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How Do R&D Programs Funded by the DG XII (Science, Research and Development Directorate) of the European Commission Impact the Upstream Oil and Gas Industry in Europe?

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Résumé — Comment les programmes de R&D financés par la DG XII de la Commission européenne influencent-ils l'industrie pétrolière amont en Europe ? — L'article apporte une vue d'ensemble sur la manière dont les financements de la DG XII pour la recherche et le développement (R&D) ont une influence, directe ou indirecte, sur l'exploration et la production dans l'industrie du pétrole et du gaz en Europe. Le niveau de ces financements est présenté comme relativement faible de façon à mettre en évidence que, comparativement, leur répercution est très significative.

L'impact de ces financements est abordé en couvrant successivement les effets sur la société, l'industrie, la technologie et finalement la recherche elle-même. Nous décrivons ici les influences de la technologie sur l'industrie et sur la société, puis les influences de la recherche sur la technologie et enfin celles des financements de la DG XII sur la recherche et la technologie en exploration-production.

Différents aspects sont évoqués : les effets directs, les effets sur l'organisation et la gestion de la R&D, les effets à travers d'autres programmes de la Commission comme le programme de démonstration Thermie. Des exemples sont donnés à partir de résultats de projets en cours ou passés, d'autre part, les conséquences futures sur les statuts de l'industrie et la politique de la Commission concernant le pétrole et le gaz sont abordées.

Les effets les plus importants escomptés, dans un futur proche, concernent les technologies de production, la contribution à la R&D long terme des industries du pétrole et du gaz et le transfert des résultats vers des programmes de démonstration.

Mots-clés : Union européenne, programmes R&D, hydrocarbures.

Abstract — How Do R&D Programs Funded by the DG XII (Science, Research and Development Directorate) of the European Commission Impact the Upstream Oil and Gas Industry in Europe? — *This paper provides an overview of the direct and indirect impact which DG XII funding for research and development has on the oil and gas exploration and production industry in Europe. Despite the relatively low level of funding, the impact is quite significant.*

These impacts are presented using a bottom-up analysis, starting with the impact of technology on industry and society, the impact of research on technology, and the impact of DG XII funding on both research and technology for the exploration and production of oil and gas.

The different aspects that are discussed include the direct impact, the impact on R&D organization and management, and the impact due to the Commission demonstration program for oil and gas (Thermie). Examples are provided from current and past project results. The future impact on the industry, and Commission policy toward the oil and gas sector are suggested.

In the near future, it is expected that there will be greater impact on production technologies, on the contribution of oil and gas companies to long-term R&D, and on the transfer of results to the Commission demonstration program.

Keywords: European Union, R&D programs, hydrocarbons.

INTRODUCTION

It is now generally accepted that research and development, R&D, determines competitiveness and economic growth in the current global market. This is quite clear when comparing the technology-related exports and R&D efforts of European Community member states. The main conclusion to be drawn is that overall R&D funding can support European economic growth and development.

This was foreseen more than ten years ago by the European Community (EC now EU), which progressively increased funding levels, and thus expenditures, under the third and fourth Framework Programs for Research, Technological Development and Demonstration (RTD). However, that funding is still only about 4% of the total public RTD budgets of the European member States (EUR, 1996). Clearly, this means that the EU can not support European RTD on its own, and that the projects supported must respond to the demands of government policy and of public opinion.

This observation is even more true for RTD in the upstream oil and gas sector (exploration and production, E&P). Here, funding is much more limited, and must be justified in light of the relatively poor image held by the oil and sector by public opinion.

This paper describes the current level of RTD support provided by the EC for oil and gas E&P, and analyses its impact on that sector. It concentrates exclusively on the issues surrounding E&P.

1 THE PLACE OF OIL AND GAS PROJECTS IN THE COMMISSION'S RTD PROGRAMS

The European Community has funded R&D activities since the late 1950s. The legal basis for R&D and then RTD actions have been progressively set through the Single European Act, 1987. Since 1984, a wide range of activities has been coordinated within a series of Framework Programs. The first and second Framework Programs (1984-1987, 1987-1991) focused mainly on the science and technology sectors (information technologies, industrial technology, advanced materials, etc.). The third program 1990-1994) included, in addition, more strategic objectives, such as dissemination of RTD results and training and mobility activities. The latest Framework Program reflects a number of innovations in that both nuclear and non-nuclear energies and dissemination and demonstration have been formally integrated. Indeed, the Framework Programs now aim to provide integrated approaches, addressing the major social and economic challenges, which include enhancing the competitiveness of European industry, that is, linking research to commercial applications and products, improving the quality of life in Europe and promoting the use of new technologies. Two other dimensions are superimposed, geopolitical objectives, such as those of sub-programs related to cooperation with non-member States and international organizations, and industry cycles or chains, objectives which are actually important to define RTD priorities, and which can be relayed by industry.

Basically, these principles apply equally to the energy sector, for which different priorities have been defined within the green and white papers on energy policy (EC, 1995) or within the "European Energy to 2020" study (EC, 1996), for instance. The role of consumers and society as a whole is recognized in addition to that of enterprises and the market place. The former is even emphasized, since it is in the general interest that public and industrial requirements be compatible. Basically, Commission policy is implemented in three ways:

- research projects on a shared cost basis;
- concerted actions, for which the Commission only assumes the coordination costs and;
- internal RTD projects, carried out in the eight institutes of the *Joint Research Center* in Ispra, Geel, Karlsruhe, Seville and Petten.

