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Institute
FOR
Prospective
Technological
Studies



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EXECUTIVE SUMMARY

1. The Institute for Prospective Technological Studies is an integral part of the Joint Research Centre (JRC) of the European Commission. It is currently sited at the JRC's main campus at Ispra, in Italy.

The Institute's main tasks are:

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

Training of young scientists in techniques of prospective analysis is an important subsidiary task.

The main instrument for fulfilling the first task is the Institute's European Science and Technology Observatory (ESTO). The second task is addressed by performing "prospective studies" for a range of clients, chiefly but not exclusively services of the Commission. The training function operates through the award of research fellowships enabling young European scientists to spend one or more years studying within the Institute.

2. In 1993 the activities concerning ESTO were still of a preparatory nature and they concentrated on the identification and analysis of structured information sources on R&D projects in the Member States and on a feasibility study for an intelligent interface for the QUI QUOD information system. In addition, two activities in the field of the Environment, originally initiated as studies, developed into longer term work of an observatory type. The subjects concerned are: "Global Change Research and Policy" and "Developments in Best Available Technologies".

Prospective studies were performed for the following services of the Commission: the Forward Studies Unit, the Directorates General for Industry (DG III), for the Environment (DG XI) and for Energy (DG XVII) and for the Statistical Office (EUROSTAT).

The themes covered are:

- energy (systems and technologies for the long term future). In particular a study on fuel cells was completed while studies on the separation, storage and sequestration technologies for carbon dioxide from power generation systems, on nuclear energy and on photovoltaics all progressed.
- environment (industrial opportunities and constraints). In particular, a large study on Business and the Environment was completed, a contribution was given to the study of the integration of environmental and economic indicators was given, information on

opportunities in environmental technologies was updated and the analysis of environmental evaluation techniques was started.

- transport. In particular the completion of the study on the European high speed train network.
- industrial competitiveness, including a study on space markets.
- science and society, covering a contribution to the preparation of the Oxford Carrefour on Science and Conscience.

The fellowship programme acquired importance through the contribution of the increased number of fellows who joined the Institute. The subjects treated covered the study of innovation diffusion, its relationship with political control, with interregional cooperation, and/or with regional development; team work on the future of transport in European cities was pursued; and a study on European cooperation in the S&T field with North African countries was going on-going.

3. In December 1993 the Institute had 16 "permanent" staff of whom 4 were in administrative/secretarial posts. In addition there were one visiting scientist, two national experts on secondment, 3 post-doctorate fellows and 6 post-graduate fellows.

1. INTRODUCTION

1.1 Background

The Institute for Prospective Technological Studies (also known as PROMPT) was created in 1989, following the new orientations and the new organisation 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".

Working from this base, 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 Community, 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, 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 and technology planners and for European industry.

The permanent staff of the Institute remains small in number. It is, however, being 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 so doing, it acts as an integrator, in the context of EC policies.

1.2 The Year in Review

In 1993 the availability of funds and staff was not yet sufficient to allow the actual implementation of the Observatory function at the Institute. It is believed that such resources will become available through the Fourth Framework Programme of R&D which has been proposed by the Commission and which should cover JRC activities, starting from 1995.

However some of the activities originally started as short term studies have developed into longer term activities with the continuous collection of information and periodical reporting. These activities, in the field of environment, may be considered as prototype actions for the technology watch function. In addition, the preparation of data bases and tools for the operation of the Observatory has continued, particularly as concerns the information system on R&D projects.

In 1993 the range of clients for the studies became broader and the number of studies increased. Multiannual agreements were signed with two additional Directorates General: Energy (DGXVII) and Transport (DGVII).

In November 1993 a Visiting Group performed an evaluation of the Institute and its activities. The report of the Visiting Group indicated appreciation of the work done, confirmed the lines of development of the Institute's activities and encouraged the full implementation of the observatory function, once funds are available.

The transfer of the Institute to a new site, in Seville, Spain, was approved by the Commission in July 1993. Conditional to the forthcoming signature of the agreement between the European Commission and the Spanish authorities, the transfer should take place in 1994.

2. ESTO (EUROPEAN SCIENCE AND TECHNOLOGY OBSERVATORY)

From the inception of the Institute it has always been considered that one of its main tasks was to establish an observatory equipped to provide European decision-makers with a science and technology awareness service covering the key areas of current and future policy concern. It was anticipated that operating this observatory (known as ESTO) would absorb a considerable part of the Institute's resources.

To date, however, no separate funding has been available for ESTO, with the result that it has still only an embryonic existence, on the margins of the specific studies for clients which provide almost all the Institute's current income. This situation will change in the near future. Indeed if PROMPT is to move from its present site, thus losing the intimate (if largely informal) scientific support structure available within the Ispra campus, substantial development of ESTO becomes a *sine qua non* of the Institute's continuing effectiveness.

Despite lack of specific funding some work on ESTO has been on-going

Given this central role foreseen for ESTO in the future development of the Institute, every effort has been made to keep the concept active, notwithstanding the lack of specific funding. Information services within the Institute have been developed in such a way as to be readily adapted to the full ESTO project.

..and substantial growth is projected for it in the near future

In the area of global change the observatory function is already operational, thanks to the sponsorship of the Forward Studies Unit and other Commission 'clients'.

The systems which should provide the informatics support for the main functions of ESTO are being developed. They are the NOVA data base and the Qui Quod information system.

..for which informatics support is being developed by PROMPT

In addition, the operation of a few, prototype, observatory functions has started in the field of environment, stemming from the evolution of ongoing studies, and some other ad hoc technology watch activities have also been carried out occasionally.

2.1 Information Systems

The collection, synthesis, storage, analysis and dissemination of a large amount of information in selected fields is an essential part of the activities of the Institute.

Some of the tools for this activity have required further development for the effective execution of this function.

The most widely utilised tool is the direct on-line access to some 500 bibliographic and patent data bases. In 1993 the total expenditure for their consultation was 27000 ecu. This is complemented by new techniques for structured searches and by a system for rapid document acquisition.

In the year under review, 328 new books and 241 other documents were added to the library, and a further 1130 documents on loan were handled.

Networks of contacts complement data base search tools

Direct access to information is also obtained through networks of correspondents, a procedure which will be strengthened in the future by the creation of antennae in key countries and regions. A PROMPT antenna is established in Brussels as a direct link with the Forward Studies Unit of the Commission.

Prompt makes extensive use of software tools for information processing. In particular, two systems have been created. The first, a data base named NOVA, is for storing the most recent information on scientific breakthroughs and technological innovations while the second is an information system named QuiQuod or "Q²", describing current R&D projects in the Community.

2.1.1 Technology Watch Function (NOVA)

Analysis of S/T developments in cooperation with existing organizations

A Technology Watch system at European level will be developed, in co-operation with the existing units and organisations active in the field at national and local level in the Community. The purpose of the Technology Watch system is to provide early warning on new developments in S&T, to identify technological trends and opportunities, and to alert decision-makers to their implications and consequences for technological research, the industrial system as well as their potential impact on the environment and on society.

Information on research achievements, scientific breakthroughs having a potential for future applications, and technological innovations will be collected and analysed. Periodical synthesis reports will be produced.

..will benefit from structured flexible database system set-up at PROMPT

Informatics links and data bases will facilitate the coherence and efficiency of the work. Access to proprietary and published documentation available in the field of technological innovation will be sought and its exploitation will be organised in a structured, flexible way.

A prototype dB (NOVA) has already been set up at PROMPT for internal purposes and it will be developed to serve as a general tool for the Technology Watch system.

This prototype includes an input mask, a retrieval system and a text acquisition mechanism. In hardware terms this has been accomplished by linking a number of Macintosh PCs to the JRC Ispra ETHERNET network backbone and to the dedicated PROMPT server. In software terms a custom-made package, based on the HyperCard Interface, was developed to facilitate access to the data records stored in the SYBASE SQL server. Since this is still an internal tool it is mainly PROMPT staff who collect and enter the information in the NOVA database. This means that a critical filter is applied to the vast amounts of publicly available information.

2.1.2 R&D Projects Information System - Qui Quod (Q²)

The "Qui Quod" (Q²) Intelligent Interface system is a tool that aims at providing a continuously updated picture of European R&D in selected research fields, as well as the facilities, funding means and the teams driving such projects.

A study aimed at identifying all R&D related databases (project, person or institution based) in all Member States (including also those databases which had wider geographical coverage) in all domains was concluded. Through this report the major obstacles to the harmonisation of distributed R&D project data have been identified and a data set has been retrieved from the whole set of R&D projects databases, for querying and comparison purposes.

Obstacles to harmonisation of national R&D databases identified

By means of the comparison mentioned above, the harmonisation level of the R&D project data bases in the EC member countries was identified and the relative importance, completeness and compatibility of these data bases, in relation to PROMPT needs, were all assessed and described in the report "EC Member States R&D Project Structured Information Sources"; Summary, June 93. The Q² prototype information system has been designed, built and tested for data in the chosen sector of Advanced Materials. This prototype provides access to the collected and harmonised data which are stored centrally in the Q² database and enables the user to make integrated queries concerning the nature and status of the projects through the use of a unique user-friendly interface.

Prototype system built and tested for data on Advanced Materials

A survey of the state-of-the-art in 'Intelligent Interface' related projects has also been carried out to obtain an insight as to the operation of such a system. From the survey two distinct sub-problems were identified, the first one related to user interaction and information retrieval, and the second one related to the integration of local databases. Also, the user requirements of an intelligent interface that will aid the final user in performing this complex process have been identified and solutions to the various integration problems have been proposed as functionalities of the intelligent interface in a feasibility study "*Q² Intelligent Interface Feasibility Study*", Dec 93.

Standardisation is aided by the adoption of EC proposed standards

Detailed functional specifications, in the form of a set of hierarchical functional decomposition diagrams and a development plan which organises the specified tasks in 4 phases, grading them according to their degree of importance and ease of implementation, have been presented. In this way, operational prototypes with only a subset of the total functionality can be available early, to enable field testing and collection of users' comments. As far as standardisation is concerned the adoption of the EC's proposed CERIF standard, as the intermediate global logical schema, and the use of CCS (Common Command Set), as the basis for a multidatabase language for the design of the Q² interface are considered essential.

2.2 Monitoring specific fields

As noted earlier, the absence of a specific funding source for ESTO places severe limitations on the number of technology areas which can be monitored.

In the area of global change, however, the observatory function is already operational, thanks to the sponsorship of the Forward Studies Unit and other Commission 'clients'.

Action has begun on global change and on BAT for environmental protection

An 'observatory' activity has also been started in the field of the development of the Best Available Technologies (BAT) for environmental protection, sponsored by General Directorate XI.

In addition, occasional concise surveys (snapshots) of current developments in science and technology were produced and work on innovation indicators was carried out.

2.2.1 Observatory of Global Change Research & Policy

This project has been in operation since 1990. It consists of an ongoing survey of scientific research progress, together with studies evaluating policy options, in relation to greenhouse effect-induced climate change and, possibly, other aspects of global environment change.

The purpose of the project is to keep the 'clients'¹ permanently updated with new findings contributed by the research world, which could affect policy makers' views about the expected significance of these issues or the best ways to respond. The continuing assessment of selected global change issues from a scientific standpoint, of their potential impacts and of possible options for response strategies are therefore intended to be the main product of this activity, to be used as a guide for, or a reference to, policy making and possibly research programming. PROMPT has not attempted to recommend specific research or policy lines because the interpretation of its mandate does not include such specific recommendations.

