INTERNATIONAL ENERGY AGENCY

INTERNATIONAL COLLABORATION IN ENERGY TECHNOLOGY

A Sampling of Success Stories

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

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

- To maintain and improve systems for coping with oil supply disruptions;
- To promote rational energy policies in a global context through co-operative relations with non-Member countries, industry and international organisations;
- To operate a permanent information system on the international oil market;
- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use;
- To assist in the integration of environmental and energy policies.

**IEA Member countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States. The European Commission also takes part in the work of the IEA.*

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- To achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- To contribute to sound economic expansion in Member as well as non-Member countries in the process of economic development; and
- To contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996) and the Republic of Korea (12th December 1996). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

FOREWORD

The International Energy Agency's collaborative R&D programme was founded more than twenty years before the 1997 Kyoto Protocol on climate change. Had it not been, the Kyoto process might well have triggered the programme's creation. Designed to foster less costly energy technology research, development and demonstration, the IEA programme offers a tailor-made response to the pressing need for cleaner, more efficient technology.

These technology needs were not new in 1997; what was new was the urgency created by the formal, quantified commitments to cut emissions of greenhouse gases. They came at a time, however, when conditions were scarcely ideal in IEA Member nations. R&D budgets in many countries had fallen victim of government cutbacks. The wave of liberalisation sweeping through the energy markets was shifting the R&D focus from long-term projects to short-term requirements. Globalisation and the advances of newly industrialising countries and the economies in transition were altering the world-wide economic status quo.

As an existing and well-tried vehicle for such co-operation, the IEA's international collaborative programme again proved its worth, notably by easing the strain on national R&D budgets. And it continues to do so. Its cost-effective and flexible tool - the IEA Implementing Agreement - enables participating nations to pool resources for R&D projects and to share the benefits. Duplication of effort is avoided, but provision is also made for the protection of intellectual property rights.

The programme has evolved over the years, keeping step with changes in energy technology objectives; reduction of greenhouse gas emissions naturally now ranks high among the priorities.

The purpose of this publication is to demonstrate, through a series of success stories, how the programme has enabled countries to join forces in developing energy technologies to meet common goals. We hope that readers will share our view that international collaboration on energy technology RD&D offers an ideal means of optimising energy technology development investments.

Robert Priddle
Executive Director

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INTRODUCTION

Developing and deploying more efficient and less environmentally damaging energy technology is critical to achieving objectives of energy security, environmental protection and economic and social development. It is a bridge to the future.

The development of energy technology is taking place in an increasingly inter-connected world. The nature of the challenges facing energy policy, including environmental concerns - especially that of climate change - economic development and energy security, are increasingly becoming international issues. At the same time, increasing reliance on competitive markets and the liberalisation of global trade and investment is adding a further dimension to the international connections. National efforts to adapt to the challenges facing the energy sector no longer suffice.

In order to respond to global challenges and opportunities, technology must be developed and deployed effectively and efficiently. This, in turn, requires efficient and effective systems for international technology transfer. Mechanisms are needed to improve the overall efficiency of the global energy technology development effort. In these circumstances, effective international collaboration has an increasingly important role.

The International Energy Agency provides a framework for collaboration on energy research and development, demonstration and information exchange. The programme brings together experts from different countries, enabling them to share the results of their work, to undertake common experiments which draw on their collective knowledge, and to build on each others' achievements.

Major activities under the programme include information dissemination and collaboration on fossil fuels, renewable energy, energy end-use and fusion power. The programme involves expenditures on energy technology of over $120 million annually and co-ordinates over half the world's nuclear fusion research.

The collaborative programme has proven highly successful in increasing the efficiency of global energy technology development. Cost sharing reduces the costs for individual countries by 50 per cent to 95 per cent from what

they would have spent if each country had to finance the projects alone. The resulting increased rate of technological progress and increased flow of information from activities and networks developed under the programme provide added benefits.

The collaboration also contributes directly to the development and deployment of new technologies. In many cases, work programmes are designed and undertaken in close co-operation with industry, helping to bring new technology developments directly to the market place.

A further major contribution lies in the area of policy development. For example, collaborative work under the programme has produced knowledge that influenced the development of the Kyoto Protocol. In addition, many policy decisions in Member countries have been based on information produced through the programme.

STRUCTURE AND FORM OF THE PROGRAMME

Implementing Agreements

Collaborative activities are set up under Implementing Agreements which provide both a legal mechanism for establishing the commitments of the participants and a management structure to guide the activity. Participants can be government organisations or business sector entities nominated by their governments. Non-IEA Member countries also participate in the programme.

The signatories - "Contracting Parties" - to an Implementing Agreement nominate an Executive Committee consisting of one representative from each participating country, which acts as the "board of directors" of the Agreement. The Executive Committee may appoint an Operating Agent to manage activities.

The Contracting Parties bear their own expenses in undertaking collaborative activities and have exclusive rights to the results. The IEA Secretariat assists by providing technical and other support.

Many Implementing Agreements conduct several separate tasks which are identified in Annexes to the Implementing Agreement. While all Contracting Parties sign the Implementing Agreement, participation in tasks under Annexes may vary according to the parties' wishes.

Form of Collaboration

The Implementing Agreement mechanism has proven very flexible and enables collaboration to take many different forms. Existing Agreements range from information exchange to basic research. Participants include representatives from governments, universities and industry. In some Agreements participants are largely from industry, while in others participants are mainly researchers.

Collaboration is financed through two broad mechanisms:

■ Task sharing, in which participants devote specified resources and personnel to conducting part of a common work programme.

■ Cost sharing, in which participants contribute to a common fund for conducting an experiment or equipment purchase, operation of a single facility, or for information exchange.

Task sharing is particularly well suited to situations where there are a number of different concepts that can be investigated by different participants in parallel, while cost sharing is appropriate for funding a single joint activity or experiment.

Many Agreements use common funds to cover the full costs of central administration, others rely entirely on task sharing. Others use a combination of mechanisms to finance their projects.

Examples of cost shared collaboration include the activities of the Energy and Environmental Technologies Information Centres, and Annex II of the Implementing Agreement on Coal Combustion Sciences which uses a common fund to support research at the International Flame Research Foundation in the Netherlands.

Examples of task shared collaboration include SolarPACES (this Agreement also has a small common fund to finance a secretariat and some other joint activities), and the Implementing Agreements on fusion power.

CURRENT STATUS OF THE PROGRAMME

There are currently 40 active Implementing Agreements. For convenience, these are classified under information dissemination, fossil fuels, renewable energy technologies, energy end-use and fusion power, although in reality many Agreements extend beyond a single category.

The Implementing Agreements are:

Information Centres

- Energy and Environmental Information Centres
- Energy Technology Data Exchange
- International Centre for Gas Technology Information
- IEA Coal Research

Fossil Fuels

- Coal Combustion Sciences
- Enhanced Recovery of Oil
- Fluidised Bed Conversion
- Greenhouse Gases R&D Programme
- Multiphase Flow Sciences

Renewable Energy Technologies

- Bioenergy
- Geothermal Energy
- Hydrogen
- Hydropower
- Photovoltaics
- Solar Heating and Cooling
- Solar Power and Chemical Energy Systems (SolarPACES)
- Wind Turbines

Energy End-Use

- Advanced Fuel Cells
- Advanced Motor Fuels
- Buildings and Community Systems
- Energy Conservation and Emissions Reduction in Combustion

Energy Technology Systems Analysis Programme (ETSAP)
Demand-Side Management
District Heating and Cooling
Energy Storage
Heat Pumping Technologies
Heat Transfer and Heat Exchangers
High Temperature Materials
High Temperature Superconductivity
Hybrid and Electric Vehicles
Process Integration
Pulp and Paper

Fusion Power

Environmental, Safety and Economic Aspects of Fusion Power
Fusion Materials
Nuclear Technology of Fusion Reactors
Plasma Wall Interaction in TEXTOR
Reversed Field Pinches
Stellarator Concept
Three Large Tokamaks
Toroidal Physics in, and Plasma Technologies of, Tokamaks with Poloidal Field Divertors (ASDEX Upgrade)

In total, 33 countries, including 11 non-IEA Member countries, and the European Commission are participating in the Agreements. Participation, by both Member and non-Member countries, increased by nearly ten per cent over the past two years, despite budget stringency in many countries (Budget cuts have led to reduced national programmes in some countries). Tables showing countries participating in Implementing Agreements are given in Appendix 1.

Descriptions of the individual Implementing Agreements are given in Appendix 2. These also include contacts for detailed information.

BENEFITS OF COLLABORATION

Cost Sharing and Data Pooling

Cost sharing and data pooling enable individual countries to achieve given ends at reduced cost. Moreover, pooling of financial and research and development resources also allows a better outcome to be achieved in a shorter time than could have been achieved alone.

Under the Implementing Agreements, sharing of knowledge and resources takes many different forms. For example, data can be pooled to build improved mathematical models to replace expensive physical experiments, some costs of experimental and pilot plant facilities can be shared, and scientists can participate in international exchange programmes. In many cases, participants share elements of a common work programme with each participant working on different concepts or materials; thus a far greater range of options can be fully explored.

Under the Implementing Agreement on Wind Turbines, aerodynamic testing was undertaken by five laboratories in four countries at a total estimated cost of $2 to $4 million. It would have cost each country around $3 million to do the same work alone. In addition, the work was accelerated by allowing data collection in parallel under a variety of wind and atmospheric conditions not readily available in individual countries.

A modern wind farm in the United States. Wind energy is one of 40 collaborative projects on energy technology among IEA Member countries. Working together in this way reduces the costs and accelerates the pace of development.

Collaboration also provides a mechanism through which several research paths can be investigated in parallel. In this way, individual participants can specialise in different fields and still have access to the research results from other participants. This can allow a large, multi-faceted work programme to be undertaken. The absence of co-operation could, at one extreme, lead to all countries separately pursuing the same path, or, at the other extreme, each country pursuing numerous paths to a limited extent.

Information Dissemination

Information dissemination helps maximise the benefits of research and development through increasing both the overall effectiveness of research and development endeavours and the rate at which new technologies are deployed.

International collaboration also enhances the dissemination of research results, thereby helping develop a common understanding of issues. One important specific mechanism is the development and use of standard methods and reporting procedures, resulting in increased transferability of research results, which allows research to be pursued less expensively and more rapidly.

Improved effectiveness of research and development arises from reductions in duplication of effort, aiding researchers to locate relevant information and others working in the same field, thus enabling them to build on one anothers' results. The Energy Technology Data Exchange is particularly relevant in this context.

Information dissemination activities also contribute to the value of research and development to the community as a whole by increasing the extent to which the benefits that accrue to the overall economy from research and development exceed the private benefits - the "spillover" effect. Spillover effects can take a variety of forms. For example, the new knowledge generated by research can benefit other organisations as it diffuses through the economy, while new products and processes provide benefits to users if product prices are lower than their social value. This characteristic of R&D - the generation of beneficial spillovers - is often used as an argument in support of government support for R&D.

Information dissemination has a particularly important role in the deployment of new technologies. By accelerating the market penetration of new, cost-effective technologies, it contributes to increased public benefits such as environmental amenity, economic development and energy security. The activities of the Centre for the Dissemination of Demonstrated Energy Technologies (CADDET) Energy Efficiency and CADDET Renewable Energy, which form part of the Implementing Agreement on Energy and Environmental Information Centres, are particularly important in this context.

Information dissemination also contributes to addressing externalities, such as the cost of climate change arising from the use of fossil fuels. The activities of the Greenhouse Gas Technologies Information Exchange (GREENTIE), which is part of the Implementing Agreement on Energy and Environmental Information Centres, is a good example of how the Implementing Agreements are contributing in this field.

If the benefits of a new technology to individuals are perceived to be small, then the costs of obtaining information can reduce the rate of market penetration. Lowering the search costs for information can play an important role in the deployment of new technologies. Any public benefits from the adoption of these technologies provide a strong rationale for government support for information dissemination activities.

Information dissemination activities under IEA Implementing Agreements operate in a number of fields filling gaps in the flow of information about energy technologies and are tailored to the needs of different target audiences. Information about on-going research and development is of particular interest to researchers. But, as technologies move beyond the laboratory to the pilot and demonstration stages, there are wider audiences. For example, the audience for the results of demonstrations include final consumers.

The information dissemination activities of the Implementing Agreements influence a very large number of decisions from basic research to technology deployment. Measuring the total impact is an almost insurmountable challenge. However, the various information dissemination centres have sought feedback from users, which has provided a large number of examples of where and how they are contributing. Some of these are cited in the boxes.

The Energy Technology Data Exchange (ETDE) provides a comprehensive bibliographic database of energy research and technology information which enables researchers to locate other relevant research and researchers. ETDE is being widely used. In 1996 the commercial on-line systems recorded users accessing more than 1.2 million citations. Data from in-house systems in the USA and Japan alone indicated usage in 1996 of 13,152 hours with nearly 750,000 citations being accessed in those countries. In addition, more than 70 CD-ROM products were sold for use in participating countries. Contracting Parties also have CD-ROM systems.

The relevance of the ETDE database is illustrated by the types of users. Data from the commercial on-line systems showed that in 1996 usage was 52 per cent business, 38 per cent government, and 9 per cent academic.

ETDE has received many "testimonials" relating to the value of the database. Some examples of these are:

- "Especially at the start of a new research area, [the database] is useful to achieve an overview of international activities in the field. By the use of ETDE, time-consuming and expensive literature studies can be reduced. As it is very comprehensive, [the database] comprises a wide range of research activities and applications. This facilitates the investigation of a new research area." Buildings-related researcher, Denmark.

- "The ETDE database is a rapid and feasible way of surveying the state-of-the-art in the field." Research Chemist, Finland.

- "The ETDE database has made a significant contribution by providing quickly accessible records on both past and very recent research ... This has led to the direct partnership of a leading academic ... and use of a facility." Research Chemist, Switzerland.

- "We use the database to identify market segments." Telesat Canada, private company.

■ "Brochures often advertise that a database is international although most of the information is strictly of Anglo-American origin. ETDE, however, is truly international." Heli Jyrkönen, Information Specialist, Imatran Voima nuclear power plant, Finland.

■ "Concerning energy-related questions [the database] is for all bibliographic searches the most important database which we access in the first line." Research Centre, Karlsruhe, Germany.

■ "With the ... Database, our company has access to all significant information contained in relevant publications in the field of power generation especially for fossil fuel power plants and nuclear power plants. The Database is also important for our research activities in material science and manufacturing processes. The indexing of all relevant items from main Russian and Japanese technical literature sources provides us with nearly complete bibliographic data." Siemens AG, Professional Information Center, Munich, Germany.

■ "The Energy Database is indispensable for our Information Service due to its broad and often unique coverage of all areas of energy technology." Ms. M. Carotenuto, ENEL Spa Electric Industry, Italy.

■ "Recently we have begun relying upon [the database] because of the exceptional amount of environmental information that covers all the DOE sites, and internationally has very good information on areas of the FSU [former Soviet Union] and Eastern Europe." Donna Berg, Los Alamos National Laboratory Research Library, United States.

The Implementing Agreement on Energy and Environmental Technologies Information Centres operates the two Centres for the Dissemination of Demonstrated Energy Technologies - CADDET Energy Efficiency and CADDET Renewable Energy, as well the Greenhouse Gas Technology Information Exchange (GREENTIE).

CADDET has recorded many cases where its activities have played a significant role in international technology transfer. Some examples from CADDET Energy Efficiency and CADDET Renewable Energy include:

■ From Canada: The head of a local government "Green Community Team" used the CADDET Analysis Report on Co-generation to help convince his board to put in a 5 megawatt co-generation unit with substantial savings for the community.

■ From Canada: The plant manager of a nylon factory used CADDET technical information to help convince his company to put in a heat recovery unit on water discharged into the St. Lawrence River. The company recovered its investment costs in only one month!

■ A Korean company and a Finnish company: Samsung Corp. were seeking heat exchangers for heat recovery from an indoor swimming pool. With the help of CADDET, they found a Finnish manufacturer, Retermia Oy, who made a product suitable for their needs and a distributorship agreement was signed in July 1996. As a direct consequence, Retermia Oy's sales increased from $1 million (1995) to $3 million (1996). Following this success, Retermia Oy decided to increase their production capacity by 500 per cent in 1997. A review of an in-door swimming facility - the largest such facility in Korea - using this system found that energy savings of 45 per cent had been achieved.

■ From the Netherlands: In 1996/97, the Dutch National Team conducted a survey into the impact of CADDET on cross-border replication. Of 22 projects identified, 11 had led to substantial or high levels of replication and 11 projects to a replication level considered to be fair.

■ From Mexico: Selling fish to inland cities is the only significant source of income for the small fishing village of Maruta in an isolated area of Mexico. The lack of refrigeration had kept the

village at a subsistence level economy, because of the difficulty in both storing the catch and transporting it to market. The installation of a solar ice making plant under a Mexican community development programme has greatly improved the village's economic situation. Following publicity for the project by CADDET, the technology is being demonstrated in Taiwan, and further installations are under consideration.

