ANNUAL·REPORT·90

Institute FOR Prospective Technological Studies

JOINT RESEARCH CENTRE

COMMISSION OF THE EUROPEAN COMMUNITIES

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EXECUTIVE SUMMARY

1- The Institute for Prospective Technological Studies (otherwise known as PROMPT) was set up in 1989. Its primary tasks, as defined by the Commission's blueprint for the restructured JRC, are two-fold:

- monitoring new developments in science and technology
- strategic analyses of new areas of science and technology

2- The support tool for fulfilling these tasks is ESTO (the European Science and Technology Observatory), currently under development within the Institute. In addition to having on-line access to some 500 data bases, ESTO is already operating a pilot version of its NOVA DB - aimed at identifying and evaluating technical innovations in key research areas - and is in the course of preparing the data base known as QUIQUOD or Q^2, an inventory of "who is doing what" in European science and technology.

3- Studies conducted by the Institute are generally performed on the request of a "client", in most cases another sector of the Commission (including other parts of the JRC). The Commission service with which PROMPT has the closest links (outside the JRC) is the Forward Studies Unit of the Presidency and two major studies, both related to the global warming theme, were undertaken for this client during the year.

4- Other "in-house" studies included a contribution to the Commission's inter-service examination of the long-term future of air transportation (LOTOS), study of the market penetration process for advanced materials, development of the concept of "technological nodes" and an overview of medium-term trends influencing R&D for the "JRC 2000" strategic planning exercise.

5- Although some problems may raise in undertaking work for private clients, given the Institute's function as an independent advisor to Commission services, one sizeable external contract was completed during the year. This consisted of a critical review of the literature on fusion energy and was undertaken on behalf of the German BMFT.

6- Of the four workshops and seminars held during the year, two were complementary to the studies already mentioned. Of the others, one was an open training seminar on innovation forecasting, and the other a workshop on the use of surveys for foresight studies.

7- Staff numbers rose slightly during the year. The Institute now has 11 scientific/technical personnel (9 of them A-grade), plus 3 administrative/secretarial staff. A further 6 posts are under recruitment. The institute has also welcomed its first scientific visitors - a post-doctoral fellow and an undergraduate undertaking a "tesi di laurea" under PROMPT supervision. A further three visitors - two post-graduate and one post-doctoral research fellows - are expected to be joining the Institute in the near future.

INTRODUCTION

The Institute for Prospective Technological Studies (also known as PROMPT) came into being in 1989, following the new orientations and the new organization of the JRC which were put into effect at the end of 1988. The official document which describes these changes for the JRC, ("A new outlook for the Joint Research Centre" - COM (87)491), contains the following statements, relating to the new Institute for Prospective Technological Studies :

"prospecting, assessment, scientific watch and strategic analysis will assume a new significance in the context of scientific and technological developments.
This work will become an integral and essential part of the process of programming Community research. In particular, the scientific and technological watch function, which is virtually unknown in the Community, will be called upon to play a key role in the future alongside the prospective studies and technology assessment functions" and *"the special feature of the JRC's role in this area is its ability to supply strategic analyses based on "inside knowledge" of the scientific and technical trends in the world of research".*

On these bases, and relying on the wide spectrum of scientific/technical knowledge available within the JRC, PROMPT supports a permanent system for information on and analysis of the state of science and technology in the European Communities, and of its relative position world-wide. The activity includes the analysis of both the potential and the drawbacks of new technologies, the prospects for their application in various fields and the developments foreseen.

The focus of the Institute's activities is advanced, applied research, with priority going to the subjects covered by the Community Framework Programme and to those newly emerging technology areas which are potentially important for European society and industry.

The main functions of the Institute are: to monitor, evaluate and alert, helping to bridge the gap between European science and European technology, with the intention of providing information on strategic options and opportunities with a European dimension, in a form suitable for users within the Commission, for science planners and for European industry.

The permanent staff of the Institute is small in number and will remain so in the near future. It has, however, to be complemented by temporary staff seconded from Member States, by visiting scientists and by research fellows. In addition, PROMPT relies heavily on contributions from outside, through formal contracts or collaboration agreements with national institutes and industrial firms and through networks of individual correspondents in various fields and countries.In particular an antenna of the Institute is being established in San Francisco and another is in prospect for Japan.

The work of the Institute covers two main, closely interrelated activities :

- the operation of a scientific/technical Observatory
- the execution of Prospective Studies

The S/T Observatory is concerned with the collection, organization and validation of the information needed for the regular assessment of the state-of-art of science and technology in Europe and for the early detection of new facts, breakthroughs and orientations in the scientific and technological field world-wide.

For this purpose structured access to existing bibliographical and documentation DBs is in operation and new DBs are in the process of being set up covering, in particular, the information on strategic subjects collected directly by the Institute.

Scientific/technical networks of correspondents are being created, composed of internal (i.e. JRC) and external experts in selected fields.

Periodic inquiries are being organized, calling on the opinion and expertise of managers and practitioners of science and technology.

The Prospective Studies concern the analysis and evaluation of information and its use for the study of prospects in specific fields of science and technology.

This activity is carried out upon request from various customers covering the following categories :

The JRC Directorate General and JRC Institutes

DG XII (Science, Research and Development)

Directorates General of the Commission in charge of the various sectoral policies

The Forward Studies Unit of the President of the Commission

Other European Institutions

National and Regional bodies

Industrial associations and individual firms

1. The Scientific and Technical Observatory (ESTO)

The S/T observatory function requires the collection, storage, analysis and distribution of a large amount of information in a number of selected fields.

In support of this activity some tools are currently being developed. They include direct on-line access to some 500 bibliographic and patent data bases, the creation (forthcoming) of specialized networks of correspondents and the establishment of "antennae " in various key locations outside the EC (with the first scheduled to open, in San Francisco, by April 1991).

Two of the Institute's own data bases are now in their prototype phase of development. These are the NOVA data base, for collecting the most recent information on scientific "novelties" and technological innovation , and the Q^2 data base, which aims at storing information on on-going R&D projects in the Community. Progress in setting up of these data bases is reported below.

1.1 NOVA : the "Innovations" Data Base

One of the tools that PROMPT has decided to activate, in order to operate the European Science and Technology Observatory, is an innovations data base. A data base system (NOVA), which allows the storage and retrieval of the information currently collected and evaluated by PROMPT, has been thus defined. The information to be collected includes the most recent achievements and breakthroughs in science and technology, in addition to information on trends and potential for innovation.