The project has concentrated almost exclusively on greenhouse effect-induced climate change, the emphasis being placed on its scientific assessment rather than on impact studies or policy aspects. The assessment of possible technologies aimed at reducing or cutting carbon dioxide emissions is the goal of another current project, framed within the context of future energy technology assessment.

Focus on the scientific assessment of greenhouse effect induced climate change

The project is based on an extensive review of published scientific articles or reports and of presentations to international conferences, which are analysed, compared and synthesised within periodic (normally bi-annual) reports. While two reports² were issued in 1993, only the second one resulted from work performed during the year, entailing the review of nearly 90 documentary items, all less than a year old. It is felt that this set of publications included all important recent papers related to the climatic change issue.

As in the past, research results were screened to try to infer a new insight into open scientific questions, which guide one's views about the reality and the intensity of the greenhouse effect and its current and future impact on climate: What is the range of climate sensitivity (i.e. the

¹ The Forward Studies Unit and the Directorate General for Environment (DG XI) of the European Commission and the Institute for Environment of the JRC.

² "Climate Change Research and Policy: Updates. No.4 - January 1993".
"Climate Change Research and Policy: Updates No.5 - October 1993".

parameter which relates the radiative forcing to the actual surface warming)? Are the signs of a greenhouse effect visible in the actual climate trends? Do investigations of paleoclimates improve our understanding of these processes? Are climate models becoming more reliable in their predictions of the greenhouse warming to come? What is the progress in understanding the global carbon cycle, which controls the accumulation of carbon dioxide into the atmosphere for any given emission scenario?

The main research progress which PROMPT highlighted this year concerned more specifically:

Research progress highlights

- the discovery, through investigations on ice cores recently drilled in the Greenland ice sheets, of very fast shifts which have affected recent past climates; such a discovery might have strong implications for the evaluation of climate change induced by the greenhouse effect (see box);

- the derivation, through paleoclimatic analysis, of climate sensitivity values within the range established by the IPCC³ based on model studies, whose credibility is thus enhanced;

- the first analytic support, coming from the first long term (500 years) climate simulation using a coupled atmosphere-ocean General Circulation Model, of a previous speculation that the oceanic circulation in the North Atlantic could shut down irrevocably as a result of a long term greenhouse warming, opening the door to "unpleasant climatic surprises";

- the finding of new possible positive feedbacks to climate warming due to terrestrial carbon storage and northward migration of boreal forests;

- the downward revision (by some 50%) of the current estimates of the cooling effect of sulphate aerosols, and hence of their suspected masking of the current greenhouse gas induced warming;

- the confirmation of the contribution (one third?) of the solar "constant" variation to the warming over the last century;

- new findings further confirming the level of the "missing sink", needed to balance the effects of the anthropogenic carbon budget, as well as its probable location in terrestrial ecosystems, especially mid-latitude forests.

³ Intergovernmental Panel on Climate Change

carbon budget, as well as its probable location in terrestrial ecosystems, especially mid-latitude forests.

The message of last year's review of greenhouse effect research was that, on the whole, those results contributing to confirming the significance of the greenhouse effect for future climate prevail over those leading to scepticism about the issue. No definitive breakthrough happened, however, and the recent set of results did not change the most common vision of the greenhouse issue: in spite of significant progress, its scientific assessment is still subject to considerable uncertainty. The need for, and the content and timing of response policies, still remain as options which cannot be guided by scientific criteria alone. Policy makers must also rely on value judgements.

In 1993, results supporting the existence of climate warming were reported

...but still more research is needed to enhance our grasp of the issue

Past climate shifts: their possible significance for the greenhouse issue.

Perhaps the most important result of climate research obtained in 1993 was the discovery, through experimental investigations on ice cores recently drilled in the Greenland ice sheet, of very fast climate shifts which have characterised the last deglaciation and the last glacial period, but also the last interglacial period (135,000-115,000 years ago), i.e. a climate similar (slightly warmer) to the current climate. In spite of their brevity and swiftness, these climate shifts could be detected because of the high snow accumulation rate in this geographical area which translates into a high resolution in the ice core timing, never reached before. Sudden warming (during glacial periods) or cooling (during interglacial periods) could be as great as 5-10°C over some years or decades, and lasted typically 500-1000 years with a comparatively slow return to initial conditions.

In fact, scientists now estimate that climate instability between two stable states (cold/warm) was the rule, rather than the exception, till the advent of our present, stable climate, 10,000 years ago.

The relevance of this important discovery for the greenhouse issue is not currently clear, notably because information on the evolution of greenhouse gas concentrations in correspondence with these climate shifts is not yet available (the measurements are in progress). The fact that climate shifts also characterised the last interglacial climate, warmer by about 2°C than our own climate, is seen with special concern. Some authors associate, perhaps too hastily, climate instability with this warming and warn against the risk of a climatic catastrophe which could be triggered by a greenhouse gas-induced warming of our climate.

In contrast, other authors visualise instability as a natural characteristic of past climates: they emphasise the next (cooling) shift to come as unavoidable, perhaps imminent and much more dramatic than a possible, but still not proven, greenhouse warming.

Evidence of fast shifts in recent past climates from drilled Greenland ice cores

2.2.2 Observatory of Developments in BATs (Best Available Technologies)

The collaboration of PROMPT with the Directorate General for Environment (DGXI) in the field of BATs during 1993 started as an exploratory exercise. Based on the results obtained, DGXI has asked PROMPT to develop for this area a continuous 'technology-watch' activity which will support the implementation of the IPC Directive (Integrated Pollution Control).

The Commission and, in particular, DGXI have adopted the BAT concept (Best Available Technologies) as a central instrument of industrial emission control and prevention policies (Directive 84/360 and the forthcoming Integrated Pollution Control - IPC-Directive). BATs are designated for specific industrial sectors by DGXI with the assistance of working groups of experts representing the public authorities and industries of all Member States. BATs are defined as the technologies or the sets of technologies which are commercially available and provide the best technological solution(s) as regards the minimisation of the emissions to the environment (air pollution control up to now and multi-media pollution control in the frame of the IPC directive). The results of each BAT exercise are documented in BAT-Technical Notes. In this way the Commission helps Member States by disseminating information about techniques and their developments. The competent authorities can then decide on the most appropriate conditions for authorisation of industrial activities.

The need for prospective work in the area of BATs is founded in the evolutionary nature of the BAT concept. A designated BAT is not fixed for all time. As techniques and technologies improve the appropriate environmental protection standards have to be updated correspondingly.

In 1993 Prompt participated in 1993 in three meetings of the DGXI BAT working group on steel coil coating (January, May and September). The scope of the involvement of Prompt was to become familiar with the BAT exercises and to find out appropriate ways for collaboration with DGXI in this area. Up to now the most significant result has been the proposal for the establishment of an "Observatory in BAT developments". As concerns the steel coil coating technology per se Prompt's main contribution was in the specification of potential future developments. The results were discussed during the third meeting, in September 1993. They may serve as a prototype approach for further BAT exercises and DGXI is considering the feasibility of adding standardised annexes on prospective technologies to all other BAT technical notes.

*Observatory on
potential future
developments of
BATs*

Based on the preliminary results, PROMPT and DGXI agreed on the establishment of an "Observatory" which will provide the following services and activities:

- to act as a contact address for the members of DGXI working groups and other experts who are willing, after the completion of the work on specific BATs, to supply information regarding new developments related to the technological base of existing BAT technical notes,
- to store centrally, classify, analyse, synthesise, periodically report and provide access to information on post - technical note developments for each of the completed BAT exercises.

Of key importance is the possibility of distributing annual reports, prepared by PROMPT, on the data entries to all members of given working groups. This will provide transparency and possibly a basis for enhanced information exchange.

The expected results and benefits from these services offered by PROMPT are the following:

- a) To support DGXI in ensuring the follow up of existing BAT technical notes and in recognising systematically the needs for updates on a continuous and factual basis.
- b) To promote the information exchange between the Commission and the experts of the working groups also in the period after the completion of the work on specific BATs.
- c) The central storage of information and its accessibility will enable all interested parties to be involved in the BAT activity on a continuous and systematic way.
- d) The work needed for updating existing BATs will be facilitated due to the improved data availability. This means reductions in the number of meetings and costs of external consultancy.
- e) The "Observatory" will be linked in future with the forthcoming IPC Directive and will support the implementation of articles 10, 14 and 15 concerning developments in BAT, access to information and exchange of information.

*Benefits from
PROMPT-provided
services*



2.2.3 Science and Technology Surveys

Results of literature based innovation output indicators were produced and published

As a preliminary Observatory activity it was decided to produce an occasional short and concise survey of selected current developments in Science and Technology. For obvious reasons this series was dubbed *snapshots*. The material for "snapshots" is obtained from the scientific literature and from PROMPT studies. The criterion for the inclusion of a topic is, in general, one of the following.

- PROMPT's own expertise
- The relevance of the subject to Commission policy
- The potential impact on the Community of the reported development

Topics covered in 1993 were global warming, biotechnology, superconductivity, thermonuclear fusion, nano-technology, eco-technology, science policy and Japanese science and technology.

2.2.4 Innovation indicators

In collaboration with SEO, (the Foundation for Economic Research at the University of Amsterdam), the Institute has been encouraging the collection and use of what are known as Literature-Based Innovation Output Indicators. An informal network of researchers interested in developing this tool has been established and, thus far, two workshops have been held to promote standardised approaches to the methodology.

PROMPT provides short concise surveys (snapshots) of selected S/T developments

1993 saw the first substantial results of this effort, with the results of surveys in Austria, Ireland and the Netherlands forming the core of a book, "*New Concepts in Innovation Output Measurement*", (A.Kleinknecht and D.Bain, eds.) published in Europe by Macmillan Press and in the U.S.A. by St. Martin's Press. Work was also completed on new surveys in Italy and the UK. Efforts continue to encourage other EEA and OECD countries to undertake parallel surveys.

3. PROSPECTIVE STUDIES

As noted above, prospective studies are performed at the specific request of clients. These are mainly Commission services but can also include so-called "third parties", under payment, providing that the work does not conflict with basic Community interests.

To provide continuity of both research manpower and funding, the Institute has sought to perform work for Commission services within the framework of multiannual agreements, formally drawn up at Director-General level. Such agreements have been signed with the Forward Studies Unit, Directorate-General III (Industry), Directorate-General VII (Transport), Directorate-General XI (Environment) and Directorate-General XVII (Energy). A small contract also exists with the JRC's Environment Institute.

Ultimately the Institute expects to be able to conduct studies on a broad range of topics in science and technology. For the moment, however, a combination of existing competences and client requests have led to a focusing of interest on the three interrelated areas of energy, environment and transport. Some activity has also been carried out in the areas of industrial competitiveness and of science and society.

Recent focus on energy, transport and environment will expand to a broader range of topics

The following sections give some details of work undertaken in each of these areas.

3.1 Energy

As a contribution to the analysis of long term energy strategies and scenarios⁴, a number of energy technologies are being studied at PROMPT. The purpose is to assess the potential future evolution of such technologies and to provide the best estimation of the data concerning their performance and costs which can be applied to energy scenarios for the year 2020 and beyond.

The energy technologies on which attention was focused in 1993 were: fuel cells, technologies for the separation, storage and sequestration of carbon dioxide, nuclear fission energy and photovoltaic energy.

⁴ Work for the Directorate General for Energy (DG XVII)

3.1.1 Fuel Cells

*Fuel cells prospects
towards 2020*

A prospective study on fuel cell technology was completed in 1993. The main purpose was to collect and evaluate data on the prospects of fuel cells and on the evolution of their key techno-economic characteristics towards the year 2020 and beyond. This data, together with similar information from parallel studies on other promising advanced energy technologies is needed for the long-term energy scenario activities of DGXVII.