The fourth Framework Program, 4FP, which ran from December, 1994 to the end of 1998, had a total budget of 13.1 GEcu (87 GF). It grouped RTD activities into 15 specific programs, horizontal activities and task forces. Oil and gas-related activities were mainly included in the Non-Nuclear Energy program, the so-called Joule-Thermie[1] program, with a budget of 1030 MEcu (6800 MF). Within this program, oil and gas E&P projects were allocated about 80 MEcu (530 MF) for demonstration (Thermie, run by DG XVII) and 17 MEcu (112 MF) for RTD (Joule, run by DG XII), i.e. 0.13% of the 4FP budget or 0.005% of the total EC budget (EUR, 1994). There were other contributions, but they were even more scarce, in Brite Euram (Industrial and Material Technologies), in Mast (Marine Science and Technology), in TMR (Training and Mobility of Researchers) and also outside DGs XII and XVII, in Esprit (Information Technologies, DG III), for instance.

This low emphasis on oil and gas E&P is actually the result of a steady change in Commission objectives, which focused on security of energy supply in the 1980s, on environment in the early 1990s and now on competitiveness. In spite of the overall increases in RTD funding, a massive reduction of the relative funding for energy (nuclear and non-nuclear) has occurred since 1984. It was 50% in 1FP (1984-1987), 22% in 2FP (1987-1991), 16% in 3FP (1990-1994) and 18% in 4FP (Fasella, 1995). In addition, within the Non-Nuclear Energy program, increasing emphasis has been given to renewable energies.

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(1) Joule: Joint Opportunities for Unconventional or Longer-Term Energies.
Thermie: Technologies européennes pour la maîtrise de l'énergie.

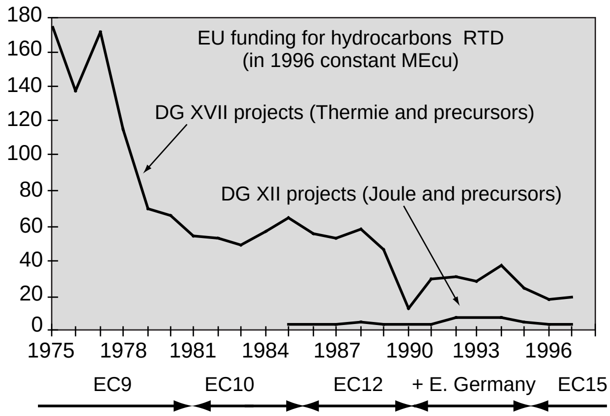

Figure 1

Variation of Thermie and Joule funding to the oil and gas sector. (Imarisio *et al.*, 1989, *Joule I*, 1993, *Joule II*, 1994, *Joule III*, 1997, *Thermie*, 1994). Funding from Joule has been averaged on an annual basis, as it occurred every two years in 4FP. Thermie funding also includes oil and gas transport and storage projects.

Since 1975, the upstream oil and gas sector has been faced with constant reduction in EU funding declining from 42 MEcus per year in 1975 to 19 MEcus in 1996, while inflation and the enlargement of the Community to include other countries has made the relative amount per potential contractor even less (Fig. 1). This represents basically three to four times less than the equivalent *DOE* support. In addition the *DOE* supports up to 100% of research costs (Phase 1 projects, IRW, 1997), while the EC only provides up to 50%. Despite the low level of support, the EC contribution to the E&P sector is heavily encouraged by lobbyists, such as the well-established *E&P Forum*, or more recently *Energ* and *Eurogif* [2]. On the one hand, this mobilization could be simply due to the fact that in the past decade up to 70% of the R&D budgets have dried up in the oil and gas industry (Pike, 1997). On the other hand, a more positive view is that past EC funding has had a significant impact. This, at least, is what has been quoted in a recent "Technology Vision" supported by a number of oil companies: "The oil and gas industry is unique in its use of joint ventures for developing resources under high risk and uncertainty. New forms of collaboration between competitors and suppliers are being implemented in a quest for increasing efficiency and profit. This trend is also prevalent in the RTD sphere. The EC Framework programs have had a positive impact on this process by encouraging alliances across borders..." (Martin, 1996).

This is also the point of view of this article. Processing bottom-up (Fig. 2, (1) to (4)), one presents the impact of technology on social and industry concerns, (Fig. 2, (2)), the impact of research on technology, (Fig. 2, (3)), and finally the impact of oil and gas E&P DG XII projects on technology and on research, (Fig. 2, (4)).

(2) *E&P Forum*: the *Oil Industry International Exploration and Production Forum*.
Energ: the *European Network for Research in Geo-Energy* is an association of about 30 European research groups in the oil and gas sector.
Eurogif: the *European Oil and Gas Innovation Forum* is an alliance of over 2650 companies in the engineering, supply and service sector of the oil and gas Industry.