After analysing user requirements, the Data Modelling, Information Flow and Data Base Structure functions were completed, a technical solution was proposed and a working model was developed by early summer. This working model, now in its second version, includes an input mask, a retrieval system and a basic import/export from/to text file mechanism. This will serve as the prototype for the Innovations Data Base pilot project.

The hardware and software tools that are used in this pilot project are :

a. A number of interlinked Macintosh PC's, also linked to the JRC centre network backbone and to the dedicated PROMPT server via ETHERNET cabling and related communications S/W.

b.The user-friendly HyperCard Interface which, at this stage, acts both as an interface and a data filing mechanism.

c. Custom made S/W that permits the input, retrieval and output of information stored according to PROMPT internal needs.

Information is collected principally on the subjects currently of importance to PROMPT, *viz.* Advanced Materials, Global Change, Biotechnology, Transport, Environmental Technology and Energy. Inputs may be entered either through the on-

line system from a Mac PC or in batch mode from any other type of PC, through the use of a common word processor application.

Retrieval may be performed on-line through the HyperCard interface and associated S/W. A free-text search mechanism has been developed, facilitated by an inverted external file word index. It is based on keywords and associated text, combining words using Boolean and/or proximity operators, that enable on-screen navigation through results, as well as producing hard copy reports.

As far as data collection is concerned, PROMPT relies heavily on contributions from outside, through collaboration agreements and formal contracts with networks of experts in S/T. At this first stage data collection, and thus input to the data base, is performed either by internal PROMPT members or by a small pilot network of experts.

1.2 QUIQUOD (Q^2) : the "R&D Projects" Data Base

A second tool of the Observatory is an information system made up of a data base (DB) and an intelligent interface. This was conceived as a complement to NOVA, with the aim of identifying activities and expertise on given subjects.

To this end, the QUIQUOD (or Q^2) information system, which allows access to existing national and international data bases (DBs) and enables integrated queries to information on European R&D projects, has been designed and is being developed. The aim is to enable the listing, for a given subject, of all current and planned R&D projects, with specific details on project description, institution particulars, budgets, staff, timing, fields of activity and progress of work.

Given the prior existence of certain national and regional DBs in this field it was decided that structured access to these should be attempted. Should this be successful, collection of "new" data will only be necessary where gaps exist.

To this end, national, regional and sectoral R&D DBs were identified in the field of Advanced Materials, which is a field of major interest to PROMPT and was therefore taken as a prototype. Contacts were made with the persons responsible for management of those DBs that contained the more promising data, namely those of Italy, Germany, England, Belgium, France, Spain and The Netherlands, and information on the contents and ways to access those data bases was requested. Those DBs that enabled on-line access were interrogated directly; in other cases the persons in charge were asked to provide us with a search on selected advanced materials topics, either on hard copy or on magnetic tape.

The primary goal was to assess the relative importance, comprehensiveness and mutual compatibility of these DBs in the context of PROMPT's needs in the field of advanced materials. The results received were matched against PROMPT pre-specified needs and those of a DGXII-A working group's recommendations on the harmonization of research data bases.

The results of this comparison pin-pointed the requirement for supplementary data in PROMPT's own DB in instances where information supplied locally was either scarce, or incomplete or not readily accessible. To this end the E-MRS (European Materials Research Society) was contacted and other relevant sources of current research in progress were identified.

2. Specific Studies

Studies constitute the main output of the Institute. Since they are performed on behalf of specific clients, however, their contents are, in principle, confidential. The summaries which follow, therefore, concern only the broad lines of the studies.

2.1 Studies for the Forward Studies Unit

The Forward Studies Unit ("Cellule de Prospective"), set up under the direct authority of the President of the Commission, was PROMPT's largest single "client" in 1990. Activity was concentrated on two studies, both related to the international anxiety that increased atmospheric concentrations of carbon dioxide, as a result of anthropogenic activities, may be creating highly disruptive changes in the global climate pattern.

The first of these studies was devoted to examining the scientific basis for predictions of fast-approaching climatic disaster. The second surveys technological possibilities for reducing CO_2 emissions.

2.1.1 Science and the Greenhouse Effect

This study was undertaken in response to the Forward Studies Unit's need to have clearer ideas about the scientific consensus (or lack of it) on the greenhouse effect, the state of the scientific debate surrounding it, the points under dispute and the current uncertainties.This evaluation was requested in connection with preparations for the Houston Summit in July and with establishing the position of the Community at the 2nd World Climate Conference in the autumn.

The study was carried out by a Working Group, under PROMPT's coordination. Membership of this Working Group included representatives of three other JRC institutes - the Institute for the Environment, the Institute for Remote Sensing Applications and the Institute for Safety Technology - in addition to members of PROMPT. A report (Ref.1) was issued in early June and presented to the Forward Studies Unit on June 20th.

The study is based essentially on a literature survey by scientists working in disciplines relevant to the greenhouse effect but not (for the most part) engaged directly in the international research effort on this theme. It is, therefore, a summary of the scientific knowledge about the greenhouse effect, based exclusively on written evidence (published research results) assembled, compared and evaluated from an independent stand-point. More than 150 papers were reviewed. In order to guarantee a fresh and independent viewpoint, previous review papers, analysis or synthesis - including the reports of the International Panel on Climate Change(IPCC) parts of drafts of which became available towards the end of the study period - were purposely not considered in our review, which therefore referred only to original (and recent) scientific papers.

The main findings of the study may be summarized as follows:

1. The balance of probability is that the Earth is growing warmer,as a consequence of the enhancement of the natural greenhouse effect by man-made emissions of carbon dioxide (CO_2) and other trace gases in the atmosphere.

   This is more than a presumption, since it is based on proven physical concepts and on the strong correlation between CO_2 concentrations and temperature in previous climates.

   It is not a certainty because the confidence levels attached to earth surface measurements of supposed warming trends are low. The 0.5 Kelvin observed warming over the past century and the "high" temperatures of the 80's could well be an incidental feature of natural climate variability.

2. Global warming might reach some 3 Kelvin (+/- 1.5 K) by the middle of next century.

   The amplitude/timing of the warming is uncertain because:

   -the extent and nature of greenhouse-type man-made forcings are themselves uncertain, due to the lack of knowledge about bio-chemical cycles and the chemistry/photochemistry of greenhouse gases

   -the model simulations of future climate (for assumed greenhouse forcing scenarios) contain many inadequacies stemming from the difficulties in understanding and modelling cloud physics, ocean circulation and the various climate feedbacks;

3. The effects of greenhouse gases on regional climates cannot currently be predicted for a specific place or time, mainly because current models have too coarse a resolution.