Since the middle of last century, fuel cells have been known to have, among all other energy technology options, the most promising potential for converting the chemical energy of fuels into electricity with minimal efficiency losses. This is made possible by an electrochemical "cold" fuel combustion route which offers additional key advantages because of the extremely low level of pollutants emissions into the environment. Today it is widely recognised that fuel cells have the potential to replace conventional power generation technologies and the internal combustion engine in transportation and stationary applications. The major benefits are seen as the possibility for significant reduction of primary energy use - up to 70%, depending on the application - as the establishment of a zero emissions technology and as strategic energy supply security advantages which can result due to the multi-fuel flexibility of fuel cells.

Significant efforts for the development of fuel cells have been made during the last thirty years and the experience has shown that the solution of many challenging advanced materials problems is still needed. Today the first generation of fuel cells, the so-called Phosphoric Acid Fuel Cells (PAFC), is at the initial phase of commercialisation. Other, more advanced, fuel cells under development are based on less conventional electrolyte materials such as molten carbonate salts, solid oxides and proton exchange membranes. The most promising variant for automotive application seems to be the proton exchange membrane based fuel cell (PEM-FC). This perception is now gaining wide acceptance following recent research results concerning the technical feasibility of achieving high power density and operability with fossil derived fuels. The major breakthroughs to date have been accomplished in the USA and refer to the development of proprietary membrane materials by Dow Chemical and Dupont de Nemours. Commercial application of these materials in the form of fuel cell powered vehicles is an extremely critical strategic target and many insiders expect its realisation within the next fifteen years. Research activity in this area expanded remarkably during 1993 in many countries and a related ambitious target, presently under discussion, refers to the development of high temperature proton conducting materials which would broaden the operability of the PEM fuel cell into the power generation sector.

*A structured expert-
interrogation
approach was used*

The data collection and evaluation procedure was based on a structured expert-interrogation approach. In total, 14 European experts, covering all important fields of R&D on fuel cells, were invited to participate in the prospective exercise. Two documents - an in-house analysis of the

present status of fuel cell technology and a questionnaire on future developments - were prepared by PROMPT and submitted to the experts. The status report was reviewed during an Expert Meeting in April 1993 and its final version constitutes the first part (Part I) of the present study. Further information exchange on the evolution of key techno-economic characteristics was facilitated by the questionnaire, which was discussed point by point with the experts until agreement was reached on the definitions of the techno-economic characteristics.

A key point of the approach developed within the questionnaire was a simple coding system which offered the experts the possibility of synthesising any desirable and promising fuel cell system configuration from several system component codes, including the type of the fuel cell, the fuel used, the type of fuel processing, the capacity range, the pressurisation level, the integration of steam and gas turbines, the application sector, etc. On this basis the questionnaire enabled the experts to compile the systems of their preference and to base, on such well defined technological structures, the requested detailed information on the evolution of technical characteristics.

Questionnaire used a coding system allowing the experts to synthesize desired fuel cells system configurations

All the information collected, is presented in the second part (Part II) of the study. It concerns mainly the specification of the most promising emerging fuel cell system configurations, the probable commercialisation dates and the priority choices on the basis of market penetration assumptions. Detailed data on the evolution of techno-economic parameters such as the efficiency, investment, operating and maintenance cost, maximum achievable power density, catalyst loading, stack and system life, reliability, emissions, etc., are presented in the study, which also outlines the main factors leading to the expectation of the suggested developments.

Promising configurations, along with possible commercialization dates were identified

Referring to the information received from the experts the general trend is that the data conforms to expectations and that the evaluations of individual experts converge towards the same ultimate goals, i.e. the experts agree on the ultimate values of the techno-economic parameters, although they may suggest different timings for the achievement of these goals. Concerning the feasibility of significant technological and commercial breakthroughs in the long-term, the expert judgements reflect optimism. However, the short-term prospects are being evaluated with considerably diverging results.

Experts agreed on values of techno-economic R&D/development goals, but not always on the timing of their attainment

The final 'results' of the study consist of the "reference technology modules" and of the corresponding "reference choice values" (of the techno-economic parameters), which represent aggregated data suggested for use in the

development of long-term energy scenarios. This data was established by specifying the major overlappings between individual proposals made by the experts. For each of the "technology modules" the present study reports the corresponding range (min-max) of values of techno-economic parameters suggested by experts and examines specific single values, the "reference choice values", which reflect a weighted assessment made by PROMPT.

High efficiency and low environmental impact boost fuel cells' attractiveness

In general, the study concluded that fuel cells offer, for the long-term energy future, the possibility of electricity generation from coal, natural gas and hydrogen (among other fossil and non fossil fuels) at efficiencies of the level of 60-70% with the lowest impact to the environment compared to any other known advanced energy technology. From this point of view, the establishment of fuel cells as a principal technology in energy options for the middle of the 21th century seems to be justified.

3.1.2 CO₂-3 S Project : Separation, Storage and Sequestration Technologies for Carbon Dioxide from Power Generation Systems

A prospective study on the evolution of CO₂ Separation (removal or capture), Storage (disposal) and Sequestration (biological fixation) technologies was initiated in 1993. The main goal of the activity is to provide appropriate technological options to DG XVII for CO₂-constrained long-term energy scenarios for the year 2020 and beyond.

CO₂ Separation, Storage and Sequestration technologies constitute an essential component of "aggressive" policies in response to the greenhouse effect. These technologies could become unavoidable if scientific research confirms the need for reducing carbon dioxide emissions in order to mitigate the greenhouse effect. In such a case, these technologies would permit us to maintain, in the longer-term and on a global scale, the use of the main primary energy sources of today i.e. fossil fuels.

Preliminary reports on removal and disposal techniques have been prepared

Technical support to the project has been provided by the IEA Greenhouse Gas R&D Programme. Preliminary in-house analysis reports were prepared on Removal and Disposal technologies. These reports will be discussed in two expert meetings scheduled for early 1994.

The expected results of the prospective exercise refer mainly to the assessment of approximate dates of future availability of technologies which have been proposed or are presently under development, their potential for penetration into the market, the main performance

characteristics, capital/operating costs, environmental implications etc.

The preliminary analysis reports highlighted the following main trends:

Technology Options for CO₂ Separation from Power Generation Systems

Despite the current uncertainties related to the potential effects of CO₂ on climatic change, significant efforts have been made in evaluating the technological prospects of CO₂ removal technologies. The most promising technology options are based on absorption, adsorption, membrane cryogenic processes and on modified fuel combustion in oxygen and carbon dioxide mixtures.

According to present calculations, the energy penalty associated with CO₂ removal can reach levels of the order of 50% of the net power output of fossil fuelled power plants. This energy penalty includes general efficiency losses from the CO₂ removal itself, as well as losses due to the operations associated with the treatment of the CO₂ gaseous product to conditions which allow its further safe transport to disposal sites, i.e. drying, removal of corrosive impurities, and pressurisation to levels above 100 bar.

High energy penalties for carbon dioxide removal

The maximum overall achievable net efficiency (coal to electricity conversion, Lower Heating Values LHV) of power generation systems with CO₂ removal equipment is reported to be feasible in the near to mid-term future (2005-2020) with integrated coal gasification fuel cells. Current calculations refer to levels of about 47-48% for the fuel cell technology while the capabilities of coal gasification plants with conventional power generation (IGCC) are evaluated at about 40%. Maximum practicable efficiency levels for pulverised coal combustion are reported to be at about 37% and are expected to be achieved with coal combustion in CO₂/O₂ mixtures and with supercritical operation and application of new types of absorbents.

Technology Options for CO₂ Storage

The most promising technology options are based on disposal in oceans, aquifers and depleted gas wells but none are ready for large-scale application today.

Oceans, oil/gas aquifers and depleted gas wells have been studied as disposal options

Disposal into the ocean offers the potential for large quantity disposal, but there are technical, safety and environmental issues to resolve. Disposal in the ocean from pipelines at depths below about 1,000m would stretch present day technology, while the residence time of CO₂ injected above this depth might be insufficient. Dumping of CO₂ as dry ice is considered as technically feasible but probably too cost intensive. A major problem in the case of aquifers is to determine whether they are suited for disposal of CO₂, i.e. whether they are well sealed off. Storage of CO₂ in depleted gas wells, on the other hand, seems fairly straightforward, although the storage capacity and location of disposal site relative to the generation site may prove a problem. Enhanced oil recovery is a possible use of CO₂ in large volumes and is presently being used in small and medium scale projects.

Global scale effect of ocean disposal could be negligible but local effect is cause for concern

All the disposal options will require additional research in order to better understand environmental impacts. Whilst it seems that, on a global scale, the impact of discharging CO₂ into the ocean would be negligible, the effects on a local scale, e.g. near injection sites, are of concern. For aquifer disposal, the potential environmental problems are dissolution of the host rock, ground stability and ground water pollution. Environmental impacts for disposal in depleted oil or gas reservoirs should be minimal. An additional environmental impact should also be avoided in the case of enhanced oil recovery.

For the disposal options in general, the parameters governing investment and costs include injection depth, distance of injection site from source and the carbon dioxide flow rate. The highest investment factor is the transportation system, i.e. the pipelines. High operating costs are incurred by the power consumption for additional compression, pumping and transportation where necessary.

3.1.3 Nuclear Energy

Present and advanced nuclear power plants have been considered, and the main problems related to fissile material utilisation have been analysed in an interim paper: *Nuclear Energy Key Issues - Reprocessing and Recycling*. The following items are identified as the main elements for a discussion on the prospects for nuclear energy:

- diversification and conservation of energy sources
- reduced dependence on foreign supply
- utilisation of present plutonium and uranium stocks
- safety and reliability of nuclear power stations

- environmental problems related to reprocessing, recycling and disposal
- economics.

All of these topics require looking into well into the next century, particularly so if the long lead times for the evolution of nuclear plant concepts and the long payback times for the installation of nuclear power stations are considered.

The review work had the following two aims:

- providing basic information on the reactors which are likely to be operational after the year 2020 in the case of the simplest policy option, i.e. direct disposal of the spent fuel.
- setting a general background by outlining the pros and cons of reprocessing and recycling, and of the associated problem of breeding.

Concerning the first point, the review of current *advanced* and *evolutionary* reactors is confined to thermal neutron reactors, and in particular to light water moderated and cooled reactors. The advanced designs are ready for an installation policy which, for a number of non-technical reasons, will not start at an economically sensible pace before the beginning of the next century. The evolutionary types will be ready for a full start, after a prototype phase, around 2020.

For both advanced and evolutionary thermal neutron reactors a full start will not begin until the next century

The past 40 years' experience with the installation of nuclear power stations does not justify any hope for a faster evolution; it rather suggests some prudence: e.g. a sensible compromise between active and passive safety features of nuclear power plants may occur, if wisdom prevails over emotional thinking. Concerning costs, there is an increasing consensus about competitiveness of nuclear energy against coal and gas for base load electrical energy production, at current fuel prices; e.g., during the recent conference "The Future of Nuclear Power", London, Jan. 94, it was stated that installation experience, standardisation and improved licensing procedures have led to such a reduction of nuclear power plant construction time and cost as to make nuclear electricity much cheaper than had been suggested by previous statements of the British Government.

..on the other hand nuclear energy is increasingly viewed as very competitive cost-wise

Concerning the second point, an analysis of the fuel cycle problems is being performed, with the aim of providing elements in favour of reprocessing and recycling, whereas the present tendency is biased towards direct disposal of the spent fuel. This policy, which now prevails in the USA and in Europe, is perhaps justified from the social and

Reprocessing is evaluated against present tendency favoring direct disposal

political point of view, but it should be admitted that many technical projections and advanced designs are now solely based on the criterion of soothing public concern.