■ From Switzerland: A Swiss Technical Brochure and Newsletter article on "Photovoltaic Roof Tiles" have attracted considerable world-wide attention. The publicity led to the establishment of links between the Swiss manufacturer and a company which is successfully promoting the product in Australia. This year, samples of the tiles have been sold to a company in California.

■ From the USA: A Technical Brochure on "Photovoltaics Provide Electricity to Rural Communities in the Philippines" has been useful as a marketing tool for an American company. The brochure has generated considerable interest, particularly among funding agencies, who are now more willing to consider funding new projects.

■ From the UK: Information has been used by UK local authorities in their studies on the implementation of a 200,000 tonnes per year metropolitan solid waste incinerator, a small-scale hydro facility and landfill gas developments.

The solar-powered ice making plant in Mexico. This technology is being transferred to other users through CADDET.

GREENTIE has also received much positive feedback:

■ A user: "I was working on a conceptual study for a 2000 MW lignite-fired power plant and wanted to find out which parties were active in the field of pressurised fluidised bed combustion. I contacted some suppliers, but did not obtain the full overview I was looking for until I contacted GREENTIE. They supplied me with a clear and comprehensive listing that has been very useful for gaining a clear insight into the range of experts in this field."

■ A source: "We are pleased that so many of our potential customers have found [our company] through GREENTIE's Website ... we think it is most likely that our entry in the GREENTIE Directory has been a first introduction for many of our customers ... This results in a wider application of energy saving systems."

■ A Liaison Officer: "The main reason why our government joined GREENTIE is that it helps us fulfil our commitments to the UNFCCC ... under which we have undertaken to co-operate internationally in the transfer of greenhouse gas mitigating technologies .... However, there are many more benefits for our country from participating ... we have a more accurate inventory of our relevant equipment manufacturers and other technology experts; we notice that users around the world are increasingly accessing these organisations' entries in the Directory on the Internet."

■ An Energy Information Distribution Centre (India): "To respond to enquiries [in the field of energy conservation] we use several national and international information sources. The GREENTIE Directory is our main information source for matching enquirers to international technology suppliers. We are impressed by the Directory's comprehensiveness and its user-friendliness. The Directory has definitely made our job a lot easier."

IEA Coal Research - the Clean Coal Centre - plays an important role in information dissemination. The Clean Coal Centre is acknowledged as the world's foremost provider of information on efficient coal supply and use. In response to a recent survey undertaken by the Centre, 73 per cent of the Clean Coal Centre's customers said that the Programme had contributed to actions leading to a reduction in the environmental impact of coal.

Clean Coal Centre publications are a valued source of information for international energy stakeholders. A South African company cites savings of one third in capital costs and expected savings approaching $2 million per year in operating costs by using Clean Coal Centre findings.

IEA Coal Research's database on the world's coal-fired power plants provides comprehensive data on the availability and performance of equipment. The picture shows a power plant at Aalborg, Denmark, which is one of the most modern coal-fired power plants in Europe. Unit 3 (at the left) at this plant achieves an electric efficiency of 47 per cent. This compares with an average efficiency of less than 40 per cent in OECD countries.

The International Centre for Gas Technology Information (ICGTI) also has a strong industry focus. After just three years of operation the technical information stock has reached a high level in terms of both volume and access frequency. More than 800 companies are registered to use the ICGTI database. Its success in attracting companies active in the global gas industry is an indicator of its commercial relevance.

ICGTI also provides an important linkage between organisations. Meetings between ICGTI personnel and the Japanese gas industry, led to ICGTI facilitating substantive discussions on the implications of US electric deregulation for the US gas industry and the implications of Japanese electricity deregulation for the Japanese gas industry.

Several other Agreements operate information centres as part of their spheres of activity. These include the Implementing Agreement on Heat Pumping Technologies which operates the Heat Pump Centre, the Implementing Agreement on Buildings and Community Systems, which operates the Air Infiltration and Ventilation Centre, and the Implementing Agreement on Advanced Motor Fuels, which operates the Automotive Fuels Information Service.

Subscriptions to the Heat Pump Centre's newsletter have trebled over the past two years and use by paying subscribers has increased steadily. Circulation of the quarterly newsletter produced by the Air Infiltration and Ventilation Centre has reached 3500.

Many other Agreements include major programmes on information dissemination within a wider work programme. The Greenhouse Gases R&D Programme's newsletter provides news about developments in greenhouse gas technologies from its own work and elsewhere. It is produced every two months and has a circulation of 6300 in 108 countries. The Programme also organises international conferences (four in the past four years), produces publicly available reports, operates a well-developed Website and has produced an educational CD-ROM on mitigating climate change.

Many Implementing Agreements operate their own Websites as means of disseminating information on their activities. The addresses of these Websites are included in the descriptions of Implementing Agreements in Appendix 2.

Fossil Fuels

Projections of energy demand show that the world will continue to be dependent on fossil fuels for at least several decades to come. It is critical, therefore, that fossil fuels are used efficiently and with minimal environmental impacts.

Research and development is essential to the new and improved technologies that are needed to achieve this. A huge body of research into fossil fuel technologies is underway internationally involving both the public and private sectors.

The IEA Implementing Agreements are contributing to the effectiveness of this effort in a number of key areas. In addition to the information dissemination activities of IEA Coal Research, the International Centre for Gas Technology Information and the Greenhouse Gases R&D Programme, described above, IEA Implementing Agreements cover a range of activities relating to coal, petroleum and greenhouse gases.

The Implementing Agreement on Coal Combustion Sciences is conducting fundamental research to reduce emissions from, and to improve the efficiency of, coal utilisation. The Agreement contains both task shared and cost shared components and has an impressive track record of achievements.

Some outcomes from the work of the Coal Combustion Sciences Agreement:

- The development of low-NOx burners. Burner designers and manufacturers in one participating country have already achieved sales of over $400 million for a new generation of low-NOx burners which have been developed under the Agreement.

- Examination of the mechanisms of slagging and fouling has led to more reliable methods for the prediction of slagging in coal-fired boilers and guidelines have been established for more efficient operation and improved boiler design. These results, which may lead to potential savings of $15 million per year per station, have been shared with all the participants.

- In one country, sales of modelling software of combustion processes and combustion consultancy services based on the work of the Agreement have already exceeded $1 million.

■ A sophisticated measuring device based on an advanced laser-based diagnostics system which was developed in one participating country has been fruitfully developed and deployed at the research facility of another participant. Commercial contracts worth an estimated $100,000 have already been signed involving the use of such laser diagnostic systems.

■ Other sectors have benefited from the improved modelling and advanced diagnostic techniques developed under the Coal Combustion Sciences Agreement. For example, through technology transfer activities, improved models developed under the Agreement have been applied in the gas industry to increase heat transfer and combustion efficiency with savings of over $60,000 per year. The same techniques have helped a manufacturer of carbon black to improve its furnace design and operation, resulting in increased annual sales of $1 million.

Under the Implementing Agreement on Fluidised Bed Conversion, the use of fluidised beds as a means of combustion or conversion of solid fuels (including waste and biomass) is being studied and the results are being shared among participants. Much of the work is addressing operational issues arising from commercial plants in participants' countries. Mathematical modelling has been a major activity and the results are being used widely.

The Implementing Agreement on Multiphase Flow Sciences is improving the understanding of the behaviour and properties of multiphase flow phenomena associated with obtaining energy from coal, oil and gas. This work has many applications in the energy sector, including for example, fluidised bed conversion, oil and gas recovery, transport of solids in slurry pipelines, and emulsions of crude oil in water.

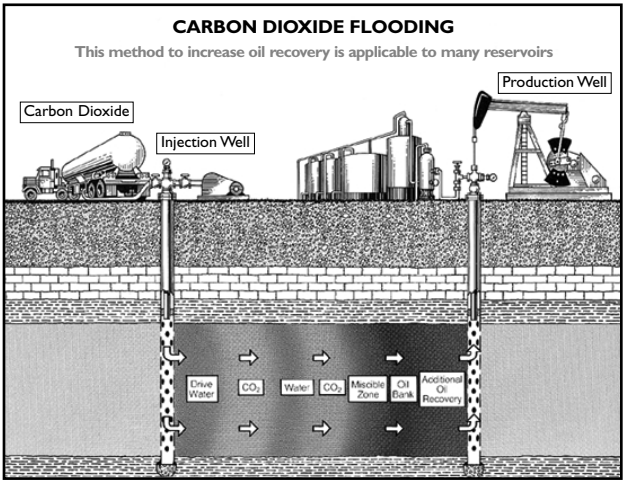
Collaboration on Multiphase Flow Sciences has led to the development and patenting of new non-invasive probes that measure the concentration and velocity of solids near the wall of industrial facilities at temperatures up to 1000°C. These probes are expected to become standard in coal combustors and gasifiers, and petrochemical units.

The Implementing Agreement on the Enhanced Recovery of Oil is investigating methods to increase the amount of oil that can be recovered from resources. Although the proportion of total oil produced using these techniques is relatively small, there is a wide range of different methods available and each country tends to apply only one technique on a wide scale.

Information exchange under the Implementing Agreement on the Enhanced Recovery of Oil led to investigations on the impact of carbon dioxide injection on crude oil composition. The resulting new knowledge is expected to yield benefits of several hundreds of millions of dollars by reducing the investment needed for enhanced oil recovery schemes using carbon dioxide.

A new approach to reservoir simulation developed under this Agreement can be run much faster and is more accurate than existing simulation models. The increased speed allows a much more extensive analysis to determine optimal production strategies, and to simulate complex production scenarios that existing simulation models cannot handle effectively. This approach has attracted the interest of oil companies and is expected to result in savings of several tens of millions of dollars.

Carbon dioxide flooding is a widely used technique for enhanced oil recovery. Investigations under the Implementing Agreement on Enhanced Recovery of Oil are expected to reduce the capital costs for this technology.



As well as the information dissemination activities mentioned above, activities under the Greenhouse Gases R&D Programme include technical studies and research and development projects. Work under the Agreement has helped demonstrate the opportunity for continued use of fossil fuels, even under scenarios involving deep reductions in emissions of greenhouse gases. The work has made an important input to policy development. Findings from the Programme have contributed to the report of the Intergovernmental Panel on Climate Change.

The Greenhouse Gases R&D Programme has contributed directly to technology deployment. For example, identification of an opportunity by the programme led one participant to start development of an improved technology for capturing CO_2 emissions.

Renewable Energy Technologies

The increased use of renewable energy technologies will reduce environmental impacts associated with energy supply and use and increase energy security. In addition, their use, where cost-effective, will contribute to improved economic efficiency.

Apart from hydro-electricity and biomass, the contribution of renewable energy technologies to global energy supplies is currently quite small. However, their potential is very large and their role is expected to increase markedly over the coming decades. Continued research and development is essential to underpin this process.

Renewable energy technologies are especially fruitful areas for international collaboration. Concerns about competitive advantage that can arise in countries are reduced by several factors. These include the relatively early stage of commercialisation of many renewable energy technologies, the importance of local factors such as climate, and the relatively limited export potential for much renewable energy technology hardware. This latter situation arises because user countries generally fabricate much of the plant, irrespective of where the technology itself was developed.

In many renewable energy technologies, there are multiple candidate technologies for harnessing the energy source. For example, in solar thermal power there are parabolic troughs, central receiver stations and dish systems. International collaboration allows these technologies to be investigated in parallel and the results to be shared.

IEA Implementing Agreements are actively pursuing a range of potential renewable energy supply technologies, as well as methods for integrating them into existing energy supply networks. The flexibility of the IEA's Implementing Agreement mechanism is illustrated by activities in renewable energy, where the scope ranges from basic research to activities aimed directly at increasing deployment.

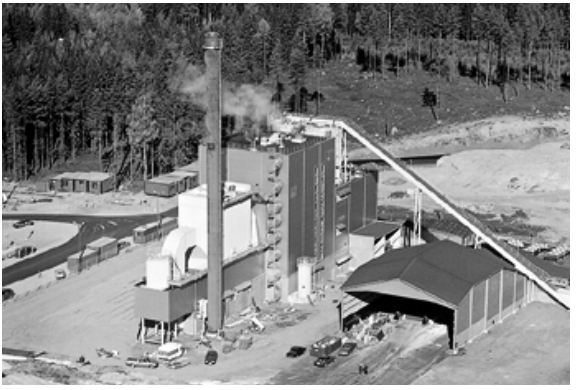
There are eight Implementing Agreements concerning renewable energy technologies, covering bioenergy, geothermal energy, hydropower, photovoltaic power supply systems, wind energy, high temperature solar thermal energy for electricity and industry, low temperature solar thermal energy for use in the buildings sector, and hydrogen production and use.

Bioenergy already makes a significant contribution to world energy supplies. There is major scope for this contribution to increase and to improve the environmental sustainability of existing biomass energy systems. The Implementing Agreement on Bioenergy is undertaking a large cost shared work programme covering a wide range of issues relating to energy production from biomass. By working closely with industrial partners the results of research flow directly to deployment. The Agreement has contributed to knowledge on issues ranging from forestry management systems to biomass combustion and energy recovery from metropolitan solid wastes. For example, plant breeding programmes are underway to develop plant varieties that combine fast growth with reduced susceptibility to pests. Indications are that some of the new clones now being tested can grow as much as 25 per cent faster than the plants presently being used.

Examples of technology deployment from the work of the IEA Bioenergy Agreement include the expanded use of biofuels in European district heating schemes and the application of short rotation forestry techniques in Sweden, where approximately 14,000 hectares had been planted by January 1998.

The Agreement has also contributed to understanding of greenhouse gas balances of biomass energy systems. Its work was also used in the development of guidelines for National Greenhouse Gas Inventories and was influential in leading to the inclusion of sinks in the Kyoto protocol.

A modern biomass-fuelled power plant at Forssa, Finland



Geothermal energy is the third largest source of renewable energy after hydropower and bioenergy. The Implementing Agreement on Geothermal Energy was signed in March 1997. Three tasks, covering environmental impacts, hot dry rocks and deep geothermal resources, were established with detailed workplans. Other tasks are under development. The full range of experts relevant to the Agreement's goals has been engaged through workshops and conferences. Work within the individual tasks is further disseminating information about the Implementing Agreement. The open discussion resulting from these activities will provide important longer-term guidance to the work of the Agreement and will provide feedback on the outcome of the work undertaken.

Hydrogen may well become a key component of sustainable energy systems. It could be applied in all major energy use sectors: transport, buildings, utilities and industry. Hydrogen can create storage options for intermittent renewable energy technologies such as solar and wind, and, when combined with emerging decarbonisation technologies, can reduce emissions of greenhouse gases associated with the use of fossil fuels. The Implementing Agreement on Hydrogen Production and Utilisation has a work programme which is investigating methods of producing hydrogen using sunlight, storage options, and system design. The information being developed under this Agreement is providing a sound basis for further development of the technology for the production and use of hydrogen.

Hydrogen powered bus and refuelling system in Canada. The refuelling system has provided the basis for systems analysis under the Implementing Agreement on Hydrogen Production and Utilisation.

Hydropower is the world's largest source of renewable energy and has considerable prospects for expansion. The Implementing Agreement on Hydropower was signed in 1995 and tasks are underway to develop recommendations on best practice on upgrading existing hydropower projects, to advance the use of small scale hydro, and to develop methods for the assessment of environmental impacts of hydropower projects. The Agreement has gained a high level of involvement by industry, with most of the work being directed and financed by industry.

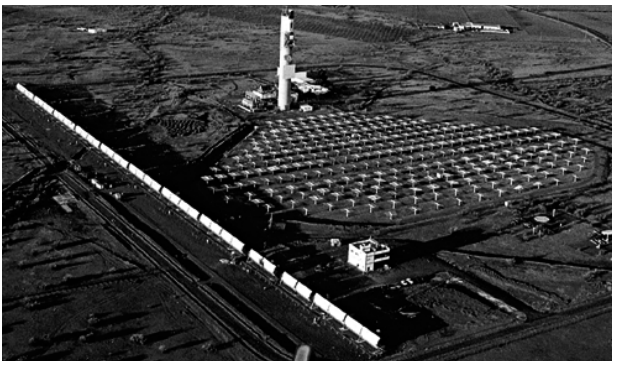
The Implementing Agreement on Photovoltaic Power Supply Systems has led to the development of strong networks involving researchers, government and industry, which has enabled countries to share knowledge, including results obtained from large experimental facilities, such as Rokko Island in Japan. Results from the work programme have been used in the development of regulations on system safety in some member countries. The Agreement has also contributed to technology transfer to developing countries.

