R&D Programs of the International Energy Agency: A Unique Exercise in International Collaboration

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This paper provides a description of the collaborative research program of the International Energy Agency. Focusing on the organization of the program, rather than attempting to cover the technical content of the research, the discussion conveys how its operation is facilitated through a framework that takes account of the interests of participating governments as well as technical objectives. Some Canadian activities in the IEA program are briefly described as illustrations and a list of current IEA Research Agreements and associated activities is presented in an Appendix.

Cet article décrit le programme coopératif de recherches de l'Agence internationale de l'énergie (AIE). Au lieu de se concentrer sur le contenu technique des recherches, la discussion porte plutôt sur l'organisation du programme et explique comment son opération est facilitée par une structure qui tient compte aussi bien des intérêts des gouvernements participants que des objectifs techniques. Quelques activités canadiennes au sein du programme de l'AIE sont fournies comme de brèves illustrations et une liste des accords actuels de recherches et d'activités correspondantes de l'AIE fait l'objet d'un appendice.

International collaboration in research and development is held in high regard. Politically it is seen as bridging economic and cultural barriers between nations and, in high profile items, as a vehicle of east-west detente. As scientists we already recognize that an international activity is an international freemasonry. Many working scientists have extensive working relations with colleagues in other countries. The resulting informal collaboration is an accepted and essential part of scientific activities.

Formal collaboration however, has its difficulties. Agreements between countries incur obligations with the legal status of an international treaty. If capital expenditures are involved, the distribution of the financial contributions among countries will be a major item of negotiation. There will also have to be provision for equity in expenditures in each of the participating countries. These questions lead to protracted and frustrating negotiations. The lawyers are in control and the poor scientist, who suggested the project in the first place, can be left wondering if international collaboration is really worth the effort!

The international collaborative R&D programs of the International Energy Agency (IEA) have developed in ways which minimize many of these difficulties. The IEA sponsors some

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thirty-two international agreements on energy R&D involving some seventy-nine collaborative projects. Since the inception of the programs in 1976 some 700 million US dollars (1978 exchange rate) have directly been spent on these projects by the countries involved.

This paper provides only a brief summary of an extensive international research program in which the participants act on behalf of national governments. The discussion concentrates on the ways in which the collaboration is organized rather than the technical content, which would require a more extended presentation. The underlying argument presented is that international collaborative programs work when they are organized so as to take account of both the general interests of participating governments and the technical objectives of the specific program. To illustrate this, as well as to provide some examples of actual research projects, some Canadian activities in the IEA program are briefly described. A list of current IEA implementing Agreements and Annexes is provided in the Appendix.

The International Energy Agency and its Mandate

The IEA was established in November 1974 within the framework of the Organization of Economic Cooperation and Development, to implement an international energy program. In essence it was a consumers group formed to counter the threat posed by the producers group, the Organization of Petroleum Exporting Countries, OPEC.

One of the three basic aims of the organization is for "cooperation among IEA Participating Countries to reduce excessive dependence on oil through energy conservation, development of alternative energy sources and energy research and development." IEA Members have, thus, a commitment of treaty status, to support collaborative R&D programs.

In organizing collaborative research and development the role of the IEA is, in essence, that of a marriage broker. It identifies topics of common interest to two or more member countries and sponsors agreements between the interested parties, shepherding them through the various legal and organizational hurdles. The end product is a free standing agreement financed on mutually agreed terms between the signatories, the member countries who have interests and capabilities in that technical area. Typically the number of signatories is between six and ten.

The IEA has established a Committee on Research and Development (the CRD) with, amongst other things, the overall mandate of encouraging and sponsoring collaborative agreements. The Committee is supported by a small permanent secretariat within the IEA at its office in Paris. Opportunities in the four main technical areas, End-Use Technologies, Fossil Fuels, Renewable Energy and Fusion Energy are identified by Working Parties of scientific and technical experts. These Working Parties are, in effect, subcommittees of the CRD. The work performed under each Implementing Agreement (as they are called) is supervised and managed by an Executive Committee consisting of delegates from each of the signatories.