The arguments put forward in favour of the reprocessing option can be summarised as follows:

- the diversification of energy sources and the abatement of the chemical pollution related to energy production are the major arguments in favour of nuclear energy. A real diversification can best be achieved with reprocessing and recycling, since this would eliminate or strongly reduce dependence on imports of uranium or thorium ore and of enrichment plant separative work: a reduction in the consumption of uranium ore by some 40% could be achieved by simply recycling the recovered fissile material in thermal reactors, a well established technique with the mixed oxides fuel. Complete independence could be achieved with the use of fast neutron breeders.

Stockpiled nuclear-weapon grade uranium and plutonium could increase available fissile material

Confining our considerations to thermal neutron reactors, a considerable increase of the readily available fissile material reserves could be achieved by burning the existing stockpile of uranium 235 and plutonium 240 from nuclear weapons. This problem is now attracting the attention of all Governments, therefore the option of using this stockpile should be discussed in any nuclear energy policy study; this option alone could provide enriched uranium and extend experience with plutonium burning for about a decade, thus postponing the need for a massive reprocessing of the spent fuel stockpiles.

Extra cost of the recycling solution is not significant

- cost is not an important issue concerning the decision about reprocessing: the cost difference between the recycling and the once-through solution lies well within the range of uncertainty in the energy production cost. The choice about reprocessing is therefore essentially dependent on the environmental and social problems related to the solution of the high level radioactive waste disposal problem. This in turn depends on the criteria embedded in the IAEA Safety Standards: 1 - no burden for future generations, 2 - independence of safety from institutional control. According to a fairly widespread opinion, the second principle should be subject to revision.

- reduced size and improved reliability of the reprocessing plants based on the PUREX cycle are achievable, in particular through waste stream partitioning and head-end refurbishment.

3.1.4 Photovoltaic Energy

A study on Photovoltaic Energy was started in 1993. Its aim is to evaluate the future evolution (towards the year 2020 and beyond) of the technological and economic parameters of this renewable energy source.

Photovoltaic systems have been used for more than 30 years to power spacecraft. The reliable performance of solar cells in space has established photovoltaics as a dependable technology; nevertheless, terrestrial photovoltaic energy consumption represents less than 0.5 % of total world energy consumption. At present, world photovoltaic shipments are 55 MW per year.

Use of photovoltaics by spacecraft has proven it to be dependable

Photovoltaics is the direct conversion of sunlight into electricity using devices made of thin semiconductor layers. Photovoltaics is one of the most benign forms of electricity generation. It requires low operation and maintenance expenditures, no fuel and no cooling water; it generates no fumes and no noise. These attributes make it a highly attractive form of energy generation.

However, sunlight is a diffuse energy source with a maximum energy density of about $1\text{kW}\cdot\text{m}^{-2}$ at the earth's surface. For example, the energy accumulated in one hour on a collector with an area of one square meter is equivalent to the energy generated by about 100 ml. of gas oil. It is variable according to time.

The preliminary report of the first phase of the study highlights:

The commercialisation of photovoltaic devices is not as fast as was predicted. The initial high cost, low module efficiencies (around 7%) and low efficiencies of energy accumulators are the main factors responsible for this slow progress.

Commercialisation is slower than expected due to high costs and low efficiency

The current low cost of the conventional energies (oil, nuclear and coal) have further slowed down the penetration of photovoltaic devices into the energy market. Environmental concerns, however, could render photovoltaic energy production more competitive.

Research should focus on achieving higher efficiencies for cells, modules and energy accumulators, in order to decrease the cost of photovoltaic technologies.

Europe is increasing its share of world photovoltaic module shipments. It accounted for 15% of world photovoltaic module shipments in 1985, and moved up to 22% in 1990. Japan is still the largest photovoltaic seller

in the world, accounting for 36% of world photovoltaic module shipments.

3.2 Environment

A substantial part of the activity of the Institute is devoted to studies in the field of the protection of the environment.

In the section above concerning the Observatory, two environmental activities were already described which, starting as studies, were subsequently transformed into periodical reviews. The first concerns Global Change Research & Policy and the second Developments in BATs (Best Available Technologies).

Other environmental studies in 1993 concerned the completion of analyses concerning Business and the Environment, work on the Integration of Environmental and Economic Indicators, updates on Opportunities in Environmental Technology, a survey on Environmental Evaluation Techniques and a study of Prospects for the Development of Atmospheric Transport Models.

3.2.1 Business and the Environment

A large study of Business and the Environment was completed in 1993⁵. The focus of the study was the interaction between business, the environment and technology. The study relied on a major literature review, technical visits and specialised support from two contractors.

The main themes treated were:

- the improbability of the environmental business resulting in large aggregate employment creation, and the need for better statistics and analyses;
- the possibility of obtaining competitive advantage from the environmental movement through better communications between industry and the regulators;
- the advantages of market-based instruments over command-and-control instruments, and industry's lack of trust in the regulators;
- the existence of a shift towards clean technologies, countered however by the fact that current opportunities remain largely in the clean-up business;

⁵ Work for the Forward Studies Unit of the European Commission.

- the need for greater use of cost-benefit analysis (including socio-economic aspects) and risk analysis in the setting of environmental objectives; and
- the need for adopting a systems approach in analyses of the environmental business.

This study will be complemented by detailed case studies and an expert workshop on *business and the environment* in 1994.

3.2.2 The Integration of Environmental and Economic Indicators

Human activity is now influencing the environment at a level which seriously threatens to affect economic growth and our well being in general. The necessity to identify sustainable development pathways has been recognised by the Maastricht Treaty, but the development of corresponding policy instruments has been hampered by the lack of integrated environmental and economic information systems at Community level. This is the conclusion of the work of one of two large interservice groups, chaired by the Forward Studies Unit of the European Commission, in which PROMPT has been involved during 1993.

Integration of environmental and economic information systems is important at the following levels:

- Efficient environmental policies may cast heavy burdens on the public. The best assurance for acceptance of these burdens is, that the *public knows* what is happening and why, i.e. that easy-to-understand integrated information systems are available.
- The Community should develop instruments to guide economic actors as to how to set up efficient sustainable policies as well as means to assess and compare policy alternatives (agriculture, industry etc.).
- Likewise economists will need - at least as a final goal - a National Accounts System which allows for an analysis of the effects of environmental policies on our economy and vice versa.

Sustainable development policies need integrated environmental and economic information systems

The integration of environmental and economic information systems has historically been developed at two levels: 1) the development of environmental indicators & indices, and 2) various attempts to inject information on the environment into national accounts.

The indicator & indices approach has evolved from simple attempts to measure the success or failure of various environmental policies, via 'state-of-the-environment' indicator systems (e.g. by CORINE), to the new generation of rather sophisticated 'pressure-state-response' indicator systems, which aim at the setting up of a more comprehensive framework, linking 1) pressures of human activities on the environment, 2) the state of the environment and 3) society's response to the observed deterioration of environmental quality.

The fact that environmental indicators differ from more traditional socio-economic indicators in their dependence on natural sciences introduces a new and important dimension of uncertainty and a need to find ways for communicating and acting in spite of this uncertainty. The pluri-disciplinary work necessary requires a better integration of social and natural sciences and the initiation of focused, social-science led research and development.

Several 'schools' are involved in the adaptation of National Accounts, an adaptation which is necessary if they are to become instruments for measuring environmentally sustainable development. Attempts to adjust the existing national accounts have been tried by several states: from the inclusion of relatively simple information in physical terms on the stock of natural resources (Norway: fish and forests resources) to more sophisticated approaches like France's Natural Patrimony Accounts System, which is intended to cover the economic, ecological and social environments and which will cover both stocks and flows of natural resources by ecozone, region, economic agents etc. The Netherlands is, on a project-basis, applying the method of R. Hueting, defining for each pollutant a sustainable concentration and then estimating the market costs for bringing the existing concentration into accordance with the sustainable facts. The UN has, after several years of studies, decided to go for a special system of Satellite Accounts, which will not necessarily require that all satellites are monetised, and which proves the way for gradual application of diverse evaluation techniques. Eurostat has developed a framework for the accounting of defensive expenditures (SERIEE).

Environmental indicators are at the crossroads between natural and social science

For National Accounts three major problems arise: 1) Is it possible and helpful to fuse into a system - so heavily based on market values - environmental values which (somewhat depending on what evaluation techniques will be applied) cannot be related to real markets? 2) What accounting convention should be applied? 3) And what are the economic, social and ethical implications of the alternatives?

There are various ways to adapt national accounts towards measuring sustainable development

A report with recommendations for future work is presently awaiting approval by the Commission.

3.2.3 Updates on Opportunities in Environmental Technology

The first interim report of the Updates on "Opportunities in Environmental Technology" was prepared by the end of 1993 and covers a wide range of information which was collected between June and September 1993⁶.

This activity on "Opportunities in Environmental Technology" is intended to provide, in regular reports, a follow up of the previous study by PROMPT which was completed in October 1991. The existing results serve as background material and the new efforts aim at monitoring the most significant accessible published information on a continuous basis. The periodical reports are designed to adopt the thematic structure of the background study and the basic definitions of the identified areas of opportunities.

The focus of the update reports is on tracing new information concerning the evolution of trends. Of particular relevance are the following topics:

- New technologies, their characteristics and applications.
- Legislative trends and impacts.
- The development of world markets for environmental technologies in general. Emphasis is given to emerging markets such as Far Eastern countries and the Eastern European countries.
- Evaluations of international aspects of competitiveness.
- Attitudes in national, multinational and corporate strategies.

The results of the activity are presented in the following two types of documents:

- The UPDATES ISSUES designed as a newsletter type document to be issued periodically.
- The SYNTHESIS REPORT designed to provide concise strategic analysis on emerging trends based on information from the Updates Issues.

In the first interim report the main effort was devoted to developing the structure of the Synthesis Report. The information collected was used directly in the Synthesis Report without going through the step of the Updates Issues. In this way the overall activity could commence

⁶ Work for the Forward Studies Unit of the European Commission.

with a critical mass of information accumulated in the Synthesis Report, which was grouped in the following three main sections:

Part I: Global Environmental Markets.

*Market size
evaluation of
environmental
business*

This part of the report compiles the current evaluations of the market size of the environmental business at global, national and regional scale. Following a consistency check of this data for completeness an important aim of the activity is to examine possibilities of interfacing reliable market data with technological information as collected in part II of the report.

Part II: Environmental Technology News classified by key industrial sectors.

*Emerging
opportunities in
environmental
technologies*

This part monitors emerging opportunities in environmental technologies. As the area is vast it is intended to adopt, during the course of the activity, the industrial classification scheme applied in DG III's "Panorama of EC Industry".

Part III: SWOT Analysis of the European Environmental Management Industry.

The data collected in parts I and II are used as input material for deriving a SWOT Analysis (Strengths-Weaknesses-Opportunities-Threats) of the European Environmental Management Industry.

A sample of the Updates Issues is annexed to the first version of the Synthesis Report and shows the layout which will be used in the following issues. In forthcoming issues the information collected will be first presented and circulated to readers with the Updates Issues. Its further selection and integration into the Synthesis Report will be based on the feedback obtained and on PROMPT internal evaluation procedures.

3.2.4 Environmental evaluation techniques

Work began on a major study entitled "Techniques for incorporating environmental considerations in project and policy appraisal". This is a 'multi-client' project for the Directorate-General for Industry (DG III), the Directorate-

General for Environment (DG XI) and the Forward Studies Unit⁷.