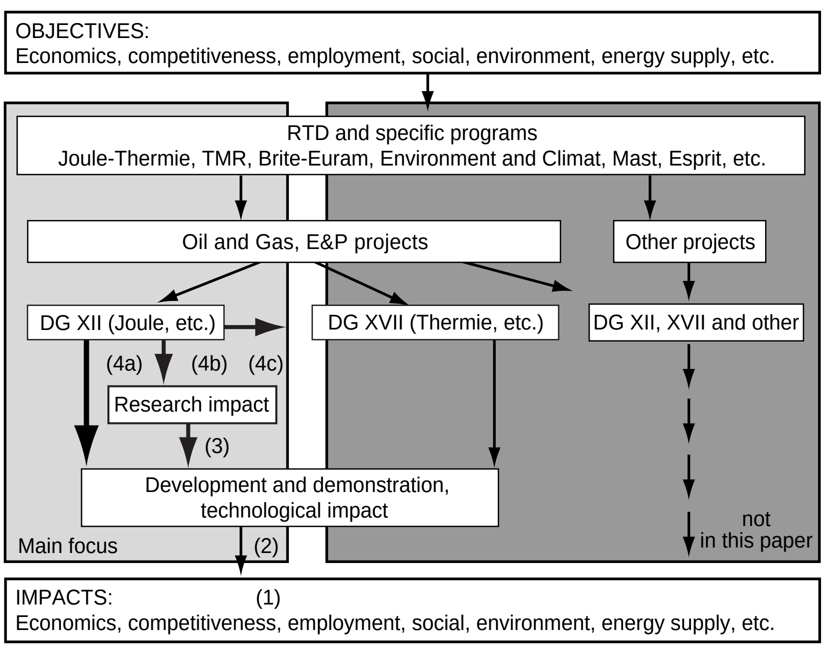

Figure 2

General scheme for objectives and impacts related to the hydrocarbon E&P projects).

2 IMPACT OF TECHNOLOGY DEVELOPMENT

There is no need to spend much time here in stressing the impact of technology on the security of supply of oil and gas for Europe. Qualitatively, the arguments are well-known. In quantitative terms, virtually all attempts to predict the future—or to develop scenarios based on a variety of assumptions about economic conditions, societal pressures or economic constraints—show that, while Europe (EU15) currently obtains more than half of its primary energy from oil and gas, under almost all assumptions this proportion will increase over the next 30 years. The scenarios analyzed in "European Energy to 2020" (EC, 1996) cover a range of possible futures but, as far as the use of oil and gas is concerned, the most significant feature is the insensitivity of rising demand to the different scenarios.

Data given in the *"2020" Report* show that in 1990 some 33% of demand for oil and gas within the EU15 was met by indigenous production. As Norway produces nearly as much oil and gas as the rest of Europe combined, the inclusion of Norwegian production raises current indigenous production to nearly 50% of demand. Europe will continue to be highly dependent on a supply of oil and gas and, although it can never hope to be self-sufficient in oil and gas production, its indigenous capacity is nonetheless significant. Any technology that optimizes oil and gas production in Europe will, therefore, have a direct impact on security of supply.

In the North Sea, the value of technology is also demonstrated by the way oil and gas production has evolved since 1975. In the 1980s, the peak of North Sea production was anticipated to be 3 Mbbl/d of oil; it now produces close to 7 Mbbl/d despite the price decrease of 1986. This situation results from the high level of technology development in the 1970s and 1980s leading to the implementation of deep water production, horizontal drilling, advanced seismic, enhanced production of mature fields, etc. The recent increase in North Sea production is due partly to the large new fields, such as Troll West and Heidrun, but also to the number of smaller fields which can now be developed economically thanks to technological progress. For instance, in 1994-95, 25 fields started production in the United Kingdom sector and ten in the Norwegian sector. Forward trends provide the same message. The *Energ* study on "North Sea Oil and Gas Production" [1], requested by DG XVII demonstrates that strong technology support could extend North Sea oil production to 15 Mboe/d (oil and gas) in 2010, extending the direct and indirect employment close to 500 000.

Such an impact on employment comes from the fact that the European oil and gas industry is a significant economic element. It comprises some 6000 companies within the EU, including Norway, most of which are SMEs. It now employs 250 000 people directly or indirectly in the North Sea area and more than 750 000 worldwide. The North Sea provides an ideal test bed for the development of technologies that will be in increasing demand in years to come. The European service and supply companies S&S have specific skills for offshore production, as 40% of the world's current offshore production is in the North Sea, and especially for production in deep water zones, of which 60% is in the North Sea. Given that 95% of the unexplored hydrocarbon basins of the world lie in deep-water areas, the European S&S companies have a strong opportunity for growth. Sustaining that growth in a competitive framework is the challenge. By enhancing the skills of the European service and supply industry, technological progress assists the industry to compete in the rest of the world and even to enhance its current 25% share of the world market.