Agreements are developed for specific contributions in cash or "in kind" for a specific period. Negotiations are largely concerned with the technical content and the level of contribution of the signatories. The projects are autonomous, providing for their own financing and management. The IEA has no role in these two activities, eliminating many layers of bureaucracy.

It should be noted that the IEA does not have a central fund for international collaborative projects. Other organizations, with such resources, have found that the administration of such a fund requires a large and cumbersome bureaucracy which spends most of its time assuring the equity of member countries rather than technical content of the agreements. For the IEA, member countries make their own choice of projects to reflect their own needs and interests. The precise operating arrangements are described in a following section.

There are two types of cooperation: task sharing and cost sharing. In task sharing, member countries put on the table work done in their own laboratories and thus gain access to the work done elsewhere. Meetings between the participants are held on a regular basis to discuss and compare current results. Duplication and development time can thereby be reduced, the incremental cost is the cost of making the information exchange.

In cost sharing agreements, member countries share the costs of research projects to be carried out in one country's laboratories. These costs are likely to be significantly greater than those in task sharing agreements. With several participants, the costs for each member are, of course, much less than the full cost.

The precise recipe varies from agreement to agreement. There are also a number of programs which are more generally exchanges of information and lead to the compilation of international information banks or databases: there are several variants of these.

The Collaborative Programs

An article of this length can only give a brief and superficial treatment of the individual projects and the results they have produced. A list of Implementing Agreements appears in the Appendix. A detailed description of all projects appears in the IEA Publication "Collaborative Projects in Energy Research, Development and Demonstration. A Ten Year Review 1976-1986" (OECD/IEA, 1987a). The IEA has also published a comprehensive bibliography of the publications made from work from these projects (OECD/IEA, 1987b).

The projects have a variety of benefits: sharing of information on demonstration projects, sharing of demonstration information together with cooperative supporting projects, cooperative fundamental studies, pooling of bibliographies and databases, international development of performance standards, access to unique experimental facilities, exchanges of experimental material and exchanges of policy information. The following discussion illustrates these benefits with examples of Canada's participation.

Sharing of Information on Demonstration Projects

Atmospheric Fluidized Bed Combustion

Many IEA countries have developed interests in atmospheric fluidized bed combustion (AFBC) of coals, wood and other fuels. AFBC has advantages in combustion efficiency, control of SO_2 emissions and low NO_x emissions. By 1980, some nine IEA countries were building or planning demonstration AFBC boilers of various specifications. In the agreement, Canada, Denmark, Italy, Japan, Netherlands, New Zealand, Norway, Sweden and Switzerland agreed to share the information gained from their facilities on technical feasibility, performance, reliability and economics. Each participant, by describing the design and operating experience of their own facility, obtained similar detailed information from the eight other participants. The capital costs of these demonstration facilities are in the range of $3 to $12 million US. The incremental cost for Canada in participating in the agreement was for preparing reports and attending meetings. With this investment, Canada gained general information on eight other comparable demonstration projects. As a result, we had ready access to unpublished data which, for example, helped resolve some of the fluidization and steam tube erosion difficulties encountered in our demonstration projects at Summerside, PEI and Chatham, New Brunswick. The information obtained in the biennial meetings is disseminated regularly to Canadian industry and other government organizations.

Sharing Demonstration Information Together with Cooperative Supporting Projects

Wind Energy

One of the wind energy agreements is similar to the Fluidized Bed Agreement. Seven countries, with plans to design and build large wind turbines with a rated power of 1 MWe or more for connection to electric grid systems, agreed to share their design and operating experience. Canada's designs have been of the vertical axis (Darrius) type; other countries have developed versions of the horizontal axis type. In this project Canada had access to information on the operating experience of other MW scale projects before starting construction of its 4 MWe vertical axis wind turbine demonstration project, "EOLE".