The starting points for the project are the statutory requirement (Article 130r (3), 3rd indent, of the Treaty on European Union) for all EC environmental policies to take into account "the potential benefits and costs of action or lack of action", and Chapter 15 ("The question of costs") in the Community's 5th Environmental Action Programme document "Towards Sustainability". This latter broadens the focus of costs and benefits to include assessment of the environmental consequences of all EC programmes, not just those specifically related to environmental objectives.

There are a multitude of environmental evaluation techniques, tools and methodologies. Their relative merits and weaknesses, their interconnections and their incompatibilities are difficult even for specialists to assess; to the hard-pressed administrator, having to deal with this issue among many others, the situation often appears opaque.

Maze of environmental evaluation techniques

In trying to provide guidelines for policy-makers and project-leaders seeking to incorporate environmental factors within their decision frameworks, the study employs a systems approach. In this way it is hoped to avoid the problems of sub-optimisation that seem to characterise many of the techniques in current use.

Study guides policymakers through the maze by employing systems approach

The first part of the study, completed in 1993, has concentrated on identifying the various evaluation techniques available. This has been done in very broad terms, both as regards the definition of "environment" and with regard to what constitutes a valuation method. Concepts such as the value of biodiversity and quantitative tools such as physical stress indicators are considered, in addition to more traditional measures of costs and benefits.

First part identifies evaluation techniques; second part analyses their characteristics

The next step will consist of analysing the distinctive characteristics of the various methodologies and integrating them all within a common analytical framework.

⁷ A substantial input to the study has been provided by a visiting scientist from the Technology Management Centre, The University of Queensland, Australia. DG II has also provided extensive comments and advice.

3.3 Transport

3.3.1 High Speed Trains

A major study of the technological factors affecting the development of the future European high speed rail network was completed in 1993⁸. The study was carried out with the aid of specialised workshops, computer simulations carried out on our behalf by various railway companies and a number of specialised contracts. In this study the role of PROMPT as an expert integrator was particularly marked. The final report was evaluated by an expert panel, representing the European Community of Railways and the main manufacturers, which applauded the study for its "excellent quality" and hailed it as "a serious base for the future development of high speed lines."

The technical results of this study are summarised in the following two sections.

Technical analysis

Comparative simulation exercises confirmed that direct voltages lower than 2 kV are unsuitable to power the more powerful and more closely spaced trains which will operate in 10 or 20 years on high-speed networks. Direct current 3 kV is still acceptable, as demonstrated by the Italian ETR 500, but is too close to its limits to justify major investments whose results will be felt in the first third of the next century. Direct current power at higher voltages (20,000 V or more) forms a promising but entirely new technology, which may be a candidate for the next generation of systems.

*Low voltage DC (3kV)
is not appropriate*

The two alternating current systems (at 16 2/3 Hz and 50 Hz), have shown that they are still capable, for at least twenty years, of facing up to the growing demand for power of ever more powerful and closely spaced high-speed trains.

The choice of the industrial frequency (50 Hz) seems more logical, with the present state of technology, for the electrification of new lines and, in so far as it can be generalised, would allow considerable savings at the European level, by the effects of scale and learning in terms of design, production and operation of rolling stock, etc. The unification of standards ensuring complete inter-

*..while between the
two alternating
current systems 50
Hz seems more
appropriate*

⁸ Work for the Directorate General for Industry (DG III).

operability of networks and the circulation of universal trains without change of configuration would stimulate traffic and improve the competitive position of the railway vis-à-vis the car and the aircraft.

But the specific merits of 50 Hz are not sufficiently decisive to make the special frequency (16 2/3 Hz) obsolete and there is a high risk that medium-term economic logic and the quantity of investment already made will favour the partition of the rail system.

..nevertheless interoperability may be sacrificed to medium term cost considerations

Economic analysis.

This fragmentation of the European area into distinct electrical regions limits demand and means that about 2,000 high-speed trains should be enough to satisfy it by 2010.

These trains would probably belong to four different classes of standards and risk being produced by 3 to 6 different manufacturers. Far from stimulating progress by competition, such fragmentation of the market for high-speed rolling stock multiplies development costs, reduces production runs, consequently reduces the advantages of scale normally associated with this and increases costs of maintenance and of the training of drivers for international trains.

Market fragmentation due to lack of interoperability reduces scale advantages and the spread of high speed trains

At the level of traffic prospects, the modelling confirms the penalising character of frontiers (even when electrical systems are harmonised by both sides) and seems to indicate that most of the high-speed traffic will run on privileged corridors, mainly national. High-speed international connections will only form a modest fraction of the traffic, which would not justify a general remodelling of electrification systems.

3.4 Industrial competitiveness

3.4.1 R&D, technology, management and competitiveness

An earlier study on "Technology Nodes" performed by PROMPT in collaboration with the "Centre de Sociologie de l'Innovation, de l'Ecole des Mines de Paris" (under a contract of DG XII), led us to question seriously the then fashionable "linear paradigm", which establishes a direct

correlation between technology, innovation and competitiveness.

After studying in depth, for DG III, the factors influencing the competitiveness of the European aero-space industries, we arrived at a number of conclusions. These were presented, as an opening report, to the Closed Seminar (June 1993) of the Industrial Research & Development Advisory Committee (IRDAC). The message, which was well received by the Committee, was the following:

Emphasise technology as a commodity to be assimilated by entrepreneurs

Technology is not per se a decisive asset; rather it is a commodity which should be strategically managed. In fact, most technology can be easily borrowed or shared through licences, alliances, acquisitions, etc. at a lower cost and with fewer risks than developing it in-house. What is paramount is the ability of the enterprise to assimilate a new technology, to adapt it to its own environment and to incorporate it successfully into its processes, products, services. Having an internal R&D capability may help in metabolising borrowed technology, but not necessarily: all too often, the R&D activities of the in-house labs are not in line with the strategic orientations of their companies, thus diverting scarce assets away from the battle front.

Employ technology-type specific approach, adopting latest lessons from the study of management techniques

Strategically managing technology does not require the same approach as for incremental technology (meant continuously to improve products and processes, without trying to leapfrog the competition) and for radical technology (which might radically change the conception, production or distribution patterns, but with high risk embedded). Corporate culture, lean organisation with few hierarchical levels, open information, team work, and a permanently retrained workforce, together with a clear and firm commitment of the top level, are key factors for the successful assimilation of technology.

Our presentation to IRDAC also covered a review of the successive management concepts, fashions and fads, which blossomed during the last 50 years, now culminating with the "re-engineering" school.

Finally, we provided IRDAC with a review of the external factors affecting enterprise competitiveness, and the role of public intervention.

3.4.2 Space markets and competitiveness

PROMPT had, in previous years, performed a first study on the competitiveness of the European Space industry,

casting some doubts on the claimed strength of our enterprises to compete effectively on an open international market, for several reasons:

-the markets are not as large as usually forecast, which makes competition more severe

-new competitors are emerging (CIS, China, Japan, etc.)

-the European domestic market, in particular the defence market, is much smaller than that in the US

-European sales are not large enough to benefit fully from scale economies, common infrastructures and standardisation

-European industry is too fragmented, compared to the US industry, and too dependent on foreign components and subsystems

-European Space programmes are not strategically targeted

Europe is lagging behind its competitors on several fronts

Following this first report, DG III asked PROMPT to scrutinise Space Markets more closely . A new study was performed, concluding that:

-commercial satellites represent a market of around only 20 to 25 satellites a year, worldwide, from which the USA takes the lion's share. European industry's share might be about 3 satellites a year, which is not enough to support a strong, integrated industry.

-pending further progress of political agreements on PESC (the European Security and Cooperation Policy) and further definition of the respective missions of the WEU (Western European Union) and NATO, there is no real European military space market, only national programmes with limited bilateral cooperation.

Europe is absent in important growing markets, whereas prospects for the markets where it is present are not encouraging

-Europe is absent from important market segments such as global positioning (GPS for instance), low orbit communication satellites (such as Iridium), advanced technology telecommunication satellites (agile antennae, etc)

-the future of remote sensing markets depends on long term commitments of European governments, on international agreements on formats, declassification and tariffs, and on redistribution of

the roles between the many agents managing the ground segment and marketing the applications.

-prospects for commercial micro gravity developments are dim, since the current launching technology is definitely too expensive and unreliable. A whole new generation of launchers should be developed to make orbital production and permanently manned stations realistic.

-Europe will face difficult times with the transition from Ariane 4 to Ariane 5, which would normally require two production lines and two launch facilities to be operated at the same time, which seems too costly. Furthermore, Ariane will face renewed competition, with the drastic restructuring of the US launcher programme and the consolidation of several American companies under Martin Marietta, while China, Japan and CIS are boldly entering the commercial launch market.

Europe will face cost escalation problems as well as new competition

-Much more important than the space segment, are the ground-based markets. Once again, Europe is lagging behind, in particular in the telecommunication and media businesses.

These conclusions were reviewed by a Panel, consisting of high level representatives of "space users", such as Eutelsat, Eumetsat, Eucosat/WEU, CAP (agriculture), etc; here is their appreciation:

"The Panel wishes first of all to congratulate the Commission by expressing its most sincere appreciation for the great interest of the information provided at the meeting as well as for the completeness and originality of the material prepared by PROMPT.

The Panel is unanimously willing to proclaim its overall agreement with the critical analysis and the constructive diagnosis produced by PROMPT in its study of space markets (...) "

Following this, PROMPT was entrusted by DG III with a new study on the cost structures and potential economies of scale if the European industry succeeds in restructuring and grasping new market shares. This study will be executed during 1994.

3.5 Science and society

3.5.1 Carrefour- Science and Conscience

The Carrefour meetings, which are organised for the President by the Forward Studies Unit, are an attempt to break the usual committee structure by creating a series of small intimate groups in which members are encouraged not only to question the Community model but also to be creative about the future. Under the general title of *Science, Culture and Society* each Carrefour has a particular sub-theme and PROMPT was asked to help with the preparation of the Oxford Carrefour on *Science and Conscience* and to write the proceedings.

The relationship between science and society has never been an easy one. Moreover, the growing public concern over a number of major technological risks - nuclear, global environmental, biotechnological, etc. - has engendered a mistrust of technological developments and even of science itself. The old conflict between the freedom of science and the perceived need for ethical constraints on this freedom is once again to the fore. At the same time the very nature of science is debated - not only within the scientific community but also in society at large.

Science and ethical constraints in a social context

Science has also become an instrument of state policy - whether in the field of national economics and wealth creation or in the defence field and the realm of power politics. The Community itself has a growing role in the field of science. (Part of the current Community programme of science, research and technological development concerns bio-ethics.)

In the light of these developments a preparatory paper for the Oxford Carrefour was produced which posed a number of questions and was designed to stimulate debate.

Any attempt to draw conclusions from the resulting wide ranging discussion is obviously fraught with difficulties. However, the following reflect the main lines of the Carrefour discussions.

Summary of main themes raised in discussions

- There is a convergence in science between the study of complex situations (biology, meteorology, etc.) and the increasing complexity of systems analysed by physics. This convergence is aided by the mathematics of complex non-linear systems and chaos. However, whether this represents a new paradigm for science is not certain.
- Current global problems require the harnessing of all scientific knowledge. Furthermore, it is necessary to

invest in major long-term scientific programmes as an investment for the future.