Another major impact of technology is environmental protection. There is no doubt that Europe's continued dependence on oil and gas carries environmental penalties arising from their use, principally the generation of greenhouse gases and other emissions during combustion, but also oil spills and leakage of methane, a major greenhouse gas, during transport. The perception is of oil fields dominated by fixed lattice drilling towers and black oil gushers or "blow-outs" as they are now called. These images date from the early years of the century; fixed towers have long since been superseded by mobile rigs, except in offshore fields, and the industry goes to great lengths to avoid blow-outs, which are a major safety hazard as well as an extremely expensive source of damage to equipment and installations. Conveying this modern image is something that technological development can do. The environmental impact of exploration and production arises from several causes, including land use and access roads (onshore), fixed platforms and sea bed disturbance (offshore), noise and other disturbance during drilling, emissions and effluent during drilling and testing. Even the oil and gas companies recognize that they will have to conform to increasingly strict environmental regulations, if they are to continue to operate. Accordingly, there is an interest in developing "greener" technologies, such as, for example, eliminating oil-based drilling muds and replacing them with biodegradable alternatives, reinjecting effluent streams, suppressing unwanted production phases, oily water, for example, etc. All of these are amenable to technology, and success will provide a competitive edge to "greener" companies in bidding for new development areas. Technical knowledge, capabilities and reputation may also play a significant role in the attribution of claims to oil companies. Of course, political and financial considerations are much more critical, but technical outlook is an additional advantage when companies are competing (SPE, 1995a).

Economically, a high value is placed on technology development by some companies, with some spending more than 100 M$/y for RTD (about 600 MF/y). Large groups such as Schlumberger (SPE, 1995b) believe strongly in the economic benefits of technological progress. Shell has estimated that the added value of its technology development was about eight times its cost (de Groot, 1995). Numerous examples can be found in recent years, such as horizontal drilling, extended-reach drilling and NMR logging. These applications provide large payoffs, and competitive strategies take technology into account. Smith Rea (1996) recently published a report on “the economic impact of new drilling technologies”. They stated that these technologies cut costs on the continental shelf by 1 G£ (about 10 GF), increase commercial reserves by 2.2 Gbbl of oil and allow development of new fields.

At a minimum, technology development improves knowledge dissemination. Companies produce fields in partnership, with a common objective, the best economical development scheme. They negotiate the share of costs and returns, but they have every interest in using the best available techniques. Techniques will, therefore, inevitably be shared. They are implemented through service companies and spread immediately to the whole industry. The driving forces in the oil industry are now partnerships, integration, methodology and organization rather than keeping innovative techniques secret.

To sum up, it is quite clear that technology development impacts societal, policy, economic and industrial concerns.

3 THE IMPACT OF RESEARCH ON TECHNOLOGY DEVELOPMENT

The way in which research impacts technology is discussed here, in order to show later how DG XII can have a beneficial impact on research.

The question of whether there is an impact of research on technology development is best addressed by first considering the history of the last 25 years. In the 1970s, oil and gas production was dominated by *Opec*. At that time, political instability in many of the resource regions forced leading western countries to focus on their energy resource policy. This was a period of increasing research. As examples, R&D expenditures at *Shell*, *Exxon*, *BP* and *Schlumberger* increased by a factor of 1.5 to 4, with the main increase in the E&P sector. Consequently, in the 1980s non-*Opec* oil production exceeded that of *Opec*, and prices collapsed in 1986. From that one should keep in mind that long-term research had a large impact on technological development with a lag time of about ten years.

By contrast, the early 1990s were a period of optimization of existing technologies, i.e. reducing costs for increasing economically recoverable oil and gas reserves. The main incentive for contractors was to offer “appropriate” technologies to the market. To a great extent, one could deduce that cost reduction was more efficient than long-term research for technological development.

This might argue for a lower impact of long-term research on technology. In addition, large increases in reserves and production occurred. For instance, ten giant fields were discovered (three oil, one condensate, five gas, one gas-condensate). Deep water developed rapidly with, for European offshore, the West Shetland fields (Foinaven, Schiehallion, Suliven, etc.). In 1996 North Sea production surpassed 6 Mbbl/d. In 1997 worldwide investments in E&P reached about 90 G$ (about 540 GF). The early 1997 Gulf of Mexico lease sale was the biggest ever, earning the United States Government more than 800 M$ (about 5 GF), and the largest number of bids was for blocks in over 800 meters of waters. The utilization rate for offshore drilling units was close to 95% and more than 99% in the North Sea.

Nevertheless, it is now accepted that this level of effectiveness was possible only by using past innovation and will only be sustained by continuing innovation. Optimization of technologies developed during the R&D boom of the early 1980s is a finite process. In a sense, the industry has been ”living off its fat”, capitalizing on investments made ten or more years ago. It is now necessary to start the process of developing new technologies to provide the basis for exploitation over the coming decades. The additional reserves necessary to prolong production from the North Sea, and other provinces, for example, will only become available when cheaper methods are developed for accessing those deposits currently considered too difficult or diffuse to be cost-effective with current methods.

In conclusion, the trends of the 1970s, 1980s, and 1990s can be seen to be consistent once one recognizes that research had a technological impact within a ten year frame and that continuing innovation is necessary to technological development.

