewable based electric power in the Organisation for Economic Co-operation and Development (OECD) countries covering both hydro and non-hydro based electric power; v) publication of guidelines for the economic analysis of renewable energy technology applications, designed as a common approach for calculating the cost of energy from renewable sources; vi) recent and proposed international Conferences and Symposia which bring together leaders in renewable technologies form across the globe.

1.2 OVERVIEW

These pages contain a view of the International Energy Agency (IEA) activities and comments on the role of renewable energy sources as we move towards the 21st century. The IEA closely monitors the renewable energy contribution to world energy supply, and the development of energy technologies which will influence the future role of renewables.

The IEA was established as an autonomous body under the framework of the Organisation for Economic Co-operation and Development (OECD). It was created by an international agreement in 1974 signed by 21 of the most industrialised countries of the world. With the membership of Finland and France, which joined during 1992, the IEA consists of 23 of the 24 OECD countries. A prime objective of the Agency since its inception has been to assist Member governments in enhancing collective and individual energy security. IEA activities have a foundation in all sectors and aspects of energy policy, including: establishing mechanisms for oil stock

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* The views expressed are those of the authors and not necessarily those of the IEA and its Member governments.

sharing in supply emergencies; promoting energy market deregulation and other methods of increasing competition in energy markets; creating a process for critical examination of IEA Member country energy policies by their peers; and operating a comprehensive programme of energy co-operation among its Member countries.

It is difficult to make definitive statements on the role of renewable energy in the 21st century due to rapidly changing technologies, the lack of standardised cost analyses, and the wide variation in regional and national situations. However, based on preliminary IEA studies, international collaborative efforts and the experiences of Member countries in the renewable energy field, some observations can be made.

In the June 1994 communiqué of the IEA Governing Board at the Ministerial level, the Energy Ministers of the Member countries recognised the continuing importance of diversity of energy supplies, both fuels and sources, in enhancing overall energy security. They reaffirmed their commitment to environmental protection in concert with energy security and sustainable economic growth. The Ministers also stressed the necessity for the IEA to expand relations with non-Member countries, assisting them with the development of energy strategies and adopting energy policies that will contribute to their development and enhance global energy security. Regarding renewable sources of energy, the Ministers stated that in view of the environmental and energy security advantages generally offered by renewable forms of energy, continued strong government support and international collaboration to develop, demonstrate and disseminate renewable technologies is desired. (Ref. 1)

The role of renewable energy in furthering these goals is readily apparent. Relative to many other conventional energy technologies, renewables can demonstrate distinct environmental advantages, since, with the exception of some biofuels applications, they do not depend on a combustion process to generate heat energy. To the extent that renewables tap very large and diffuse resource bases, their energy may often be extracted with minimal environmental disruption. For the same reason, and because they typically use indigenous fuels, the use of renewables can potentially enhance energy security. In addition, the indigenous nature of the renewable fuels makes them well suited for use by newly industrialising countries. While there are exceptions to these and other generalisations regarding renewable energy, the promise of renewable technologies resides in the unique ways renewable energy content may be extracted and stored. Thus the potential benefits of continued and increased use of renewable energy sources are considerable. There are, however, technical considerations, particularly in energy storage and distribution, which must be overcome before dramatic increases in utilisation of these energy sources can be achieved.

During 1992 and 1993, the IEA Committee on Energy Research and Technology (CERT), through its Working Party on Renewable Energy Technologies (REWP), established two Task Forces to focus on central questions in deployment and environmental impacts of renewable energy technologies. The Task Force on Market Deployment Issues is addressing the cost reduction, economic viability and technological questions that are key to a broader share of the energy market for renewable energy technologies. The Task Force on Environmental Impacts of Renewable Energy Technologies will explore the identification of environmental benefits and costs associated with such technologies, covering the local, regional and global levels. IEA will, of course, continue its efforts across a spectrum of activities to monitor national energy programmes of member and selected non-Member countries, foster international co-operation on renewable technology development and enhance the current data available on the contribution of renewable energy to world energy demand.

2.0 EXPECTED ROLE OF RENEWABLE ENERGY SOURCES IN MEETING THE WORLD'S ENERGY NEEDS: CURRENT SITUATION AND STRATEGIC OBJECTIVES

Between 1973 and 1989, world total primary energy production increased 41 per cent, from 5616 Mtoe to 7900 Mtoe, which represents an average annual growth rate of 2.2 percent. It is significant to note that world total primary energy supply in non-OECD countries nearly doubled over the same period, growing at an average annual rate of 4.1 per cent. This represents a significantly higher energy demand growth than that in the OECD region which registered an average annual growth of only 1.0 per cent over that period. (Ref. 2) It is in the developing nations and transitional economies outside of the OECD region that IEA projects the most dramatic increases in energy demand into the next century. By 2010, the IEA estimates that overall energy consumption in non-OECD countries could be more than twice their 1990 levels due to rapid growth in population and economic activity, as well as increasing industrialisation, road transport needs and urbanisation. By 2010, IEA forecasts that OECD total energy consumption will be less than half of world consumption. (Ref. 3).

Also during the period 1973 to 1989, world output of electricity from hydro and other renewable sources (e.g. geothermal, solar, wind and other renewable sources) increased 74 per cent, from 119 Mtoe to 207 Mtoe, with hydro sources accounting for the major portion. (Ref. 4) Nevertheless, renewable sources including hydropower make up a small portion of world commercial fuels use. It against this backdrop that IEA Member country Ministers have renewed their commitment to development and deployment of renewable technologies, and constructive relationships with non-Member countries.

The amount of energy that renewable energy technologies currently contribute in most of the OECD countries today is quite small compared to their technical potential. Measuring the future role of renewables by their technical potential alone is misleading, however, due to the high relative costs of renewable energy compared to conventional sources. This analysis focuses on the technical development and general market potential of renewable sources, rather than the complex issue of the relative costs of renewable technologies which is the subject of a number of in-depth analyses.

Technical potential is determined by the size of the renewable resource, which varies from country to country, and the expected conversion efficiency of a particular technology. While the technical potential of renewable energy technologies appears substantial, their present state of development, coupled with uncertainties regarding their economic viability, market factors and institutional constraints, accounts for their relatively small contribution. It is possible, however, that incorporating external factors, such as environmental or energy security concerns, into energy system costs could enable renewable energy technologies to display improved economics, and therefore contribute a more significant proportion of their technical potential. However, public finance alone will not necessarily bring about a more competitive situation.

The patterns of utilisation of renewables are generally divided into hydro- and non-hydro use, though the statistics are not precise. Apart from the distinct category of hydropower, most renewable use today is in non-commercial fuels. This category is primarily composed of renewable energy in the form of biomass, which is not readily quantifiable in national energy balances. Preliminary studies from renewables experts in IEA countries estimate that 15 percent of world primary energy usage is in the form of these non-commercial fuels. In the commercial fuels sector, slightly more than 6 percent of world commercial fuels use is renewable energy, primarily as hydropower. (Ref. 5)

In terms of renewable energy solely for the production of electricity, more detailed statistics are available. Hydroelectric capacity in OECD countries in 1990 constituted the equivalent to 357 Gigawatts of electricity (GWe),** and solar, wind and geothermal collectively about 5 GWe. When non-utility operations are taken into account, and smaller, more dispersed electricity producers are included, the total OECD installed capacity for non-hydroelectric renewables rises from 5 GWe to over 15 GWe. This includes about 7 8 GWe produced by biomass (agriculture and forest residues), 3.2 GWe by geothermal, 1.8 GWe by municipal and industrial solid waste, 1.7 GWe by wind, and about 0.3 each by landfill gas, solar thermal, and tidal energy. (Ref. 6) These figures on electrical generation should be considered on the basis of dispatchable as opposed to non-dispatchable generation technologies. Energy from solar, ocean and wind energy may be extracted when available, but are not readily dispatchable in the absence of economic storage techniques. Thus, renewable based capacity is not as reliable as conventional electricity generation. This storage problem is one of the enduring technological challenges to expanded use of renewable energy.

** 1 GWe = 1,000 Megawatts (MWe)

With respect to the technical potential of specific renewable resources, it is clear that for renewables using intermittent energy sources such as solar and wind, the economics of electricity production will depend strongly on reducing the capital and operational costs of installations and associated back-up and storage systems.

While some technologies such as wind turbine generators are relatively mature and economic in specific market niches currently, the more significant future systems, i.e. those having greater potential for widespread application, must still achieve significant improvements in system efficiency, cost reduction and performance characteristics. Some preliminary assessments compiled by renewable energy experts in IEA countries reveals, in general terms, the status and potential of major renewable energy technologies. These assessments are inconclusive and do not include representations of the relative costs of these technologies. Nevertheless, they present a considered view of technology potential. (See Table 1)

Although many renewable energy sources are available commercially, they are still relatively immature technologies that are only available at high cost relative to conventional technologies. This, of course, excludes large hydroelectric production. Most still face the challenge of competing costs of other forms of delivered energy, increasing the ability to deliver energy when needed, and improving their simplicity, reliability, and durability. Preliminary analyses by the IEA, indicate that the renewable energy resources most likely to reach technical and economic feasibility in their intended applications are active and passive solar heating, daylighting, photovoltaics and solar thermal electric, bioenergy fuels and wind energy. In all seven technology areas there is further scope to reduce current capital and operating costs.