- Pure science is in essence neutral and must be supported and allowed freedom to develop along independent lines. There is an urgent contemporary need to achieve a better balance between science as knowledge and science as a utilitarian instrument.
- The need for an understanding and appreciation of ethics by scientists was clearly felt. There was, however, a division between those who felt that an ethical framework was essential and those who felt that such a framework would be of little practical value.
- Oversight by ethical experts was considered to be a dangerous development. The use of ethical (advisory) committees, however, as a counterweight to (official) expert witnesses, is a desirable development.
- There is a need for education in ethics at an early stage in the educational process.
- The public understanding and appreciation of science must be improved. Science journalism can help but it is essential that scientists also explain their science to the public - including the uncertainties.
- The traditional European university ethos should be re-established.
- The problems of Russia are orders of magnitude worse than those of the countries of Central and Eastern Europe.
- The need to support science in these countries is based on mutual interest. Firstly, there is much that the Community can learn - particularly in the field of theoretical science. Secondly, there is a need to prevent the collapse of the science base due to the economic crisis as this would be a major loss for the world.
- Co-operative activities are highly worthwhile but there is a need for more co-ordination and exchange of information.
- There is a real risk of an under use of modern biotechnology due to public antipathy unless the Community acts to redress the lack of public understanding. The positive aspects with regard to human welfare must be made more visible.
- Science will only retain its freedom if the public perceives that the scientific community is internally responsible. Controls on the applications of science must be open and clear.
- Community science must become less bureaucratic.
- The Carrefour concept should be used more extensively.

3.6 Prospects for the development of atmospheric transport models and related data base

A review of the state-of-the art of atmospheric transport models and related emission inventories for Europe was performed, in order to provide elements for the development of JRC and Commission research in the field, with particular attention to international/interregional impact.

In this context a paper was prepared for the JRC Environment Institute:

Emission Inventories and Atmospheric Transport Models for Inter - regional Environmental Impact Assessment.

State of the art - Possible R&D support

The paper is an attempt to identify possible R&D support that the Commission might provide in favour of research for better atmospheric transport models and/or related emission data. The purpose and constraints of the work are outlined by the following keywords: *Airborne pollution, Inter-regional environmental impact, Routine emissions, Subsidiarity.*

Theoretical studies on airborne pollution have received increasing attention during the recent 15 years. The understanding and modelling of the basic physics and chemistry of transport and deposition, as well as the struggle against constraints posed by computer speed and capacity, have absorbed the major part of the resources.

In this pioneering phase, computer models have been considered mostly as aimed at the description of "emission episodes", i.e. of emissions which, for the purpose of the present discussion, can be considered well defined and detailed in terms of space and time. At present, though model development has still a long way to go, concern about *inter-regional environmental impact* is promoting a different use of models and data: the calculation of pollutant concentrations is required, as detailed as possible, over broad areas and long periods of time; for this purpose, *routine emission* data, covering *all* surrounding areas over long distances, are required.

Shift of attention from 'emission episodes' description to inter-regional environmental impact

What is lacking today is an effort to improve the knowledge about the amount and consequences of the routine release of pollutants, which accounts for the bulk of the interregional environmental impact and requires major investments, particularly in data collection and homogenisation.

Need to improve knowledge about routine release of pollutants

In this field very few experimental validations of model prediction of pollutant concentrations have been carried out as yet, not only for practical reasons but also as a matter of principle, since the parameters for such an experimental campaign cannot be clearly defined. *Only*

theoretical evaluations (supported by experimental model validation based on emission episodes) can be used widely to support the discussion about requirements for models and emission inventories in this context (an alternative approach, (though partial and yet to be proved feasible), is to check model predictions against observations during a "meteorological episode").

Since the discussion about the desirable quality of inventories and models seems not to have been pursued with sufficient detail, something should be done to improve the situation.

Existing model accuracy is often inadequate

Many models, of different types, have been developed, particularly during the 80's.~ It is difficult to state which type of model is best for a given task. Model accuracy is in many cases inadequate, depending on emission type, topography, weather conditions etc.: sometimes the basic parameters are poorly defined, sometimes the physics is poorly modelled, sometimes the geometry and the boundary conditions cannot be taken properly into account because of input size and computer capacity.

The errors in the evaluation of pollutant concentration, due to modelling and data inaccuracies, are frequently of the order of 100% and more, when the results are considered over relatively small areas and short time intervals.

..but accuracy can be improved

Model accuracy can in many cases be improved by increasing the detail in space and time partitioning. Since, in some countries, constraints are imposed by law on average values of pollutant concentrations over small areas and short time intervals (say 10x10 km and a few hours), a similar level of detail would be desirable in computer evaluations. The corresponding increase in computer time and memory requirement could in some cases be justified, but only if supported by a detailed emission inventory (and meteorological data base).

..through detailed basic emissions data or the theoretical elaboration of data on 'averages'

This detail is usually not available at the level of the basic emission data, since these are provided as averages over broad time and space intervals; it can however be achieved, at least formally, by theoretical elaboration of such average data; this is what is usually meant with "modelling work on emission inventories".

Broadly speaking, there is no doubt that the emission inventories should be improved by collecting better "average" data as well as by providing more detail in their theoretical elaboration. A similar statement about improvements in computer models is not equally straightforward; some experts seem to be inclined to

suggest that, whilst model parameters undoubtedly deserve improvement, the state of the art with the model structure is satisfactory for present purposes, in view of the quality of the emission inventories and of the meteorological data.

The conclusion that seems to emerge from the literature is not completely in line with this statement, which is thought to be only acceptable when broad averages of model predictions over large areas (150 x 150 km²) and long times (season or year) are required.

The requirement for better data is particularly stringent when the pollutants of interest are subject to chemical transformations as a function of temperature, humidity and sunlight.

As a very sketchy conclusion, it may be stated that uncertainties in the meteorological data, particularly wind, are of great importance if the predictions are intended for a particular location, *even* when the averaging period is long (one year).

Uncertainty in meteorological data is of great importance for individual locations

For wider areas, the accuracy of the meteorological data is not very important (as well as the geographical distribution of the emissions), so that the use of an "average" meteorological year is justified for the evaluation of long-distance impact matrices.

..but not for wider areas

However, since the use of big models and related *routine* emission inventories must be foreseen for the assessment of *local* concentrations during *meteorological episodes*, an improvement in the meteorological data base should be considered of primary importance. Possibly only the accuracy of forcing parameters, deposition velocity and scavenging rates can be more important.

The analysis of the bibliography seems to suggest that a lot of computer experiments, supported by observations, should yet be done before satisfactory and detailed statements can be made in this context.

4. STUDIES UNDER THE RESEARCH FELLOWSHIP PROGRAMME

The Institute is able to host research fellows in receipt of grants under various schemes, notably the Commission's Human Capital and Mobility (HCM) programme.

By December 1993, nine fellows were in place. Four of these are registered for Ph.D. degrees (at the London School of Economics, at the University of Manchester, at the University of Stuttgart and at the University of Deusto - Bilbao).

Since PROMPT has virtually no additional resources to allow Institute staff to participate in the projects, fellows have to be largely self-reliant, although benefiting from the Institute's information systems and expertise. To encourage inter-disciplinary synergies, fellows are assigned (wherever possible) to specific project teams, all members of which are engaged in exploring a common theme from different standpoints.

Themes are chosen on the basis of their perceived future importance, including areas where PROMPT has no current client to sponsor studies. Research teams are around 3-4 strong, representing different disciplines and (of course) different nationalities. A particular strength of such an arrangement is that each team member has a unique range of contacts (or "personal network"), both disciplinary and national, to contribute to the joint effort. Close contacts with "home" institutions and researchers are also encouraged, particularly in the case of doctoral candidates.

4.1 Innovation diffusion and political control: A comparative case-study on cogeneration technology

The emission of greenhouse gases and the exhaustion of fossile primary energy resources are two main obstacles to a sustainable future. Cogeneration, i.e. the combined production of heat and power, is an important means to contribute to the reduction of both CO₂-emissions and primary energy consumption by substantially increasing the overall efficiency of the energy conversion process. Nevertheless the diffusion of this technological principle has not met earlier expectations and varies considerably among the different European countries. Therefore, the purpose of the project is to illuminate some determinants

Combining production of heat and power promotes sustainability

of diffusion processes of new technologies by investigating the case of cogeneration.

A review of theoretical approaches to innovation diffusion has been carried out which reveals their limitations in dealing with this phenomenon in a sector such as energy where political and public actors at different levels play decisive roles. For that reason, a conceptual framework has been formulated which attempts to integrate economic, technological and political aspects of innovation diffusion and which is based on a systems approach and evolutionary arguments. Apart from providing an explanatory basis for the analysis of diffusion dynamics, its purpose is to guide and structure the empirical part of the research work.

Framework proposed integrating economic, technological and political aspects of innovation diffusion

..based on systems approach and evolutionary arguments

The study of the technological example of cogeneration has pointed to the importance of institutional and political constraints to its diffusion, technological and economic ones being less restrictive. Until recently, the effects on diffusion patterns of national policies and policy-making processes, as well as of structures of the national energy economies, have rarely been investigated in detail and are still poorly understood. Therefore, the empirical research will put emphasis on these determinants and their impact on the technological choices of the key actors for diffusion, namely the relevant enterprises of the energy sector: technology manufacturers and different types of user.

Political/ institutional constraints are shown to overshadow technoeconomic ones

A comparative methodology has been chosen in order to be able to single out the effects of the structural and political determinants inside the national systems. The countries included in the comparative study are Denmark, Germany, the Netherlands and the United Kingdom. Apart from consulting relevant publications and accessible statistical data sources, interviews and a questionnaire survey will be carried out in order to gather information at the different levels of investigation.

4.2 Interregional Cooperation in Technological Innovation

The spatial dimension of technological innovation constitutes an important factor for the long term prospect of regional development. Cooperation between territorial entities across national borders inside the European Union is considered an important strategic option. The apparently low practical significance contrasts with the high expectations regarding cooperative strategies. The study aims at elucidating the conditions of such arrangements, pursuing the improvement of the execution of regional prospective studies.

Game-theoretic framework provides conditions under which horizontal and vertical cooperation can be obtained

The heuristic conjectures that had been postulated in the preceding course of the research have been embedded in a theoretical framework established using game theoretic notions. This allowed the detailing of the conditions under which horizontal and vertical cooperation can be obtained. The regional dimension has been incorporated by a territorial application of the concept of appropriation based on theories of regional development. A thorough analysis of the logic governing cooperation was thus obtained, as well as an explanation for the low incidence of cooperation in technological innovation.

Endogenous forces outweigh exogenous ones in shaping cooperative patterns

The empirical investigation carried out in 1993 has confirmed the theoretical results. Regarding the forces shaping the cooperative pattern, however, the cases examined so far do not permit irrefutable confirmation of the hypotheses. Endogenous factors appear to dominate over exogenous ones. In the concluding stages, research is directed towards shedding more light on the interplay and relative significance of endogenous and exogenous factors.

4.3 Technological Policies in European Regional Systems of Innovation

Development perspective in analysing regional systems of innovation and associated policies

An interdisciplinary collaborative research effort has begun on Regional Innovation and Policies for Development in Europe. A model is being developed for the analysis of different Regional Systems of Innovation and associated policies from the perspective of endogenous development. This will take into account both the transformation in the organisational forms of industrial economies and the factors determining the development of networks among firms at the local level and in an international framework. Analysis initially focuses on the Lombardy region in Italy and the Basque Country in Spain, in geographic terms, and on the agro-alimentary industry in sectoral terms. The study aims to identify the different regional innovation patterns focusing on the factors which hinder the generation and diffusion of technological innovation in these regions.

The relevance and the impact of the Regional Innovation Policies and the R&D Policy of the Commission of the European Union will also be studied. In particular, the study will seek to establish the potential and limits of these policies and suggest improvements to the decision-making process for such techno-economic issues.