This comparison of demonstration systems was supported, in a separate agreement, by a number of cooperative fundamental studies. Nine independent tasks were identified; Canada participated in five, including studies of wake effects behind single turbines and in wind turbine parks, studies of local wind flow at potential hill sites, and an evaluation of wind models for sites. Canada (Environment Canada) was the Operating Agent and Task Leader for this last study. An extensive full scale data set describing flows and turbulence over a typical hill site was compiled. These data can be used to evaluate and compare particular sites.

These studies together form a basis for further implementation of wind energy. Canada's participation and contribution gives us access to a total research effort perhaps five times our own.

Cooperative Fundamental Studies

Conservation in Combustion: Fundamental Studies of Combustion Processes

Combustion of fossil fuels provides more than 90% of the energy of industrial countries. While many combustion technologies have been developed very effectively, the internal combustion engine being the prime example, the development was largely empirical. The practical efficiency of many existing combustion systems is far from optimum.

A number of powerful experimental tools have been developed in recent years which can give detailed insight into combustion processes. The application of laser scattering techniques to measure turbulence, Raman spectra to measure fuel product distributions and temperatures in flames, pulse techniques and numerical modelling, are but a few examples. The objective of the Agreement on Combustion Processes is to develop these techniques for a detailed fundamental understanding of combustion processes which can then be used to improve the overall efficiency of combustion. The cooperative program involves nine countries including Canada. These activities have recently been summarized in a well-illustrated brochure published by Sandia Laboratories, the Operating Agent (SANDIA, 1988).

The work involves application of these techniques to advanced piston engines, to furnaces and to fundamental work on turbulent flows, physical chemistry, numerical modelling and diagnostics. Within each of these three general areas, the Executive Committee designates tasks for the participating countries. An annual Task Leader Meeting discusses the eventual results. Canada hosted this group in Ottawa in 1987, attended by more than fifty scientists.

The significance of this cooperative effort becomes apparent when one considers the competitiveness in the commercial world related to combustion. Within this agreement very broad cooperation is occurring at the pre-competitive level amongst workers whose companies could not cooperate at the application stage.

Pooling of Bibliographies and Databases

Energy Technology Data Exchange

The IEA has been instrumental in establishing a number of information databases on specific topics, the Heat Pump Information Centre and the Coal Technology Information Centre being examples. Compiling and sharing existing information is a valuable collaborative activity in its own right.

The recently established Energy Technology Data Exchange is a recent and comprehensive example. Many IEA members have compiled bibliographies and abstracts of energy technology publications in their own countries and have, to a varying degree, also abstracted the international literature. These bibliographies are stored in data banks, accessible by on-line systems.

In 1987 twelve IEA countries including Canada, pooled their bibliographies of unclassified energy research for their common, decentralized use. Each country abstracts, within an agreed scope and format, the energy-related technical information reported in its national literature. Once a month (in the case of larger countries twice a month) these abstracts, on computer tape, are sent to the US Office of Science & Technology Information in Oak Ridge, Tennessee. The whole compilation including the database previously compiled by OSTI is available to any person in the member countries via commercial on-line systems. This database is now accessible from Canada through DIALOG Information Services.[1] More details can be obtained directly from the Canadian representative.[2]

While this service has only been available for less than two years, it is being widely used. The international usage amounts to about 700 connect hours per month. Industry makes about 70% of the enquiries. The balance is approximately equally shared between academia and government. For Canada an estimated one thousand searches are done each month, a statistic which compares favourably with the usage of other data banks. The costs to Canada are for collecting and preparing the abstracts and a management fee to OSTI for the compilation and maintenance of the whole database.

International Development of Performance Standards

Performance Testing of Solar Systems

While many solar collectors are, in essence, quite simple devices (a thin film of water under glass, flowing over a black surface), the accurate measurement of their efficiency requires considerable sophistication. Well established performance standards are required for any evaluation of the effectiveness and economics of solar systems. They are also an essential prerequisite for implementation and marketing, particularly in export markets.