TABLE 1

Technology	Stage of Development	Feasibility	Unit Size	Efficiency
Active Solar Heating Cooling	 Deployed Potential	 High Medium	1-500 MWt	25-50%
Passive Solar Heating Cooling Daylighting	 Deployed Potential Deployed	 High Medium High	1-500 Mwt	25-50%
Photovoltaic	Demonstrated	High	1-7000 KWe	10-14%
Solar Thermal Electric	Demonstrated	High	3-100 Mwe	7-15%
Bioenergy Fuels	Demonstrated	High	N/A	N/A
Wind	Deployed	High	1-500 Kwe	N/A
Ocean Wave	Potential	Medium	3-500 Kwe	N/A

Notes
MWt = megawatts thermal
MWe = megawatts electric
KWe = kilowatts electric
N/A means not applicable or not available

Source: Draft IEA Assessment of Energy Technology Priority Areas

Clearly, technical feasibility and cost-effectiveness are major factors for further market penetration of renewable energy technologies. More specifically, the penetration rates for renewables will depend on a number of factors, including:

- The rapidity and extent of technical and economic progress, and the evolution of the costs of conventional fuels, which together will establish the magnitude of economic benefits to be achieved by swift market deployment;

- Increased reliability, maintenance-free intervals and durability of renewable facilities, and thus their true levelised life-cycle costs;

- The availability of markets of sufficient size to attract investments in pioneer systems, infrastructure, and manufacturing to achieve economies of scale; and

- The influence of government policy measures, such as taxes and subsidies, in the development of such markets. (Ref. 7)

There should be no doubt that renewable energy technologies have technical potential and, with further research, development and demonstration, considerable market potential as well. Renewables offer attributes which, in addition to their promising environmental and energy security characteristics, have a wider public acceptability than more conventional systems, though there is evidence that further development of large-scale hydropower in OECD countries as well as wind power in some countries could meet with strident public opposition. Most renewables are modular, allowing flexibility in matching load growth, and are suitable for use in decentralised energy systems. However, when using currently available technology they require capital intensive investments in order to capture their diffuse energy sources. In addition, as is well understood for hydropower, the levelised costs of energy will depend on a facility's lifetime and the amounts of operating and maintenance costs associated with continued and reliable plant operation, including repowering opportunities using the same site infrastructure, and eventual clean up.

Because of the technical and economic challenges associated with facilitating the market entry of renewable resources, infrastructure and systems, the pace of application of renewables may depend highly on the degree of international co-operative effort which is given to this strategic technology area. Addressing the strategic objectives of removing technical and non-technical barriers to market deployment and identifying the major environmental costs and benefits of renewable energy technologies are relevant priorities for international collaboration.

3.0 COLLABORATIVE ACTIVITIES OF THE IEA AND IEA MEMBER COUNTRIES

The IEA and its Member countries are engaged in a variety of activities with respect to renewable energies, ranging from studies of technology potential and national programmes to actual systems design and materials testing. Recent activities have included: i) studies of the role of renewable based electric power in the OECD countries covering both hydro and non-hydro based electric power; ii) publication of guidelines for the economic analysis of renewable energy technology applications, which are designed as a common approach for calculating the cost of energy from renewable sources; and iii) numerous international Conferences and Symposia which bring together leaders in renewable technologies form across the globe. In addition, IEA countries also have been actively involved in international research and development collaboration in eleven Implementing Agreements in the renewable energy technology area.

Since its foundation in 1974 the IEA has sponsored over 50 multilateral collaborative agreements in the area of energy technology R&D and technology development. The topics covered, as illustrated in Figure I, may be viewed as more representative of the potential contribution of existing and new technology areas than the technology R&D spending patterns of IEA Member countries might otherwise indicate. As seen in Figure II, spending directly by Member countries is historically dominated by nuclear and fossil fuels, with R&D spending on renewable energy technologies dropping from 13 percent in 1980 to 7 per cent in 1989. Although renewable R&D spending has increased somewhat through 1991, it still accounts for only 7 per cent of total Member country R&D expenditures. On the contrary, IEA Implementing Agreements reflect a broader scope, including a 17 per cent share for renewable energy technologies. (Ref. 8)

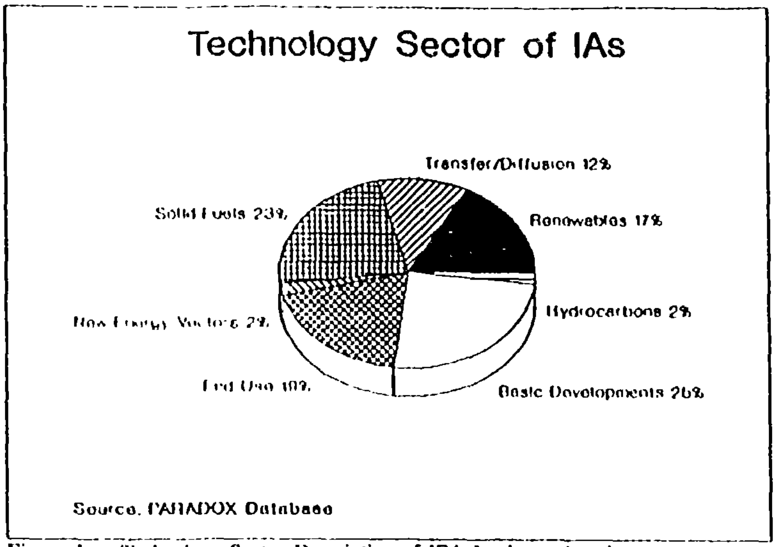

Figure I Technology Sector Description of IEA Implementing Agreements (Source IEA Computerised Register/PARADOX).

This focus on new technology areas, and comparatively low cost activities, has provided the collaborative activity with a robust and flexible base which has weathered the overall decline in Member governments R&D funding at the national level. National programmes dependent on government support have contracted considerably. However, Member government funding is not the best indicator of overall R&D and technology development activity, due to the considerable resources expended by the private sector on new energy technology. (Ref. 9) The major role played by private industry in developing, demonstrating and deploying energy technologies underscores the necessity for reliable and comparable cost analyses for renewable energy systems.

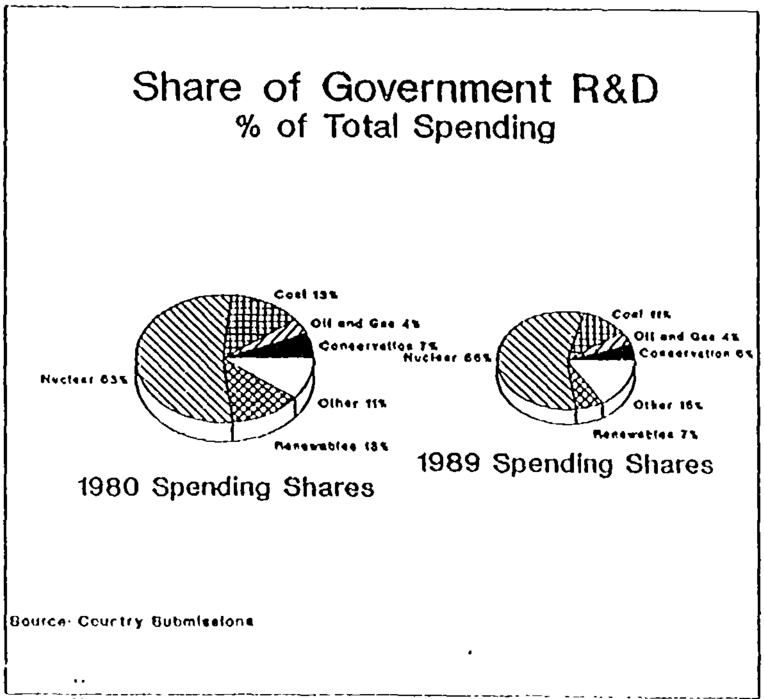

Figure II Share of IEA Member Governments R&D Spending by Topic in 1980 and 1989 (Pies are proportional in terms of real spending levels)

The IEA sponsored collaboration on renewable energy technologies began in 1977 and has included 11 Implementing Agreements in the fields of bioenergy, biomass (including peat), geothermal, solar, wave, wind and hydrogen. There are currently 7 operating IEA Implementing Agreements in the renewables category, in the areas of bioenergy, solar heating and cooling, solar power and chemical energy systems, wind turbine systems, photovoltaics, hydrogen, production and dissemination of information on demonstrated renewable technologies. These umbrella programmes in turn have 23 separate research tasks, or annexes, now underway. IEA renewable energy technology development programmes enjoy the participation of 20 countries and the Commission of the European Community (CEC). Many new annexes are under discussion. The technology areas identified by IEA Member country experts as key to increasing the contribution of renewable sources to the energy mix in IEA/OECD countries are reflected in the IEA renewables programmes conducted by Member countries. In its Implementing Agreements, IEA provides a mechanism for Member countries to collaborate on technology development and information exchange, leveraging national resources and advancing new technologies to market. Detailed explanations of the scope of IEA collaborative research and development programmes in the renewable energy field are included in the annex to this report.

The increasing interdependences in the global energy system suggest that IEA Member country interests can be pursued through improved contact and co-operation with non-Member countries to help them plan and develop efficient and environmentally sound energy supply and end-use systems. IEA Member countries' policy advice may provide users in the non-IEA region with a better understanding of the potential benefits of the technology options, as well as possible investment regimes and institutions that can encourage and efficiently manage structural adjustment, and facilitate the energy technology adoption and absorption process. A significant element in the Implementing Agreements is the mechanism for participation of non-Member countries in international energy R&D collaboration and information dissemination. The IEA has created an "associate contracting party" status in the IEA Implementing Agreements which represents a fundamental innovation in relations with non-Member countries. A priority will be the continued enhancement of these collaborative ventures with non-Member countries in areas where there are opportunities for mutual sharing of experiences and know-how as well as for information dissemination.

The IEA Committee on Energy Research and Technology (CERT) has general responsibility for the IEA programme to co-ordinate international energy technology collaboration. The CERT has established various Working Parties to advise it in specific technology areas. The Working Party on Renewable Energy Technologies (REWP) specialises in the range of technologies associated with renewable energy sources. Two priority themes have been identified by the REWP in designing the strategy for its future work on renewable energy technologies. These are: addressing barriers to market deployment of renewable energy technologies; and consideration of environmental aspects of renewable energy technologies. To address these priority areas, the REWP has established two Task Forces on relevant issues: The Task Force on Market Deployment Issues, chaired by the Delegate of Italy, and the Task Force on Environmental Impact of Renewable Energy Technologies, chaired by the Delegate of the United Kingdom. These themes are viewed by the REWP as part of a rolling four year programme, culminating in the publication of a compendium of regional, national and international assessments of renewable energy technologies.