Because most of the E&P Joule projects were completed less than ten years ago, and because most of them are not followed more than two years after completion (Kinsella *et al.*, 1997), it is quite unusual for project results to have been tracked to the stage of routine application. Significant impacts can, however, be found all along that ten year process. In the case of DG XII’s Joule program as a whole, impacts have been assessed recently by Kinsella *et al.* (1997), despite the difficulty in doing so. Results from a standard questionnaire sent to a sample of 120 Joule II project coordinators (Kinsella *et al.*, 1997) show that the main outputs were new methods (one for every two projects), new products and processes (one for every two projects), patents (one for about three projects), technical papers (an average of 13 per Joule project), and training of PhDs (for most of the projects). It was shown that only 19% of Joule contractors think that the scientific community is the end user of their results, while 54% see it as just an intermediate user before long-term applications.

That fixes, more or less, the types of potential impact for any part of the Joule program and especially for the E&P related projects. That is, Fig. 2, (4a, 4b, 4c):

– direct impacts on technology, processes, patents and subsequently on employment, the economy or society;

– Impacts on research (scientific results, methodologies, training, education in general);
– Impacts on long-term application through future demonstration activities (Thermie).

These routes are investigated below.

4 DIRECT IMPACT OF DG XII E&P PROJECTS

Numerous success stories can be found in recent years when assessing the Thermie or Brite Euram programs related, for instance, to horizontal, extended-reach and slim-hole drilling and NMR logging, Smart Leg, etc. For Joule projects, as noted above, it may be ten years before they achieve concrete results. However, success stories also exist. For some of the older projects, an impact on E&P can be found, even though the projects were not designed initially for the E&P sector.

This is the case, for instance, for the geothermal energy projects of the Non-Nuclear Energy program of the 1980s. During that period, the EU and the United Kingdom *Department of Energy* (now *DTI*) supported the *Camborne School of Mines* Hot Dry Rock project (CSM HDR project). Throughout the phase 2B (1983-86, partially supported by DG XII), a microseismic detection and processing system was developed [2]. It was successfully used to locate fractures and fault-planes and to monitor fluid injection in the *CSM* geothermal reservoir (Baria *et al.*, 1989). It continues to be used at the Soultz HDR site, which is still within the Joule program. The sensors have been continually improved for pressure and temperature resistance.

Recently *CSM Associated Ltd.* collaborated with the University of Keele and the *Compagnie générale de géophysique (CGG)* to carry out an 18 day microseismic survey for *Phillips* in the Ekofisk field using a modified *CGG* tool. The success of the survey has attracted great interest from other operators in the region. Another recent application of microseismic technology was carried out in the Miskar field off Tunisia for *British Gas*. It involved monitoring a hydraulic fracturing operation to determine the extent and direction of the fracture. In addition to these short term surveys, the main application of microseismics technology will be in long-term reservoir monitoring. The technologies used in the permanent, high reliability, high temperature resistant (200°C) 4-axis sensors developed by *CSMA* will find application in the next generation of smart well completions. Permanent microseismic monitoring will help to provide information on pressure changes, faults and bypassed zones a kilometer or more out from the producing well. Basically, DG XII contributed to launching the technique, which companies like *CSMA* have successfully taken to market. In addition, it has been applied by other companies in the Netherlands (*SW* of Groningen) where monitoring surface seismic activity is a crucial public concern.

For the early 1990s, one example from the E&P program is the project "Structural Transects of the Rim of Europe to Africa by Marine Exploration Reflection Seismics"—Streamers (Joule I, Nov. 1990-Nov. 1993). DEP-EKY, the Greek state-owned company, and the project partners conducted geophysical data acquisition which allowed them to identify the Mediterranean ridge as a potential new frontier deep water area for exploration. This, in turn, enabled DEP-EKY to justify additional exploration work. Images of the crust of the Ionian and Aegean basins were obtained, revealing a number of structural and stratigraphic traps with source rocks, reservoirs and seals. Recently, exploration and production licenses in western Greece were awarded to *Enterprise Oil*, *Union Texas* and *Triton Resources*. The Joule contribution was a small part of the whole process, but again, it certainly assisted the development. The Streamers line was, for instance, included in the documentation of the permit bidding round, a significant oil industry concern.

In another project, "Topic 6 of Stratigraphic Modeling and Inversion" (Joule II, Jan. 1993-Jan. 1996), the group developed a new 3D seismic inversion routine. The method allows a more accurate characterization of reservoir geometry and, therefore, more productive drilling. The Danish company *Odegaard* and *Danneskrold-Samsoe (ODS)* patented and developed the method. *ODS* and *CGG* are now selling the corresponding services and software packages (*Isis* for *ODS*, *TDROV* for *CGG*). *ODS* is currently the North Sea leader in 3D global seismic inversion services. The 3D inversion group at *ODS* is growing rapidly (about 15 staff), after having employed only four persons at the beginning of the project. As such, this project has had both an employment and a technology impact.

For most of the other projects the impact can only be estimated, as they are still in progress. The Commission, however, clearly encourages shortening the time from research to commercialization. Partnerships are now encouraged to include an end user from the oil industry or, even more efficiently, a manufacturer from the S&S industry. This is likely to become mandatory for new projects. Those projects that include S&S companies are potentially driven to market R&D results within the oil industry. For instance, *Robertson Ltd*. is coordinating a project "*In Situ* Saturation Monitoring in Core Analysis by Electrical Impedance Tomography" devoted to the development of a fast, low cost 3D fluid imaging tool [3].