   However, broad trends, common to all models,indicate

   - increased warming at high latitudes

   - a strong stratospheric cooling,

   both phenomena which could help in the early detection of any man-made greenhouse effect;

   - higher frequency of extreme climatic events (drought, storms, tropical cyclones).

4. Prediction and quantification of impacts of the greenhouse effects generally depend on prediction of regional climate, and are therefore uncertain.

Predictions of sea-level rises have been revised drastically downward in recent years and do not seem dramatic if compared to other natural processes affecting low-lying areas.

5. Significant progress should take place in the ascertainment and prediction of the greenhouse effect within the next ten years because

- model simulations predict that the warming trend will be clearly distinguished from the natural climate "noise" during the 90's;
- a further decade (2 instead of 1) of the highly reliable temperature measurements from space satellites will be available;
- model simulations should improve, especially as far as the representation of clouds and oceans is concerned, and also, to some extent, as a result of the availability of more computing power;
- the first results of large-scale international efforts, such as the World Climate Research Programme and the International Biosphere-Geosphere Programme launched during the 80's, will become available and will help significantly in the understanding of key processes and in establishing the comprehensive data sets (e.g. from space satellites) necessary for improvements of models.

A follow-up to this study has been requested by the Forward Studies Unit, and will be provided by PROMPT in the form of short periodic reports, highlighting new facts, findings and opinions resulting from, or related to, the intensive current research in the field.

2.1.2 Technological Response Options to the CO_2 Issue

Parallel to their request for an evaluation of the greenhouse debate, the Forward Studies Unit also requested a survey of the technological options available for reductions in CO_2 emissions. A three-part report, covering the potential for reducing energy consumption, the potential for greater efficiency in electricity generation and the prospects for renewables, was delivered in December, 1990. In addition, an expert workshop on energy conservation potential was held, in Brussels, in November, 1990 (see Section 3.3 below).

2.1.2.1 CO_2 and Energy Conservation: Setting consumption targets for Europe

Conservation is taken here to encompass both reduction in basic demand and improvement in the efficiency of equipment and processes.

There are, of course, good reasons for reducing the consumption of fossil fuels, quite apart from possible greenhouse effects:

- reduction of chemical and thermal pollution

- the economic advantages of reducing energy consumption
- decreased dependence on external fuel supplies

The objective of the study was to provide answers to such questions as:

How far is it possible to increase energy conservation in the main sectors of energy consumption - industry, residential and commercial, transport - for the EC Member States?

To what extent is the information available suitable for this assessment?

What should be done to improve this information base?

Attention was primarily devoted to assessing the recent trends of energy consumption in the various end-use sectors, the quality and quantity of the available data and the effort required to bring both technical and economic information to the level necessary to perform the evaluation of potentials.
It was pointed out that several levels of potential must be identified, corresponding to the rate of return of the investment and to the availability of financial resources; hence the requirement not only for the technical information necessary to evaluate the technological potential but also for sound information on the cost of the various conservation measures.

The analysis of past energy consumption trends and of the potential for first and second level measures (short and medium payback times) was carried out in detail for the UK, with less detail for France and Europe, with the expectation that the associated workshop (see Section 3.3 below) would provide fuller information.

In the final report (ref.2) the following figures, concerning reasonable targets to be achieved with cost effective measures, were quoted as a tentative statement:

20-30 % in transport, 15 % in residential energy use, 20 % in manufacturing industry

In the transport sector, road traffic is by far the largest energy user, covering more than 50% of its fossil fuel consumption.The candidate technologies are essentially those related to the improvement of car engine efficiency (gains in current technology, development of the spark ignition engine or new concepts such as General Motors' two stroke orbital engine) and to car body weight reduction (through the use of new materials such as carbon fibre, plastics and ceramics, together with increased use of glass-fibre and aluminium). It is reported that cars with a consumption potential of 100 mpg (35 km/lt) may be in production by the end of the century: this can be compared with a current average consumption figure, in Europe, of 31 mpg.

In the residential sector the largest potential is offered by space heating, with improvements up to 50% possible. Most of the savings would occur by reducing building heat losses but significant gains are possible by means of more efficient heating systems and better controls.

Building insulation improvements include wall and loft insulation, full double glazing and draught proofing; taken together, these cost effective measures

could reduce energy consumption by 25%. It must be recalled that, since the rate of construction of new buildings is only 1-2% of the total housing stock per year, the main contribution to energy savings within the next 10-20 years must come from retrofitting.

As for heating systems, better control and substitution of old boilers could give a 20% energy saving. New technologies such as condensing boilers, where heat is recovered from the flue gas, may allow an additional 15% improvement.

Combined heat and electric power production (CHP) offers considerable potential for energy saving in the residential, commercial and public sectors, since the overall efficiency may be higher than 80%.

Other savings in the residential sector may come from more efficient lighting methods and controls (over 50% potential saving), better design and management of cooking appliances (20-30% potential saving) and improvements in other domestic appliances such as water heaters, refrigerators etc. .

In the industrial sector, the following examples are quoted:

- high temperature heating/melting, with direct heating of crucible furnaces for non-ferrous metals, via a ceramic immersion tube
- radiant heating by gas-fired ceramic tubes instead of electric devices
- heat recovery with recuperative and regenerative burners which can recover up to 50% and 90% respectively of the heat carried by the flue gases.

2.1.2.2 The role of energy conservation in reducing carbon dioxide emissions from the electricity supply sector

Approximately 50 per cent of electricity generated in the European Communities comes from the combustion of fossil fuels in power plants, 70 per cent of which are coal-fired. The electricity generating sector produces about 200 million tonnes of carbon annually which amounts to some 30 per cent of total EC carbon dioxide emissions and about 4 per cent of the global total

At present, an average fossil-fuelled power plant operates at 33 per cent efficiency. New power generation technologies currently offer efficiencies above 45 per cent, with the potential to achieve 55 per cent in the next 10-20 years.

The best new but conventional fossil-fuelled power plants offer thermal efficiencies of 35-38%. Typically, these plants run on the combustion of pulverised coal with the exhaust gases 'scrubbed' clean of noxious sulphur (flue-gas desulphurisation).

New power generation technologies are based on so-called 'combined-cycles' and use gas-turbines which are closely related to jet-engines. Essentially, fuel is burnt in air pressurized by a compressor in a combustion chamber and the hot gases used to drive a gas turbine and

generate electricity. The exhaust gases are passed on to a heat recovery steam generator (HRSG) and the steam produced is used to drive a conventional condensing turbine which again generates electricity.These combined-cycle plants can have an efficiency of about 45 per cent.