Guidelines for the 1994 Programme of Work focus on the central priority areas outlined above but also include monitoring of national R&D and demonstration programmes, and enhancement of international collaboration. The Task Force on Market Deployment Issues will concentrate on three major topics during 1994: Implications of Large Scale Deployment of Renewable Energy Technologies; Centralised versus Distributed Power Generation by Renewable Energy Sources; Proposals for a Critical Survey of Selected Applications of Renewable Energy Technologies - Lessons Learned. Another key element in the REWP Programme of Work is the ongoing review and evaluation of renewable energy related Implementing Agreements under its purview. Over the forthcoming 12 months, the REWP will conduct a thorough review of IEA collaboration in the renewables field in support of the broader CERT efforts. The Working Party Programme of Work for 1994 also envisages at least one new renewable technology dissemination activity, several seminars and conferences and several major publications.

During 1992 the IEA published a comprehensive study of electricity supply in the OECD. This in-depth investigation examined trends in electricity supply and demand in OECD Member countries, co-operation and competition in OECD electricity markets, and delved into the environmental consequences of electricity generation and use. The role of both hydropower and non-hydro renewable generated power are specifically addressed. In general, the study notes that the main hydroelectric sites in OECD countries have already been developed and there is evidence of public opposition to additional large-scale developments. Hence, further contributions from hydroelectricity are not likely to be significant in the OECD. In addition, given the high costs and other factors mentioned, non-hydro renewable sources are not likely to make a major contribution to electricity generation in the OECD before 2005.

As noted earlier, the IEA has published a set of guidelines for a standardised approach to assessing the costs of energy from renewable resources. Decisions on the development of new energy systems depend on their relative economics. Cost comparisons between systems employing different primary energy sources is a trade-off between capital intensive projects with low fuel prices and projects with relatively small capital investments and high fuel costs. This is especially the case in the applications of renewable energy technologies. Typically, such technologies are less susceptible to fluctuations in energy prices but are more capital intensive than conventional energy systems such as fossil fuel fired systems. (Ref. 10) Many governments and private companies had performed assessments of these costs but results often differed and no attempt had been made to integrate these disparate approaches.

The IEA guidelines present a step-by-step approach to estimating costs, and show how methodologies can be applied to practical cases. In brief, the methodology provides technology specific energy cost information in the form of various "economic indicators," which include: net present value; required revenues; levelised costs; internal rate of return; and payback. These are calculated using economic analysis models for the building, industry and utility sectors. The inputs for these models are compiled in specially developed cost and performance parameters for the eight renewable energy technologies covered by the IEA analysis. Cost and performance parameters were developed for the following technologies: active solar; biomass; geothermal; passive solar; photovoltaic; small hydro; solar thermal; and wind. (Ref. 11) The guidelines were based on the results of the International Workshop on the Economics of Renewable Energy Technologies, organised under the auspices of the IEA.

The IEA sponsors a host of international conferences on renewable technologies and related topics. Many serve as the genesis for substantive international collaboration on renewable technologies. Among other international conferences sponsored by the IEA, the Executive Conference on Photovoltaic Systems for Electric Utility Application: Opportunities, Critical Issues and Development Perspectives held during December 1991 in Taormina, Italy is of particular note. As a result of the high level of international interest in the subject of that Conference, the IEA co-ordinated the work of 13 Member countries to conclude a new international collaborative agreement on photovoltaic technology development earlier this year. These IEA Member countries are currently in collaborating on six separate research tasks related to photovoltaics for grid applications. Fostering such international co-operation among member countries is a primary goal of the IEA. One good example of such co-operation is the IEA Implementing Agreement on Solar Heating and Cooling which has been active since 1976, and was one of the first IEA collaborative R&D agreements to be established. Eighteen IEA countries and the CEC are participants in the agreement's co-operative activities. Eighteen individual research projects have been established on issues ranging from solar collector and system testing to handbooks on insulation and instrumentation.

The IEA has a large number of renewables related activities. In May 1993, the REWP conducted an exploratory Workshop to examine the basis for further work on the greenhouse gas aspects of renewable energy sources and the environmental impacts of utilising indigenous renewable sources. The programme included presentations on and discussion of: the global environmental impacts of renewable energy technology applications; local environmental impacts; internalising external costs in costing renewable energy technology applications; and public perception of and institutional barriers to renewable technology applications. The programme also included examination of the potential benefits of renewable energy applications in developing economies and emerging market economies. The primary sponsor of the Workshop was the United Kingdom Department of Trade and Industry.

The International Conference on Hydropower, Energy and the Environment: Options for Increasing Output and Enhancing Benefits was held in Stockholm, Sweden during 14th-16th June 1993. This Conference was sponsored by the IEA in collaboration with Vattenfall of Sweden, the OECD Environment Directorate, and the International Union of Producers and Distributors of Electrical Energy (UNIPEDE). The conference included discussions on: the potential for reducing costs, limiting environmental impacts, and increasing power output through a combination of performance improvement, retrofitting and repowering; the respective roles of industry and government in development and marketing of hydro repowering technologies; and opportunities and means for international R&D collaboration and technology transfer. This was a joint activity between the REWP and the CERT Group of Experts on Electric Power Technologies.

During September 1992, the IEA sponsored the International Symposium on Solar Energy in Kanazawa City, Japan. The aim of the Symposium was to seek specific methods of efficient utilization and feasibility of solar energy. It was designed to review unresolved issues associated with the practical application of solar technologies, probe the future development of solar technologies, seek concrete avenues of international collaboration, and provide a forum for reevaluation of solar energy issues from the technical, economic and social perspectives. Outcomes included: exchange of technical information on the status of solar energy technologies; enhanced multilateral co-operation among participating countries, including establishment of world-wide "Centres of Excellence" in renewable energy technologies; conclusions on concrete steps toward effective utilisation of solar energy; and organisation of subsequent conferences on solar energy to be held in other countries around the world.

The IEA is also preparing to publish an updated and expanded edition of its comprehensive report on renewable energy technologies which was originally issued in 1987. The 1987 report described the status of renewable energy technologies and market penetration in the period to 1986. The new edition will take account of the technological developments, market situations, government policies, and economic and environmental implications of changes in the renewable energy arena in the ensuing six years. This project will enhance the ongoing discussions among IEA Member countries on technology options for energy production and conservation. In summary, the new edition will include an update of the 1987 report, complemented by new analyses treating energy production from renewables, economics of renewable energy sources, and environmental impacts.

All of these collaborative efforts reflect the concentrated effort on renewable energy technology which has been directed and endorsed by the 23 IEA Member countries.

4.0 PLAN OF ACTION FOR THE DECADE 1995-2005

Renewable energy technologies offer prospects of a useful contribution to the future energy supply of IEA/OECD Member countries and the rest of the world. Much remains to be done before new (non-hydro) renewable energy sources achieve their full technical, economic and market potential. While many of the issues can be addressed effectively at the national level, there is little doubt that international collaboration can accelerate the progress of development and deployment by working towards common goals through shared tasks and experiences. International collaboration stimulates the cross-fertilization of ideas exchanged between government, scientific, and industry personnel in the participating countries.

The overall approach over the next 10 years or so is one of evolution, of opening up avenues for renewable energy technologies as and when appropriate, determined by the state of the technology and by circumstances prevailing at the time. Although the potential contributions from renewable energy sources in the IEA/OECD countries vary significantly, these technologies need to be pursued because of their inevitably increasing importance as well as the promise they offer of a useful contribution to diversification and sustainability of energy supply.

The potential value of reducing greenhouse gas emissions alone, could be sufficient to re-order priorities and justify a much more aggressive approach to the development and deployment of renewable sources. An emphasis in this direction could be particularly useful for newly industrializing countries, because large infrastructures to support other types of energy systems are not in place to the same degree as in fully industrialized countries, and because modular systems, based on indigenous fuels and capable of effective decentralization, may be particularly appropriate for their needs.

At the national level, in the course of the decade which is in front of us, IEA/OECD Member countries may consider individual and collective government policies that would facilitate progress in the maturation and increased deployment of renewable energy sources, including the following:

- Support a leadership posture, and economic and regulatory environment, that maximizes the internalization of appropriate national and social costs into the market prices of all energy fuels and systems.

- Establish an analytical framework and transparent energy accounting structure in which all sources of energy can be consistently compared, from resource to use;

- Based on the results of ongoing comparative analysis, support the development and use of all those economic sources of energy that can be produced, supplied and used as efficiently as possible, basing upon open competitive market principles, while at the same time meeting acceptable safety and environmental criteria, in order to provide a diversity of supply and reduced risks associated with over-dependence on any one source of fuel;

- Provide stable long-term support for underlying and advanced technologies that can identify, strengthen and advance renewable options in the context of an environmentally sustainable economy for the longer term;

- Reduce the risks associated with pioneer efforts in the demonstration of new cost-effective renewable energy technologies, to help promote technology transfer and commercial uptake, and to inform the general public of technological change and of alternatives to conventional energy technologies;

- Enhanced use of the international workshop forum for technology information transfer with invited participation of IEA non-Member countries;

- Supporting workshops and collaborative research on the methodology and data bases necessary for determining the environmental and social costs and benefits of current and renewable energy technologies; and

- Development of new and innovative means for increasing collaboration which are specifically oriented to addressing market barriers, including possible efforts in compiling country case histories of specific means used to assist entry, and the benefits obtained thereby, comparative evaluation of applicable standards and regulations in various countries which both assist and inhibit entry of renewable energy systems, and the sharing of experience on effective technical, economic and regulatory means to increase synergism between renewables and conventional energy systems through transition periods of market entry for renewables.