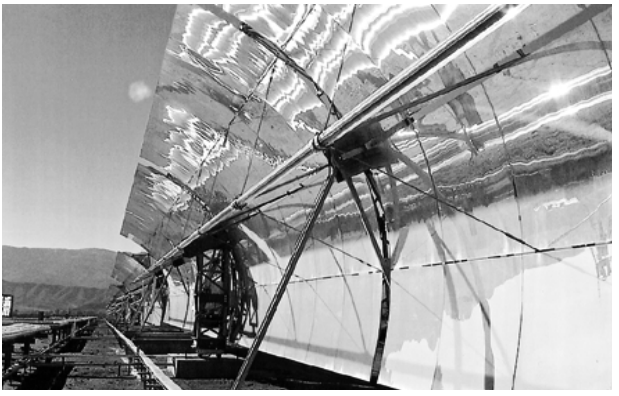
Solar energy can also be used to produce high grade heat for the production of electricity or for use in other processes. The Implementing Agreement on Solar Power and Chemical Energy Systems (SolarPACES) has shown that the cost of electricity from solar thermal power can be reduced from its current level of over 12 cents/kWh to 4 to 6 cents/kWh over the next 15 to 20 years.

The work of SolarPACES is contributing to reducing costs of solar thermal power. A co-operative effort with industry on system operation and maintenance cost reduction has led to improvements in many areas of the large parabolic trough power plants operated in California and has reduced annual operating and maintenance costs by 25 per cent since the inception of this programme in1992.

The Agreement has also made important contributions to the development of power tower technology and the continued development and testing of dish/Stirling systems.

The Agreement provided a mechanism for countries to share the costs of building a major test centre at Almeria in Spain. The first picture shows a view of the whole site with the central receiver station and a row of parabolic trough collectors. The second picture is a close up of the parabolic trough.





SolarPACES has a very active outreach programme aimed at involving developing countries with high potential to use solar thermal energy. This includes Solar Thermal Analysis Review and Training (START) missions to countries with high direct solar irradiation, to evaluate the technical potential for solar thermal systems. In addition, an agreement with the World Bank provides a mechanism for experts associated with SolarPACES to assist with work related to solar thermal technology in client countries.

A third Implementing Agreement on solar energy, Solar Heating and Cooling, is focused on solar heating, cooling, daylighting and building-integrated photovoltaic technologies. The work programme is closely co-ordinated with that of other relevant Agreements, especially with the Agreements on Buildings and Community Systems and Photovoltaic Power Supply Systems.

Many technologies developed or conceptualised under the Solar Heating and Cooling Agreement are now being commercially manufactured and marketed.

The photograph shows an energy efficient house in Finland constructed under the Implementing Agreement on Solar Heating and Cooling. By using a combination of a photovoltaic array, a solar thermal collector, and a ground-based heat pump, energy use is reduced by 80 per cent.

Examples of commercial outcomes from the work of the Solar Heating and Cooling Programme include:

- Danish and Swiss domestic solar water heaters are now being commercially manufactured. The cost/performance of the Danish system has improved by 39 per cent over the country's "typical" system. In Switzerland, the new system costs 30 per cent less than the "typical" system.

- Manufacturing of an optimised single-pole photovoltaic connector system for direct current cabling interconnection, which was conceived under the Programme, began in Switzerland in 1993. Since then, approximately 25 per cent of photovoltaic power world-wide uses this improved connector system.

- A new, more efficient solarwall technology is now being installed in industrial and commercial buildings in North America and Europe and the technology has recently been licensed in Japan.

- A procedure for comparative analysis of state-of-the-art building energy simulation tools is finding widespread application in a number of member countries.

- A new vacuum glazing technology developed under the Agreement has been commercially launched.

Wind energy has emerged as a commercial option in parts of the world with good wind resources. Its use is growing rapidly. The Implementing Agreement on Wind Turbine Systems is undertaking a range of activities with the aim of promoting and fostering the use of wind energy, where feasible.

Examples of how the IEA Wind Agreement has contributed to the development and deployment of technology include:

- Practices for wind turbine testing and evaluation developed under the programme have served as the basis for the national and international standards. This harmonisation facilitates the transfer and acceptance of technology by enabling different countries to accept foreign certification procedures in lieu of their own.
- Concepts tested under the programme are now used in commercial wind turbines.
- Data produced by the Agreement provides a basis for on-going research and development aimed at improving the cost and performance of wind turbine systems.

Wind turbines against a background of an oil refinery in the Netherlands. These 1 MW turbines incorporate technology developed under the Implementing Agreement on Wind Turbines.

Energy End-Use Technologies

Improved energy end-use technologies offer the potential to contribute to economic, environmental and energy-security goals. IEA Implementing Agreements are playing a role in disseminating information on best-practice technologies already in the market place, in demonstrating near-term technologies and in developing advanced technologies for application in the medium to longer terms.

The scope of work covered by energy end-use technology Implementing Agreements is very diverse. The nature of collaborative programmes is also diverse, reflecting the different characteristics, such as the commercial maturity of the technology, the nature of industry in the sector and the types of energy used.

Buildings

Energy use in buildings is an important focus of activity. Government support for research, development, demonstration and deployment is particularly important in the sector, because there is no natural owner for many relevant technologies. This arises because the diffuse nature of end-users makes it hard for the private sector to capture the benefits of much research and development. In addition, the building industry is generally regional or national in nature, and so there is room for productive international collaboration on technologies which are near commercialisation.

Achievements of the Buildings and Community Systems Agreement include:

- Techniques for energy efficient methods to avoid condensation in buildings have been developed. This is vital for the construction and retrofit of energy efficient buildings.
- New information technology has been used to develop systems to link building energy management systems to remote monitoring and control centres via the Internet. Strong co-operation with industry is leading to the increased use of this technology.

■ Numerous guides have been produced and are finding widespread use with practitioners and researchers. For example, the Guide to Ventilation, which is specifically aimed at policy-makers, architects, building services engineers, designers and building owners and occupiers, who need to acquire a background knowledge of ventilation, is used as a teaching text in several universities.

■ Technologies such as night cooling, air flow and building optimisation, and fault diagnosis have been successfully deployed. For example, algorithms developed under the Agreement are being used in design guides and building energy simulation models.

The Implementing Agreement on Buildings and Community Systems has a large work programme aimed at reducing energy consumption in non-industrial buildings. The work of this Agreement is closely co-ordinated with and complements that of the Implementing Agreement on Solar Heating and Cooling.

Transport

The almost total reliance of the transport sector on oil and its large share of total oil use (60 per cent) are the major reasons behind concerns about long-term energy security. Transport, because of its large share of total energy use (some 32 per cent of final energy consumption) is also a large contributor to emissions of greenhouse gases. Road transport, which accounts for 83 per cent of transport energy use, is the major source of urban air pollution in many countries. Continued technology development is essential to address these issues.

Government funded research in the transport sector is heavily outweighed by private sector research - especially by motor vehicle and engine manufacturers. Nevertheless, there are niches of activity where international collaboration can be productive. In particular, there are opportunities to link private sector researchers in different countries, or link the private and public sectors. There are several areas where pre-competitive technology

development can take place. Similarly, there are opportunities to develop common test methods and standards.

The Implementing Agreement on High Temperature Materials has been focusing on standardisation of testing and characterisation methods for high performance ceramics for advanced engines and other applications to enhance energy efficiency.

> Information generated by the Agreement on High Temperature Materials is being used by relevant standards organisations in Member countries and has influenced activities of existing research bodies. Results have also led to the creation of new bodies in several countries, for example, the establishment of consortiums of companies in Japan and the United States to further advance concepts initiated under the Agreement.

The Implementing Agreement on Hybrid and Electric Vehicles shares technical and policy information on hybrid and electric vehicle technologies and systems. Work under the Agreement has provided useful input for the development of national programmes.

It has also underpinned movement towards the development of an international consensus on the environmental impacts of electric vehicles. Depending on such factors as the electricity generating mix in a country, electric vehicles can, at a minimum, shift emissions out of urban areas to power stations, and, at a maximum, make major contributions to reductions in emissions of greenhouse gases and oil use.

The Implementing Agreement on Advanced Motor Fuels allows participants to assess the current state of technical and environmental performance of alternative motor fuels. The main achievements of the Agreement include authoritative source books on fuel assessment and comparison.

The Automotive Fuels Information Service, an activity under the Implementing Agreement on Advanced Motor Fuels, surveys relevant publications about road transport fuels. Information is systematically organised, assessed,

interpreted and processed to provide a sound overview of the current state of affairs in any part of the field.

The Automotive Fuels Information Service has undertaken a major analysis of all current and potential vehicle fuels. The study examined the raw materials/conversion and the distribution/use of each fuel type and provided an estimate of the potential supply, processing, transport and use costs, storage techniques and emissions at each stage of the energy chain. The interim conclusions of the study suggest that switching to alternative fuels will involve higher costs, but would be significantly more environmentally-friendly. The study also concludes that the introduction of a new fuel would take around ten years to penetrate the vehicle fleet.

The Energy Industry

Collaboration relating to the energy industry, especially among electricity and district heating and cooling utilities, provides an opportunity for utilities to share the costs of developing new technologies. Productive collaboration can often occur because utilities do not always compete in the same market.

Demand-Side Management (DSM), Superconductivity and District Heating and Cooling are the three Agreements in the energy industry category.

The Implementing Agreement on Demand-Side Management aims at allowing energy systems and utility investments to function more effectively and enhancing the value of investments for gas and electricity customers. The on-going restructuring of utility business in many countries has underlined the importance of sharing and transferring experiences, replicating successes and avoiding mistakes to assist the successful introduction and use of DSM techniques. One notable task involves consideration of DSM and energy efficiency in the changing electricity business environment.

The information shared through the Implementing Agreement on Superconductivity has helped the national programmes of member countries in evaluating the future importance of ceramic superconductors to the electricity supply industry. Representatives from utilities, research organisations and government come together at international meetings. A large number of publications have contributed to the information sharing process.

Achievements in the field of Demand-Side Management include:

■ Major breakthroughs in shaping communication instruments have enabled utilities to meet customers' needs more efficiently.

■ Software has been developed which will be used in an EU supported evaluation project.

■ The procurement programme, in which purchasers group together and seek bids for energy efficient equipment, has led to major improvements in energy efficiency in two areas. The first of these is the development of a clothes dryer which reduces energy use by 50 per cent and is now entering the market. The second involves the development of more efficient electric motors which cut losses by 25 to 50 per cent compared with average motors. These motors will also have a longer life because operating temperatures are reduced.

The essence of a good end-use technology is one the consumer finds at least as easy to use as the older technology. This energy-efficient clothes dryer, developed as a result of the activities of the Implementing Agreement on Demand-Side Management, is virtually indistinguishable from conventional models in looks and operation. However, by using heat pump technology, it uses only half the energy.

The Implementing Agreement on District Heating and Cooling is studying a range of technology issues. Technology deployment flows from the organisations involved in the work programme and through special seminars. The Agreement has produced a large number of publications, including a handbook on district heating.

Industry

The Implementing Agreements on Pulp and Paper and Process Integration deal directly with the industrial sector. The relatively small number of Agreements in the industry sector reflects the competitive nature of research undertaken by industry. Nevertheless, there are opportunities for productive collaboration in some pre-competitive areas.

The Implementing Agreement on Pulp and Paper has undertaken a task on life-cycle assessment, focussing on energy consumption and environmental impacts. Tasks recently completed focussed on the recovery and use of black liquor. The improved techniques developed from this work will reduce energy use and environmental impacts. Participants include representatives from governments, universities and industry, thus enabling the new knowledge gained to flow directly to industry.

The initial work of the Implementing Agreement on Process Integration, which began in 1995, has focused on surveying recent advances in process integration methods, software, and applications, as well as the needs of consumers. This was a first step towards the further development and implementation of process integration technologies in industry. As part of its initial work, the Agreement developed a Catalogue on Process Integration, which is a unique collection of information about technology developers, software, consultants, text books and other relevant data. The Catalogue briefly describes and classifies existing and emerging methodologies.

Cross-Cutting Technologies

Cross-cutting technologies, that is those which are applicable to a range of end-use sectors, are an important area for collaboration. The nature of Agreements in this area vary depending on the nature of the technology involved.

The Implementing Agreement on Energy Conservation and Emissions Reduction in Combustion is investigating combustion processes in applications including automobile and truck engines, gas turbines, and furnaces and process heaters, as well as fundamental physical phenomena relevant to the combustion process. A high degree of industrial involvement ensures that industrial needs are met and that technology reaches the marketplace. One of the main achievements has been the development of robust diagnostic capabilities.

Improving efficiency of heat transfer and heat exchangers can improve the efficiency of energy use, including new cost-effective ways to recover waste heat. The Implementing Agreement on Heat Transfer and Heat Exchangers is co-ordinating the research and the exchange of experimental results and modelling work.

The Implementing Agreement on Heat Pumping Technologies covers research, development, demonstration and deployment of heat pumping technologies for applications such as space heating and cooling, and refrigeration. A study under the Agreement found that industrial heat pumps had the potential to reduce global industrial energy demand by 2 to 5 per cent. The Agreement also operates the Heat Pump Centre, referred to in the section on Information Centres.

The Implementing Agreements on Heat Pumping Technologies and Energy Storage developed concepts which are used in the design, application and promotion of heat pumps in buildings. An example is the ground-based heat pump in this commercial building in the Netherlands, where the ground-based heat pump system saves 7 per cent of electricity requirements and 84 per cent of natural gas. Carbon dioxide emissions are reduced by 52 per cent.

A recent highlight from the work of the Heat Pumping Technologies Agreement was the establishment of world-wide standard reference data on the properties of the new refrigerants, which have been sanctioned by the International Institute of Refrigeration.

Activities in Aquifer Thermal Energy Storage (ATES) Systems began in Belgium in 1994 with a feasibility study undertaken at the request of the Ministry of Economic Affairs of Flanders. This study included a survey of energy storage systems and related activities in Europe. The collection of data and rapid market introduction of ATES in Belgium was made possible by an intensive exchange of knowledge and experience with other countries. This involved the participation of Belgium in Annex 8 (Implementing Underground Thermal Energy Storage Systems) of the IEA Implementing Agreement on Energy Conservation through Energy Storage and bilateral co-operation between Belgium and the Netherlands within the framework of the EC THERMIE-B programme.

Two years of intensive action has resulted in a wide knowledge of ATES within the Belgian market and a number of feasibility studies have been undertaken.

In the autumn of 1996, the first ATES System was installed in Flanders. The project involved integrating a cold/heat storage system in an aquifer into existing infrastructure in a large commercial building. It replaced a previous (non-ATES) system which had not functioned adequately. The new system involved a capital expenditure of $650,000 and has provided a substantial energy saving.

A second major project involving an ATES system in a new 440 bed hospital has recently been completed.

Five other potential projects are being considered.

The Implementing Agreement on Energy Conservation through Energy Storage is working on the development of advanced energy storage technologies for application in a range of energy systems. The work programme includes both thermal and electrical energy storage systems. Work has influenced large plants in the USA, Sweden and Germany.

The Implementing Agreement on Advanced Fuel Cells operates through the co-ordination of activities in participating countries, task sharing and information exchange. Examples of how the work programme is contributing to technology development include compilation of an inventory of molten carbonate fuel cell stack and system testing procedures, and development of an improved model for the steam reforming of methanol.

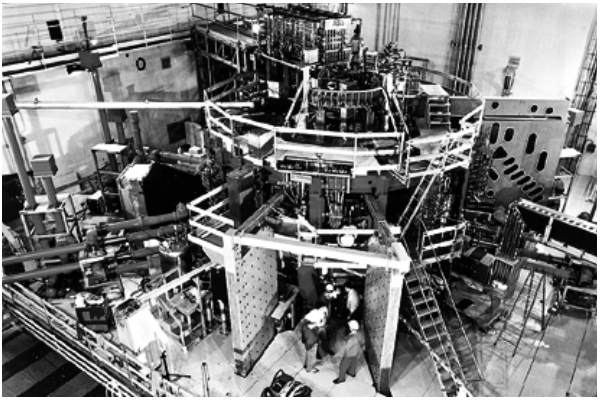
The Implementing Agreement on Energy Technology Systems Analysis Programme (ETSAP) concerns the application and ongoing development of a family of computer models named MARKAL (for MARKet ALlocation). This system allows policy analysts and decision-makers to identify and explore feasible energy technology scenarios that balance energy budgets and meet a range of environmental requirements at minimum overall cost. The current research emphasises dealing with uncertainties, whether they be in the form of eventual environmental requirements or the availability or acceptability of certain technologies.

ETSAP has contributed to policy development in many countries. Over 70 teams in more than 35 counties around the world make use of the MARKAL family of energy/economy/environment models. These have been used to perform analyses in support of national emission inventory and abatement studies, for example, to provide input to national communications in the United Nations Framework Convention on Climate Change (UNFCCC) process. The work also contributed to IEA/OECD studies for Annex-1 Experts Group of the UNFCCC Kyoto Statement. The model has also been used by some countries, notably the United Kingdom and the Netherlands, as a tool in developing policy and priorities for energy R&D.

Fusion Power

Fusion power has the potential to become a major supplier of the world's energy needs in the long term. The resources needed for its operation are effectively limitless, it would have low environmental impacts and it produces no greenhouse gases.