Natural gas is not the only fuel which can be used to power the gas turbine; gasified coal is another possibility. Several integrated coal-gasification combined cycle (IGCC) plants have been constructed around the world. Coal is transformed into synthetic gas (a mixture mainly of hydrogen and carbon monoxide, with smaller quantities of methane , carbon dioxide and hydrogen sulphide) by reaction with steam and oxygen. Most of the hydrogen sulphide is removed by commercially available desulphurisation processes before the gas is burnt.

In a reverse configuration, the exhaust gases from a conventional power plant are heated by the addition of a topping gas from a separate gasification system. This gas is then fed to a high temperature gas turbine. These so-called topping cycles can push the efficiencies of conventional plants up to around 45%.

Other gas-turbine strategies are expected to push efficiencies of power stations to 54% in the next 10-20 years.

All the coal-fuelled advanced technologies are similar in price to, or cheaper to install than, a conventional power plant with flue-gas desulphurisation. At present, the best candidate appears to be pressurized fluid-bed combustion (PFBC, coal, combined-cycle) with a relatively low plant cost and efficiency of around 42 per cent. Pressurized exhaust gases from the fluidized-bed combustion of coal are used to run a gas-turbine in a combined cycle configuration. This method of coal-combustion also gives rise to lower NOx emissions.

The results of the study (ref.3) suggest that, if new power station efficiencies can reach 55 per cent efficiency by 2005 and existing power stations are replaced after a running-time of 30 years, then the average efficiency of power stations will improve to 40 per cent by 2000-2005, and 50 per cent by 2015-2020. This would mean a saving in the primary energy used for electricity generation from fossil fuels - and a corresponding drop in carbon-dioxide emissions - of 20% and 55% by 2000-2005 and 2015-2020 respectively, if electricity demand were to remain constant. Due to the much lower carbon emission factor of gas as compared to coal, carbon dioxide emissions would drop further if the fuel-mix of fossil-fuel power stations were to become gas-based rather than coal-based.

Electricity demand, however, is likely to rise rather than remain constant. Assuming that there is no increase in nuclear power generation over the next 15-30 years, the improvements in electricity generating efficiency given above would be capable of producing 10% and 27% more electricity overall (since about half the electricity currently produced comes from fossil-fuelled power stations) by 2000-2005 and 2015-2020 respectively, assuming combustion of the same amount of fossil-fuel primary energy as is used at present.

2.1.2.3 The Potential of Renewable Energies

Renewable energies and fusion are the principal long-term options for mankind's energy supplies. Fusion may, in the best case scenario, become a commercial reality in about 50 to 60 years time, assuming that,at a minimum, "scientific feasibility" is reached within the next 10 years .

Renewable energies, on the other hand, have already been demonstrated to be technologically achievable; their potential is such that investments in large scale efforts could start immediately.

Nuclear and most renewable energies are quasi CO_2-free. Nuclear reactors have the disadvantage that they pollute the environment with radioactive substances and that there are considerable problems with public acceptability; although this could change with a new generation of reactors, the issue of waste management still remains to be discussed properly.

Renewable energies produce neither radioactivity nor nuclear waste, and they do not generate additional waste heat. As the report (ref.4) points out, the contribution from renewables in the EC amounted to about 68 Mtoe in 1986, of which 55% came from hydropower. The ratio of renewables to nuclear power was about 0.5, the corresponding values for the USA were 167 Mtoe (in 1988) and a ratio of 1.25 for renewables (again mainly hydro) to nuclear. The potential increase in hydroelectricity, especially for Europe, is limited; at present the investment and unit costs for energy from most other renewables are too high to encourage any wider use.

With the exception of conventional hydro-electric schemes, the main commercial opportunities today in renewable energy exist mainly for small local needs, where social aspects often dominate. Cost effectiveness calculations are doubtful, since there are,currently, very limited markets for these technologies and it is thus difficult to estimate the economies of scale which would operate in large-scale systems. Price developments of renewables are, in general, in the opposite direction to those of fossil or nuclear energy sources. The cross-over is not yet predictable, since it is influenced by boundary conditions not easily converted to money terms, chief of which might be fiscal or pricing regulations aimed at internalising the social costs of competing energy options. A determining factor could be the value one assigns to the avoidance of a CO_2-catastrophe (in the sense of an insurance premium).

It has been estimated that the fraction of total energy met by renewables will increase. in the EC, from about 6.2% of total consumption in 1986 to about 12% in 2010; for the USA the corresponding values are 8.6% and 19.5%.

The avoidance of CO_2, in the EC, due to the use of renewable energies corresponds at present to about 7.6% of total emissions (cf. 10% in the USA). Taken together with nuclear energy, this implies a reduction in fossil-caused emissions of 166 MtC/a for the EC (and 250 MtC/a in the USA). By 2010 the quantity avoided by the use of renewables (in the EC) could reach about 140 MtC/a, which is 19% of present levels of fossil-caused carbon emissions.

A further reduction could be obtained if, in addition to the local, decentralised, use of renewables, large-scale/large-area production of solar electricity were introduced. A combined solar electricity/solar hydrogen approach seems to be

the most promising. If hydrogen could be produced cheaply and in large quantities it could, in the long term, eliminate all fossil fuels from our energy system, and thus stabilise the CO_2-level. It must be remembered, however, that the lead time for introducing such a technology is of the order of 50 years.

The energy for generating the energy carrier (and fuel) hydrogen could come from large photovoltaic systems. Such systems have the decisive advantage that they are based on an investment (vs. consumptive) use of a widely available material. Moreover, they offer the possibility of using a 'solar breeder' concept, in which plants build other plants: this would eliminate the need to increase pressures on the existing energy system, would reduce build-up times, and facilitate introduction. Again, however, lead times for introducing such a system would be lengthy.

In summary, renewable energy sources are today, and for some time to come, not sufficiently developed to lead to any essential reduction of the CO_2-level or to a major improvement in supply security, unless schemes based on large-scale-use-of-solar-radiation concepts, e.g. in the form of a large scale production of solar hydrogen (later, perhaps, supported by the use of high-temperature superconducting technologies) were to be introduced. Combination with pumped hydro could also become a solution, simulating to some extent the 'natural' sun-weather cycle.

Such a scheme would lead to a system in equilibrium. We cannot run out of hydrogen, as we cannot run out of electrons. The system is coherent with nature, almost as part of the natural hydrological cycle. Solar electricity could become a viable solution, not only for electricity but ultimately also as a substitute for the generation of energy from oil and, some day, even from gas and coal.