Other methods also exist. In the project "Development of Low Cost Dynamically Stable Slim Hole Drill and Core Bits [4], a bit manufacturer and a drilling company are participating as subcontractors. The manufacturer is able to advise on the development of commercially acceptable new bits and will be able to bring them onto the market, since the drilling company will already have field-tested them. The project QC-Scale, "Quantitative Risk Prediction of Carbonate

Scale..." [5] included an SME end-user, *Altra Consultants Limited*, a company with a staff of 70 and with its main office in Aberdeen, at its own cost. The goal of the project is to develop quantitative software for forecasting changes in water chemistry within an oil reservoir and for assessing the risk of precipitation of carbonate scale and its influence on well productivity. *Altra* is providing market studies including industrial clients' requirements. In return, it will be receive a share of the commercialization of the software. This ensures that the software will ultimately have an impact in the industry. In the process, an additional impact will to be foster a more market-driven relationship between the partners. *Altra* intends to commercialize executable versions of the software, while some partners were planning, instead, to sell services using the software.

In another case, "Well Treatment and Water Shutoff by Polymer Gels", partners are setting up an industrial consortium, in parallel with the core of the Joule project. From this consortium, which includes major oil companies, they receive the proper information to conduct the project and they have access to a polymer manufacturer. Because the goal of the project is to develop efficient and environmentally acceptable polymer gels, one can be confident that it will have an impact on both technology and the environment.

5 IMPACT OF E&P DG XII PROJECTS ON RESEARCH

For public opinion, the more obvious impact of EU programs on research is the in-flow of additional R&D funding. Basically, most of the E&P projects are funded on a cost-sharing scheme, up to 50% for companies or institutes that operate a project costing system and up to 100% of additional costs for others. For Joule, however, this impact is probably the least important, once the duration of the preparation and the call-selection-negotiation process, the acceptance rate of project proposals and the extra costs incurred are taken into account.

In practice, it is observed that the preparation of a suitable proposal can take as much as one year and that proposals prepared within the last three months before the call are usually poor, from both a technical and partnership point of view. After submission, the selection-evaluation-negotiation process up to the point of contract signature can take as much as another year, although steps are being taken to shorten this process. The acceptance rate has typically been 20% or less, and, therefore, may be a cause for concern because of the financial effort involved in proposal preparation. It is generally claimed that a good proposal can cost 20 to 50 kEcu to prepare (130 to 330 kF). The trend toward increasing cooperation, which is highly beneficial from other points of view, has decreased the average funding for each partner by a factor of three in constant prices during the last ten years (Table 1). The task of administrative project coordination has been transferred to the project coordinator while, at the same time, his support has decreased. In the 1980s, single partner E&P projects received on average 326 kEcu (close to 500 kEcu in 1997 currency) while the coordinators in the last Joule III round received on average 250 kEcu. In other words, the financial impact on R&D budgets is certainly decreasing, more difficult to obtain, and certainly not the main expected benefit when applying for Joule support.

TABLE 1

Evolution of size, funding and number of partners for the E&P related projects within the Joule program

Programme	No. of E&P projects	Total MEcu**	Funding (%)	Average no. of partners by project	Average contribution by partner (kEcu)**
NNE	25	19.9	41	1	326
Joule I	19*	19.9	68	3.2	223
Joule II	21*	39.4	50	5.9	159
Joule III	18	27.6	60	5.6	167

* Including "Deep Reservoir Geology" projects.
** In current prices.1 Ecu = 6.61 F.

More important is the impact of efforts to prevent duplication. The oil and gas industry as a whole is now driven by cost reduction. Clearly, developing in-house technologies is no longer strategic. Getting the best available technology on the market, at the best price, is the current outsourcing behavior.

In the recent past the oil companies have been down-sizing their R&D activities, the most common thinking being that the service and supply companies should fill the gap (*Oil Field Review*, 1995). This could be a quite logical position because, in the past, many technologies, such as bits, oil treatments, cementing and completion methods, geophysics and well logging, were improved or developed by service companies (Blair, 1995). The S&S companies also take advantage of the situation to become part of oil company networks, attending internal meetings, gaining access to fields and, therefore, being well placed to initiate effective R&D. In 1990, 80% of industrial R&D expenditure was supported by oil companies and 20% by service and supply companies. In 1994 these contributions moved respectively to 67% and 33% (Grijalva, 1995). However, most S&S companies are SMEs that are not used to making, nor have the capabilities for, significant expenditure on R&D. If they do have these capabilities, most of them are not going to share R&D, in order to ensure their profit and survival. This factor increases the risk of fragmented and confidential R&D and, therefore, of duplication.

On the other hand, it might be thought that research institutes and universities can compensate by providing more R&D. The volume of R&D in research institutes and universities is still large. Some institutions, such as Heriot-Watt University, Trondheim University and the *Institut* *français du pétrole (IFP),* for example, have R&D budgets for oil and gas E&P that is larger than those of the oil and gas companies. There is considerable technical capability within these institutions and they certainly carry out some longer term R&D. However, the key is to ensure adequate communication and focus, otherwise duplication will arise automatically from the large volume of R&D involved. One can recall, for instance, that in the 1980s it was recognized that most valuable R&D activities were duplicated seven to eight times around the world. Preventing duplication is certainly a major issue for R&D institutes as well. It is actually affected by Joule projects.