A large amount of research has been devoted to fusion power, and a number of very large scale experimental devices have been constructed and operated around the world. As a result of these efforts, fusion power is now ready for technical demonstration. The proposed vehicle for this demonstration is the International Thermonuclear Experimental Reactor (ITER). Detailed assessment of the proposed ITER design concluded that it was both comprehensive and based on established physics and technologies. The question of whether to proceed with the construction of ITER is currently under consideration by a consortium consisting of the European Commission, Japan, Russia and the United States.



This picture shows the ASDEX Upgrade, a research Tokamak in Germany. The experiments undertaken in this and other research establishments are co-ordinated through the Implementing Agreements on fusion power.

Although the basis for demonstrating the technical feasibility of fusion power has been established, there are a number of possible technological approaches, both within the Tokamak concept proposed for ITER, and alternative confinement concepts such as the Stellarator concept and Reversed Field Pinches. Some countries believe that the technology development and basic science should be pursued and further refined before proceeding to demonstration, even though this would delay the possible commercial exploitation of fusion power. Other countries, however, believe that demonstration should be pursued as quickly as possible.

Even if an early decision is made to commence construction of ITER, the commercialisation of fusion power will be a very lengthy process. The construction of ITER is expected to take about ten years, which would then be followed by a period of operation spanning some years. The next stage after ITER would be full demonstration to establish commercial-scale technical feasibility and overall economics. The design and construction of such a plant would take at least ten years. Once built, perhaps ten years of operation would be required to demonstrate economics fully. On this basis, commercial scale demonstration of fusion power could occur within 30 to 40 years.

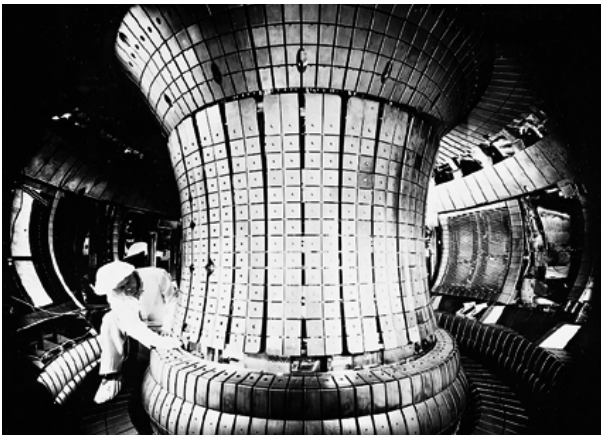
Nuclear fusion research is inherently complex, requiring the use of advanced equipment, and is therefore costly. Its successful exploitation in the longer term will require a long-term, steady commitment from governments. This is where international collaboration can play a critical role. Besides enhancing the gathering and exchange of scientific information, international collaboration provides mechanisms for co-ordinating distributed programmes and for cost-sharing on larger, unique facilities. Such co-ordination and cost-sharing allow a greater number and variety of experiments to be carried out than would otherwise be possible.

The IEA's programme of research and development in fusion power is managed by the Fusion Power Co-ordinating Committee. The programme provides co-ordination for over half of the world's fusion research effort. The scheduling of experiments, sharing of experimental equipment and the sharing of results provided through the programme greatly increases the efficiency and effectiveness of the global research effort.

The IEA programme is closely co-ordinated with national research programmes and with other international programmes, including the European Atomic Energy Community (EURATOM).

The working substance in a fusion reactor where the energy is released is known as a plasma. The temperatures and pressures of the plasma are so high that it is not possible to confine it using any known materials. Most concepts for harnessing fusion power require the use of magnetic fields to confine the plasma. Of the ways in which magnetic fields can be used, the most developed and promising concept is the Tokamak. In this concept, the plasma is confined within a torus, which is a doughnut shaped ring, by the magnetic field.

The IEA Implementing Agreements include work on both Tokamaks and alternative confinement concepts, and include studies of plasma physics and confinement technology, as well as work on components for fusion reactors such as first walls (that is, the material wall facing the plasma) and breeder blankets (which would be located inside the first wall of a reactor and would produce the fuel).



The heart of a Tokamak. This is the inside of the ASDEX Upgrade, a research Tokamak in Germany.

The Implementing Agreement on Three Large Tokamaks enables researchers at each of the world's three large Tokamak facilities - EURATOM's JET, Japan's JT-60 and the United States' TFTR - to co-ordinate research activities. Co-operative research at these facilities is fundamental to improving understanding of the physics of the operational regime for the ITER. High capacity, dedicated communications links allow remote participation in experiments and exchange of detailed information. This has enabled the different institutions involved in the collaboration to use a range of different techniques to analyse the outcomes of experiments. This co-operation has enabled the best use to be made of the different capabilities of the large Tokamaks in developing the necessary physics basis and testing reactor components.

The main focus of the Implementing Agreement on Toroidal Physics in, and Plasma Technologies of, Tokamaks with Poloidal Field Divertors (divertors are devices to shape the magnetic field which confines the plasma) is edge physics (which covers subjects such as poloidal field configuration, energy transfer to first walls, control of impurities, and helium pumping) and plasma control. Collaborative activity is concentrated on plasma shape and position

control. The ability to compare results of experiments from different machines with different characteristics has played an important role. Research undertaken and databanks developed under the Agreement are helping in developing concepts for incorporation in ITER. Future activity of the Agreement will continue to be directed towards the design of ITER, including the divertor and confinement.

The Implementing Agreement on Plasma Wall Interaction in TEXTOR (Torus Experiment for Technology Orientated Research) is based on a particularly strong and valuable collaboration between Canada, EURATOM, Japan, Switzerland and the United States. The collaboration has led to a large number of specific actions. Work under the Agreement has contributed to the solution of problems concerning the interaction between the plasma and the reactor wall; including controlled heat transfer onto and through the wall, impurities released from the wall, retention of the nuclear fuel (tritium) in the wall and removal of the helium ashes produced by the fusion process. It has enabled the partners to make use of the TEXTOR-94 facility to progress technology development. It has also enabled the transfer of knowledge from TEXTOR-94 to other research facilities, contributing to the total development process.

The Stellarator Concept is an alternative to the Tokamak concept and has the potential to provide a more integrated and effective confinement field. World Stellarator research is now moving from mid-size experiments to large scale experiments. The theory of the underlying physics has matured and experimental verification of the theoretical predications is expected. The Implementing Agreement on the Stellarator Concept has provided the possibility to collect all the world activities on stellarators (except the Ukraine, which is expected to join the activity shortly) in one co-ordinated programme, allowing joint participation in the experiments, joint development of theory and information sharing activities. Co-ordinated research utilises the diversity of available Stellarator experimental devices to conduct matched experiments with comparable scales in differing devices.

The Implementing Agreement on Reversed Field Pinches is developing this magnetic confinement concept through task sharing, co-ordination of research activities and information exchange, including through exchange of personnel. Differences between existing experiments means that their results complement one another and co-ordinated activities are underway

to compare and optimise the results from the different laboratories. In this way, the collaborative framework enables the results of the many small individual efforts to be combined to effectively form a significant research programme. Recently, several laboratories working on the Reversed Field Pinch concept have demonstrated improved confinement, one of the major challenges to the concept.

The Implementing Agreement on Fusion Materials investigates fusion reactor components and studies the effects on materials from the expected environment in the reactor. The work is aimed at the development of data needed by ITER and other fusion system design activities. The development of a high-flux neutron source for materials testing has been investigated and agreement has been reached to initiate its development. Methods for materials testing have been developed. A range of candidate materials has been investigated and promising materials identified.

The Implementing Agreement on Nuclear Technology of Fusion Reactors focuses on the technology of components relating to tritium production and processing and radiation shielding of components and personnel. The work programme includes formulating a research and development programme to conduct experiments on prototype components and verify computational methods and computer codes for analysing component behaviour. Experiments are being undertaken to verify computer methods. Participants have begun concept definition for a high-volume, plasma-based neutron source which would be used to test components.

The Implementing Agreement on the Environmental, Safety and Economic Aspects of Fusion Power conducts studies on the development, validation and the data requirements of environmental and safety analysis models and computer codes, as well as work on the economic aspects. The studies compare methods to ensure consistency and accuracy and the development of databases for safety analysis, together with experiments to validate these methods. The work has helped guide participants' own national research programmes.

POTENTIAL DISADVANTAGES

The potential *disadvantage* of collaboration is that a country risks missing an opportunity to gain a competitive advantage. However, the importance of this consideration depends on a number of factors, including the characteristics of the industry that would apply the technology and the maturity of the technology. Regional or local industries are thus less likely to be concerned about competitive advantage than industries that are multi-national. This is one of the reasons why the collaborative research programmes relating to building energy use - the Implementing Agreement on Buildings and Community Services and the Implementing Agreement on Solar Heating and Cooling - are amongst the largest Agreements under the Programme.

The further a technology is from the market place, the less concerned participants are likely to be about loss of possible competitive advantage. Even in technology areas close to the market place there may well be areas of common non-proprietary interest where collaboration can be mutually beneficial. For example, the development of system components or understanding of issues common to a range of competing "core" technologies, may be fruitful areas for collaboration.

APPENDIX 1: PARTICIPATION IN IMPLEMENTING AGREEMENTS

PARTICIPATION IN AGREEMENTS ON INFORMATION CENTRES, 15 January 1999

	EETIC	ETDE	Gas Technology Information Centre	IEA Coal Research	Total
Australia	●			●	2
Austria				●	1
Belgium	●	●			2
Brazil		●			1
Canada	●	●		●	3
Denmark	●	●	●	●	4
European Commission	●		●	●	3
Finland	●	●		●	3
France	●	●			2
Germany	●	●			2
Italy	●	●		●	3
Japan	●	●	●	●	4
Korea	●	●			2
Mexico		●			1
Netherlands	●	●		●	3
New Zealand	●		●		2
Norway	●	●			2
Poland		●		●	2
Portugal			●		1
Russia			●		1
Spain		●	●	●	3
Sweden	●	●		●	3
Switzerland	●	●			2
United Kingdom	●	●		●	3
United States	●	●	●	●	4
Total	18	19	8	14	59

Note: Some countries may be inactive or in the process of withdrawing.

PARTICIPATION IN AGREEMENTS ON FOSSIL FUELS, 15 January 1999

	Coal Combustion Sciences	Enhanced Recovery of Oil	Fluidised Bed Conversion	Greenhouse Gases	Multiphase Flow Sciences	Total
Australia	●	●		●	●	4
Austria		●				1
Canada	●	●	●	●	●	5
Denmark	●	●		●		3
European Commission				●		1
Finland	●		●	●		3
France		●	●			2
Germany	●					1
Italy	●		●	●		3
Japan	●	●	●	●		4
Korea			●	●		2
Mexico	●				●	2
Netherlands	●			●		2
New Zealand				●		1
Norway		●	●	●	●	4
Poland				●		1
Portugal			●			1
Russia		●				1
Spain			●	●		2
Sweden	●		●	●		3
Switzerland				●		1
United Kingdom	●	●	●	●	●	5
United States	●	●		●	●	4
Venezuela				●		1
Total	12	10	11	18	6	57

Note: Some countries may be inactive or in the process of withdrawing.

PARTICIPATION IN AGREEMENTS ON END-USE TECHNOLOGIES, 15 January 1999

	Advanced Fuel Cells	Advanced Motor Fuels	Buildings and Community Systems	Energy Efficiency in Combustion	Demand Side Management	District Heating and Cooling	Hybrid and Electric Vehicles	Energy Storage
Australia	●		●		●			
Austria					●		●	
Belgium		●	●	●			●	●
Canada	●	●	●	●	●	●	●	●
Denmark	●		●		●	●		●
European Commission								●
Finland		●	●		●	●	●	●
France	●		●		●		●	
Germany	●		●	●		●	●	●
Greece			●					
Ireland								
Israel			●					
Italy	●	●	●	●	●		●	●
Japan	●	●	●	●	●		●	●
Korea	●				●	●	●	
Netherlands	●	●	●		●	●	●	●
New Zealand	●		●					
Norway	●		●	●	●	●		
Poland			●					
Portugal			●					
South Africa							●	
Spain					●			
Sweden	●	●	●	●	●	●	●	●
Switzerland	●		●	●	●		●	
Turkey			●					●
United Kingdom	●	●	●	●	●	●	●	●
United States	●	●	●	●	●	●	●	●
Total	15	9	21	10	16	10	15	13

Note: Some countries may be inactive or in the process of withdrawing.

PARTICIPATION IN AGREEMENTS ON END-USE TECHNOLOGIES, 15 January 1999 (continued)

	Heat Pumping Technologies	Heat Transfer and Exchangers	High Temperature Materials	Process Integration	Pulp and Paper	Super Conductivity	Systems Analysis	Total
Australia							●	4
Austria	●						●	4
Belgium	●		●		●	●	●	10
Canada	●			●	●	●	●	13
Denmark	●			●		●	●	9
European Commission							●	2
Finland				●	●	●		9
France	●							5
Germany	●	●	●			●	●	11
Greece							●	2
Ireland							●	1
Israel						●		2
Italy	●					●	●	10
Japan	●		●			●	●	11
Korea						●	●	6
Netherlands	●	●			●	●	●	12
New Zealand								2
Norway	●	●			●	●	●	10
Poland								1
Portugal				●				2
South Africa								1
Spain	●				●		●	4
Sweden	●	●	●	●	●	●	●	15
Switzerland	●	●		●		●	●	10
Turkey						●	●	4
United Kingdom	●	●		●	●	●	●	14
United States	●	●	●		●	●	●	14
Total	15	7	5	7	9	16	20	188

Note: Some countries may be inactive or in the process of withdrawing.

PARTICIPATION IN AGREEMENTS ON RENEWABLE ENERGY, 15 January 1999

	Bio-energy	Geo-thermal	Hydro-gen	Hydro-power	Photo-voltaic Power Systems	Solar Heating and Cooling	Solar PACES	Wind Turbine Systems	Total
Australia		●			●	●	●	●	5
Austria	●				●	●		●	4
Belgium	●					●			2
Brazil	●						●		2
Canada	●		●	●	●	●		●	6
China				●					1
Croatia	●								1
Denmark	●				●	●		●	4
Egypt							●		1
European Commission	●	●	●		●	●	●	●	7
Finland	●			●	●	●		●	5
France	●			●	●	●	●		5
Germany			●		●	●	●	●	5
Greece		●				●		●	3
Israel					●		●		2
Italy	●		●	●	●	●		●	6
Japan	●	●	●	●	●	●		●	7
Korea					●				1
Mexico		●			●		●	●	4
Netherlands	●		●		●	●		●	5
New Zealand	●	●				●		●	4
Norway	●		●	●		●		●	5
Portugal					●				1
Russia							●		1
Spain			●	●	●	●	●	●	6
Sweden	●		●	●	●	●		●	6
Switzerland	●	●	●		●	●	●	●	7
Turkey			●		●	●			3
United Kingdom	●	●	●	●	●	●	●	●	8
United States	●	●	●		●	●	●	●	7
Total	18	9	13	10	21	21	13	19	124

PARTICIPATION IN AGREEMENTS ON FUSION POWER, 15 January 1999

	ASDEX Upgrade	Environmental and Safety	Fusion Materials	Large Tokamaks
Australia				
Canada		●	●	
China			●	
EURATOM	●	●	●	●
Japan		●	●	●
Russia		●	●	
Switzerland			●	
Turkey				
United States	●	●	●	●
Total	2	5	7	3

PARTICIPATION IN AGREEMENTS ON FUSION POWER, 15 January 1999 *(continued)*

	Nuclear Technology of Fusion Reactors	Reversed Field Pinches	Stellarator Concept	TEXTOR	Total
Australia			●		1
Canada	●			●	4
China					1
EURATOM	●	●	●	●	8
Japan	●	●	●	●	7
Russia	●		●		4
Switzerland				●	2
Turkey				●	1
United States	●	●	●	●	8
Total	5	3	5	6	36

Note: Some countries may be inactive or in the process of withdrawing.

APPENDIX 2: DESCRIPTIONS OF IMPLEMENTING AGREEMENTS

ENERGY AND ENVIRONMENTAL TECHNOLOGIES INFORMATION CENTRES

Dissemination of information is essential to the deployment of energy technologies. The Energy and Environmental Technologies Information Centres (EETIC) plays a key role in this process by complementing national programmes for energy technology demonstration to make available information from other countries.

EETIC is an umbrella Implementing Agreement which came into being in 1996 with the merger of the Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET) and the Greenhouse Gas Technology Information Exchange (GREENTIE).

CADDET's objective is to disseminate information on newly demonstrated technology. It has two operations: CADDET Energy Efficiency and CADDET Renewable Energy.

CADDET Energy Efficiency and CADDET Renewable Energy collect, analyse, and distribute information on energy technologies. Products include regular newsletters, technical brochures and range of other supporting information. Through these publications, CADDET disseminates high quality, up-to-date information that assists decision-makers evaluate energy efficiency and renewable energy technologies.

GREENTIE's objective is to improve the awareness of, and facilitate the access to, suppliers and experts of 'clean technologies', particularly technologies that help mitigate the emissions of greenhouse gases.