Technologically, therefore, renewable energy offers a solution to the CO_2 emissions problem. Economic and institutional problems, however, ensure that it is a solution only in the long term.

2.2 Critical Literature Survey on the Prospects for Thermo-nuclear Fusion Energy.

This report was commissioned from PROMPT by the BMFT.

Projects concerned with the exploitation of thermo-nuclear fusion reactions as a potentially limitless, clean and inexpensive energy source started around 1952. In 1990, some thirty eight years on, and in spite of major world-wide R&D programmes in this field, commercial exploitation of fusion energy is still not expected before the middle of the 21st Century. When this is considered alongside rising costs, with global expenditure on fusion R&D expected to be of the order of $US 100 billion by 2050, it is not surprising that a number of programme reviews are under way or have taken place in recent years.

This particular report (ref.5) differs from other recent reviews in that it is based on a critical analysis of the fusion literature as a means of assessing certain programme-

relevant issues. The purpose was not to make judgements on success or failure but to provide a succinct guide to published results and analyses.

The report consists of three parts: Part I provides an overview of thermo-nuclear fusion R&D, with sections devoted to technology, environmental issues, economics, costs, etc. It is descriptive and aims to be comprehensive and up-to-date, based on analysis of the literature up to early-1990.

Part II outlines the prospects for various elements of the fusion programme, by means of summary sheets. Each sheet has a succinct statement of the element under consideration, its positive and negative aspects and the prospects for the future.

Part III consists of a list of references to the literature on which the report is based.

The main issues considered are

- the total cost of developing and building a demonstration fusion reactor which will be commercially attractive,
- the anticipated economics of fusion energy,
- the possible environmental impact, or benefits, of fusion technology,
- the choice of the most promising and advantageous technology,
- the anticipated time and energy supply frames for building the first electricity generating plant.

As far as the technical possibility of fusion power is concerned, the study demonstrates that, while it is true that tokamak research has come closest to demonstrating scientific feasibility it is equally the case that, even here, (equivalent) "breakeven" in the plasma has still not been reached and there is still no experience with a deuterium-tritium mixture. Nevertheless, without the systematic and sustained effort of the European programme focussed on JET, the situation would be much more critical.

To date, however, material lifetime problems are still unsolved and no measurements have been made with deuterium-tritium mixtures. A lack of experience with such a critical component could lead to major financial losses and, if not treated openly and comprehensively from the start, to acceptability problems.

As far as can be ascertained from the open literature, inertial confinement has also not yet reached the goal of breakeven, notwithstanding the fact that substantial progress has been made with such machines as NOVA, GEKKO or PBFA II.

The complexity of traditional fusion machines remains one of the major obstacles and it is still not very clear to see how such devices, working at the limits of physical possibilities, can ever compete in any utility market characterized by the need for low maintenance and high availability.

Other paths are still open and other magnetic confinement systems show progress, as do the inertial line and the muon-catalysed concept. To explore these alternatives vigorously would undoubtedly improve the chances of ultimate success, but would also increase overall costs substantially.

Even if fusion does not possess the degree of radioactive risk present in fission many aspects still require clarification: tritium containment and handling, the risk of magnetic field breakdown, the damage caused by high energy neutrons, the volume of

contaminated structural materials, the extremely critical choice of radiation resistant, high strength materials with low activation,etc. Waste volumes from fusion decommissioning will be larger than those from fission, but they will be mainly low-level wastes without alpha-emitters. While the wastes from fusion plants will remain a potential hazard, to be stored for many hundreds of years, they will be many orders of magnitude less dangerous than fission wastes.

Costs, however, remain the major obstacle. Although the limitations of the various studies mean that no firm conclusions can be drawn, even the most optimistic projections are at the high end of estimated ranges of costs for competing technologies. For the moment commercial fusion power seems still "something of a mirage, a moving target which recedes as one tries to approach it".

2.3 Pre-LOTOS: study on Long Term Outlook of the Air Transportation and Aeronautic Industries.

This study was commissioned from Prompt by three Directorates General with different but complementary concerns: DG III (competitiveness of European industry), DG VII (transport policy) and DG XII (aeronautics research programme).

Although the end product (ref.6) of this exercise ran to two volumes and some 200 pages, the objective was relatively modest: to prepare the meeting of the LOTOS Panel, a group of senior experts, convened by DG XII to prepare further actions in the field of aeronautics research and development.

However, DG III and DG VII were interested in many more issues than just technology. To this end, PROMPT prepared a general survey of the commercial aviation and aeronautics industries over the coming 25 years, concentrating on the major market (the large airlines), and placing it in the broader context of traffic control, airports and related infrastructures, inter-modal competition, companies' management, human resources, environmental impact, and financing.

In addition to summarising this information and highlighting a number of potential conflicts and challenges, PROMPT produced several scenarios ranging from "business as usual", through industry forecasts, technological optimism, ecological pessimism and economic depression, in a deliberate attempt to provoke discussion.

The different options led to different priorities in terms of research and development, but also to different challenges for governments and European industry.

This pre-LOTOS report was much appreciated by the LOTOS Panel, whose only regret was that regional transport and helicopters had not been given more space; while recognising that this was not possible in view of the limited time allocated to this study, it was felt to be something to be attempted in the future.

2.4. Study on the concept of "technological nodes".

This study was performed at the request of the Director-General of DG XII (Science, Research and Development) of the Commission. The scope was to assess the concept of "technological nodes", which has been advanced by the Institute as a possible means of identifying priority areas for CEC research activity in support of industrial competitiveness.

The technological nodes concept starts from the premise that a matrix can be used to express the interaction between industrial sectors (automobiles, white goods, construction materials, etc.), on the vertical axis, and pervasive technologies (electronics, optics, materials science, etc.) on the horizontal. Technological nodes express the industrial reality which lies behind the points of intersection.

From the policy stand-point the importance of the concept lies in providing a new focus for industrial policy. Governments have typically assisted industry through direct aid measures such as subsidies, preferential purchasing, tariffs, etc., at the vertical level. Community policy-makers, on the other hand, have preferred to give support at the horizontal level, by sponsoring so-called "pre-competitive" and "pre-normative" research in generic technologies. By concentrating on the most promising technological nodes, it is argued, it is possible to use scarce R&D resources more precisely and much more effectively, with the risk, however, of going against the concept of balanced regional development (cohesion).

To explore these ideas in more depth a study on this theme was commissioned from the Centre de Sociologie de l'Innovation of l'Ecole des Mines, in Paris. Their findings were then discussed with a three-man panel, of senior national experts, which met three times over the year.