A significant example is the production forecasting R&D supported by Joule (van Kruijsdijk, 1996). This activity started within topic 5 of the Reservoir Engineering Project (1993-96) focusing on reservoir characterization, especially when constrained by production data. The first step was for partners to work basically following their own habits and topics, but sharing their results regularly. The second step was to begin to coordinate and share their R&D planning. In practice, they achieved a 3D forward modeling tool coupled to geostatistical modeling. They assessed the limitations of different modeling techniques and provided a way to combine a number of modeling approaches, including deterministic, stochastic and random field methods. The effectiveness of each methodology was known and the efficiency of each partner as well. In this way, the best partnership and about ten of the most appropriate approaches and partnerships were selected for the Joule III projects "Production Forecasting with Uncertainty Quantification", Punq, parts 1 and 2 [6, 7]. Basically, Punq 1 allowed the partnership to focus again on the best approaches. For the optimization methods, the group started with eight to ten potential methods, and is now working on only two. For the choice of the software to implement the method, the group moved from three or four possibilities to one or two. The current Punq 2 project is now designed to concentrate all the efforts on developing and testing the main approach based on the "Pilot Points Method". It is very clear that cooperation within these projects made it possible to prevent a lot of duplication and kept a lot of effort from being wasted on dead-end approaches. The results are quite comparable to those obtained by other large teams elsewhere, such as at Stanford and Texas A&M University.

To be honest, this kind of R&D focusing also has a drawback. It is basically that narrowing the research path reduces cost and waste, but it also reduces the chance of seeing unexpected and valuable applications emerge. This is actually quite frequent in R&D, the most successful case in E&P perhaps being the origin of Coflexip[3]. The case was illustrated during the last SPE Fall meeting (San Antonio, 5-8 October, 1997), where four of the six presentations during the session "Conditioning Reservoir Models with Dynamic Data" dealt with the same Pilot Points method.

(3) Coflexip developed flexible steel pipes from the results of an R&D programme devoted to flexible drilling in the 1970s. It is now the world leader for providing and installing offshore pipes, risers for both conventional, deepwater and floating production systems. It received a Distinguished Achievement Award at the *1995 Offshore Technology Conference* (JPT, 1995).

To sum up, Joule certainly has a significant impact in preventing duplication. However, one must be careful not to go too far and to avoid mimicking market-driven initiatives such as Crine (Cost Reduction Initiative for the New Era, United Kingdom) or Norsok (Norway), where efficiency is addressed by standardization and capitalization on existing assets, which could penalize innovation in R&D.

DG XII funding for E&P also has the effect of attracting companies to sustain long-term R&D on the production side. As stated above, blue sky research is less attractive for most of the industry, the main exception being R&D for exploration, and especially for seismic imaging. This is because developing R&D is strategic for the company that can implement its own in-house techniques. In practice, the only upstream area in which companies can still operate on their own is exploration. Their R&D, therefore, focuses on that sector while long-term R&D for production is supposed to be carried out in R&D institutes and by S&S industry contractors. Unfortunately, R&D centers may not have sufficient access to production sites, while contractors do not seem to apply emerging, and sometimes very effective, technologies, which may only be cost-effective in the long term or when they are developed for several exploitation sites. One main challenge is, therefore, to improve the communication between R&D centers and companies, and to attract companies to long-term R&D, especially for production.

To encourage this, the priority topics for Joule III were displaced from exploration to production (see Table 2). In Joule I and II, 67% of projects addressed exploration topics while in Joule III, 68% of the topics concerned production.

TABLE 2

Distribution of Joule E&P projects by domain
(*Joule I*, 1993, *Joule II*, 1994, *Joule III*, 1997, Imarisio *et al.*, 1989)

E&P-R&D project topic	Joule I – Joule II (%)	Joule III (%)
Exploration	67	10
Drilling-logging	5	22
Production	23	68
Enhanced oil recovery	5	–

In addition, the involvement of oil and gas companies in the Joule projects has been a formal requirement, as they are potential end users. In Geoscience I projects (Joule I), the partnerships involved 14 different universities, four R&D institutes and three oil companies (Bemtgen and Rocca, 1993). In Joule III projects there are about 15-17 of each. It is not unusual to learn from some oil companies that, even if public funding is only a small part of their total R&D budget, it actually makes the difference when selecting the projects to be developed. Within Joule III, therefore, the number of companies participating in long-term R&D for production has been significantly affected.

More generally, DG XII affected R&D partnerships and collaboration. From the beginning of the Framework Programs, the Commission staff contacted several tens of R&D providers in Europe. Being familiar with these R&D skills allows efficient links to be established, when needed, between future partners. This was a minor role which increased significantly due to the objective of including more and more SMEs in the R&D programs. For example, an SME has recently been provided with contacts in R&D centers. These have been useful for providing technical skills required for the technology project of that SME. It allowed the preparation of a European project proposal that was submitted on time and in good shape for funding. The corresponding R&D is now in progress, which would not have otherwise been the case.