Sixteen IEA members, including Canada, developed standard test procedures for solar collectors in solar heating applications. "Round-robin" trials were conducted to investigate the sensitivities of test results to test conditions and the accuracy of the instrumentation. Reliability and durability were studied using data from many sites. Based on these and other studies, reliable test procedures were developed for component parameters, storage heat loss, heat exchanger effectiveness and the validation of system performance.

The results of this work are now reflected in the Canadian standards test methods for solar collectors and solar systems.

Access to Unique Experimental Facilities

Fusion Technology: Plasma Wall Interaction

Research in fusion requires the construction of large expensive experimental facilities and the development of sophisticated diagnostic tools. Because of the cost and complexity, there are many international collaborative arrangements besides those sponsored through the IEA.

Under the IEA the fusion device "TEXTOR" (Torus Experiment for Technology Oriented Research) has been built by the European Atomic Energy Community and Kernforshungsanlage Julich GmbH at the Julich Nuclear Research Centre in Germany. The contributions of the IEA partners (other than KFA and EURATOM) to the construction phase amounted to approximately 30 man years and some 1.4 million DM.

The TEXTOR program is focused on a key technical area, plasma wall interactions. Means must be found to limit the interaction of the plasma with the wall of the containing vessel,

1 / DIALOG Informational Series Inc, Marketing Dept, 3460 Hillview Ave, Palo Alto CA 94304 USA.

2 / Dr. J.E. Kanasy, Director, Technology Information Division CANMET/Energy Mines & Resources, 562 Booth St, Ottawa, Canada KIA OGI.

which introduces impurities into the plasma, and lowers its temperature. Control of impurities is essential to the development of long pulse high temperature plasma which would be required for a practical fusion device. This contribution entitled Canada to seven percent of the experimental time on the machine.

Our participation in this project has had a significant impact on the design of the Canadian fusion device, the *Tokamak de Varennes*, which was designed explicitly to explore long pulse plasma. Several developments from TEXTOR have been incorporated into the Varennes machine. With the contributions made to instrumentation and diagnostics of TEXTOR, Canada has earned recognition for its scientific and industrial expertise and has enabled Canadian industry to compete in a very competitive area of high technology.

Canada as an Operating Agent: Exchange of Experimental Material

Bioenergy

This program addresses the use of biomass resources — from specially selected and intensively cultivated species, to the use of forestry residues — to produce fuels, petrochemical substitutes and other energy-intensive products. The Agreement has three Annexes: (I) Growth & Production, (II) Harvesting & Onsite Preparation and (III) Conversion. Canada (the Canadian Forestry Service) is signatory to the agreement, the Operating Agent in Annex I, and participates actively in Annex II. Energy, Mines & Resources is the participant in Annex III.

Annex I involves the selection and cultivation of fast-growing varieties of willows, poplars and aspen. Plantations are established with cuttings from selected stock. The individual trees are thus genetically identical (clones). We have now a great deal of new information on the selection and propagation of clones and, through breeding programs, will provide stock far more suitable for energy plantations. Studies have been made on the needs for fertilizer, herbicides and the control of insect pests.

With this program Canada, together with the other nine participants, has rapidly compiled a body of information on bioenergy production and conversion techniques. For example, Canada has established a technique for modelling long term environmental effects of intensive biomass removal. This is an area in which we are regarded as a world leader.

We now have a better understanding of lignocellulosics through a better understanding of relationships in enzyme accessibility, enzyme-substrate interaction and hydrolysis kinetics.

International standards for research materials and analytical methods have been developed. The scientific network is presently conducting round-robin comparisons of analytical protocols that will enable process developments to be compared.

In direct biomass liquefaction, two world leading Canadian pyrolysis technologies have been chosen to undergo a techno-economic assessment of processes for primary oil production and upgrading to gasoline.