In the course of these discussions the original concept underwent some modifications, becoming multidimensional in an attempt to give full consideration to themes (interaction with defence and infrastructural matrices) not fully taken into account previously, and being re-examined in relation to such concerns as regional policy. Further studies have been recommended to DG XII, in the hope that these might produce new instruments to increase the impact of Community R&D programmes.

2.5 The "JRC 2000" Study.

As part of a JRC strategic planning exercise ("JRC 2000"), the Director General asked PROMPT to prepare an assessment of the likely state of technology in ten years time. To this end the Institute prepared three papers (ref.7):

1. **This World Around Us** - an overview of the main social and political trends impacting on science and technology policy by the end of the century;

2. **Science and Technology Issues** - an analysis of the main trends in European science and technology policy , together with a discussion of the key policy issues emerging in regard to various key sectors of R&D;

3. **S/T Assessments** - detailed examination of the key R&D potential in a number of specific areas, combined with an assessment of the extent to which the JRC might contribute to their development.

These are discussion papers, not meant for external publication.

2.6. Perspectives on the Process of Innovation for Advanced Materials

This study, conducted at the request of the JRC's Institute for Advanced Materials, has as its aim the prediction of market penetration of advanced materials through extrapolation of the innovation cycle of certain traditional materials.

Planning for development of materials technology requires an understanding not only of the diffusion of new materials into the various market sectors but also of the whole innovation cycle. The PROMPT study focuses on general trends, in the various stages of the innovation process, with a view to anticipating the pattern of diffusion for new materials.

Part of the study involves a contract, jointly sponsored by UNIDO (United Nations Industrial Development Organisation) and PROMPT, with Dr. C. Marchetti of the International Institute for Applied Systems Analysis in Laxenburg, Austria. Under the terms of this contract, data on various types of new materials have been collected, covering the stages of research, patenting and market penetration. A mathematical model has been applied to the data in order to establish the morphology of the innovation process.

Marchetti's model assumes that the diffusion process is described by a logistic equation, derived from the Volterra-Lotka conceptual frame of biological competition. Types of materials investigated include:

advanced composites, metallic glasses, thermotropic liquid crystals, sialon and silicon nitride, conducting polymers, gallium arsenide, optical fibres and rare earth-cobalt magnets.

For all of these materials it was found that the data for R&D outputs, measured in terms of publications and patents, fit the model well.

In order to expand and enhance this project, additional work is being undertaken in the PROMPT Institute to gather statistical data on consumption and production of the above-mentioned types of advanced materials. Using the statistical analysis tools and on-line data bases available at the Institute, further analysis of patenting and publication trends for selected materials is also taking place.

3. Seminars, panels, workshops

3.1 LOTOS Panel on "Long Term Outlook for Aeronautics Research and Technology"

This Panel was appointed and convened by DG XII/H; PROMPT prepared the working documents (the pre-LOTOS report, cf. point 2.3) and took care of the practical organisation of the meeting on behalf of DG XII.

The Panel, which consisted of 14 senior individuals, embracing a wide spread of experience in diverse disciplines relevant to aeronautics and aeronautical operations, met for a full week at Stresa (4-10 November 1990).

It concluded that despite many geopolitical uncertainties, the future of the European aeronautical industry is encouraging but that there are important problems which must be recognised.
Sustained growth in world demand for air transport will maintain a substantial market for new aircraft. However, the size of the market foreseen is not large in terms of the manufacturing capacity of the main suppliers and competition will be fierce, a situation further aggravated by the general decline of defence expenditure and the emerging Japanese (and even Russian) ambitions in this sector.

In response to this challenge, the Panel felt that further industrial cooperation, at a European level, is needed to keep the EC industry's technology base abreast of competitors and to adapt to the growing constraints posed by the environment, traffic congestion, human resources, etc...

Besides the LOTOS Panel, and in the same framework, PROMPT organised other meetings of aeronautic specialists at Ispra: viz. general assembly of the Académie de l'Air et de l'Espace; ad-hoc meeting of the Managers of National Aeronautic Research Centres) and visited Airbus.

3.2 Seminar on "Forecasting Technological Innovation", Ispra,22nd-26th October 1990

This Seminar was organised by PROMPT, within the framework of EUROCOURSES, the Education and Training arm of the Joint Research Centre, in view of the interest not only of PROMPT but also of other Services of the Commission in technological forecasting and in the observation and study of the technological innovation process. It was the first external event organised by PROMPT since its creation in 1989. The scope of the Seminar responded on one hand to the general objectives of the Eurocourses - i.e. to contribute to the continuing scientific and technical education in advanced fields connected with an activity of the Commission - while being aimed, on the other hand, at stimulating PROMPT's own reflection and work in the fields of technological forecasting and innovation.

The week-long Seminar consisted of three parts:

The first part was devoted to a summary review of the innovation process, of its modelling and of various technological forecasting methodologies.Some technological innovation models were surveyed, especially those based on economic driving forces and technological competition.The macro-economic (at national or world level) and micro-economic(at the business level) approaches to technological forecasting and innovation were both considered.

The second part was devoted to a review of short-term prospects for innovation in various key sectors: electronics and information technology, telecommunications, advanced materials, machinery and automation and transportation. These forecasting exercises served on one hand to illustrate the methodologies reviewed in the first part, on the other hand to a better understanding of the current trends of technological innovation, the recognition of which constitutes a common background for all technological forecasters.

The third part was intended to provide the views of innovation practitioners of various kinds - from contract research organizations to innovation consultants - on their rôle in the innovation process and, where possible, their practice of and need for technological forecasting.It contributed to answering the question "who does what?" in the field of technological forecasting and innovation.

The Seminar brought together 20 participants: 14 external - from various European countries and of very varying backgrounds and professional levels - and 6 of PROMPT's staff members.The 18 invited lecturers (primarily academics for the 1st part and industrialists for the 2nd and 3rd parts), were all experts at high levels in their fields.

In spite of some weak points - e.g. the programme was judged too broad by many of the attendees - the Seminar was generally considered a success.The discussions stimulated by the high quality of the lectures and the multi-disciplinarity of the attendees had generally a lively and immediate character. To give one example: the lecture by Dr.Karsten Drangeid, Director of the IBM Research Laboratory in Zürich at the time when scientists of this laboratory were awarded Nobel prizes (in 1986 and 1987) for the discovery of the tunneling microscope and of high temperature superconductivity, was an excellent opportunity to discuss the sometimes unexpected course of innovation and the difficulties of its prediction.