GREENTIE operates a world-wide database, the Directory, which contains contact details for more than 9,000 suppliers of technology and expertise. GREENTIE has a network of Liaison Offices in 37 countries around the world, which help maintain the Directory, and also promote and distribute it to policy planners, decision-makers and scientists in government and industry. Both registration in the Directory and access to it is free of charge.

EETIC operations are funded by participant contributions to common funds to operate the Centres themselves. In addition, participants incur costs in preparing and providing data.

There are Contracting Parties from 17 countries (Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Korea, the Netherlands, New Zealand, Norway, Sweden, Switzerland, the United Kingdom and the United States) and the European Commission.

CADDET Energy Efficiency, CADDET Renewable Energy and GREENTIE have Internet sites:

CADDET Energy Efficiency	http://www.caddet-ee.org/
CADDET Renewable Energy	http://www.caddet-re.org/
GREENTIE	http://www.greentie.org/

- Further information on EETIC is available from:

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Novem
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6130 AA Sittard
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Tel: 31 46 4202 205, Fax: 31 46 4510 389
E-mail: g.van.hoof@novem.nl

CADDET Renewable Energy
ETSU
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Oxfordshire OX11 0RA
United Kingdom
Tel: 44 1235 43 27 19, Fax: 44 1235 433 595
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GREENTIE
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ENERGY TECHNOLOGY DATA EXCHANGE

Within Energy Technology Data Exchange (ETDE) Member countries energy research and development is being conducted by tens of thousands of researchers in thousands of research institutions. More than $10 billion is provided annually to support this activity. This research effort generates a huge amount of information. Ensuring the optimum utilisation of such a massive amount of information is an enormous undertaking.

ETDE's principle objective is to ensure the exchange of such research information. Since 1987, ETDE has provided a comprehensive bibliographic database of energy research and technology information, which enables researchers to locate other relevant research and researchers in ETDE Member countries and beyond. Government reports, journal articles, conference papers, technical reports, books, theses, and other sources are abstracted and indexed and made available on the electronic database. The full texts of hard-to-locate materials such as government reports and conference proceedings are also made available to users. ETDE's Energy Database contains the world's largest collection of energy literature, and is updated twice monthly.

Input to the database is provided on a task-sharing basis by participants who are responsible for preparing, to a common format, citations and English language abstracts of pertinent information published within their boundaries. This input is consolidated by an Operating Agent and the resulting database is then made available to everyone in participating countries via commercial on-line host systems, compact disk products, and through local products and services such as in-house database systems or publications.

ETDE contributes materially to the efficiency of research by reducing the time required to locate information, reducing duplication of research efforts and helping establish productive collaborative activities. There are many testimonials which demonstrate these benefits.

The Exchange is integrated with major databases in the energy field such as the International Atomic Energy Agency's International Nuclear Information System, and the Coal Abstracts Database of IEA Coal Research.

The operation of ETDE is funded by participant contributions to a common fund. In addition, participants bear the costs of preparing and providing input to the database.

There are Contracting Parties from 19 countries: Belgium, Brazil, Canada, Denmark, Finland, France, Germany, Italy, Japan, Korea, Mexico, the Netherlands, Norway, Poland, Spain, Sweden, Switzerland, the United Kingdom and the United States.

- For further information, visit the ETDE's Internet site at http://www.etde.org/ or contact the Operating Agent:

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Operating Agent Representative
IEA Energy Technology Data Exchange
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Oak Ridge, Tennessee 37831
USA
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Fax: 1 423 576 2865
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INTERNATIONAL CENTRE FOR GAS TECHNOLOGY INFORMATION

Demand for natural gas is growing faster than demand for other fossil fuels, with natural gas having increased its share of total energy demand from 18.4 per cent to 20.2 per cent over the decade from 1986 to 1996 and to 21.7 per cent in 1997. This pattern is expected to continue. Rapid and flexible means of providing up-to-date information on technology is critical to capturing the full potential environmental and economic benefits from the increased use of natural gas.

The International Centre for Gas Technology Information (ICGTI) seeks to meet this need. Its mission is to provide an international forum on gas technology information so that gas technologies are transferred and global gas market needs are met efficiently.

ICGTI provides user-friendly access to gas technology information through an Internet based system called GTI Online. This system provides information on gas technologies covering the complete fuel cycle: from exploration to end-use. Information includes technology research, market assessments, and gas industry global news. GTI Online also provides an online link between gas technology experts in member countries. The information provided through ICGTI also gives participating companies and countries an opportunity to develop and expand collaboration with non-competing firms and organisations to co-fund research and development.

An example of how the ICGTI is contributing is its role with the International Institute for Energy and Environment. This Institute, which is a non-profit, non-governmental organisation, was established by collaboration between the US Environment Protection Agency (EPA) and Russia's Gazprom. It provides a single focus for methane emission reduction activities across the entire Russian oil and gas sectors and encourages technical, educational and commercial co-operation. ICGTI aids the EPA in monitoring the Institute's activities to ensure that it meets the EPA approved project plan.

More than 800 companies are registered to use GTI Online, demonstrating its commercial relevance. The GTI Online directory also includes a list of thousands of firms active in the global gas industry.

The operations of ICGTI are funded by participant contributions to a common fund.

There are Contracting Parties from 7 countries (Denmark, Japan, New Zealand, Portugal, Russia, Spain, and the United States) and the European Commission. In addition, there are test members, observers and subscribers from Australia, Brazil, Canada, Finland, Germany, the Netherlands, Poland, Sweden, Trinidad & Tobago, and the United Kingdom.

- For further information, visit the ICGTI Internet site at http://www.icgti.org/ or contact the Headquarters Office at:

1600 Wilson Blvd. Suite 900
Arlington, VA 22209
USA
Phone: 1 703 526 7810
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E-mail: icgti@gri.org

IEA COAL RESEARCH - THE CLEAN COAL CENTRE

Coal is the world's largest source of energy for stationary applications and currently supplies almost 40 per cent of the world's electricity. Coal is expected to remain as the single largest source of electricity for the foreseeable future, even though other sources, such as natural gas and renewables, are expected to take an increasing share. Coal's role as a fuel for electricity generation in developing countries, in particular, is expected to show strong growth. It is critical, therefore, that the best use is made of coal technologies to ensure that this fuel contributes to capturing economic opportunities and minimising adverse environmental impacts.

The objective of the IEA Clean Coal Centre is to enhance innovation and the development of coal as a clean source of energy by gathering, assessing and disseminating information on efficient coal supply and use. The success of the Centre in achieving this objective is demonstrated by its acknowledgement as the world's foremost provider of information on efficient coal supply and use.

The Centre gathers, assesses and distributes knowledge on the energy efficient and environmentally sustainable use of coal. Specific activities include:

- undertaking in-depth studies on topics of special interest;
- assessing the technical, economic and environmental performance;
- identifying where further research, development, demonstration and dissemination are needed;
- reporting the findings in a balanced and objective way; and
- showing, where appropriate, the opportunities for technology transfer world-wide.

The Centre also undertakes studies for members, and clients have reported favourably on the value of the Centre's extensive databases and expert search capabilities.

It is difficult to attribute a value to an organisation primarily generating underpinning knowledge and information. However, a recent survey of the

Centre's customers showed that 97 per cent had increased their knowledge of R&D or operational experience, and 73 per cent said that the Programme had contributed to actions leading to a reduction in the environmental impact of coal.

The Clean Coal Centre also produces a newsletter, which is available free of charge.

The operation of the Clean Coal Centre is funded largely by participant contributions to a common fund. However, some additional funding is derived from income from services.

There are Contracting Parties from 13 countries (Australia, Austria, Canada, Denmark, Finland, Italy, Japan, the Netherlands, Poland, Spain, Sweden, the United Kingdom and the United States) and the European Commission.

- For further information, visit the Clean Coal Centre's Internet site at http://www.iea-coal.org.uk/ or contact:

  Mr. Graham Broadbent
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  E-mail: mail@iea-coal.org.uk

COAL COMBUSTION SCIENCES

Coal is the world's largest source of energy for stationary applications. This role is expected to continue for the foreseeable future, even though other sources, such as natural gas and renewables are expected to take an increasing share. The use of coal as a fuel for electricity generation in developing countries, in particular, is expected to show strong growth. Technology development is a key to economic opportunities and minimising adverse environmental impacts.

The focus of the Implementing Agreement on Coal Combustion Sciences is the basic science of coal combustion. The specific objectives are to encourage, support and promote research and development that will lead to improved understanding and characterisation of conventional combustion processes; develop techniques that control and reduce solid, liquid and gaseous emissions associated with combustion processes; improve operating efficiency; and identify methods for the effective utilisation of combustion by-products.

The Agreement embraces a wide range of activities associated with coal combustion, including work related to advanced power generation technologies, improved modelling and diagnostic methods, and the development of low-NOx burners.

The work of the Agreement has led to numerous commercial applications, including the development of a new generation of low-NOx burners which has already achieved sales of over $400 million in one participating country.

The work programme is conducted using both task sharing and cost sharing. The cost shared component involves a common fund which is used to support coal research studies at the International Flame Research Foundation in the Netherlands.

There are Contracting Parties from 12 countries: Australia, Canada, Denmark, Finland, Germany, Italy, Japan, Mexico, the Netherlands, Sweden, the United Kingdom, and the United States.

■ For further information, contact:

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ENHANCED RECOVERY OF OIL

Oil is the world's largest single source of energy. Transport is almost totally dependent on liquid fuels derived from crude oil. The development and deployment of advanced techniques to increase the amount of oil that can be recovered economically has the potential to make a large contribution to the world's oil supplies. This is particularly important given the relatively limited nature of the world's conventional oil resources, production from which could peak between the years 2010 and 2020.

The objective of the Implementing Agreement on the Enhanced Recovery of Oil is to evaluate and disseminate the results of research and development and to undertake demonstration, laboratory and field tests.

The work programme is largely one of basic research and laboratory investigations in areas of mutual interest. These include studies of fluids and interfaces in porous media, research on surfactants and polymers, development of techniques for gas flooding, thermal recovery, dynamic reservoir characterisation and emerging technologies. This work is contributing to technology development within the oil industry.

One major achievement has been the determination of the impact on crude oil composition of miscible carbon dioxide injection. This could ultimately provide benefits to the industry of hundreds of millions of dollars through savings in investment in enhanced oil recovery processes. Another achievement concerns the development of a new approach to reservoir simulation which is expected to lead to benefits of many tens of millions of dollars.

The work programme is conducted through task-sharing with participants conducting their own research and sharing results at an annual workshop.

There are Contracting Parties from ten countries: Australia, Austria, Canada, Denmark, France, Japan, Norway, Russia, the United Kingdom, and the United States.

- For further information, contact:

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FLUIDISED BED CONVERSION

Fluidised beds offer several advantages over pulverised fuel combustion, notably low NOx emission, in-process capture of SO_2, and the ability to burn a wide range of low-grade and potentially difficult fuels (including waste and biomass), as well as mixed fuels. The "conversion" (combustion or gasification) of solid fuels for production of heat and/or electricity can be made by various fluidised bed techniques working at atmospheric pressure or under pressure, usually: "bubbling" and "circulating" fluidised beds. Supercritical steam conditions can be used for fluidised bed boilers (atmospheric and pressurised) and efficiencies in the range of 45 per cent may be attained in the near future.

In addition, the technology can be employed for incineration. Existing units have been successfully used for the disposal of high level PCB contaminated wastes, oil remediation and the elimination of low calorific wastes. The technology is also widely used in the metallurgical industry among others.

The Implementing Agreement on Fluidised Bed Conversion aims to bring together experts wishing to work on common problems. The main activity is technical exchanges during meetings and workshops. Participants are carrying out research on operational issues in support of local commercial fluidised bed conversion activities and sharing the results. Mathematical modelling has been a major activity in the past and a "1D" model for atmospheric fluidised bed combustion of coal has been developed. The exchanges on "3D" modelling of gas/solid flows has also been very fruitful in permitting the development of knowledge of local solid concentration and heat transfer.

In addition, efforts are being developed in the field of solids attrition and fragmentation, NOx and N_2O formation and reduction, sorbent reactivity and sulphur capture mechanisms, bed sintering/agglomeration problems and ash utilisation.

The Agreement has published a series of compilations of outstanding papers on R&D activities in fluidised bed conversion and a guide-book for the use of the "1D" CFB combustion model.

There are active Contracting Parties from ten countries: Canada, Finland, France, Italy, Japan, Korea, Portugal, Spain, Sweden and the United Kingdom.

■ For further information, contact :

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GREENHOUSE GASES R&D PROGRAMME

The use of fossil fuels, at least until the medium term, will be necessary to underpin world economic development. However, combustion of fossil fuels produces greenhouse gases, especially carbon dioxide. Some reduction in emissions of greenhouse gases is the only way in which the continued use of fossil fuels can be reconciled with deep reductions in emissions.

The Greenhouse Gases R&D Programme has an important role to play in responding to the challenge posed by climate change through developing and demonstrating opportunities to reduce emissions from the use of fossil fuels.

The aims of the Greenhouse Gases R&D Programme are to evaluate technologies for reducing emissions of greenhouse gases from fossil fuel use, to disseminate information, to prepare research, development and demonstration proposals and, where appropriate, to conduct R&D projects. Activity under the programme initially focused on the capture and disposal of carbon dioxide from power stations and has since broadened to explore a range of opportunities for reducing emissions of greenhouse gases (for example, additional sources of carbon dioxide, other greenhouse gases and comparison with alternative mitigation options).

Work under the Programme includes studies, research and development projects and information dissemination. Three research and development projects have been initiated: geological storage of carbon dioxide, carbon dioxide recycle combustion, and modelling of ocean storage of carbon dioxide. The strong information dissemination component includes a regular newsletter, published reports, international conferences and an Internet home page.

Work under the Agreement has helped demonstrate the opportunity for continued use of fossil fuels, even under scenarios involving deep reductions in emissions of greenhouse gases. Findings from the Programme have contributed to the report of the Intergovernmental Panel on Climate Change.

Costs of the work programme are shared between participants.

There are Contracting Parties from 17 countries (Australia, Canada, Denmark, Finland, Italy, Japan, Korea, the Netherlands, New Zealand, Norway, Poland,

Spain, Sweden, Switzerland, the United Kingdom, the United States and Venezuela) and the European Commission. In addition, industries from the Netherlands, Germany, the United Kingdom and the United States are participating as Sponsors.

- For further information, visit the IEA Greenhouse Gases R&D Programme's Internet site at http://www.ieagreen.org.uk or contact:

  IEA Greenhouse Gas R&D Programme
  CRE Stoke Orchard Cheltenham
  Gloucestershire GL52 4RZ
  United Kingdom
  Phone: 44 1242 680 753
  Fax: 44 1242 680 758
  E-mail: mail@ieagreen.demon.co.uk

MULTIPHASE FLOW SCIENCES

Multiphase flow concerns the transport of mixtures of solid-liquid, solid-gas and liquid-gas materials. An improved understanding of multiphase flow phenomena has many applications in the energy sector, including for example, transport of pulverised coal in power stations, oil and gas recovery, transport of solids in slurry pipelines, and emulsions of crude oil in water. Improved knowledge in these areas will lead to more efficient and cost-effective energy production, transport and use technologies.

The Implementing Agreement on Multiphase Flow Sciences co-ordinates the exchange of information and complementary research tasks in a wide range of research programmes which are improving the understanding of the behaviour and properties of multiphase flow phenomena associated with obtaining energy from coal, oil and gas.

The coal related research is focused on granular material flows, the development of theory and computer codes for modelling multiphase flows, and the development of advanced instrumentation for characterising a material's flow behaviour and observing and measuring the flow. For oil, research has been directed at unconventional sources such as undersea and horizontal wells.

Information has been exchanged between national research teams on the science of multiphase flow phenomena relevant to the oil and coal industries, and energy use in process industries. Work has occurred in three main areas: gathering experimental data; mathematical modelling; and the development of innovative instrumentation. Projects have included the modelling of high viscosity oils in horizontal wells; particle transport in pipes and emulsions of water in crude oil; the mathematical modelling of granular flows; the development of laser instrumentation of flames; and the application of computer codes to model slurry behaviour.

Collaboration between countries takes the form of exchange of information and visits by scientists. Experts from government programmes, academia and industry are involved in the research. The Agreement is task shared.

There are Contracting Parties from six countries: Australia, Canada, Mexico, Norway, the United Kingdom and the United States.

■ For further information, contact:

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BIOENERGY

Biomass already makes a useful contribution to the world's energy supplies. However, there is potential for biomass to make a significantly larger, cost-effective contribution and, at the same time, to reduce adverse environmental impacts associated with the use of fossil fuels.

The Implementing Agreement on Bioenergy has the objective of realising the use of environmentally sound and cost-competitive bioenergy on a sustainable basis to make a substantial contribution to meeting future energy demands.