Free market principles are viewed as highly important to renewables because of the need to increase internalization of national and social impacts in market prices. Technical break-throughs are still required to achieve an extremely high degree of reliance on renewables and thus address energy security and global environmental concerns, but are of somewhat less importance to increased globalization because of the significant use of renewables in newly industrializing countries.

The pace of progress in renewables is particularly dependent upon successful energy policy integration. While in one sense renewable energy technologies are competitors to existing energy systems, renewables may also operate in synergism with them and assist in maintaining them through extended transition periods. Renewables provide not only diversification with conventional fuels, but also diversification of technologies within themselves.

But the perception that national energy R&D and policies are the only means for developing new and improved energy technology is diminishing with the growing costs of the programmes and the increasing world wide basis for business activities and technological innovation. IEA Member countries and their energy industries compete in the short-term perspective. However, they may find in the long-term increasingly more reasons for co-operating through integrated multilateral programmes with a view to responding to the global energy security and environmental issues. Intensified international collaboration will provide a means to accelerate progress in developing new and improved technologies by sharing limited financial and human resources, and broadening the prospects of market deployment in all countries. Along this perspective, elements that contribute to the benefits of cooperative projects or decrease their costs are:

- Pooling knowledge, expertise and experience;
- Increasing reliability of result by coordinated replication work;
- Dividing a large task into more or less independent sub-tasks to facilitate task sharing;
- Doing together what no partner could do alone (pooling resources and sharing risks);
- Contributing to financial leverage;
- Focusing and coordinating national programs;
- Facilitating more rapid use of results;
- Providing access to facilities not available nationally and to improved links between public and private sectors, and
- Coordinating standards development and implementing them across broad market areas.

During the past ten to twelve years, international collaboration on renewable energy research and development under various IEA Implementing Agreements has significantly contributed to the progress made by these technologies. These benefits could be continued during the next decade or so, by a commitment to

- Reconfirm the importance of maintaining international collaboration through the IEA where common needs and interests continue;
- Increase efforts on coordinated data assembly, on a world basis, on the energy use of commercial and non-commercial fuels, economic and technical status of renewable energy;
- Intensify government assistance for basic science in areas that are relevant to the developing renewable industry and sponsor appropriate programs of research and development in collaboration with industry, nationally and internationally;
- Ensure that information is made available in the most relevant form to the public, investors, decision-makers and other interested parties;

- Establish through timely legislation (e.g., laws, regulations, standards) and appropriate fiscal incentives (e.g., tax credits, accelerated depreciation allowances), an institutional framework which will encourage and facilitate the integration of renewable energy technologies on a competitive basis in the market place. Strategies chosen should be such that the manufacturer has an interest to produce, as well as the customer an interest to use, the relevant renewable technologies.

- Review and revise appropriate laws, regulations and technical performance standards, if necessary, in order to facilitate the integration of the renewable energy technologies into the conventional energy systems, and to be sensitive to the critical issue of timing of these activities relative to the technology's developmental stage.

The future is highly uncertain. There is no doubt that because of the many institutional challenges associated with facilitating the entry of new fuel resources, infrastructure and systems, the success and large-scale deployment of new renewable energy sources will depend highly on the degree of international priority and hence co-operative effort and stewardship that all the countries in the world will be able to develop.

APPENDIX

IEA COLLABORATIVE ENERGY TECHNOLOGY PROGRAMMES

WIND ENERGY IN THE IEA

Contributed by W.G. Stevenson, Chairman of the IEA Implementing Agreement on Wind Turbine Systems

Status and Prospects of Wind Energy

The wind energy in the world represents a vast resource. If only a minute part of the raw wind potential is harnessed, a significant proportion of global energy needs can be met and a substantial contribution to the reduction of harmful substances in the atmosphere can be achieved.

The past fifteen years has seen the development of modern wind turbine generators from preliminary concepts to commercial products. More than 23000 wind turbines are now connected to the grid in the western world. The installed capacity is about 1000 MW in Europe and 1600 MW in the USA. The rate of increase is about 300 MW per year at the present. It is estimated that the total capacity in the world may reach 10,000 MW by the turn of the century, 4000 MW of which in Europe, 4000 MW in the USA and 2000 MW in other countries.

Most of the capacity is in wind farms ie, arrays of small and medium-sized wind turbines. The average unit rated power in today's wind farms is about 110 kW. The unit size in new installations is increasing. The average unit rating in wind farms installed in 1992 was about 200 kW. Commercial wind turbines of 500 kW rated power (rotor diameter 35-40 m) are now put on the market. The leading manufacturers are developing megawatt-sized machines with rotor diameters larger than 50 m.

Most of the installations are owned by private investors or co-operatives. Publicly sponsored market incentive programmes have played a decisive role for the installation boom experienced in some countries and states like California and Denmark during the 1980s and Germany, England and Wales at present.,

Utilities are taking an increasing interest in the development of wind systems. Wind energy still faces barriers to utility application, however. Falling oil prices have resulted in a lack of competitiveness. The integration of large amounts of wind power into utility networks causes control problems due to the intermittency of the wind. Although wind energy is generally considered as environmental benign, local concerns about noise and visual intrusion have led to planning difficulties in some countries.

Large wind power plants in utility systems are necessary if wind energy is to make a significant contribution to global energy needs. Small and medium-sized wind turbines are commercially available today from several manufacturers in many countries. There is a market pull for larger unit size. Large machines make better use of available land and are visually less intrusive than a number of smaller units of the same total power. They are suited for offshore installation, should the siting of wind turbines on land become prohibitive.

The feasibility of designing and operating large wind turbines with rotor diameters up to 100 m has been demonstrated since the early 1980s, but generation costs have been two to four times higher than from small and medium-sized machines. A reason is that large wind turbines have not yet benefited from the economics of large scale production. Studies indicate that the cost of energy from commercial large machines should be comparable to, if not lower than, that of small and medium-sized units.

Many design options for large wind turbines are available. It seems important to stimulate both the developments of a sufficient number of types and the manufacture of a sufficient number of units in order to demonstrate the economics of series production while reducing the risk for the developer. In parallel, supporting research on advanced technology is needed.

The IEA Wind Energy Programme

The rapid development of wind turbines has only been possible through vigorous national research programmes. In this context, the IEA co-operation has played an important role in providing a flexible framework for joint research projects and information exchange.

Two Implementing Agreements in wind energy were set up in 1977:

• A Programme of Research and Development on Wind Energy Conversion Systems (the "R&D Agreement").

• Co-operation in the Development of Large-Scale Wind Energy Conversion Systems (the "LS Agreement").

The R&D agreement was originally entered by parties from nine countries and the LS Agreement by parties from four countries (Denmark, Germany, Sweden and USA). Participation in the LS Agreement was limited to countries with R,D&D programmes involving wind turbines with a rated power of approximately 1 MW or more.

Following the evolution of the national wind energy R,D&D programmes and the commercial breakthrough of small and medium-sized wind turbines, the character of the IEA activities also changed gradually. In 1991, the two Agreements were merged into the "Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems", or IEA R&D Wind for short.

At the present time, IEA R&D Wind has 16 Contracting Parties from 13 countries. The scope of activity comprises co-operative research projects and information exchange. So far twelve cooperative, called Tasks, have been initiated, nine of which have been successfully completed and three of which are in progress, see Table 2.

The Tasks are regulated in Annexes to the Implementing Agreement. Each Task is managed by an Operating Agent, usually one of the Contracting Parties. Control of the overall programme is vested in the Executive Committee, in which each Contracting Party is represented.

TABLE 2 IEA R&D WIND TASKS

NO	TITLE	OPERATING AGENT	DURATION
I	Environmental and Meteorological Aspects of Wind Energy Conversion Systems	National Swedish Board for Energy Source Development	1978-81
II	Evaluation of Models for Wind Energy Siting	Battelle Pacific Northwest Laboratories, USA	1978-83
III	Integration of Wind Power into National Electricity Supply Systems	Kernforschungsanlage Julich GmbH, Germany	1977-83
IV	Investigation of Rotor Stressing and Smoothness of Operation of Large-Scale Wind Systems	Kernforschungsanlage Julich GmbH, Germany	1977-80
V	Study of Wake Effects behind Single Turbines and in Wind Turbine Parks	Netherlands Energy Research Foundation	1980-84
VI	Study of Local Flow at Potential WECS Hill Sites	National Research Council of Canada	1982-86
VII	Study of Offshore WECS	UK Central Electricity Generating Board	1983-88
VIII	Study of Decentralised Applications for Wind Energy	National Engineering Laboratory, UK	1985-90
IX	Intensified Study of Wind Turbine Wake Effects	National Power plc, UK	1985-91
X	Systems Interaction	US Department of Energy	Postponed
XI	Base Technology Information Exchange	Department of Fluid Mechanics, Technical University of Denmark	1988-
XII	Universal Wind Turbine for Experiments (UNIWEX)	Institute for Computer Applications, University of Stuttgart, Germany	1988-
XIII	Co-operation in the Development of Large-Scale Wind Systems	National Renewable Energy Laboratory, USA	1991-

In one of the Tasks, IEA R&D Wind is addressing the testing and evaluation of wind turbines by having experts from the participating countries prepare joint recommendations. To date, recommendations have been issued in eight areas. They are serving a very useful purpose in the wind energy community, until international standards are established.

Information exchange is taking place at the Executive Committee meetings twice a year and at workshops and expert meetings. A special Task is devoted to the exchange of information on large wind turbine systems. Input to a computerised information system is provided by a network of contact persons in the participating countries. The collected and disseminated material comprises national wind and generation summaries; design, test and operational data on large prototype wind turbines; and summary data for wind farms.