The publication of the Seminar proceedings is currently in preparation.(ref.8).

3.3 Workshop on Energy Conservation Potential, Brussels, 12-14th November 1990.

This workshop, attended by fifteen experts in energy demand efficiency from Europe and North America, was intended principally to review and augment the PROMPT study on this subject, performed at the request of the President's Forward Studies Unit. (See section 2.1.2.1. above).

The workshop confirmed that the figures quoted in the PROMPT report were reasonable, but it gave a more detailed insight into national positions. There was general criticism of the cut-backs in data collection during the past decade, although positive trends were noted in The Netherlands, Denmark and Germany.

Apart from its obvious synergic value in bringing international experts together to compare and contrast the state of the art, the workshop also created an opportunity for fruitful discussions on the critical issue of data availability and collection. In addition it permitted discussions on differing perspectives of energy futures and on the very different estimates of costs (of responses to climate change and CO_2 abatement policies) provided by top-down economic models, on the one hand, and bottom-up physical/engineering approaches, on the other.

The following comments attempt to highlight the key issues which arose from the workshop presentations and discussions, with a view to helping the PROMPT group complete its report.

Several country case studies demonstrated that there are large potentials for economic ("cost-effective") reductions of energy consumption and related CO_2 emissions; that is, reductions which result in lower payments for energy, interest on capital investments, and operating and other costs compared to "no action" or "business as usual". These economic potentials which result in lower overall cash outlays are considerable when one considers only demand-side technologies; they are substantially greater when one also considers the effects of reduced investments and other costs incurred by energy supply utilities as a result of lower consumer demand.

Country estimates produced a wide range of figures about either the technical or the economic potential for energy efficiency. One participant claimed that the potential for improved efficiency was much higher than is assumed in certain Commission studies. He made reference to a University of Utrecht study which identifies, for the Netherlands, a 35% reduction potential, of which some four-fifths (i.e. a 28% reduction) has a negative system cost. A similar study for the UK suggested that CO_2 levels could be reduced by 20% by 2005, again with negative costs.

A paper previewing the US National Energy Strategy was less sanguine about potential savings, foreseeing that cost-effective efficiency measures can reduce 2010 energy demand by 14% compared to the business as usual ("where we are headed") scenario. This would result in an 8% rise of CO_2 emissions, compared to 25% for business as usual (and assuming a 38% rise in GDP).

One message which emerged forcefully from the workshop is that the methodologies, assumptions and projections underlying the various country studies are so varied as to make cross-national comparisons difficult. In addition, the use of "business as usual" base-lines for measurement of possible impacts introduces a package of highly subjective variables in each instance.

Therefore, if PROMPT aspires to collect data which is homogenous and policy-relevant at an EC level, it may be necessary to impose certain guidelines and restricted objectives on the study. In particular it is important that technology impacts are measured against the existing (and thus known) energy situation rather than against some future scenario.This approach makes the clearest possible statement, to policy-makers and others without any special energy expertise, about the effectiveness of energy efficiency measures.

3.4 Workshop on "The Use of Survey Techniques in Technology Foresight Studies", Ispra, 19th-20th November.

This was the first in what is intended to be a series of seminars and workshops aimed at exploring possible development of the Institute's technological watch function.

Participants included representatives from a wide range of European research institutes engaged in innovation surveys, from the OECD Directorate for Science, Technology and Industry, from the Commission of the European Community's Directorate General for Science, Research and Development (DG XII) and from the Community's Statistical Office.

The first part of the workshop was given over to description of relevant surveys already carried out or on-going, with particular emphasis on difficulties encountered and continuing gaps in knowledge. A recurrent theme was the need to harmonise future surveys, for the sake of international comparability, and the related need for efforts to be made to bring together the results of the various studies already completed.

One outcome of this part of the discussions was the creation of a schematic map, defining the rôle of various types of survey (face-to-face interviews, expert surveys/panels and large-scale questionnaire surveys) in relation to official statistical series. Participants were at pains to stress the complementarity of these various techniques.

During the second part of the workshop the emphasis was more sharply focussed on the potential of surveys for technology foresight. It was agreed that most surveys currently undertaken are retrospective rather than prospective, although opinions differed as to how far questions on future trends might be incorporated. A key difficulty here is that industrial managers, who are the main source of survey responses, tend to operate on time-horizons of - at most - two years.

There was general consensus on the idea that PROMPT should institute a European-wide innovation data-bank, using literature-based surveys to identify new technologies and amplifying this with findings from the various innovation surveys. This is something which will be investigated as a matter of urgency.