The production and use of bioenergy embraces a complex set of wide-ranging topics. This is reflected in the scope of the work being undertaken which includes the production, processing and utilisation of biomass resources for energy purposes. Work underway includes the technical improvement of biomass crop production technologies; development of systems and guidelines for environmentally sustainable and economic production of biomass for energy; combustion; thermal gasification; pyrolysis; techno-economic assessments; municipal and industrial solid wastes and refuse derived fuels; and analysis of bioenergy systems on a full fuel cycle basis to establish overall greenhouse gas balances.

The work is conducted through a series of tasks, each having a designated work programme. Each participating country makes a financial contribution towards administrative requirements, shares the costs of managing the tasks and provides in-kind contributions to fund participation of national personnel in the tasks.

By working closely with industrial partners during the research process, deployment tends to flow directly from the technical development stage and to be integrated with it. For example, the work of the Agreement has contributed directly to the expanded use of biofuels in European district heating schemes, and the application of short rotation forestry in Sweden. Work on greenhouse gas balances also has been very successful, generating new and useful knowledge, including a contribution to the Kyoto Protocol relating to net changes in greenhouse gas emissions by sources and removal by sinks.

There are Contracting Parties from 17 countries (Austria, Belgium, Brazil, Canada, Croatia, Denmark, Finland, France, Italy, Japan, the Netherlands, New Zealand, Norway, Sweden, Switzerland, the United Kingdom and the United States) and the European Commission.

- For further information, visit IEA Bioenergy's Internet site at http://www.forestresearch.cri.nz/ieabioenergy/home.htm or contact:

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GEOTHERMAL ENERGY

In some areas of the world with high grade resources, geothermal energy is already making a useful contribution to energy supplies. There are huge potentially available resources of geothermal energy, much of it in the form of hot dry rocks within the earth, which could potentially be harnessed to both make a large contribution to global energy supplies and to reduce emissions of greenhouse gases.

The Implementing Agreement on Geothermal Energy commenced in March 1997. It has the objectives of exchange of information, common development of new technologies, and disseminating information on the environmental advantages of geothermal energy.

Work underway includes identification of, and the development of means to avoid or minimise, adverse environmental impacts that can arise from the use of geothermal energy; development of hot dry rocks and other technologies for commercial heat extraction; and the commercial development of deep geothermal resources.

Athough the Agreement is relatively new, work in the tasks has commenced and linkages have been established.

The work programme is conducted through task sharing.

There are Contracting Parties from eight countries (Australia, Greece, Japan, Mexico, New Zealand, Switzerland, the United Kingdom and the United States) and the European Commission.

■ For further information, contact:

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Visit Professor Rybach's home page at:
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HYDROGEN

Hydrogen could well become the major component of clean sustainable energy systems in the longer term. It is relevant to all of the energy sectors - transportation, buildings, utilities, and industry. Hydrogen can provide storage options for intermittent renewable technologies such as solar and wind, and, when combined with emerging decarbonisation technologies, can reduce greenhouse gas emissions from continued fossil fuel utilisation.

The vision of the IEA Implementing Agreement on Hydrogen Production and Utilisation is one of clean sustainable energy supply of global proportions that plays a key role in all sectors of the economy. To achieve this vision, the work of the Agreement is directed towards the development of advanced technologies, including direct solar production systems and low-temperature metal hydrides and room-temperature carbon nanostructures for storage.

Hydrogen can be produced directly from sunlight and water by biological organisms and using semiconductor-based systems similar to photovoltaics. Hydrogen can also be produced indirectly via thermal processing of biomass or fossil fuels. Global environmental concerns are leading to the development of advanced processes to integrate sequestration with known reforming, gasification, and partial oxidation technologies for carbonaceous fuels. These production technologies have the potential to produce essentially unlimited quantities of hydrogen in a sustainable manner.

Storage of hydrogen is an important area for international co-operative research and development, particularly when considering transportation as a major user and the need for efficient energy storage for intermittent renewable power systems. Although compressed gas and liquid hydrogen storage systems have been used in vehicle demonstrations world-wide, the issues of safety, capacity, and energy consumption have resulted in a broadening of the storage possibilities to include metal hydrides and carbon nanostructures. Stationary storage systems that are high efficiency with quick response times will be important for incorporating large amounts of intermittent solar and wind power into the grid as base load power. Through the Hydrogen Implementing Agreement, a database of metal hydride material properties has been produced to aid in the development of this important storage technology (http://hydpark.ca.sandia.gov).

Achieving the potential benefits of a hydrogen system requires careful integration of production, storage and end-use components with minimised cost and maximised efficiency, and a strong understanding of environmental impacts and opportunities. System models combined with detailed life cycle assessments provide the platform for standardised comparisons of energy systems for specific applications. Individual component models form the framework by which these system designs can be formulated and evaluated.

There are Contracting Parties from 12 countries (Canada, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States) and the European Commission.

- Further information is available from the IEA Hydrogen Implementing Agreement's Internet site at http://www.eren.doe.gov/hydrogen/iea.htm or from:

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HYDROPOWER

Hydropower is a significant contributor to the world's energy supplies, providing nearly 20 per cent of all electricity generated. There are opportunities to increase this contribution while at the same time reducing the adverse environmental impacts associated with energy supply and use.

The Implementing Agreement on Hydropower Technologies commenced in 1995 with the objective of improving the technical and institutional aspects of the existing hydropower industry, and increasing the future deployment of hydropower in an environmentally and socially responsible manner.

Projects include:

- development of recommendations for best practices for upgrading existing hydropower facilities, with a focus on installations with a capacity of more than 10 MW;
- technological, organisational and regulatory issues related to small hydro projects (from 50 kW to 10 MW in capacity);
- developing recommendations for environmental impact assessments of hydropower projects, and criteria for application of associated mitigation measures; and
- preparation of methods and tools for education and training in hydropower.

The nature of activities includes information exchange about independent activities, informal co-ordination of activities, formal co-ordination through shared tasks and information exchange to achieve shared objectives, and formal co-ordination of cost shared projects. Many industries and utilities participate in the work of the Agreement.

The work programme is conducted using both common funds and task sharing. A common fund is also used to support the Executive Committee.

There are Contracting Parties from ten countries: Canada, China, Finland, France, Italy, Japan, Norway, Spain, Sweden and the United Kingdom.

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PHOTOVOLTAIC POWER SYSTEMS

Photovoltaics directly convert the energy in sunlight into electricity. Photovoltaic power is already in widespread use, largely for small scale stand-alone applications such as isolated homes, water pumping, telecommunications and navigation aids. In the near future, the most important applications of photovoltaics in IEA Member countries are expected to be decentralised generators connected to the grid, either integrated into buildings and structures, or ground-based plants to provide grid support and peak power, when cost reductions will encourage the ever larger deployment in these market segments.

The scope of the Implementing Agreement covers all aspects of photovoltaic systems, excluding photovoltaic cells and modules. The Agreement's mission is to enhance international collaboration to make photovoltaic energy a significant energy option in the near future. The Agreement has the objectives of reducing costs, increasing awareness and fostering market deployment by removing non-technical barriers. Efforts are also being made to enhance transfer of knowledge to developing countries.

Current activities include exchange and dissemination of information on the technical, economic and environmental aspects of photovoltaic power systems for utility applications; collecting and disseminating information on design and operational performance of systems and subsystems; the use of photovoltaic systems in stand-alone applications; developing and verifying technical guidelines for grid interconnection of dispersed photovoltaic systems; design and operation of modular photovoltaic plants for large-scale power generation; and the use of photovoltaics in the built environment.

The Agreement has led to the development of strong networks involving researchers, government and industry. It has enabled countries to share knowledge, including results obtained from large experimental facilities, such as Rokko Island in Japan. Results from the work programme have been used in the development of regulations on system safety in some member countries. The Agreement has also contributed to technology transfer to developing countries, including through the provision of advice to the World Bank.

The work programme is conducted through task sharing.

There are Contracting Parties from 20 countries (Australia, Austria, Canada, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Mexico, the Netherlands, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States) and the European Commission.

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SOLAR HEATING AND COOLING

Energy use for heating and cooling, lighting and hot water in buildings accounts for nearly 30 per cent of total energy use in IEA Member countries. While the use of solar energy is already making a significant contribution to reducing the conventional energy needs of buildings, there is great potential for additional major contributions.

The Implementing Agreement on Solar Heating and Cooling is addressing this area. It focuses on solar heating, cooling, daylighting and building-integrated photovoltaic technologies and applications, with the objectives of:

- undertaking international collaboration on high-priority research, development, demonstration and technology transfer projects to expedite the development and demonstration of reliable, cost-effective technologies;
- enhancing their acceptance to achieve penetration of the most promising markets;
- stimulating productive and effective interaction among researchers, industry and end-users in participating countries to provide a forum for the exchange of ideas, methods and data.

Current priorities are: daylighting; solar heating and passive cooling in commercial buildings; active low temperature (less than 95 °C) air and water heating systems; solar domestic hot water; heat storage for solar technologies; and solar aspects of high performance windows.

Solar Heating and Cooling's work programme, which has a total value of around $10 million annually, includes tasks on solar air heaters, solar concepts for building renovations, daylighting, building energy analysis tools, solar thermal collectors, solar assisted cooling systems, and combined solar space and water heating. Work is closely co-ordinated with the work of the Photovoltaics Power Systems and the Building and Community Systems Implementing Agreements.

The work programme is conducted mostly through task sharing, although some commonly funded work is also undertaken.

The Agreement has contributed substantially to the development and deployment of technologies, including the demonstration of low-energy buildings, solar technologies and concepts, pioneering research on a number of relevant technologies, publication of a handbook on photovoltaics in buildings, and computer design tools. There are numerous success stories. An example is the commercial launch of vacuum glazing, which was developed under the programme.

There are Contracting Parties from 20 countries (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States) and the European Commission.

- For further information, visit the IEA Solar Heating and Cooling Programme's Internet site at http://www.iea-shc.org or contact:

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SOLAR POWER AND CHEMICAL ENERGY SYSTEMS

Solar energy can be used to produce high grade heat for the production of electricity or use in other processes. This technology has the potential to make a large contribution to energy supplies, especially in areas with high intensity sunlight. Technologies have been developed to the point where commercial facilities could be built within the next few years. In addition, solar thermal energy can drive innovative chemical processes.

The Implementing Agreement on Solar Power and Chemical Energy Systems (SolarPACES) has three specific objectives: to support technology development; to support market development; and to expand awareness of the potential of solar thermal technologies.

The work programme consists of three related tasks. The first addresses the design, testing, demonstration and commercial application of solar thermal power systems to advance the state-of-the-art and bring these systems closer to economic maturity. The second is on solar chemistry and covers solar driven thermochemical and photochemical processes for the production of energy carriers, processing chemicals and for the detoxification and recycling of waste materials. The third is on advancing the technical and economic feasibility of solar thermal power technology through theoretical analysis and simulation and through co-ordinated experiments of an RD&D nature. The work programme includes a special effort to disseminate information on the technical and operational results obtained through the Agreement.

The Agreement has in place a very active outreach activity aimed at involving developing countries with high potential to use the technology. This includes Solar Thermal Analysis Review and Training (START) Missions which are sent to countries with high direct solar irradiation and which have the goal of helping to evaluate the technical potential for solar thermal systems. An agreement with the World Bank provides a mechanism for experts associated with the SolarPACES Implementing Agreement to assist with work related to solar thermal technology in client countries.

Work under the programme has shown that the cost of electricity from solar thermal power can be reduced to 4 to 6 cents/kWh over the next 15

to 20 years. There are numerous examples of how the work programme is contributing to this improvement in cost-effectiveness. One of these is a co-operative effort with industry on system operation and maintenance cost reduction. This effort has led to improvements in many areas of the large parabolic trough power plants operated in California and has reduced annual operating and maintenance costs by 25 per cent since the inception of this programme.

The work programme involves co-operative research, technological development and exchanges of information and technological personnel. These activities are conducted through task sharing. A common fund is used to support a secretariat and other joint activities, such as publicity, workshops, and START Missions.

There are Contracting Parties from 12 countries (Australia, Brazil, Egypt, France, Germany, Israel, Mexico, Russia, Spain, Switzerland, the United Kingdom and the United States) and the European Commission.

- For further information, visit the SolarPACES Internet site at http://www.demon.co.uk/tfc/SolarPACES.html or contact:

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WIND TURBINE SYSTEMS

Wind energy technology has developed and matured over the past two decades. Wind turbines are being commercially deployed in some markets and wind energy is now making a useful contribution to electricity supplies in some countries. There is potential for this contribution to grow substantially as continued technological development improves the cost-competitiveness of wind energy systems.

The Implementing Agreement on Wind Turbine Systems aims to promote and foster collaborative research.

Current activities under the Agreement include:

- development of recommended practices for wind turbine testing and evaluation;
- joint actions in the form of workshops and symposia on subjects such as aerodynamics of wind turbines, fatigue of wind turbine blades, offshore wind systems, and wind conditions/turbine loads;
- reviewing progress in the implementation of wind energy by the IEA Member Countries to provide an overview of progress in the commercial development of wind turbine systems to present to decision makers in government, planning authorities, the electricity supply industry, financial institutions and the wind energy industry; and
- validation of wind turbine testing procedures through a round robin test programme.

The Agreement has an impressive track record of achievements. For example, work on the development of recommended practices has served as the basis for national and international standards for a wide range of factors relating to wind turbines. Another example concerns experiments conducted under the Agreement, which have led to concepts now embodied in commercial wind turbines.

The work programme is undertaken largely through cost sharing, with common funds for some parts of the activities. A common fund is also used to cover the costs of the secretariat and printing and distributing publications.

There are Contracting Parties from 18 countries (Australia, Austria, Canada, Denmark, Finland, Germany, Greece, Italy, Japan, Mexico, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, the United Kingdom and the United States) and the European Commission.

- For further information, visit the Wind Energy's Internet site at http://www.afm.dtu.dk/wind/iea/ or contact:

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ADVANCED FUEL CELLS

Fuel cells have the potential to convert fuels to electricity at very high efficiencies compared with conventional technologies. In addition to reductions in emissions of greenhouse gases resulting from the increased efficiency, their use does not result in the production of the other noxious emissions that are usually associated with combustion.

The objectives of the Implementing Agreement on Advanced Fuel Cells are to advance the state of understanding of participants in the field of advanced fuel cells through co-operative research, technology development and system analysis on molten carbonate, solid oxide and polymer electrolyte fuel cell systems. There is a strong emphasis on information exchange through meetings, workshops and reports.

The main areas of activity are aimed at reducing the cost and improving the performance of molten carbonate, solid oxide and polymer electrolyte fuel cells and examining ways in which fuel cells and systems can be optimised for stationary and transport applications, taking into account users' requirements.

The main achievements to date have been the establishment of expert networks and the initial exchanges of information on cell, stack and system performance, testing methods and application requirements. The formation of experts groups and the exchange of information between them have strengthened national capabilities and is expected to lead to the achievement of significant technical objectives.

The work is conducted through task sharing with each participating country providing an agreed level of effort. A common fund provides support for the Executive Committee Secretariat.

There are Contracting Parties from 15 countries: Australia, Canada, Denmark, France, Germany, Italy, Japan, Korea, the Netherlands, New Zealand, Norway, Sweden, Switzerland, the United Kingdom, and the United States.

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ADVANCED MOTOR FUELS

Fuel for transport accounts for some 32 per cent of final energy use. Almost all of this energy is in the form of oil and transport accounts for 60 per cent of total oil usage. Of this, road transport accounts for 83 per cent. Alternative motor fuels, therefore, are important to increasing diversity of supply. In addition, many alternative motor fuels, either from fossil fuels or from renewable resources, offer advantages in terms of emissions of greenhouse gases and other pollutants compared with conventional fuels.

The objectives of the Implementing Agreement on Advanced Motor Fuels are to:

- promote understanding of alternative motor fuels, their role in energy security, relative efficiencies and environmental consequences;
- facilitate understanding of impacts of economic, environmental and technical factors on the market for alternative motor fuels;
- facilitate the harmonisation of legislation, standards and regulations concerning alternative motor fuels.

The Agreement is focused on the end-use of alternative motor fuels, as opposed to their production. Environmental implications are an increasing focus of the work programme.

Tasks include establishing an Automotive Fuels Information Service, joint energy and emission tests of heavy duty engines and fuels; evaluating current testing procedures and identifying shortcomings arising as a result of changing diesel fuel composition; improving understanding of the nature of particulate emissions resulting from the use of alternative fuels, emission performance of selected biodiesel fuels; and environmental assessment of dimethyl-ether as an automotive fuel.

The strength of the co-operation is the production, exchange and evaluation of information concerning almost all aspects of the use of automotive fuels in a closely co-operating network of experts. The Automotive Fuels Information Service (AFIS), which has been established as part of this Agreement, has produced several authoritative source books on fuel assessment and comparison and maintains an Internet site (http://home2.swipnet.se/~w-24173/). In addition,

Annex 14, "Dimethyl-ether as Automotive Fuel" operates a website at http://www.automotive.tno.nl/icengines/html/lob/dme1.html.