The detailed results of the Tasks have been documented in more than 200 technical reports, publications and conference papers. The Executive Committee issues an Annual Report which reviews the progress of the Tasks and highlights the national wind energy activity in the member countries. The Executive Committee also publishes a Wind Energy Newsletter, which is distributed to wind energy professionals and renewable energy programme planners worldwide.

A programme of activity for the next five years (1994-1998) is now being prepared. Goals for future action and areas for co-operation are identified. In addition to the traditional activities of co-operative research projects and information exchange, increased emphasis will be given to state-of-the-art assessments of wind technology, the market potential and penetration and the environmental benefits and costs of wind energy. Efforts will be made to improve the dissemination of information, to increase industry involvement and to extend the co-operation to non-participating countries.

Conclusions

The IEA Agreements have provided a useful framework for international co-operation for more than fifteen years. The scope of the activity had adapted to a changing environment. A network of professional contacts has been created. The sharing of research and information has effectively stimulated the development of wind technology, has eliminated unnecessary redundancy in the national programmes and has encouraged efficient approaches to solve common problems.

IEA SolarPACES - SOLAR POWER AND CHEMICAL ENERGY SYSTEMS

Contributed by C.-J. Winter, The German Aerospace Research Establishment (DLR), Germany and Chairman, Executive Committee, IEA SolarPACES

After the First Solar Civilization, which lasted until the 18th century, and after the fossil interlude of the following two to three centuries, a renaissance in the utilization of renewable energies is approaching for the 21st century in the form of a Second Solar Civilization.

The continuous growth of the world's population, the need for an ecologically responsible energy supply, and the dwindling amounts of many energy raw materials will force the transition to this Second Solar Civilization. It will be characterized by technology and financial capital alone, since it will do without any energy raw materials.

The IEA SolarPACES programme is making a contribution in all three classic solar energy activities: solar thermal, solar electric, and solar chemical energy conversion. Ever since it was established in 1977 it has continuously provided valuable results for the solar thermal power plant market in the earth's sun belt, and in the long term it will provide useful information for the solarchemical industry.

SolarPACES is on a path which can hardly be travelled without cooperation between industrialized and developing countries in the earth's sun belt, since it requires a merging of technological expertise, the essential geographic precondition of high insolation levels, and financial capital.

History and Structure - Situation in Recent Decades

The IEA SolarPACES programme has existed since 1977 (it was formerly called SSPS - Small Solar Power Systems). The Contracting Parties of the Implementing Agreement are currently:

Germany
DLR - The German Aerospace Research Establishment (appointed Secretary to SolarPACES)
Israel
WIS - The Weizmann Institute of Science
Spain
IER/CIEMAT - The Instituto de Energias Renovables of the Centro de Investigaciones Energeticas Medioambientales y Tecnologicas
Switzerland
FOE - The Federal Office of Energy
United States
USDOE - The United States Department of Energy

Contracting Parties which have withdrawn from the Agreement are:

The Republic of Austria

The Government of Belgium

Greece; The National Energy Council of the Ministry of Coordination

Italy; Ansaldo Meccanico Nucleare, Consiglio Nazionale delle Ricerche, Franco Tosi, Snamprogetti

Sweden; The National Swedish Board for Energy Source Development

United Kingdom; The United Kingdom Atomic Energy Authority

The members of the Executive Committee are:

C.-J. Winter, Chairman, Germany
Gerd Eisenbeiß, DLR, Germany
I. Dostrovsky, WIS, Israel
Fernando Sánchez S., CIEMAT, Spain
Paul Kesselring, PSI, Switzerland
Gary Burch DOE, United States

The head of the Secretariat is Wilfried Grasse, DLR, Germany.

The program of work has been divided into three main Tasks. The titles, participating institutions, operating agents and lead countries are listed in Attachment 1.

IEA SolarPACES and its predecessor, the IEA SSPS Programme, were and are cost-shared and task-shared. Whereas the SSPS programme was predominantly cost-shared, task-shared programmes prevail in SolarPACES.

The overall accumulated budgets so far are approximately DM 200-250 million, DM 100 million of which were cash contributions from participating countries. The rest were personnel expenses, in-kind contributions and task-shared projects financed nationally. SSPS/SolarPACES is one of the largest IEA programmes. During the course of its c. 15 years, 600-800 person years of scientific, technical and administration personnel have been committed to the different tasks of the programme.

Achievements - Strategic Objectives

No doubt, the most important achievement of this international venture of the IEA SSPS/SolarPACES programme is the PSA - Plataforma Solar de Almería in Spain, the world's most versatile solar test field under the insolation conditions of southern Europe. In the meantime, some DM 200 million have been invested there. SolarPACES' responsibility for the PSA ended in 1986. Since then, operational and financial responsibility has been jointly shared by Germany and Spain. The major technical equipment includes two dissimilar solar towers, several parabolic trough plants of various designs, a dish-Stirling test site, a solar furnace of high accuracy, a water desalination rig, and solar chemical test stands, to name only these. The Plataforma welcomes scientific collaboration with laboratories all over the world.

The most significant test results achieved on the PSA include [1]:

- A wealth of operating data from three experimental solar thermal power plants which has provided a significant part of the technological basis for the SEGS and PHOEBUS programmes,
- An efficiency above 90% for a point-focused solar receiver,
- 1050 °C heat-transfer-medium temperature in a gas-cooled solar absorber atop a tower,
- Synthesis gas production in a first-of-its-kind solar chemical steam reforming experiment with a hydrogen output of up to 75%.

One result which is far more significant than the scientific results, as important as they are, is the intensive, high quality cooperation of the participating countries beyond their own national borders. One can claim that the knowledge accumulated is shared with all participating countries, regardless of where it was gathered. All results have been well documented and published [2].

Of major significance from a technical and economic point of view are the parabolic trough power plants, specifically the 354 MW_e "SEGS - Solar Electricity Generating Systems" in California, U.S.A., which are based in part on results from the SSPS/SolarPACES programme and which so far produce c. 90% of all solar generated electricity worldwide - a convincing example of the immediate, industrial application of scientific results achieved in international cooperation.

SolarPACES has three time-lines for its technology development activities.

- Central Generation Systems are either on the market or close to it. The time constants are one year to one decade. The next imminent or planned major experiments are Solar TWO (not formally a part of SolarPACES) in Barstow, California, U.S.A., a 10 MW_e two-cycle salt/water steam tower power project worth approximately US$ 50 million, the DSG - Direct Steam Generation Parabolic Trough Pilot Experiment - with an investment of US$ 12-20 million in Sde Boker, Israel, and the joint European-American DISTAL dish/Stirling project.

- Solar Thermal Technology and Applications concentrate on longer range issues with time constants of 5 years to 1-2 decades. Examples are the low cost, long life, lightweight stretched membrane heliostats of 100-200 m^2 surface area, or the multi-megawatt volumetric solar absorber for advanced air-cooled power towers, or high temperature storage development.

- Solar Chemistry is in the basic research stage and has the longest time frame, with time constants of 1-3 decades.

Of major economic and environmental importance is the immediate demonstration of technologies ready for the marketplace. Here there have been a number of initiatives taken:

- The Study Commission of the 12th German Bundestag, "Protecting the Earth's Atmosphere" has unanimously decided on a recommendation to the Federal Government to install a first solar thermal power station together with other interested industrialized countries and a developing country in the earth's sun belt [3], [4].

- The European Community and the Maghreb countries are considering the erection of a first parabolic trough power plant in North Africa [5].

- PHOEBUS, a gas-cooled solar tower power project of 30 MW_e is under consideration for erection in Jordan.

- Studies for plants in India, China and other countries have been carried out.

Four basic preconditions must be met before the steady, dependable and efficient market introduction of solar thermal power plants is possible [6]:

1. Suitable and technically productive development facilities, e.g., Plataforma Solar de Almería, the U.S. test facilities at Albuquerque, New Mexico, and multiple test facilities in Israel.

2. Stable and adequate research and development funding focused on critical test and equipment qualification needs.

3. Appropriately qualified, vertically integrated, and financially stable power plant suppliers or industrial consortia having clear, valid and committed business plans.

4. Fully funded market entry incentives and predictable high value entry markets that create temporary subsidized opportunities for profitable power plant sales and provide the organizational learning necessary to bring costs to economically competitive levels.

Only the first precondition has been achieved to date. Plans and proposals exist all over the world for the other three, but the concerted effort required to achieve them must be based on a clear political will to allow renewable energy sources their fair chance to address the ever-more-urgent global problems associated with economic development and with the protection of the environment. An agreement to put solar energy technologies to use in a "World Solar Energy Decade" could be an important step in that direction, opening the way to the necessary international financing and coordination.

Literature

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[3] Enquete Commission "Protecting the Earth's Atmosphere" of the German Bundestag (ed.), Climate Change - A Threat to Global Development, Economica Verlag, Bonn, Verlag C.F. Müller, Karlsruhe, 1992

[4] Expertise on a proposal to the United Nations Conference on Environment and Development (UNCED): "To install a solar thermal power plant in the earth's sun belt as a joint effort by selected industrial countries and a developing country," Future Energies Forum Publications, Volume 14, Bonn, 1992

[5] Systems Comparison and Potential of Solar Thermal Installations in the Mediterranean Area, in M. Grenon (ed.) Revue de L'Énergie, Numéro spécial: Coopération énergétique dans le bassin Méditerranéen, No. 441, Août-Septembre 1992, pp 602-618

[6] G. Braun, Solar Thermal Power - Finishing the Job - A Strategic Concept, paper presented to the 6th International Symposium on Solar Thermal Concentrating Technologies, September 28, 1992, Almería, Spain

Attachment I

Task I: Solar Thermal Electric Power Systems
Operating Agent: SANDIA National Laboratories, United States. Participants: DLR, WIS, IER/CIEMAT, USDOE.