In municipal solid waste, participating countries bring to the table their own expertise and commercial experiences in different technologies and strategies for dealing with urban refuse and its conversion to energy. Canada's contribution is incineration emissions data and testing protocols.

Exchange of Policy Information

Country Reviews and Technology Reviews

The reviews which the IEA makes of member countries' energy and energy R&D programs and the thematic reviews of the status of specific technologies are examples of international collaboration of a different kind.

Such program reviews are a standard exercise for the Organization for Economic Cooperation and Development of which IEA is a part. In a review of Canadian programs, a visiting team of rapporteurs from other member countries visits Canada for a week or more, receiving briefings on our energy resources, energy policies, energy prices, consumption level trends, taxation policies and energy R&D programs. The reviewers are asked to describe Canada's activities in the context of general questions such as "What is being done to reduce dependence on hydrocarbons?" "What are the policies to encourage energy conservation and energy efficiency?" "How effective are they?" "How do government R&D programs mesh with those in the private sector?". The final review is a public document.

The long term object of these reviews is to encourage member countries to become more responsible world citizens. More immediately it is useful and salutary to explain and defend one's own programs and program objectives to outsiders.

The benefits are both for the country being reviewed and for the rapporteurs. It is valuable, for instance, for a Canadian rapporteur to learn that there are other federal states which have their own problems in resolving questions of federal as opposed to provincial (or state, laender or cantonal) responsibility. Rapporteurs from countries with more centralized governments are, conversely, educated on the complexities of federal systems of government.

Reviews of energy R&D programs are, of necessity, general in scope, addressing questions such as the overall level of effort, the relationship between government and private sector R&D programs, the relationship between the R&D and energy policy, and mechanisms for implementation. It is impossible, within the time available for these reviews, to discuss the technical content of the programs in any detail. Specific projects are only discussed as examples.

The status of individual technologies appears in the thematic reviews. In 1985, for example, six countries with major programs in Synfuels (synthetic liquid fuels derived from coal, bitumen or natural gas) were reviewed: New Zealand, Germany, United States, Australia, Canada and Japan. Canada, particularly AOSTRA, (the Alberta Oil Sands Technology Research Authority), played a major role in this review and in the seminar which was held to summarize the results of the reviews of individual countries (OECD/IEA, 1985).

At that time, Canada was the only country with a full scale commercial synfuels production activity. (New Zealand's natural gas to methanol to gasoline plant was, at the time, still under construction.) The tar sands plants exemplify many of the common features of all future synfuels projects: the volumes of material to be handled, the capital costs of the plants, the need for performance reliability in all steps in the process and the potential environmental impacts. For example, if the process involves a hundred thousand tonnes of material a day, even a very small percentage of material in a waste stream will amount in years or months to a large, potentially embarrassing accumulation which has to be put somewhere. While these features are intuitively obvious, one needs to see an operating full scale plant to be able to grasp its full magnitude. As a consequence, Canada made a valuable contribution to this review.

The most recent series of thematic reviews were on "Technologies for Energy Efficiency and Fuel Switching." Programs in the Industrial Sector were reviewed in Japan, Portugal, Spain and the UK; buildings were examined in Austria, Canada, Norway and Sweden; transportation was studied in the USA.

The reviews have been published in a series of monographs, for example: "Consensus and the Competition in the Japanese Industrial Sector" and "Sweden's Integrated Approach to the Building Sector" (OECD/IEA, 1988). As noted, such reviews are useful to the country being reviewed; we see ourselves as others see us. With independent evaluation and constructive criticism they can also be helpful in arguing for continued support of government programs.

Their value to the outsider is at least as great. One can learn in detail about the way in which, in the examples cited above, the Japanese and the Swedes conduct their affairs; how they organize their programs and get R&D results implemented by the private sector and accepted by the consumer. There is no source, other than the IEA, for this information at the level of detail provided by the IEA reviews.