4.4 The Future of Transport in European Cities

The working group on the long term future of transport in major European cities has been established now for over a year. The aim is to examine how transport as a system can evolve in order to satisfy present and future concerns regarding a better quality of life (in particular the environmental aspects), given the technological limitations and the associated strong social context. A time horizon of thirty years was chosen to permit the systems both to be imaginable and to have time to develop.

*Thirty year horizon
chosen for the study*

A multi-disciplinary approach was selected in order to cover the main fields associated with urban transport. The group comprises a geographer, an economist, a physicist and a political scientist. Each, in addition to contributing to a specific study corresponding to his or her field of competence, has been asked to explore different prospective methodologies and assess their usefulness, along with their limitations.

*...as well as a
multidisciplinary
approach*

One study was thus directed toward the exploration of the alternatives, in terms of technical possibilities, to existing transportation systems. This work was carried out by means of a morphological analysis followed by a multi-criteria scoring procedure on the one hand and by seeking the advice of experts in the field and intensively reviewing the existing literature on the other hand.

*Alternatives to
existing transport
systems were
examined*

Briefly, the numerous drawbacks induced by urban transport can be lessened by either an improved transport system or the substitution of a physical trip by means of telecommunications.

Regarding the particular environmental concern, the results of the survey have underscored the fact that there is a large discrepancy in terms of energy density stored in the vehicle between chemically-fuelled and electrical vehicles which translates in particular to a lower user acceptance. Clearly a large, albeit partial, improvement lies in a hybrid vehicle using an electrical transmission (i.e. an electrical vehicle which also carries a thermal engine responsible for recharging the vehicle's batteries, and which operates at a high efficiency/pollution tradeoff ratio.) Additionally, while the prospects for batteries are not very bright, other long-term energy storage devices, such as flywheels or SMES (Superconductive Magnetic Energy Storage), appear more attractive - not to mention fuel cells, which appear to be the best compromise in terms of energy and power density and efficiency.

*Hybrid vehicles were
studied*

Information technology can play an important role by boosting trip efficiency and helping match offer and demand for modal transport. However, this use of information technology is likely to constitute a short-to-mid-term improvement, analogous to new road building, and could significantly limit people's mobility.

Information technology can reduce the need for travel

A way out could lie in the capability of information technology to reduce the demand for transport by acting as a substitute for travel. While traditional telecommunications modes lack the necessary richness and realism to be employed outside very specific communication needs, the development of televirtuality appears very promising in terms of realism, immersion and interactivity. Clearly, future developments of broadband commercial networks and continued improvement of virtual reality technologies, both in software and hardware, open up the long term possibility of building an artificial world in which people could meet mobility-dictating needs without actual spatial movement.

Another contribution to the Urban Transport Studies team has come from the economic perspective. The original idea consisted in the assessment of Input-Output analysis (IO) as a potential forecasting tool for the study of the urban transport system both at the theoretical and empirical levels. To this end, a mission to the city of Seville - chosen for applying the theoretical results - was undertaken. This allowed the research fellow to meet experts at the 10th International Conference of Input-Output Techniques and, at the same time, to collect data on the urban transport system. Difficulties, however, in coupling the Input-Output analysis with the field of urban transport slowed down progress on the theoretical part.

Yet it was possible to specify major positive aspects and limitations of the Input-Output method regarding the specific field of transport.

Input-Output analysis is a robust quantitative tool which can be used as a forecasting technique for dealing with certain aspects of urban transport, some difficulties arising when dealing simultaneously with the entire system.

Input-Output analysis was explored as a tool for the study of the issues at hand

IO's major limitations at present are related to the construction of the technical coefficients, their constant value and the data requirements for filling in the IO table, among others. Nonetheless, IO can be used for analysing sub-fields strongly related to urban transport such as environment and energy. Thus, the Input-Output technique can contribute with its richness to the construction of well-defined scenarios describing the aspects of urban transport that can be approached from a quantitative

perspective. It has also been possible to describe the main approaches used for urban transport modelling. These models can be considered as alternative tools for analysing the future trends of urban transport.

A third contribution regards a joint project between the PROMPT Institute and the University of Manchester and constitutes part of a PhD programme on the theme "Prospective on the environmental consequences of urban transportation". This study is aimed at analysing the overall problems for the environment and social welfare which are caused by urban transport. As for the other contributions mentioned above, this study has two separate objectives:

It aims to describe and analyse the urban transport system in European cities in terms of major variables such as pollution levels, quality of life, public policies, transport demand, economic needs and technological opportunities.

At the same time it is intended to experiment with and apply a prospective method to the future of urban transport. The method that has been chosen is SMIC (Cross Impact System and Matrices), an alternative methodology to the well-known Delphi technique. SMIC is a sophisticated tool in the sense that it permits one not only to know experts' opinions but also assess their coherence through an interdependence between the questions and a subsequent statistical processing. The whole computation is eased by the use of dedicated software whose output leads to a scenario ranking and, ultimately, to the most likely forecast of the future of urban transport as seen by experts.

Study of the future of urban transport through the use of the SMIC prospective method

To be statistically reliable, the effective number of experts needed is several dozen which means that over one hundred experts will have to be contacted initially. This step has already started and a personal information network has been established in Manchester with university researchers and people working for the local authorities. The establishment of similar networks in other European cities is foreseen in the near future.

The aim of this methodology study is to evaluate the extent to which various 'prospective' or technology foresight techniques are capable of providing valuable insights and/or valid policy guidelines when applied to societal problems such as those posed by urban mobility/environment conflicts.

Furthermore, the results of this prospective exercise will be compared with the forecasts that the authorities or planners are making in this field. The three cities selected for comparison are Manchester, Milan and Seville.

Case studies of Milan, Manchester and Seville are being conducted

A further project, analysing transport needs in terms of labour market dynamics, and testing the utility of GIS (Geographical Information Systems) as a tool for integrating such considerations within the prospective process, is still at a very early stage.

4.5 European Community S&T Activities With North African Countries

In May 1993 a prospective study was launched on the future actions and strategies for the European Community and its member countries, with respect to their scientific and technological cooperation with the North African Countries.

The purpose of the study is to enhance our understanding of the following issues:

- the R&D capacity of North Africa and its growth requirements, in order to improve the competitiveness of the industrial structure of the Maghreb region.- The steps undertaken in 1993 to accomplish this task have been the identification of the relevant variables and work towards the construction of a data base on the activities of the R&D Centres operating in Mediterranean regions.

- the experiences of cooperation and the technical problems in the following three priority sectors: energy; water-soil-agriculture; and communications-settlements-regional planning. This selection was discussed in the Workshop with European experts⁹ held at the Institute in September 1993.

- the prospective analysis of the role of the European and North-African actors in future scientific and technological cooperation. With respect to this research task, during 1993 progress was made on the methodological side with the selection and application of the MACTOR prospective method.

Overall, this study has a geo-strategic dimension for the European Community because of demographic/migratory pressures across the Mediterranean, fostered by low industrial and socioeconomic development in the countries of the southern Mediterranean littoral.

⁹ Workshop on "the Western Mediterranean Development and Technical Requirements. Goal and Approach Definition. The Role of the EC". "PROMPT", Ispra, 16-17 September 1993.

On the other hand, the study is an application of the results reached in another background study (1991-1992) in which scenarios of Industrialisation and Cohesion in the Western Mediterranean were built in order to explore the role of the EC R&D policy¹⁰.

Three scenarios were developed at that time: "On their own and divided"; "Maghreb Community" and "Euro-Maghreb Cooperation". Of the three Scenarios, the third was the most attractive. It implied strengthening inter-Maghreb regional cooperation and their multilateral S&T cooperation with the European Countries, under EC leadership. It is a scenario that promotes an industrialisation that preserves high social cohesion, aiming at enhancing resource mobilisation, while limiting adverse environmental impacts.

In this context, the prospective study that is being carried out aims to analyse the strategies of European actors that are well prepared to support sustainable economic development in North Africa.

¹⁰ T. Rojo (FAST). THE FUTURE OF THE WESTERN MEDITERRANEAN. Issues and Prospects for Science and Technology Development. FOP 342. MONITOR-FAST Programme. Commission of the European Community. DG XII. (Internal Paper). November 1992.

5. SEMINARS AND WORKSHOPS ORGANISED IN 1993

High Level Panel on Space Markets and European Space Industries

With the participation of six experts, five rapporteurs and 8 observers (Belgirate 25-26 March 1993).

Seminar on "Entraînement à la démarche prospective"

M. H. de Jouvenel, Futuribles International, Paris (Ispra 10-11 May 1993).

Seminar on "The IEA greenhouse gas R&D programme"

Dr. I. Webster, IEA Greenhouse Gas R&D Programme, Cheltenham, U.K. (Ispra 28 May 1993).

Seminar on "Cohesion in the European Community: illusion or reality?"

Dr. R. Leonardi, London School, London (Ispra 11 June 1993).

Seminar on "The effects of information technologies on cities and regions"

Prof. M. Castells, Universitat Autònoma, Madrid (Ispra 29 June 1993).

Workshop on "Affaires Méditerranéennes"

With the participation of four independent experts (Ispra 16-17 September 1993).

"High Level Panel on the Electrification of the European High Speed Network"

With the participation of five members of the panel, nine rapporteurs and four observers (Brussels 20-21 September 1993).

Workshop on "Methods and Tools in Strategic Prospective - 25 years of research, retrospective and perspectives"

With the participation of 22 invited experts (Ispra 30th September and 1st October 1993).

Seminar on "CO₂ Mitigation Technologies: an Overview"

Dr. M. Steinberg, Brookhaven Nat. Lab., Upton, USA (Ispra 4 October 1993).

Presentation of the Portuguese industrial development programme

M. A. Santana, Manager of PEDIP, Specific Program for Dev. of the Portuguese Industry (Ispra 12 November 1993).

Seminar on "Environmental Evaluation in Practice"

Dr. H. Williams, ECOTEC Research and Consulting Ltd, Birmingham, U.K. (Ispra 26 November 1993).

Seminar on "Technological Evolution Variety and Competition"

Dr. P. Saviotti, INRA-SERD, Grenoble and Dept. of Economics, Univ. of Manchester, U.K. (Ispra 3 December 1993).

Seminar on "Discussion of a System for Conducting Science and Technology Monitoring"

Dr. G. Reigeluth, Vice-President and Managing Director Europe, Decision Resources Inc., Waterloo (B) (Ispra 9 December 1993).

Seminar on "Technological choice in the real world: how transport telematics are being formed by social and political pressures"

Dr. K. Ducatel, PREST, The Univ. of Manchester, U.K. (Ispra 10 December 1993).

Seminar on "Applied Prospective"

Dott. F. Meunier, CNAM, Paris (Ispra 13-15 December 1993).