- I.1 Central Generation Systems (central receiver and parabolic trough technologies)
- I.2 Distributed Generation Systems
  - Subtask I.2.1 Evaluation of Dish/Stirling Systems
    Lead Country: U.S.A.
  - Subtask I.2.2. Lightweight/Low Cost Dish/Stirling System Experiments
    Lead Country: Germany

Task II: Solar Chemistry Research (photochemistry, thermochemistry, electrochemistry)
Operating Agent: Paul Scherrer Institute, Switzerland, which is required to regularly exchange information with the Operating Agents and Chairmen of the IEA Implementing Agreements on: Hydrogen, Bioenergy, Advanced Fuel Cells, and Greenhouse Gases. Participants: DLR, WIS, IER/CIEMAT, USDOE, FOE.

- II.1 Solar Chemical Systems (precommercial and demonstration projects emphasizing engineering aspects)
  Sector Leader: NREL/U.S.A.
  - Subtask II.1.1 Exploration of New Ideas
    Lead Country: Germany
  - Subtask II.1.2. Water Detoxification
    Lead Country: U.S.A.
  - Subtask II.1.3. Reforming Systems
    Lead Country: Germany
  - Subtask II.1.4. Gas-Phase Detoxification
    Lead Country: U.S.A.

- II.2 Basic Solar Chemistry Research (on solar-specific chemical reactions and processes)
  Sector Leader: Paul Scherrer Institute
  - Subtask II.2.1. Exploration of New Ideas
    Lead Country: Switzerland
  - Subtask II.2.2. Direct Absorption/Conversion Processes
    Lead Country: Germany
  - Subtask II.2.3. Selective Solar Photoreactions for the Production of Chemicals
    Lead Country: Germany
  - Subtask II.2.4. Solar Photoreactions for Energy Storage and Carbon Dioxide Fixation
    Lead Country: Germany
  - Subtask II.2.5. Solar Photo-Degradation of Hazardous Wastes and Environmental Pollutants
    Lead Country: Germany
  - Subtask II.2.6. Solar High Temperature Chemistry and Thermochemical Cycles
    Lead Country: Germany
  - Subtask II.2.7. Chemical Storage and Transport of Solar Energy
    Lead Country: Germany
  - Subtask II.2.8. Diagnostic Methods and Instrumentation for Solar High Temperature Technology
    Lead Country: Switzerland

Task III: Solar Technology and Applications
Operating Agent: DLR.
Participants: DLR, WIS, IER/CIEMAT, USDOE, FOE.

III.1 Solar Specific Technology Components and Subsystems Technologies)
Sector Leader: DLR

Subtask III.1.1 Solar Concentrators
Lead Country: Germany

Subtask III.1.2 Solar Receivers
Lead Country: Germany

Subtask III.1.3 Storage Systems
Lead Country: Germany

III.2 Supporting Tools and Test Facilities
Sector Leader: IER/CIEMAT

Subtask III.2.1 Test Facilities, Controls and Measurement Techniques
Lead Country: Spain

Subtask III.2.2 Optical, Thermal, Chemical and Mechanical Performance Calculations
Lead Country: Germany

Subtask III.2.3 System Evaluation and Standardization
Lead Country: U.S.A.

III.3 Research in Advanced Technologies and Applications
Sector Leader: NREL/U.S.A.

Subtask III.3.1 Low to High Temperature Process Heat Applications
Lead Country: U.S.A.

Subtask III.3.2 Materials Developing and Testing
Lead Country: U.S.A.

IEA SOLAR HEATING AND COOLING PROGRAMME

Contributed by Fritjof Salvesen, Det Norske Veritas Industri Norge AS, Norway, Chairman of the IEA Solar Heating and Cooling Programme

The Solar Heating and Cooling Programme (SHC) was one of the first research agreements to be established within the IEA body. Since 1976, its member countries have been collaborating to develop technologies which use the energy of the sun to heat, cool, light and power buildings. The following 19 countries, as well as the Commission of the European Community, are signatories to the agreement:

Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.

The overall Programme is headed by an Executive Committee with one representative from each participating country, while the management of the individual research projects (20 have been established so far) is the responsibility of Operating Agents.

While solar energy technologies have many advantages, they must meet the requirements of any energy source - they must be reliable, economical, be compatible with industry practices and acceptable to the public. To achieve that goal, the members of the IEA SHC have joined together to solve common technical problems and provide the information needed by engineers, architects and industry to make better products and designs.

Buildings of the Solar Age

Buildings that utilize solar energy instead of conventional fuels are critical components of a sustainable energy future. Experts in building technology predict that, in the not-too-distant future, we will live and work in buildings which are much more energy-efficient and environmentally-sensitive. This can be accomplished without sacrificing comfort, aesthetics or economy. Heating, cooling and lighting systems will become an integrated part of "smart building" systems. Buildings will be designed to take maximum advantage of solar energy which will supply most of the energy needs. Energy-efficient components, equipment and appliances will be common-place.

Active solar heating systems will cost less and perform better as a result of more efficient collectors. New types of cover glazings, convection barriers made of transparent insulation materials, and optimized designs, as well as other advances, will make these improvements possible. Storage of excess thermal energy will be accomplished through phase change materials incorporated into structural elements of the building (for example wallboard). Another solar technology will supply heat and hot water to multiple building utilizing large storage units and central solar heating plants.

The cost of photovoltaic systems will decrease, resulting in much greater use of solar electricity in buildings. PV modules will be integra'ed into roofs or building facades (even windows), supplying much of the power needed for electric lights and appliances. A new generation of analysis and design tools will make the effective integration of solar systems in residential, commercial and industrial buildings possible. These tools will be part of larger building energy design simulation programmes routinely used by architects and engineers to ensure effective designs.

There is an enormous potential for reducing the use of purchased energy in the building sector: An average of 30% of the total energy consumed in IEA countries as a whole is used to provide energy for residential and non-residential buildings - for heating, cooling, ventilation, hot water, lighting, and appliances.

Much of this energy is currently supplied by fossil fuels - coal, oil, natural gas - and much of it is imported. Solar energy technologies, in combination with improved energy - efficient designs and products, could supply a significant portion of these energy needs, freeing more expensive and limited fuels for other uses within a nation's overall energy mix, and reducing harmful CO_2 emissions. For instance, a typical solar water heating system will, over its lifetime, displace 10.5 tons of CO_2 if replacing a natural gas system or 71.5 tons if replacing a coal or oil-fired electric system. Although solar energy technology is still relatively young and will benefit from further development, its advantages are clear. As a non-polluting, safe, indigenous and renewable energy source, solar energy will surely play an important role in the buildings of the 21st century.

The projects formed since the beginning of the programme centre around the following topics:

- Solar resource assessment
- Materials for solar application
- Residential and commercial passive solar buildings
- Active solar collectors and systems
- Building energy analysis tools
- Photovoltaics for buildings
- Minimum energy buildings
- Building renovation

Activities have been directed toward performing basis research, testing hardware and materials, improving reliability and durability, developing better design tools, field-testing systems and components, and producing handbooks and manuals. Special importance has been attached to providing the solar industry and the building industry with the results and information needed to make better products or designs and to encourage greater and more effective use of solar technologies.

IEA researchers are working in each of these key areas with the goal of making the buildings of the solar age a reality. The following pages give a short review of some of the work.

Solar Radiation

Because accurate solar radiation data and other related meteorological information are essential for solar energy design and testing, solar resource assessment has always been given an important part in the programme.

An extensive programme has been carried out to improve the accuracy of pyranometer measurements (an instrument used to measure global solar radiation) and developed guidelines for solar engineers on proper solar radiation measurement procedures. Experts from several IEA member countries identified the problem and compared various approaches to its solution.

As part of the collaborative work on solar radiation measurements, Finland developed an advanced pyranometer which is capable of measuring the incident radiation in 360 degrees.
In addition to global solar radiation, the performance of components, systems and buildings may be affected by a particular band of solar radiation or by its distribution. Important examples are high performance glazings, transparent insulation materials and photovoltaic systems.

New Materials

New materials will revolutionize building energy technology. For example, windows will be net energy gainers instead of losers as a result of new glazing materials capable of maximizing solar gain, minimizing thermal losses and reducing unwanted solar transmission. Transparent insulation materials will result in structural materials which are transparent of translucent but have the insulating property of traditional walls. The SHC task 18: "Advanced Glazing and Associated Materials for Solar and Building Applications" is developing the scientific and engineering basis which will support the appropriate development and use of these materials. Key words are transparent insulation, switchable glazings, selective coatings and light transport.

Passive Solar

To effectively incorporate passive solar features into a building, a designer needs information on how various design approaches have worked and also requires the proper tools to aid in the design process.

The IEA programme have:

- documented the performance of monitored passive solar buildings
- improved design and analysis tools
- produced national design guidelines
- produced design information booklet series to provide guidance on how to design cost-effective energy efficient passive solar homes.
- produced a sourcebook on "Passive Solar Design of Commercial Buildings"

Solar Collectors

Collector reliability and durability are crucial issues. Large numbers of systems in the field were inspected to establish the different mechanisms responsible for failure in collectors, their frequency and seriousness.

Methods were developed to measure and quantify the forms of material degradation which occur and the factors of the internal collector environment which are the main cause. This allowed recommendations to be made on minimum standards for collector durability, and the best choice of materials and design to minimize failure and degradation.

An IEA task on solar collector testing helped developed improved test procedures which are used to determine the performance that can be expected of a solar collector in an actual installation. Both indoor and outdoor testing were addressed.

Systems using evacuated tubular collectors were studied in great depth in another long-term project, as were large solar heating systems using large seasonal storage capabilities.

Work on active systems continues in a working group that is developing a new and highly effective test method for Solar water heating systems. Innovative designs which improve the performance and reduce the cost of active solar collectors and systems are being investigated in another active solar project.

Design tools

Design tool development and evaluation are extremely important but costly and complex. Through IEA task sharing, the cost that must be borne by any single country is significantly reduced.