In those instances, while both countries have approaches which are not at first sight applicable to Canada, one can address the question "How could such an approach be adapted to the Canadian situation?" Without the IEA reviews, almost the only source of information, such questions could never be raised.

The Implementation of R&D: Private Sector Collaboration in International Projects

In the late 1970s and early 1980s there were expectations that new energy technologies would rapidly develop and be implemented and that there would be considerable market penetration of energy efficient technologies in periods of 5 to 10 years. Collaborative projects sponsored by the IEA were expected to facilitate implementation and market penetration. They were expected to provide the prerequisite demonstrations of economics and efficiency. Joint programs between governments and private sector were expected to further facilitate this process.

The implementation of new technologies has, however, turned out to be a much slower process than was hoped or expected. There are several reasons for this.

There is the basic inertia in energy supply technology capitalization. Hydro dams, power stations and oil refineries, for example, are built with a life expectancy of 20 to 40 years or more. Houses and buildings, together with their heating and ventilation systems, are expected to last at least as long. Further, while there have been many incremental improvements in, for example, the internal combustion engine, the large capital commitments of the automobile companies and the oil companies who provide the fuel inhibit drastic or rapid change.

There are also institutional problems which make it difficult for governments to sponsor R&D and have it quickly implemented. Government R&D, supported by the taxpayer, is almost axiomatically in the public domain. The private sector will, however, only be interested in investing in and selling a new technology if they own the intellectual property, the patents and the operating experience. Without the ownership of intellectual property, they will have little chance of establishing a reasonable market share. Government supported programs and particularly international government supported programs are, by their nature, not the preferred vehicle for private sector R&D investment.

In spite of all these circumstances, which only compound the difficulties of implementation and private sector participation in IEA programs, private sector organizations have participated effectively. A total of 37 industrial participants were involved in some 21 agreements. In some of these agreements all the participants were in the private sector, in others both private sector and government organizations were signatories.

The agreements stipulated protection of intellectual property generated under the agreement (the IEA terms of reference and protocol readily permit such restrictions). Many of these agreements attracted private sector participants who, for one reason or another, were willing and able to take a relatively long term view of their R&D investments; they weren't expecting a marketable product within three years!

Conclusion

The general reader will be interested in how the IEA manages to get this process to work. Firstly, the IEA is a strong organization. Its members are obliged in general terms to contribute and participate in its activities. The IEA has cachet and visibility. If, for example, it offers to sponsor a conference, it can attract the major player.

The individual projects are, however, funded and organized only by the interested participants. This eliminates a great deal of bureaucracy. Member countries only participate in projects which interest them and from which they themselves can derive benefits. These benefits are plainly proportional to the number of participants.

The success of the IEA programs stems from a combination of the strong obligation of membership of the IEA together with voluntary participation in specific projects.

Appendix
List of Current IEA Implementing Agreements and Annexes

This list is not necessarily complete. The work in some Annexes may have been completed and those Annexes are not in force. (Name of Agreement is shown in italics, numbers represent the Annex number.)

END-USE TECHNOLOGIES

Alcohol and Alcohol Blends as Motor Fuels
2: Technology Information Exchange on Motor Alcohols
3: Methanol Diesel Field Trials and Analyses
4: Information Exchange on Alcohol Production from Fossil Fuels
5: Alcohol Production Methods

Advanced Heat Pumps
4: Heat Pump Centre
7: New Development of Evaporator Parts
8: Advanced In-Ground Heat Exchange Technology
9: High Temperature Industrial Heat Pumps
10: Technical and Market Analysis
11: Stirling Engine Technology
12: Modelling Techniques for Simulation and Design
13: State and Transport Properties of High Temperature and Non-Azeotropic Mixtures
14: Working Fluids and Transport Phenomena in Absorption Heat Pumps