The work programme is conducted through cost-sharing and task-sharing, together with a common fund to support the secretariat and publications.

There are Contracting Parties from nine countries: Belgium, Canada, Finland, Italy, Japan, the Netherlands, Sweden, the United Kingdom and the United States. In addition, industries from Austria and France participate as Sponsors to the Agreement.

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BUILDINGS AND COMMUNITY SYSTEMS

Approximately one-third of final energy use in IEA Member countries occurs in residential, commercial and public buildings. Uses include heating, cooling, lighting, appliances, and general services. Buildings, therefore, are a major demand on energy resources and are consequently a major contributor to emissions associated with energy supply and use. Despite a general improvement in the thermal performance of buildings, much energy is still inefficiently used.

The Implementing Agreement on Energy Conservation in Buildings and Community Systems (ECBCS) focuses its work on ways to improve energy efficiency in buildings. Its programme includes developing techniques to analyse how energy use in buildings impacts on the interior, local, regional and global environments; work on the optimisation of building envelopes, advanced local energy planning, computer-aided fault detection and diagnosis, and the use of daylight in buildings (in collaboration with the Implementing Agreement on Solar Heating and Cooling); and improving the availability and use of design tools.

ECBCS administers the Future Buildings Forum. In co-operation with other buildings-related Implementing Agreements, the Forum organises workshops aimed at identifying long term energy, environmental, economic and technical issues related to buildings and the R&D needs associated with them. The Agreement also operates the Air Infiltration and Ventilation Centre, which distributes R&D results and undertakes selected studies on specific topics. The Centre operates an Internet site at http://www.aivc.org.

Work by ECBCS has resulted in numerous achievements. These include the development of techniques for energy efficient avoidance of condensation in buildings; the development of a tool to assist practitioners in the design of non-refrigerative cooling of buildings; evaluation of the performance of computational methods for heat loss, ventilation and air/pollutant transport; the development of techniques for fault monitoring and the optimising of building services systems; and the use of new information technology to link building energy management systems to remote control and monitoring centres via the Internet. These and other results have been successfully applied in participating countries.

The majority of ECBCS' work is conducted through task-sharing in which each country commits resources to the programme.

The Implementing Agreement on Energy Conservation in Buildings and Community Systems is essentially aimed at all energy consuming activities in buildings and at creating methods by which they can be reduced.

There are Contracting Parties from 21 countries: Australia, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Poland, Portugal, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

- For further information, visit the Building and Community Systems' Internet site at http://www.ecbcs.org, or contact:

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ENERGY CONSERVATION AND EMISSIONS REDUCTION IN COMBUSTION

Understanding of combustion processes is fundamental to achieving further improvements in fuel use efficiency, reduce the production of pollutants such as nitrogen oxides, and ease the transition to alternative fuels.

The goal of the Implementing Agreement on Energy Conservation and Emissions Reduction in Combustion is to accelerate the development of combustion technologies for use by industry that demonstrate reduced fuel consumption and have lower pollutant emissions. The focus on emissions is primarily concerned with toxic or noxious emissions, rather than greenhouse gases, although improved combustion efficiency will lead to a reduction in emissions of carbon dioxide.

The work programme includes: studies for improving the efficiency and fuel flexibility of automobile and truck engines; developing calculation procedures, instrumentation and information to reduce the excess air level required in furnaces; studies in emissions formation and control mechanisms and in fuel injection and fuel/air mixing for gas turbines; and investigations of the fundamental physical phenomena relevant to the combustion process.

A high degree of industrial involvement insures attention to industrial needs and the dissemination of technology to the marketplace. One of the main achievements has been the development of robust diagnostic capabilities, such as the Laser Induced Fluorescence and the improved Computational Fluid Dynamics and Chemical Kinetics codes.

The work programme is conducted through task sharing and information exchange between participants. Participants also undertake collaborative work at each others' facilities.

There are Contracting Parties from ten countries: Belgium, Canada, Germany, Italy, Japan, Norway, Sweden, Switzerland, the United Kingdom and the United States.

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DEMAND-SIDE MANAGEMENT

Demand-Side Management (DSM) encompasses actions to affect demand for electricity undertaken by the electricity supply industry. The objective is to manage the timing, magnitude and sharpness of daily and seasonal load curves to provide an economically efficient mechanism for matching supply capacity to load. DSM can also be applied to the gas supply industry. DSM thus provides a valuable tool for improving the technical efficiency of electricity use and at the same time improving the economic efficiency with which energy services are provided to consumers.

The overall objective of the Implementing Agreement on Demand-Side Management is to help DSM technologies reach their full market potential, thereby allowing energy systems and utility investments to function more effectively and giving energy system investments enhanced value for gas and electricity customers. Specific objectives are:

- Information exchange on technologies and programmes for DSM;
- Co-operative support for development and demonstration of DSM technologies;
- Investigation of techniques for implementation of DSM in the market place;
- Development of improved methods for incorporating DSM into integrated resource planning;
- Helping DSM technologies reach their full market potential; and
- Give utility investments enhanced value for customers.

The on-going restructuring of utility business in many countries has also made it obvious that tools may not be as readily accessible to utilities in the future. In this situation, sharing and transferring experiences, replicating successes and avoiding mistakes is important to the successful introduction and use of DSM techniques.

The main areas of work include:

- Demand-side management programmes;
- Energy-efficient technologies;

- Communication technologies for demand-side management;
- Innovative procurement of demand-side technologies;
- Techniques for implementing demand-side management in the marketplace; and
- DSM and energy efficiency in the changing electricity business environment.

Software developed by the Agreement is to be used in an EU supported evaluation project; its system for data-collection is now recommended to be used for national data collections in Hungary and the Czech Republic and was used in the development of a European evaluation guide book.

There are Contracting Parties from 16 countries: Australia, Austria, Canada, Denmark, Finland, France, Italy, Japan, Korea, the Netherlands, Norway, Spain, Sweden, Switzerland, the United Kingdom and the United States.

- For further information, visit the DSM Agreement's Internet site at http://dsm.iea.org/ or contact:

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DISTRICT HEATING AND COOLING

District heating and cooling involves the use of waste heat from industrial processes, electricity generation or waste incineration, as a source of energy for heating and cooling over a local area, with the heat being transported through a pipeline system. It thus provides an effective system for improving the efficiency of energy use and reducing adverse environmental impacts of energy supply and use.

The Implementing Agreement on District Heating and Cooling, including the Integration of Combined Heat and Power, deals with the design, performance and operation of distribution systems and consumer installations. The Agreement is dedicated to helping to make district heating and cooling a powerful tool for energy conservation and to reduce the environmental impacts of supplying heat and electricity.

The work programme is conducted through cost shared activities. Projects currently underway and nearing completion include studies of the optimisation of district heating operating temperatures, the benefits of low temperature district heating, balancing production and demand in combined heating and cooling systems, cost effectiveness in DH&C networks, and DH&C needs in future buildings. The preparation of a handbook for the use of plastic pipe systems is also in progress. A new series of projects, to be undertaken in the period 1999-2001, is currently being planned.

There are Contracting Parties from ten countries: Canada, Denmark, Finland, Germany, Korea, the Netherlands, Norway, Sweden, the United Kingdom and the United States.

- For further information, visit the Implementing Agreement's Internet site at http://www.iea-dhc.org/home.htm or contact:

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HYBRID AND ELECTRIC VEHICLES

Fuel for transport accounts for some 32 per cent of final energy use. Almost all of this energy is in the form of oil and transport accounts for 60 per cent of total oil usage. Of this, road transport accounts for 83 per cent. Hybrid and electric vehicles offer an opportunity to reduce the dependence of transport on oil and at the same time, can offer the potential to reduce adverse environmental impacts of energy supply and use. The use of hybrid drive systems incorporating an electric motor together with another power source may be the best way to capitalise on the potential benefits of electric traction systems.

The objective of the Implementing Agreement on Hybrid and Electric Vehicles is to help these technologies reach their full market potential, with attendant advantages for diversification of energy supplies and environmental protection.

The work programme includes extensive information exchange about the electric vehicle programmes and technologies in each country; studies of the energy and environmental impacts of electric vehicles (including development of a model for the assessment of large scale market penetration of electric vehicles; data collection on the environmental impacts of battery systems; and characterisation of alternative transport chains, impacts on local urban environments); studies on infrastructure (covering such issues as standardisation, comparison of technical features, cost and deployment across participating countries); and exploratory research in batteries and supercapacitors (including organisation of expert workshops, outlook/appraisal of long-term research aspects for different battery technologies). Assessment and evaluation of trends and technological needs for hybrid vehicles are a new area of activity.

The work programme is conducted through informal co-ordination of activities by participants; formal co-ordination or initiation of activities to achieve shared objectives through shared tasks and information exchange; and formal co-ordination of activities based on cost sharing.

There are Contracting Parties from 15 countries: Austria, Belgium, Canada, Finland, France, Germany, Italy, Japan, the Netherlands, Korea, South Africa, Sweden, Switzerland, the United Kingdom and the United States.

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ENERGY CONSERVATION THROUGH ENERGY STORAGE

Energy storage systems themselves do not save energy. However, their application enables the introduction of more efficient energy systems and can improve the utilisation of renewable energies, in particular solar and wind and the greater utilisation of waste heat.

The overall objective of the Implementing Agreement on Energy Conservation through Energy Storage is to develop and demonstrate various advanced energy storage technologies for application within a variety of energy systems and encourage their use as standard engineering options.

The balance of activities is mostly focused on case studies, demonstrations and deployment measures and design tools. The work programme includes a range of tasks relating to the development of underground thermal energy storage systems in the building, industrial and agriculture sectors; examination of the potential role of electrical storage technologies in optimising electricity supply and utilisation; examination of the role of phase change materials in energy systems; and the development of procedures and screening and decision tools to facilitate the adoption of energy storage in standard project designs.

Most of this activity is undertaken through task sharing although some cost shared work is also undertaken.

Work conducted under the programme has influenced many large projects, and several plants using direct cooling and cold storage were built or are under construction in participating countries as a result of programme activities.

There are Contracting Parties from 12 countries (Belgium, Canada, Denmark, Finland, Germany, Italy, Japan, the Netherlands, Sweden, Turkey, the United Kingdom and the United States) and the European Commission.

- For further information, visit the Agreement's Internet site at http://www.luth.se/depts/sb/vatten/projects/iea/ or contact:

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HEAT PUMPING TECHNOLOGIES

Heat pumps and related heat pumping technologies such as air conditioning and refrigeration are in widespread use. There are opportunities both to improve the efficiency of heat pumping technologies in existing applications and for heat pumps to be used in new applications where they can offer a highly efficient way to heat and cool living and work space. For instance, a study undertaken by the Implementing Agreement on Heat Pumping Technologies found that the use of industrial heat pumps could reduce global energy consumption for process heating by two to five per cent.

The activities of the Agreement are referred to as the IEA Heat Pump Programme (HPP). It has four main priorities: to exchange information and promote heat pumps; to facilitate the phasing out of chlorine-containing working fluids; to support the development of heat pumping technology; and to monitor and support the world's heat pump markets. The HPP also operates the Heat Pump Centre in order to collect, analyse and disseminate information on the development, use and advantages of heat pumps as an energy conservation alternative, and to promote market penetration and collaboration with related international organisations. The Centre operates world-wide by way of a network of national teams in its member countries. As well as publishing a newsletter, task reports and workshop proceedings, the Centre publishes results from other activities under the Agreement.

The HPP's work programme includes projects on the properties of modern working fluids; air conditioning and refrigeration plants using natural working fluids including ammonia, hydrocarbons, carbon dioxide, water and air; investigations of absorption technology; research and development on heating systems for future buildings with a high potential for energy savings and carbon dioxide emissions reduction. The work programme includes both task shared and cost shared activities.

The Agreement has a record of useful contributions. Activities such as co-operative research projects, conferences, workshops, and a database containing over 1000 publications have led to improvements in and a better understanding of heat pump technologies in participating countries. An illustration is the establishment of world-wide standard reference data on the properties of the new refrigerants, which were subsequently sanctioned

and published by the International Institute of Refrigeration. Another important contribution has been the "International Heat Pump Status and Policy Review". This report provides an assessment of policy measures regarding heat pumps, along with information on the technical status of the various heat pumping technologies, the current and expected penetration of heat pumps, and the potential for new or intensified international collaboration in the field of heat pumps. The report has been so well received that an update is being prepared.

There are Contracting Parties from 15 countries: Austria, Belgium, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, Switzerland, the United Kingdom and the United States. Mexico is in the process of joining the Programme.

- For further information, visit the Heat Pump Centre's Internet site at http://www.heatpumpcentre.org/ or contact:

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HEAT TRANSFER AND HEAT EXCHANGERS

Heat exchangers are used in large numbers, to a lesser or larger extent, in all branches of industry. Improving efficiency of heat transfer and heat exchangers offers opportunities to improve the efficiency of energy use, including enabling new cost-effective ways to recover waste heat.

The Implementing Agreement on Heat Transfer and Heat Exchangers, therefore, concentrates on research exchange and co-ordination of national programmes for the development and exploitation of heat transfer technology.

The Agreement identifies needs and gaps and makes recommendations for future research and development. Assistance to deployment of research results is provided through design guidelines and computer codes.

The work programme includes information exchange, co-ordination of activities, data exchange on experimental research as well as computer simulation. Information exchange and co-ordination cover: hydraulic design and performance in heat transfer equipment; heat transfer system design for integrated processes; improving the structural reliability of heat transfer equipment; and heat transfer in vaporisation and condensation.

The work programme is conducted through task sharing and exchange of information between participants.

There are Contracting Parties from seven countries: Germany, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom and the United States.

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HIGH TEMPERATURE MATERIALS

Fuel for transport accounts for some 32 per cent of final energy use. Almost all of this energy is in the form of oil and transport accounts for 60 per cent of total oil usage. The use of ceramic materials in engines has the potential to allow the use of higher operating temperatures and hence improved efficiency.

The objective of the Implementing Agreement on High Temperature Materials is to carry out co-ordinated research on ceramic materials.

The work programme is focused on standardisation of testing and characterisation methods for high performance ceramics for advanced engines and other conservation applications. As well as technical information exchange, the work programme includes tasks on mechanical characterisation of structural ceramics, and characterisation of ceramic powders.

The information flowing from the Agreement's work programme has acted as a catalyst for further activities, and in particular is flowing on to relevant standards organisations in member countries. The results have also influenced the activities of existing research bodies and have led to the creation of new bodies in several participant countries, for example, the establishment of consortiums of companies in Japan and the United States.

The work programme is conducted through task sharing and exchange of information between participants.

There are Contracting Parties from five countries: Belgium, Germany, Japan, Sweden and the United States.

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PROCESS INTEGRATION

Process integration is the common term used for the application of methodologies developed for system-oriented and integrated approaches to industrial process plant design for both new and retrofit applications. Process integration has considerable potential to contribute to increased energy efficiency.

The main focus of the Implementing Agreement on Process Integration is on efficient use of energy and reducing the environmental impact from process industries. The initial work of the Agreement, which began in 1995, focused on surveying the state-of-the-art in process integration methods, software, and applications as well as the needs of end-users. This was a first step towards the further development and implementation of process integration technologies in industry.

The main technologies being considered are pinch analysis for heat recovery, heat and power systems and wastewater minimisation, exergy analysis, optimisation techniques such as mathematical programming and stochastic search methods such as simulated annealing and genetic algorithms, and the use of heuristics and knowledge based systems.

The main outputs of the Agreement are an end-user survey and the Catalogue on Process Integration. The Catalogue contains a unique collection of information on technology developers, software vendors, software packages, consultants, training courses, text books, and other resources on process integration. It also describes and classifies various existing and emerging process integration methodologies.

The Agreement is working closely with the Implementing Agreement on Pulp and Paper on the development of a joint activity on process integration in the industry.

Activities have had both cost shared and task shared elements: a common fund has supported the work of the Operating Agent, while participating countries have made task shared contributions to the products produced by the Operating Agent.

There are Contracting Parties from seven countries: Canada, Denmark, Finland, Portugal, Sweden, Switzerland, and the United Kingdom.

- For further information, visit the Agreement's Internet site at http://www.maskin.ntnu.no/tev/iea/pi/ or contact:

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PULP AND PAPER

The pulp and paper industry accounts for about five per cent of total final energy use in IEA Member countries, which is about 15 per cent of final use in the industrial sector.

The objective of the Implementing Agreement on Pulp and Paper is to improve the efficiency with which energy is used in the industry.

The work programme is focused on pre-competitive research and development. Specific activities include information exchange and dissemination, life cycle assessment of the pulp and paper industry with emphasis on energy consumption and environmental effects, and research leading to methods for reducing environmental contaminants and the use of non-renewable energy resources. An important focus is closing water loops in mills, which has the potential to reduce emissions, increase energy efficiency and decrease requirements for fresh process water.

The Agreement is working closely with the Implementing Agreement on Process Integration on a joint activity on process integration in the industry.

The work programme is conducted through task sharing, with a common fund being used to support a secretariat.