Accurate building energy analysis tool and design tools are important for design purposes and for establishing the economic feasibility of various solar products, systems and design approaches. In the course of several IEA active and passive solar tasks, it became clear that existing analysis and design tools had serious shortcomings.

Major efforts were carried out to assess design tool accuracy, develop evaluation methods that could be used by engineer and designers, improve existing models, and develop more simplified and user-friendly models. A crucial part of this was to gather high quality performance data in order to validate the analysis programmes.

Presently, IEA participants are jointly developing new algorithms (or identifying the best existing ones) which can effectively analyze the newer and more complex solar building materials, components and systems. These include atria, high performance glazings, and daylighting.

Photovoltaics

Another project - the first in the IEA to deal with photovolatics - is generating a great deal of interest among industry, utility, and building designers in most of the IEA member countries. Participating experts will study the architectural integration of photovoltaics with buildings as well as the engineering integration of PV systems with solar thermal and conventional energy systems. A joint IEA SHC test centre have been established in Switzerland where different integration approaches will be investigated. IEA demonstration houses will be designed, constructed and monitored. This new collaborative project will address both residential and commercial buildings, and both stand-alone and grid-connected systems.

Advanced low energy buildings

One IEA project has the goal of developing the knowledge and experience necessary to design residential buildings which require little or no conventional energy for heating and minimal purchased energy for other energy requirements. Innovation and long-range perspective are key words, and analysis and testing of promising materials and components are being performed. IEA minimum energy demonstration houses will be built. Designs are being carefully (and sometimes brutally) reviewed and critiqued by the full group of experts, an approach which catches design flaws and helps to achieve the best designs possible. This task is creating the buildings of the future.

Building Renovation

If solar energy is to displace a significant amount of the use of fossil fuel in buildings, solar systems must be adaptable to existing buildings. By the year 2000, appr. 80% of the building stock will consist of buildings more than 20 years old. A large number of these will require renovation. The SHC have recently established a new project with the objective to increase the use of solar energy in existing buildings by developing strategies for effectively and economically integrating widely-applicable solar designs and concepts in the renovation process.

International Collaboration

IEA collaboration makes a difference - to the advancement of solar technology and to national programmes.

There are many benefits of collaboration:

- Provides access to a wide range of ideas and experience
- Leverages research funds through task sharing
- Provides access to specialized facilities in other countries
- Increases the size of the information pool/data base
- Enables complex or expensive projects to be more easily undertaken
- Avoids unnecessary duplication of effort
- Enhances R&D programmes
- Brings results to industry through direct or indirect participation

As a consequence of the overall IEA policy, the SHC encourage non-Member countries to participate in our work. There has been several contacts from Eastern Europe to the new material project. Slovenia is expected to present an application for Associate Participant to the Executive Committee in the near future. The IEA Solar Heating and Cooling Programme is committed to helping to realize the Renewable Energy vision of the future.

BIOENERGY - THE IEA BIOENERGY AGREEMENT

Contribution by Dr. Adam Brown, Chairman of the IEA Implementing Agreement on Bioenergy

Introduction

Bioenergy is a term used to cover the use of any biologically derived material for energy purposes. There is a wide range of potential feedstocks that can be considered. These include wastes from forestry and agriculture, as well as those from municipalities and industry. There are also a number of crops that can be grown with energy use in mind. These include forestry and herbaceous species, starch and sugar crops, and oil bearing plants. These feedstocks can be used in a number of different ways - by direct combustion, or by one of a number of thermal or biological processes - to produce solid, liquid or gaseous fuels that can then be used to provide heat, electricity or transport fuel. Bioenergy therefore provides a diverse and flexible range of renewable energy options.

Status

Looked at from a world wide perspective, bioenergy is already a significant supplier of world energy needs, providing perhaps 14% of primary energy needs. While a more predominant energy source in developing countries, even in OECD countries it is a significant source of energy, contributing some around 3% of primary energy needs. There is considerable potential for increasing the contribution that bioenergy can make, so reducing the depletion of fossil fuels and the attendant environmental effects. The challenge is to identify the opportunities that can best be integrated with the modern energy economy and also find a role that complements agricultural, forestry or waste disposal practice.

Of the wide range of options, some are now commercially deployed - for example the use of forestry products to raise steam or power in the paper industry, or municipal waste incineration. Others are at the demonstration stage, or reaching the point where pilot plant operation is appropriate - for example gasification of woody materials to produce electricity at enhanced efficiency. There are also some technologies that are still at the R and D stage. In many cases the technology has been demonstrated technically, and for these options future progress will depend on the way that the economics of the systems are perceived, and on overcoming a number of other non-technical barriers that face such new technologies. Progress will very much be determined by national energy and environmental policies and these will to a large extent determine the rate of further development and deployment in particular nations or regions.

IEA Bioenergy Agreement

The IEA Bioenergy agreement has its origins in a Forestry Energy Agreement that was first established in the mid 1970's. Over the course of the years the scope of the Agreement has been broadened to include a much wider range of issues of interest to members. There are now 15 participants - Austria, Belgium, Canada, the CEC, Denmark, Finland, France, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, United Kingdom, and the United States.

The aim of the Agreement is to provide an opportunity for co-operation in research, development and demonstration activities among the participants, both at the programme and project level, and so provide a way for the national efforts to be more economically and effectively planned, managed and executed. This is achieved by project task sharing, joint workshops, field studies, etc. Each participating country pays a small contribution to a common fund used to operate a secretariat, and to produce and distribute reports on the work. Work in the Agreement is organised into Tasks, which are in turn made up of a number of discrete activities covering specific work areas, each with objectives, a work programme and budget agreed by the participants. Members choose which activities they wish to participate in, and the costs of each activity are shared equally among the participants.

The benefits of participation are of three main types :

- agreed products from activities, such as reports, workshop proceedings, or agreed sampling or analytical protocols;
- opportunities to use resources in national programmes more effectively by sharing tasks;
- involvement by national experts in a network of international colleagues, so providing information on significant developments in other participating countries;

At present there are four Tasks in operation. These were initiated at the start of 1992 and will run to the end of 1994. The current Tasks are considering issues concerned with Biomass Production Systems (Task 8), Harvesting and Supply of Biomass (Task 9), Biomass Utilisation (Task 10), and Municipal Solid Waste (MSW) Utilisation (Task 11).

Task 8 is concentrating on identifying and developing efficient and environmentally sound ways of producing energy crops that can give a high biomass yield. Effort is primarily devoted to short rotation forestry systems, looking at ways to develop higher yielding varieties that are appropriate for a range of climatic conditions and are resistant to disease. The potential for other possible energy crops is also being reviewed, and environmental issues associated with the development and deployment of energy crops are also being studied. One topic of particular interest at present is the use of energy crops as a way of treating waste waters and sludges biologically, with the wastes providing nutrients for the crops.

Task 9 is examining a range of systems for mechanical planting and harvesting of energy crops, and for transporting, processing and storing the resulting fuels. The environmental impact of intensive harvesting of forestry crops has also been thoroughly investigated. One area where there has been a great deal of recent progress is in the development of systems for planting and harvesting short rotation forestry. Participants in this Task have been able to share experience of these new systems. The impact of these developments on the overall costs of producing these fuels has also been studied and it is now clear that these advances will lead to significant cost reductions.

Task 10 is concentrating on the development and evaluation of more efficient methods of converting wood and other biomass sources. Activities cover combustion, thermal processing (with a concentration on gasification to produce electricity more efficiently) and on biotechnology for the production of ethanol and other products from ligno-cellulosic feedstocks. Of course, utilisation systems cannot be considered independently from biomass production, harvesting and processing and so there is also an activity that takes an overall systems approach, in close collaboration with the other Tasks.

Task 11 is a new Task, which build on earlier work in the Agreement on the utilisation of MSW. The range of ways of using MSW as a fuel is being considered, with particular emphasis on combustion, anaerobic digestion and the effective utilisation and collection of landfill gas. Particular attention is being paid to the environmental aspects of these energy sources, and on the likely interactions between developments in waste minimisation and recycling and the potential for using un-recyclable material for energy purposes.

As well as the work in the Tasks there are other aspects to the work in the Agreement. A number of events have been organised to look at topics that will influence the development of Bioenergy. These have considered the possible role of Bioenergy in ameliorating the Greenhouse Effect, and also considered Non Technical barriers to the Development of Bioenergy. A further workshop on the Environmental Impacts of Producing and Using Bioenergy is to be held in September 1993 in Denmark.

Every effort is made to make the results of work undertaken in the Agreement widely available. Reports on individual activities and on workshops are available, and summary reports of the work in the agreement have been published periodically, along with a Newsletter and an Annual Report.

Conclusion

Bioenergy offers a range of sustainable energy supply options that can supply the need for heat, electricity or for transportation fuels. The IEA Bioenergy Agreement is providing an opportunity to allow co-operation in the development of systems most appropriate to national needs, so allowing more effective use of available resources and talents.

IEA AGREEMENT ON PHOTOVOLTAIC POWER SYSTEMS

The IEA Committee on Energy Research and Technology (CERT), at its meeting of 23rd-24th June 1992, approved a multi-lateral Implementing Agreement on Photovoltaic (PV) Power Systems. The Implementing Agreement is under the auspices of the CERT and its Working Party on Renewable Energy Technologies. The focus of the Agreement would be on PV systems for use by electric utilities and their customers.

The concept for the Agreement grew out of the Executive Conference on Photovoltaic Systems for Electric Utility Applications which was sponsored by IEA in cooperation with the Italian Electricity Authority, ENEL (Taormina, Italy, 2nd-5th December 1990). Since that time, numerous experts meetings including wide participation from among IEA Member countries were held. At the conclusion of the initial six-month signature period, November 1992 - May 1993, fifteen IEA Member countries had joined the PV Agreement. These include Austria, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Portugal, Spain, Sweden, Switzerland, Turkey, and the United Kingdom. The European Community and the United States have also indicated that they expect to join shortly. Furthermore, there have been serious signs of interest from a number of non-Member countries, including Brazil, Israel, and Korea. Thus, it is expected that almost every country with major producers or users of photovoltaic systems will be working on IEA's new PV programme over the next five years.The Agreement includes work related to each of these markets, as well as cross-cutting informational and design activities.