6. LIST OF PROMPT'S REPORTS

State of technology in ten years time

- * **This World Around Us**
- * **Science and Technology Issues**
- * **S/T Assessments**

F 1 (Contribution to the Strategic Planning for the JRC, March 1990)

Science and the Greenhouse Effect

A CdP 1 (Report Prepared for the Forward Studies Unit, June 1990)

A Critical Literature Survey on the Prospects for Thermonuclear Fusion Energy

G 1 (Report prepared in fulfilment of a contract with BMFT - Germany, August 1990)

Technological Response Options to the CO2 Issue

- * **Overview**
- * **CO2 and Energy Consumption Setting Targets for Europe**
Annex : The role of electricity generation
- * **The role of Renewable Energies**
Annex : Energy from biomass

A CdP 2 (Report prepared for the Forward Studies Unit, September 1990)

Pre-Lotos Study :

Air Transport and Aeronautic Industries

- * **Part 1: Highlights and Scenarios**
- * **Part 2: Background information**

B 1 and B 1a (Report prepared for DG III, DG VII, DG XII, September 1990)

Forecasting Technological Innovation

F 2 (proceeding of a Eurocourse, published by Kluwer Academic Publishers in 1991)

The "Technological Nodes" Concept

E 1 (Report prepared for DG XII, January 1991)

Climate Change Research and Policy: Updates

(A periodic survey: N.1)

A CdP 3 (Report prepared for the Forward Studies Unit, May 1991)

The Japanese Technological Response to Global Environmental Problems

A CdP 4 (Report prepared for the Forward Studies Unit, May 1991)

Nuclear Energy-Reprocessing and Recycling are Key Issues

A CdP 5 (Report prepared for the Forward Studies Unit, July 1991)

The Technological Response to Global Environmental Problems - California

A CdP 6 (Report prepared for the Forward Studies Unit, September 1991)

L'alimentation en énergie des réseaux européens de Trains à Haute Vitesse (THV)

Annexes :

- * **Technologie de la traction électrique à grande vitesse: évolution historique et aspects énergétiques**
- * **Technologie de la traction électrique à grande vitesse: état de l'art et perspectives**
- * **Aspects environnementaux**
- * **Perturbations causées par la traction électrique par Electricité de France**
- * **Industries et marchés de la grande vitesse ferroviaire**
- * **Lancement de l'enquête auprès des réseaux par la CCFE**

C 3 (Report prepared for DG III, September 1991)

Prospectives on the Process of Innovation for Advanced Materials

F 3 (Post-doctorate report, September 1991)

Opportunities in Environmental Technology

A CdP 7 (Report prepared for the Forward Studies Unit, October 1991)

Climate Change Research and Policy: Updates

(A periodic survey: N.2)

A CdP 8 (Report prepared for the Forward Studies Unit, November 1991)

Foci of interest and attention in global environmental change research; a literature-based assessment

F 4 (Post-doctorate report, December 1991)

Ruolo dei Materiali Innovativi nello Sviluppo delle Industrie ad Alta Tecnologia in Europa

F 5 (Student's thesis with Milan University, December 1991)

A prospective Assessment on the Role of Renewable Energies in response to the CO2 problem

A CdP 9 (Report prepared for the Forward Studies Unit, January 1992)

Some Technology Options for dealing with Environmental Pollution

D 1 (Report prepared for DG XI, January 1992)

Research and Technical Prospects for Cork. Phase I Study

G 2 (Report prepared in fulfilment of a contract with the Cork Experimental Station, Sardinia, in January 1992)

Energie et environnement

F 10 (Presented at the 4th Energy Forum in Barcelona, January 1992)

Lotos, update

B 2 (Report prepared for DG III, DG VII, DG XII, March 1992)

Compétitivité des industries spatiales européennes

Rapport final de la phase 1 + annexe au rapp. final

C 1 (Report prepared for DG III, April 1992)

L'alimentation en énergie des réseaux européens de Trains à Haute Vitesse (THV)

Rapport final de la phase 1
C 3a (Report prepared for DG III, May 1992)

Pollution Prevention: Exploiting the Technical Potential

D 2 (Report prepared for DG XI, May 1992)

Climate Change Research and Policy: Updates

(A periodic survey: N.3)

A CdP 10 (Report prepared for the Forward Studies Unit + DG XI and Env. Institute, June 1992)

The strategic importance of high power GTOs (gate turn off) silicon controlled rectifiers (3000 amperes plus and 3000 volts plus) for the development of the future high speed rail network

C 4 (Report prepared for DG III, June 1992)

European network for training in strategic prospective

F 6 (Published in Futures, June 1992)

Market Based Instruments for Environmental Protection

A CdP 11 (Report prepared for the Forward Studies Unit, September 1992)

The inter comparison of the three main European HST electrical supply systems by simulation of the network requirements for three possible high speed lines

C 5 (Report prepared for DG III, September 1992)

Q² Information system

F 7 (Progress report, September 1992)

"R&D Projects" - Information systems

F 8 (Presented at the 2nd meeting of the DG XII-A Working group on the Harmonisation of Data Bases on Research in Progress, September 1992)

Brainstorming workshop on the prospective for higher electrical voltage supply systems for the future European HST network

C 6 (Report prepared for DG III, November 1992)

Climate Change Research and Policy: Updates

(A periodic survey: N.4)

A CdP 12 (Report prepared for the Forward Studies Unit + DG XI and Env. Institute, January 1993)

Aerodays 1993: updating the LOTOS report

B 3 (Report prepared for DG III, DG VII, DG XII, February 1993)

Space: Future Markets

C 2 (Report prepared for DG III, April 1993)

R&D, Technology, Management and Competitiveness

C 7 (Report prepared for IRDAC, June 1993)

Electrification of High-Speed Trains in Europe

(Final report and summary) *(also in French)*

C 8 (Report prepared for DG III, June 1993)

Emission Inventories and Atmospheric Transport Models for Inter-regional Environmental Impact Assessment

F 11 (Report prepared for the Environment Institute, August 1993)

New Concepts in Innovation Output Measurement

F 9 (published by Macmillan Press Ltd, September 1993)

Climate Change Research and Policy: Updates

A periodic survey: N. 5)

A CdP 13 (Report prepared for the Forward Studies Unit + DG XI and Env. Institute, October 1993)

Exploratory Study of the Technologies to Lessen Urban Transportation Drawbacks

F 12 (Post-Doctorate Report, December 1993)

Input-Output analysis as a forecasting tool for the study of Urban Transport and Environment

F 13 (EUR 15604 EN, January 1994)

Marchés de l'Espace et éléments d'une politique spatiale

G 3 (Report prepared in fulfilment of a contract with CNES, Paris, January 1994)

Fuel Cells - Part I and Part II

H 1 (Report prepared for DG XVII, March 1994)

Developing an Environmental Management Strategy:

1. The strategic context and implications for organisations

F 14 (To be published in Waste Management and Environment)

Developing an Environmental Strategy:

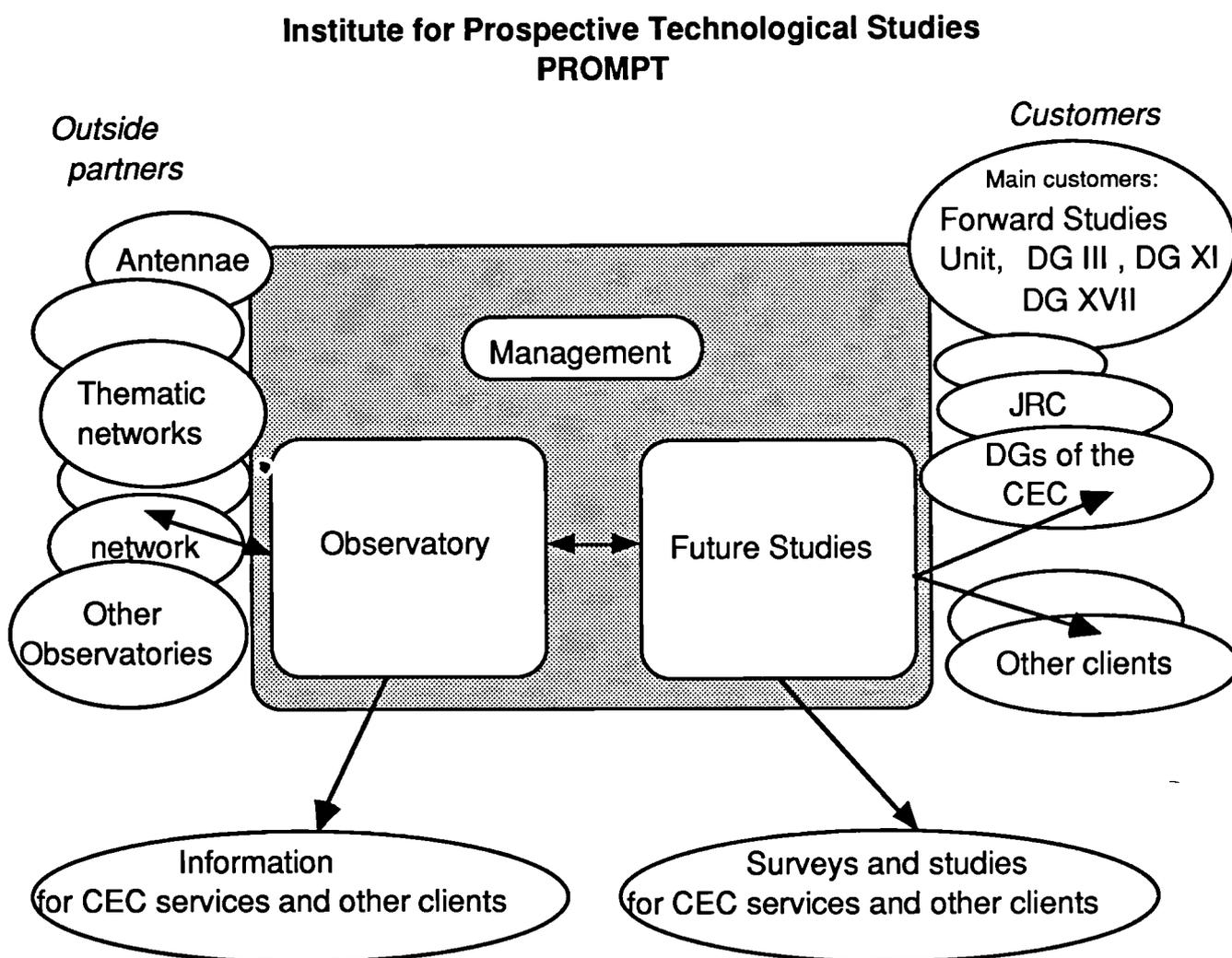
2. Management tools for planning and operation

F15 (To be published in Waste Management and Environment)

7. STRUCTURE AND STAFFING

As of 31st December 1993, the Institute's staff numbered 16, of whom 12 were scientific personnel. The Institute also hosted one visiting scientist, two national experts on secondment, 3 post-doctorate fellows and 6 post-graduate fellows.

Organization Chart:



European Commission

EUR 15704 – Institute for Prospective Technological Studies - Annual Report 1993

Editors: C. Rinaldini, D. Bain

1994 – 60 pp. – 21.0 x 29.7cm

CL-NA-15704-EN-C

In 1993 the activities concerning ESTO were still of a preparatory nature and they concentrated on the identification and analysis of structured information sources on R&D projects in the Member States and on a feasibility study for an intelligent interface for the QUI QUOD information system. In addition, two activities in the field of the Environment, originally initiated as studies, developed into longer term work of an observatory type. The subjects concerned are: "Global Research and Policy" and "Developments in Best Available Technologies".

Prospective studies were performed for the following services of the Commission: the Forward Studies Unit, the Directorates General for Industry (DG III), for the Environment (DG XI) and for Energy (DG XVII) and for the Statistical Office (EUROSTAT).

The themes covered are:

- Energy (systems and technologies for the long term future). In particular a study on fuel cells was completed while studies on the separation, storage and sequestration technologies for carbon dioxide from power generation systems, on nuclear energy and on photovoltaics all progressed.
- Environment (industrial opportunities and constraints). In particular, a large study on Business and the Environment was completed, a contribution was given to the study of the integration of environmental and economics indicators was given, information on opportunities in environmental technologies was updated and the analysis of environmental evaluation techniques was started.
- Transport. In particular the completion of the study on the European high speed train network.
- Industrial competitiveness, including a study on space markets.
- Science and society, covering a contribution to the preparation of the Oxford Carrefour on Science and Conscience.