There are Contracting Parties from nine countries: Belgium, Canada, Finland, the Netherlands, Norway, Spain, Sweden, the United Kingdom and the United States.

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HIGH TEMPERATURE SUPERCONDUCTIVITY

High temperature superconductors are ceramic materials which carry electricity without loss. They operate at temperatures which may permit the use of inexpensive refrigeration, using liquid nitrogen. As a result they have the potential to be cost-effective in commercial applications in the electric power sector. The use of superconductivity can result in substantial environmental improvements by energy saving, replacement of oil in cables and transformers by inert liquid/gas nitrogen, and by enabling more economic underground power transmission, thereby reducing concerns about electro-magnetic radiation, visual pollution and noise.

The objectives of the Implementing Agreement on High Temperature Superconductivity are to better enable each member to keep abreast of progress being made toward applications in the power sector, to catalyse concerted consideration of issues that have not yet been subject to definitive attention by individual participants, and to provide a network and venue that may lay the basis for future international co-operation on joint projects.

The work programme is focused on the exchange of information. Activities include preparation of essays on outstanding issues; fostering debate and appropriate action by holding workshops and seminars; evaluating and synthesising the results of on-going work; establishing a contacts register of names and addresses of institutions and published documentation; and promoting international co-operation and planning that may lay the basis for future joint projects, including hardware projects.

The shared information has aided the national programmes of the participants in evaluating the future importance of ceramic superconductors to electric utilities and of specific devices that are under development.

The work programme is conducted through task sharing together with participant contributions to a common fund to pay for the work of an Operating Agent.

There are Contracting Parties from 16 countries: Belgium, Canada, Denmark, Finland, Germany, Israel, Italy, Japan, Korea, the Netherlands, Norway, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

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ENERGY TECHNOLOGY SYSTEMS ANALYSIS PROGRAMME (ETSAP)

The objective of the Implementing Agreement on Energy Technology Systems Analysis Programme (ETSAP) is to serve national governments and work in international forums by fostering and supporting the development of constructive, economically and technologically informed, policy options.

ETSAP concerns the application and on-going development of a family of computer models named MARKAL (for MARKet ALlocation) that allow analysts and decision-makers to identify and explore energy technology scenarios that balance energy budgets and meet a range of environmental requirements at the minimum overall cost.

Members of ETSAP co-operate to establish, maintain and expand a consistent multi-country energy/economy/environment analytical capability. Key features are individual national teams and a common, comparable and combinable methodology, based on the MARKAL model, permitting in-depth national and multi-country evaluations.

The current research emphasises dealing with uncertainties, whether they be uncertainties in eventual environmental requirements, the availability or acceptability of certain technologies, the availability and price of resources, or the future demand for energy services.

Over 70 teams in more than 35 counties around the world make use of the MARKAL family of energy/economy/environment models. These have been used to perform analyses in support of national emission inventory and abatement studies, for example, to provide input to national communications in the United Nations Framework Convention on Climate Change (UNFCCC) process. The work also contributed to IEA/OECD studies for Annex-1 Experts Group of the UNFCCC. The model has also been used by some countries, notably the United Kingdom and the Netherlands, as a tool in the development of policy and priorities for energy R&D.

There are Contracting Parties from 19 countries (Australia, Austria, Belgium, Canada, Denmark, Germany, Greece, Ireland, Italy, Japan, Korea, the Netherlands, Norway, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States) and the European Commission.

- For further information, visit ETSAP's Internet site at http://www.ecn.nl/unit_bs/etsap/ or contact:

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THREE LARGE TOKAMAK FACILITIES

Establishment of the International Thermonuclear Experimental Reactor (ITER), which will both demonstrate the technical feasibility of fusion power and that test reactor components will perform in a reactor relevant environment, is a major focus of fusion research activities globally. Collaborative research carried out at the three existing large tokamak facilities - JET (EURATOM), JT-60 (Japan) and TFTR (United States) - is fundamental to an improved understanding of the physics of the operational regime for the ITER.

The Implementing Agreement on Three Large Tokamaks promotes collaboration among the three large tokamak facilities and enables the teams from each facility to co-ordinate research activities to accelerate progress on establishing the scientific and technological basis for the tokamak concept.

The focus of collaboration has been the study of the physics of production, sustainment and termination of high performance plasmas. The three tokamak facilities are collaborating on three main areas of current tokamak research: high beta-poloidal plasma research, the amelioration of major disruptions and the development of divertor plate technology.

Joint papers have been presented at international meetings concerning high beta-poloidal plasma and the amelioration of major disruptions results. A disruption database has been created by the merging of data collected under the same criteria at JET and JT-60. Research divertor plate prototypes have been collaboratively constructed and tested, making best use of the different capabilities of the three large tokamaks.

High capacity, dedicated communications links allow remote participation in experiments and exchange of detailed information. This has enabled the different institutions involved in the collaboration to use a range of different techniques to analyse the outcomes of experiments. This co-operation has enabled the best use to be made of the different capabilities of the large tokamaks in developing the necessary physics basis and testing reactor components.

There are three Contracting Parties from two countries (Japan and the United States) and EURATOM.

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STELLARATOR CONCEPT

The Stellarator Concept is an alternative to the tokamak concept and has the potential to provide a more integrated and effective confinement field. It is, however, less developed than the tokamak concept. World stellarator research is now moving from mid-size experiments to large scale experiments. The theory of the underlying physics has matured and experimental verification of the theoretical predications is expected.

There are different approaches to the stellarator concept being pursued in different countries and the Implementing Agreement on the Stellarator Concept provides a mechanism to jointly investigate the properties of the different stellarator approaches and to compare them with the tokamak concept.

The Implementing Agreement on the Stellarator Concept effectively enables all activities on stellarators world-wide (except the Ukraine, which is expected to join the activity shortly) to be collected into one co-ordinated programme.

Co-ordinated research utilises the diversity of available stellarator experimental devices to conduct matched experiments in differing devices. The collaboration programme consists of joint planning of experiments with comparable scales for comparison purposes, mutual participation in experiments and theoretical activities, the joint evaluation of results, and information sharing activities.

Exploiting a larger number of devices provides a broader basis for conclusions drawn from experimental results, and better progress is made on the physics of confinement configurations. The exchange of around 40 scientists per year for experimental programmes increases the reliability of the comparisons of the results from the various facilities. The results established through collaboration will contribute to the improved design of the next-step device. Reducing technical uncertainties will reduce construction costs because engineering margins can be reduced as uncertainty is reduced. The Agreement has established a joint stellarator database which collates experimental information from the participating facilities.

There are Contracting Parties from four countries (Australia, Japan, Russia and the United States) and EURATOM.

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REVERSED FIELD PINCHES

Reversed Field Pinches (RFPs) is one of the possible magnetic confinement alternatives to the tokamak concept which the International Thermonuclear Experimental Reactor (ITER) is based on. This concept is less developed than the tokamak, but has potential advantages, and is therefore the subject of on-going parallel research. The RFP operates with a much weaker magnetic field than the tokamak. The reduced magnet requirements can lead to many advantages in a reactor. However, the reduced magnetic field also reduces plasma stability and confinement. Improvement of confinement is one of the thrusts of on-going research.

The general objective of the Reversed Field Pinches Agreement is to advance the confinement concept through task sharing, co-ordination of research programmes and the exchange of information. The close co-operation of the four active RFP groups in the world led, in 1994, to the preparation of a joint development plan for co-ordinated research entitled "A Possible Outline of RFP Research towards DEMO" (DEMO is a concept for a demonstration nuclear fusion reactor).

Exchange of scientists under the Agreement ensures that progress is quickly and effectively transmitted between the organisations. The participants also meet at workshops to exchange information on experimental and modelling progress.

A Task on the Co-ordination of Research and Development Work on RFPs (Annex 1) has three joint working groups which compare experimental data to report on scaling, plasma-wall interaction and field errors. Collaborative activities such as the exchange of diagnostic tools and joint campaigns to measure plasma edge properties, ion anomalous heating and plasma fluctuations. A Task on Joint Work on the Investigation of Plasma Confinement Physics and Technology in RFX (RFX is a Reversed Field Pinch experiment in Italy) (Annex 2) accelerated the start-up of RFX through the provision of a computer database system and several experienced scientists from the United States and Japan. Recently, several RFP laboratories have demonstrated improved confinement, one of the major challenges of RFP research. Co-ordinated activities are underway to compare and optimise the results from the different laboratories.

There are Contracting Parties from two countries (Japan and the United States) and EURATOM.

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PLASMA WALL INTERACTION IN TEXTOR

Twenty per cent of the thermal power of a fusion reactor has to be transferred from the hot plasma through the wall components of the burn chamber. This has to be achieved without overheating and excessive erosion of the plasma facing materials, without degrading the thermonuclear burn process by impurities released from the walls, and without burying too much tritium. Moreover, the helium ashes produced by the fusion processes have to be removed from the plasma with sufficient efficiency.

The objective of the Implementing Agreement on Plasma Wall Interaction in TEXTOR (Torus Experiment for Technology Orientated Research) is to study these processes, to evaluate their relative importance and to develop methods for their control. This includes the development of novel specific diagnostics and of methods to condition the wall, to structure the wall and the magnetic field, and to influence the transport features of the confined plasma. The Implementing Agreement is based on a particularly strong and valuable collaboration between Canada, EURATOM, Japan, Switzerland and the United States.

In the course of the world-wide research on fusion power, heat removal, particle exhaust and the other objectives of this Agreement coupled with plasma confinement as a whole, have emerged as priority tasks for developing a long pulse reactor. They require a variety of approaches (for example, materials, divertors, limiters) to be developed, tested and evaluated. Medium-sized machines like TEXTOR (after significant pulse length prolongation now called TEXTOR-94) have the particular mission of exploring new methods and concepts before transferring them to the large devices of reactor grade performance. The research programme is highly relevant for next generation machines, both on the tokamak development path (ITER) and the stellarator path (Wendelstein 7-X).

Work under the Agreement has contributed to the solution of problems concerning the interaction between the plasma and the reactor wall; including controlled heat transfer onto and through the wall, impurities released from the wall, retention of the nuclear fuel (tritium) in the wall and removal of the helium ashes produced by the fusion process. It has enabled the partners to make use of the TEXTOR-94 facility to progress technology

development and enabled the transfer of knowledge from TEXTOR-94 to other research facilities, contributing to the total development process.

Boronisation techniques pioneered through this Agreement are now applied world-wide as a method to reduce oxygen impurities in tokamak and stellarator plasmas. Edge radiation cooling developed through TEXTOR-94 is regarded as a promising technique to alleviate the heat transfer problems of ITER and other fusion devices. Their application lead to a new regime of very good and stationary confinement, the so-called Radiation Improved Mode. Mechanisms to remove helium (in particular by a toroidal pumplimiter), have been successfully demonstrated. Low Z and high Z materials like carbon and tungsten have been tested and evaluated. A series of useful edge diagnostics has been developed and applied.

There are Contracting Parties from five countries (Canada, Japan, Switzerland, Turkey and the United States) and EURATOM.

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TOROIDAL PHYSICS IN, AND PLASMA TECHNOLOGIES OF, TOKAMAKS WITH POLOIDAL FIELD DIVERTORS

An important requirement for a fusion reactor is ensuring sufficient plasma confinement, and simultaneously, protecting the wall components of the containing vessel and avoiding the introduction of impurities.

This Implementing Agreement encompasses the investigation of toroidal physics and plasma technologies in tokamaks with poloidal divertors. It is based on the ASDEX-Upgrade, with supporting activities in other relevant facilities such as DIII-D and Alcator C-Mod. The main components of the work programme are edge physics and plasma control which will contribute to the development of the International Thermonuclear Experimental Reactor (ITER). Other issues relevant to ITER and other fusion reactor concepts, such as transport and confinement studies and heating and refuelling issues, have also been investigated. Co-operative activity is concentrated on plasma shape and position control, plasma disruptions, vertical displacement and tokamak edge modelling. ITER divertor design is largely based on the results achieved through this co-operative programme.

The ability to compare results of experiments from different machines with different characteristics has played an important role. Research undertaken and databanks developed under the Agreement are helping in developing concepts for incorporation in ITER. Future activity of the Agreement will be continue to be directed towards the design of ITER, including the divertor and confinement.

A package of computer codes on plasma edge physics (which covers poloidal field configuration, energy transfer to first walls, control of impurities, and helium pumping) has been built and is being steadily improved. A plasma disruption data bank has been completed, and the design of a disruption data bank for the ASDEX-Upgrade facility has started. These data banks will help in scaling data for extrapolation towards ITER. Plasma confinement and transport studies have been concluded, covering pellet ablation modelling, high performance confinement, and the impurity retention capability of divertors. A data base for divertor materials was established, and material issues concerning plasma wall interaction were studied. The Agreement has

also facilitated the exchange of information, equipment and codes on Ion Cyclotron Resonance Heating.

There are Contracting Parties from EURATOM and the United States.

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FUSION MATERIALS

Establishment of the International Thermonuclear Experimental Reactor (ITER), which will both demonstrate the technical feasibility of fusion power and test reactor components, is a major focus of fusion research activities globally. The role of ITER is to demonstrate "burning plasma" conditions and to test reactor components. This will require the development of materials suitable for nuclear fusion reactors.

The objective of the Implementing Agreement on Fusion Materials is to test fusion reactor components. This involves research on the effects on materials of the expected environment in fusion reactors and the development of appropriate test facilities, which involves the development of a high-flux neutron source. The work is aimed at the development of data needed by the ITER and other fusion system design activities.

An international team has successfully developed a conceptual design for a high-flux neutron source for testing materials (called the International Fusion Material Irradiation Facility). The next stage is to evaluate key components and to commence work to underpin possible construction and operation of the facility.

Consensus has been reached on potential low activation alloys for structural materials. Each candidate alloy was investigated and results were discussed at workshops. Information on ceramic insulators was also exchanged through workshops. Investigation of fast flux neutron irradiation of candidate fusion breeder blanket materials demonstrated better than expected performance of lithium oxide (it is chemically and physically stable over a wider temperature range than previously believed), greatly increasing confidence in the feasibility of this approach to producing tritium for fusion reactors.

There are Contracting Parties from six countries (Canada, China, Japan, Russia, Switzerland and the United States) and EURATOM.

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NUCLEAR TECHNOLOGY OF FUSION REACTORS

Developing technologies relating to the breeder blanket, including handling and processing of tritium produced in the blanket, and radiation shielding, are an essential element of fusion power development.

The scope of the Implementing Agreement on Nuclear Technology of Fusion Reactors includes the technology of components concerned with tritium production and processing, energy extraction and radiation shielding of components and personnel. The Agreement focuses on the first wall, blanket, shield and nuclear elements of plasma-interactive components.

The work programme includes formulating and co-ordinating a research and development programme to conduct experiments on prototype components and verify computational methods and computer codes for tritium breeding blankets (both solid and liquid blankets), radiation shielding and tritium processing systems. The Agreement has begun concept definition for a high volume plasma-based neutron source.

Blanket related R&D carried out by the participants to the Agreement includes investigations (including irradiation experiments) on ceramic breeder and beryllium pebble beds, on liquid metal technology and neutronics studies. Joint planning for collaborative work on liquid blankets is proceeding in line with the strategy agreed by the ITER Test Blanket Working Group.

There are Contracting Parties from four countries (Canada, Japan, Russia, and the United States) and EURATOM.

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ENVIRONMENTAL, SAFETY AND ECONOMIC ASPECTS OF FUSION POWER

Environmental, safety and economic aspects are fundamental issues for nuclear fusion in the same way as they are for nuclear fission. System studies and experiments are essential to improving understanding of these issues.

The Implementing Agreement on Environment, Safety and Economic Aspects of Fusion Power is helping to co-ordinate the national research programmes of its participants in these areas. This programme has several objectives which include developing analytical tools such as codes and models, conducting experiments to validate these codes and models, analysing different safety methodologies, conducting assessment studies of safety and environmental aspects of fusion power and helping to guide the national research programmes of the participants.

The work programme includes development and assessment of environmental and safety analysis methodologies. Methodologies are compared to achieve consistency and accuracy and to develop data bases for use in safety evaluations. A study of the different safety systems study methodologies in Europe, Japan and the United States is being conducted to improve methodologies adopted by each participant.

Joint studies to develop, validate and determine data requirements of environmental and safety analysis models and computer codes have been undertaken. The results of a tritium release experiment, conducted under the Agreement, are being used to validate computer models. Computer codes for dose calculations for activation products have been compared and discrepancies identified. A computerised Failure Rate Data Base has been developed and is used to predict maintenance schedules, and is a necessary element in any safety analysis for fusion reactors.

A new task on radioactive wastes from fusion power will commence in 1999. This study will clarify issues relating to the disposal of radioactive waste from fusion reactors and investigate the potential for recycling and re-use of activated material for fusion reactors. A study to investigate the socio-economic aspects of fusion power will also be given priority.

There are Contracting Parties from four countries (Canada, Japan, Russia and the United States) and EURATOM.

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