Buildings and Community Systems
5: Air Infiltration & Ventilation Centre
8: Inhabitant Behaviour with Regard to Ventilation
10: Building Systems Simulation
11: Energy Auditing
13: Energy Management in Hospitals
14: Condensation
15: Energy Efficiency in Schools
16: BEMS-1 User Interfaces and System Integration
17: BEMS-1 Evaluation and Emulation Techniques
18: Demand Controlled Ventilation Systems
19: Low-Slope Roof Systems
20: Air-Flow Patterns within Buildings

District Heating
2: Implementation of Cooperative Projects in the Field of District Heating

Energy Conservation in Combustion
1: Energy Conservation in Combustion

Energy Conservation in Industry
5: Heat Pump Applications
6: International Standard Method for Comparing Energy Use in the Pulp and Paper Industry

Energy Storage
3: Aquifer Storage Plants
4: Short Term Water Heat Storage
5: Full-Scale Latent Heat Storage Installations
6: Environmental and Chemical Aspects of Thermal Energy Storage in Aquifers and R&D of Water Treatment

Heat Transfer/Heat Exchangers
4: Improvement of Themohydraulic Design and Performance in Heat Transfer Equipment
5: Optimal Design of Heat Exchanger Networks
6: Improved Structural Design and Reliability of Heat Transfer Equipment

High-Temperature Materials for Automotive Engines
2: Cooperative Programme on Ceramics for Advanced Engines and Other Conservation Applications

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FOSSIL FUELS

Atmospheric Fluidised Bed Combustion

Coal Combustion Sciences
1: Cooperation on Investigations into Advanced Analytical Techniques and Basic and Applied Research in the Field of Coal Combustion Sciences
2: Basic and Applied Research in the Field of Environmentally Favourable Coal Combustion

Coal/Oil Mixtures
2: Cooperation on Coal Liquid Mixtures

Coal Pyrolysis

Coal Technical Information Service

Control of NOx Emissions during Coal Combustion
3: Dissemination of Information of Low NOx Burners and Sorbent Injection

Enhanced Oil Recovery
9: Enhanced Oil Recovery

Multiphase Flow Sciences
1: Coordination of Investigation into Basic and Applied Research in the Field of Multiphase Flow Sciences

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RENEWABLE ENERGY

Bioenergy (formerly Forestry)
2: Short Rotation Forestry for Energy
3: Methods for Harvesting, Processing and Transport
4: Biomass Conversion into Usable Energy

Hydrogen
1: Thermochemical Production

4: Electrolytic Production
6: Photocatalytic Production
7: Storage, Conversion and Safety
8: Technology and Economic Assessment
9: Hydrogen Production

Large Scale Wind

Peat Production
1: Peat Production

Small Solar Power Systems
3,7: High-Temperature Receiver Technology
4: High-Temperature Thermal Storage
5: Solar Fuels, Chemicals and Energy Transport
6: Long-Term Solar Fuels and Chemicals

Solar Heating and Cooling
3: Performance Testing of Solar Collectors
6: Performance of SHAC Using Evacuated Collectors Energy
7: Central Solar Heating Plants with Seasonal Storage
8: Passive and Hybrid Solar Low Energy Buildings
9: Solar Radiation and Pyranometry Studies
11: Passive and Hybrid Solar Commercial Buildings

Wind Energy
8: Study on Decentralized Applications for Wind Energy
9: Intensified Studies on Wake Effects

FUSION POWER

Asdex Upgrade
1: Joint Work on the Investigation of Torodial Physics and Plasma Technologies in Asex and Asdex-Upgrade

Large Tokamaks

Radiation Damage in Fusion Materials
2: Experimentation on Radiation Damage in Fusion Materials

Stellarator
1: Cooperation on Research and Planning for the Development of the Stellarator Concept

Superconducting Magnets
1: Large Coil Task

Textor
1: Plasma Wall Interaction in Textor

SYSTEMS ANALYSIS
3: International Forum on Energy Environment Studies

ENERGY TECHNOLOGY DATA EXCHANGE

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