The first Annex of the Agreement relates to Exchange and Dissemination of Information on Photovoltaic Power Systems. A major objective of this task is to trace the progress of the diffusion model identified at Taormina, compiling data each year on the amount of photovoltaic capacity purchased in each major market, and then assessing the model's accuracy in light of the data compiled. The Italian National Agency for New Technology, Energy and the Environment, ENEA, has agreed to be task leader or Operating Agent. The work is to be performed mainly by analysts and technical writers in the participating countries. The information produced is to be aimed at utility executives, senior government officials, and local and regional regulators.

The second Task of the Agreement deals with the Operational Performance and Design of Photovoltaic Systems and Subsystems. An international data base on the operational performance of PV systems and subsystems will be established. The data collected will then be analysed to arrive at improved procedures for monitoring and measuring performance. Finally, based on performance measurements, the participants will develop recommendations for improved PV system and subsystem design. The Forschungszentrum Jülich of Germany has indicated interest in serving as Operating Agent for the task. Most of the work will be done by photovoltaic systems experts and engineers in participating countries, while the audience will consist mainly of powerplant system designers.

The third Annex of the PV Agreement, on Use of Photovoltaic Systems in Stand-Alone and Island Applications, will attempt to develop improved designs, better operation and maintenance strategies, and more sophisticated planning and evaluation methods for such decentralised PV applications. The Groupement Energetique de Cadarache (GENEC) in France has been nominated as Operating Agent for this task. The work will be performed by designers and operators of stand-alone and island PV systems, who will also be the principal users of the results.

The fourth Annex deals with Modeling of Distributed Photovoltaic Power Generation in Support of the Electric Grid. The idea here is to determine the true value of distributed PV systems to electric utilities, particularly in terms of reduced requirements for transmission and distribution capacity, and to model the optimal amount, sizing, and placement of dispersed PV capacity in an electric grid. It is anticipated that a utility in the United States may be nominated as Operating Agent for this task. Most of the analysis would be done by photovoltaic systems experts and transmission and distribution planners, who would then make use of the consequent modeling improvements in their work.

The fifth Task of the PV Implementing Agreement will focus on the Design and Grid Integration of Roof-Mounted and Other Dispersed Photovoltaic Systems. This would expand upon the work begun under Annex XVI of the Solar Heating and Cooling Agreement, which deals with the integration of rooftop photovoltaics into building architecture, to arrive at an improved understanding of how to integrate dispersed photovoltaics systems into the electric utility grid. The New Energy and Industrial Technology Development Organisation (NEDO) of Japan has expressed the intention of serving as Operating Agent for this task. The work will be performed mainly by systems engineers and transmission and distribution engineers, who will also be its primary beneficiaries.

The sixth Annex of the IEA Implementing Agreement on Photovoltaic Power Systems would concern Design of Modular Photovoltaic Plants for Large-Scale Power Generation. This is to focus on the longer-term markets for large-scale PV systems controlled and operated by electric utilities. The Italian Electricity Authority, Ente Nationale per l'Energia Elettrica (ENEL), has agreed to be the task's Operating Agent. The work is to be performed by a mix of structural engineers, electrical engineers, and photovoltaic industry specialists. The resulting products will be aimed at electric utility executives and government planners.

IEA IMPLEMENTING AGREEMENT ON THE PRODUCTION AND UTILISATION OF HYDROGEN

The IEA programme on the Production and Utilisation of Hydrogen began in 1977 and its current term runs through December 1993. Nine IEA Member countries and the CEC are active participants in this Implementing Agreement. The Member countries are: Belgium; Canada; Germany; Italy; Japan; Sweden; Switzerland; the Netherlands; and the United States. There have been a total of nine annexes, of which one is still active. The completed annexes include:

- Annex 1 Chemical Engineering Evaluation of Thermochemical Processes;
- Annex 2 High Temperature Reactor Thermochemical Plant Interface;
- Annex 3 Assessment of Potential Future markets for the Production of Hydrogen;
- Annex 4 Advanced Alkaline and Solid Polymer Water Electrolysis;
- Annex 5 Solid Oxide Water Vapour Electrolysis;
- Annex 6 Photocatalytic Water Electrolysis;
- Annex 7 Hydrogen Storage, Conversion and Safety; and
- Annex 8 Technical and Economic Assessment of Hydrogen Production.

Annex 9 on Hydrogen Production is currently active. It was initiated on 1st January 1991 and is scheduled for completion on 31st December 1993. The goal of this collaborative programme is to develop and characterise cost effective hydrogen production process via advances in the state-of-the-art of water and steam electrolysis technologies, thermochemical hydrogen production, and photocatalytic hydrogen production. The participants undertook this task by each country conducting intensive experiments, exchanging information and publishing country reports.

The Executive Committee is currently discussing revitalisation of the programme, reaching into new areas of collaborative research in hydrogen production. Considerable progress was made in this area during the spring 1993 Executive Committee with discussion focusing on a draft Strategic Plan prepared by a strategy working group. The Strategic Plan will be distributed as part of the 1993 Annual Report.

The EC agreed to work towards the approval of three new Annexes:

Annex X: Advanced Hydrogen Production

This annex would include photocatalytic processes, renewable energy-based water decomposition [advanced water electrolysis] and transitional hydrogen sources including biomass, solid waste, and fossil feedstocks. Interest was indicated by the United States, Canada, Switzerland, Germany, Italy and Japan. Sweden or Switzerland are likely task leaders.

Annex XI: Integated Systems

This would include systems analysis, economic, environmental and energy analysis and simulation, demonstrations and component tests. Interest was indicated by Germany, Italy, Japan, Canada, the United States, the Netherlands, Sweden, Norway and Switzerland. Italy will consider taking the lead with Japan being approached if Italy is unable to take the lead.

Annex XII: Hydrogen Transport and Storage

Interest was indicated by Germany, Switzerland, Canada, Japan and the United States with the Netherlands indicating possible interest. The United States agreed to take the lead.

Lead countries would set up workshops in September 1993 to scope out specifics for each of the proposed Annex agreements which would be addressed by the Executive Committee at its autumn 1993 meeting.

Several other possible annexes were discussed including Safety and Standardisation and Utilisation of Hydrogen and Hydrogen Mixtures. A number of countries voiced possible interest in each of these annexes but given the significant interest in the other three annexes these were put on hold pending action of the three proposed annexes discussed above.

The Executive Committee has developed a set of Common Principles underlying the efforts of the IEA Hydrogen Implementing Agreement and will develop formats for: detailed Biannual Reviews of National Hydrogen Programmes; a Directory of Hydrogen Expertise; and a Survey of Government Policies Encouraging Hydrogen Energy.

IEA CENTRE FOR THE ANALYSIS AND DISSEMINATION OF DEMONSTRATED ENERGY TECHNOLOGIES (CADDET RENEWABLE ENERGY TECHNOLOGIES)

The IEA Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET) was established during 1987 to analyse and disseminate information on energy efficiency technologies. It was created for a period of five years, and was recently renewed for an additional five years, to expire in March 1998. At the CADDET Executive Committee of 8th-9th February 1993 formal approval was given to restructuring of the agreement from a single task agreement covering energy efficiency technologies to an "umbrella" or multi-task agreement. Energy Efficiency activities of CADDET will continue under Annex 1 of the agreement, with NOVEM of the Netherlands continuing as Operating Agent. Annex 2 of the agreement will focus entirely on analysis and dissemination of Renewable Energy Technologies. The Energy Technology Support Unit (ETSU) of the United Kingdom was selected as Operating Agent by the nine countries involved in the Annex, at a meeting which took place on 17th December 1992. The selection of ETSU as Annex 2 Operating Agent was ratified by the CADDET Executive Committee at their February 1993 meeting.

The objective of CADDET Renewable Energy Technologies is to broaden and improve the collection and exchange of demonstration and other appropriate information on renewable energy technologies in order to provide governments, utilities, industrial and other end-users in the countries of Participants with a better understanding of renewable technologies, environmental advantages and measures available, thus leading to better informed decision-making, and increasing replication of successful demonstration and similar projects.

CADDET Renewable Energy Technologies will develop, analyse, compare and disseminate to the Participants detailed information on demonstration and similar projects to increase awareness of developments in and aid in the promotion of renewable energy sources in all relevant sectors.

In the areas of information and analysis, CADDET Renewable Energy Technologies' work shall include:

(i) Collection of information and data on current and completed demonstration (including field tested technologies) and similar projects;

(ii) Documentation and dissemination of the results of the collection and analysis of the information and data to the Participants;

(iii) Provision of technical and economic analyses of the information and data on demonstration and similar projects;

(iv) Facilitation of the widespread dissemination and adoption of innovative renewable energy technologies, and, to this end, CADDET Renewable Energy Technologies shall analyse and compare such technologies and make known to the Participants the resulting policy implications, market choices facing manufacturers and consumers, and design methods and tools for the proper application of such technologies;

(v) Monitoring of developments in the energy markets which may impact on the potential for the commercialization of demonstrated technologies; and

(vi) Organization of experts' meetings as appropriate to discuss specific questions on renewable energy technologies and the results of the evaluation and analyses.

To that end the Operating Agent will propose and maintain a methodology and an international format for the submission of all renewable technology information which is utilised in the collaboration; organize experts' meetings as necessary; perform the technical and economic analyses necessary to meet the goals of effective technology dissemination; and propose, prepare and distribute information products, such as Newsletters, etc.

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