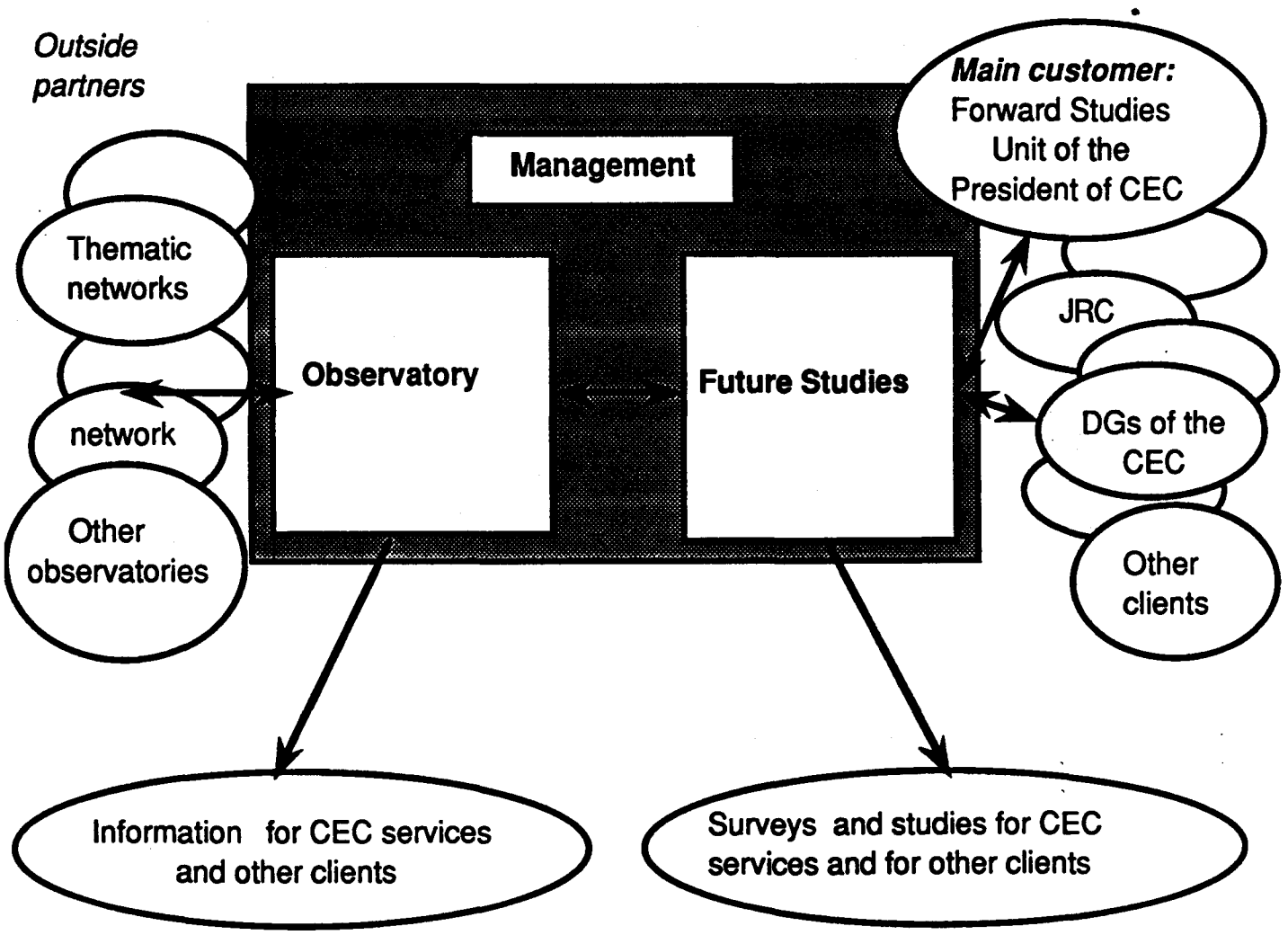
Other areas where participants felt that PROMPT could provide valuable support to the technology survey community included coordination of the results of existing surveys, sponsoring their extension into new areas (such as biotechnology and advanced materials), and re-examining the way in which current surveys treat services, particularly in near-manufacturing areas such as engineering and design consultancy.

4. Human resources and organization chart

As of 31st December,1990, the Institute's staff numbered 14, of whom 11 were scientific personnel. The Institute also hosted a post-doctoral fellow and an undergraduate trainee.

ORGANIZATION CHART

Institute for Prospective Technological Studies (PROMPT)



5. List of Reports

1. Science and the Greenhouse Effect. A literature survey for the Forward Studies Unit of the CEC.
   June 1990

2. CO_2 and Energy Consumption. Setting Targets for Europe (A review of current opinions).
   September 1990

3. Technology Response Options to CO_2 Abatement & Reduction. The Role of Electricity Generation.
   September 1990

4. CO_2 Abatement and the Role of Renewable Energies.
   September 1990

5. A Critical Literature Survey on the Prospects for Thermonuclear Fusion Energy.
   August 1990

6. PRE-LOTOS Study. Long Term Outlook of Air Transport and Aeronautic Industries.
   September 1990

7. Contribution to the Strategic Planning for the JRC:
   First Part This World Around Us (1990-2000)
   Second Part Science and Technology Issues (1990-2000)
   Third Part S/T Assessments (1990-2000)
   March 1990

8. Forecasting Technological Innovation. Proceedings of a Eurocourse Seminar held at Ispra on 22nd-26th October 1990

6. GLOSSARY

BMFT	Bundesministerium für Forschung und Technologie, Germany
CEC	Commission of the European Communities
DB	Data Base
E-MRS	European Materials Research Society
ESTO	European Science and Technology Observatory
GEKKO	Osaka University's light power gas laser system
ICF	Inertial Confinement Fusion
JET	Joint European Torus
JRC	Joint Research Centre
LOTOS	Long-Term Outlook Survey for the Aviation Industry
MtC/a	Million tons of carbon per year
NOVA	Innovation data base
NOVA (fusion)	Glass laser facility for fusion at Lawrence Livermore
OECD	Organisation for Economic Co-operation and Development
PBFA II	Particle Beam Fusion Accelerator (Sandia)
PC	Personal Computer
PROMPT	Institute for Prospective Technological Studies
QUIQUOD	R&D projects data base
R&D	Research and Development
S/T	Science and Technology
S/W	Software
TOE	Tons of Oil Equivalent

European Communities - Commission

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1. The Institute for Prospective Technological Studies (otherwise known as PROMPT) was set up in 1989. Its primary tasks, as defined by the Commission's blueprint for the restructured JRC, are two-fold:
   - monitoring new developments in science and technology
   - strategic analyses of new areas of science and technology
2. The support tool for fulfilling these tasks is ESTO (the European Science and Technology Observatory), currently under development within the Institute. In addition to having on-line access to some 500 data bases, ESTO is already operating a pilot version of its NOVA DB - aimed at identifying and evaluating technical innovations in key research areas - and is in the course of preparing the data base known as QUIQUOD or Q^2, an inventory of "who is doing what" in European science and technology.
3. Studies conducted by the Institute are generally performed on the request of a "client", in most cases another sector of the Commission (including other parts of the JRC). The Commission service with which PROMPT has the closest links (outside the JRC) is the Forward Studies Unit of the Presidency, and two major studies, both related to the global warming theme, were undertaken for this client during the year.
4. Other "in-house" studies included a contribution to the Commission's inter-service examination of the long-term future of air transportation (LOTOS), study of the market penetration process for advanced materials, development of the concept of "technological nodes" and an overview of medium-term trends influencing R&D for the "JRC 2000" strategic planning exercise.
5. Although some problems may raise in undertaking work for private clients, given the Institute's function as an independent advisor to Commission services, one sizeable external contract was completed during the year. This consisted of a critical review of the literature on fusion energy and was undertaken on behalf on the German BMFT.
6. Of the four workshops and seminars held during the year, two were complementary to the studies already mentioned. Of the others, one was an open training seminar on innovation forecasting, and the other a workshop on the use of surveys for foresight studies.
7. Staff numbers rose slightly during the year. The Institute now has 11 scientific/technical personnel (9 of them A-grade), plus 3 administrative/secretarial staff. A further 6 posts are under recruitment. The Institute has also welcomed its first scientific visitors - a post-doctoral fellow and an undergraduate undertaking a "tesi di laurea" under PROMPT supervision. A further three visitors - two post-graduate and one post-doctoral research fellows - are expected to be joining the Institute in the near future.