Under the recently introduced, voluntary, pre-proposal check procedure, DG XII also has the opportunity to comment on the partnership and technical content with the aim of improving or discouraging the formal submission. The impact was quite significant for E&P proposals under the last Joule III call (January, 1997) as the acceptance rate increased to 50%, from 20% at the previous call.

R&D brokerage is also supported by the Commission Cordis data bases, available on the Internet. Cordis allows anyone to find existing projects, partners and publications, and results on selected R&D topics. It also allows readers to enter partner requests, R&D skills or technology offers.

In addition, DG XII has also led to the creation of R&D brokers in the European oil and gas sector. The rule requiring projects to be multinational has led national organizations to deal with many more companies and institutes. In France, *Gerth*[4] was created in 1975 to organize R&D cooperative projects for French partners. Now, it manages projects which include institutes, universities, S&S and oil companies from most of the EU member States. It is able to advise on an appropriate membership much more efficiently than when restricted to France. In the United Kingdom, *CMPT*[5] recently established itself as a world-wide R&D and technology broker. It coordinates different networks, such as the facilities and infrastructure part of *AMJIG (Atlantic Margin Joint Industry Group*) and *Deepnet* (for deep water and hostile environment knowledge), that are also supported by a number of oil companies. European level organizations, such as *Eurogif* and *Energ* have also developed brokerage capabilities centered on the S&S industry and R&D centers, respectively.

The role of R&D brokerage emerged within the last FPs, and the development of new brokers outside the Commission demonstrated that the demand exists. It actually opened a new way for DG XII to have a positive impact on R&D organization.

As noted above, Kinsella et al. (1997) reported that most of the Joule project coordinators consider that training of PhDs is one of the main project results. This is obviously another major impact of any support to R&D. Training within an R&D environment is necessary for high quality employment purposes and for high level communication between R&D and industry. It has significant economic value because, in the mature oil and gas sector, the application of the appropriate technology by competent staff is the main advantage, not the technology itself. For instance, well logging performance is now much higher than ten years ago. Very large amounts of data are recorded, but the cost has increased by a factor of two. A very cost effective behavior for a company is to have staff able to recognize the specific needs of each well and to apply the corresponding logging technology. Several messages can be found in the current literature concerning “the value of fit-for-purpose technology”. Desmarest (1995) focused also on the capability “...to recognize the different needs, keeping exotic tools for exotic problems, simple and low spec tools for routine developments”. A *PSTI* report (1995) recommended not to use “...high tech for its own sake”. Owens (1994) argued the value of “...fit-for-purpose data during field life”. Then, assuming that the industry needs such a well educated and efficient staff, teachers must be fully aware of the state of technological development (Economides, 1995). They need to be involved in current developments and to have students to train. This can be accomplished within the Joule projects. In addition, the Joule multi-partner projects offer a very good place to learn about different disciplines. They contribute to training geo-engineers, that is, generalists able to bridge several disciplines. As recognized by Corbett (1997), this is currently important, both because the petroleum industry is still thinking in terms of “integration”, that is, of forming teams of specialists, usually within oil companies, and because the educational system doesn’t take into account geo-engineering and generalist courses. Within the E&P projects of the first Joule III call, including related TMR grants, 33% of the labor cost, about 600 man-months, is for PhD students and post-docs, who are quite often hired by the industry, sometimes even before the end of the Joule projects. This indicates that a very significant part of the Joule E&P funding supports training in R&D that benefits future industry employment.

Another impact, related to collaboration and partnership, is that on the dissemination of R&D results. A survey completed by *Arco* demonstrated that collaboration is the most efficient way to have an impact on technology transfer, being more important than seminars, conferences and print or

(4) *Gerth*: *Groupement européen de recherches technologiques sur les hydrocarbures.*

(5) *CMPT*: The *Centre for Marine Petroleum Technology.*

electronic media. Collaboration was also recognized as the most cost effective way (Reinart, 1997). The same message came from the Technology Vision reported above (Martin, 1996). Most of the member states with interests in the oil and gas industry recognize this and operate national support schemes for R&D, with the aim of ensuring a more collaborative effort among their own companies and institutes. National funding schemes, however, are designed to benefit only the nationals of that country. From the European perspective, there is a similar objective to ensure dissemination across national boundaries. This has been formalized through the multi-nationality rule for the Joule projects. This rule has also led, outside the Commission, to the creation of new organizations, such as *Energ*, which aims to recognize common European R&D needs and to enhance dissemination and technology transfer.

Within Joule, project dissemination is impacted by:

– The simplified access and transfer of partners' data, basically of field data from companies to R&D centers;
– The transfer of R&D results, basically from R&D centers to companies.

A number of projects now use new information technologies to do so, that is regular reporting and exchanges by e-mail and common data storage sites. The project Smaccers (8) created a large ftp site (file transmission and storage system) located at Heriot-Watt University to support field data and information shared in the project. Partners have a direct connection to the site from their own offices. For external dissemination, the project has also created a home page on the Web. Dissemination was also supported by the organization of oil and gas-related conferences (Imarisio *et al.*, 1989) and by funding for conference organizing (on NMR, Louvain, 1995, or on modeling of reservoir geological structures, Scarborough, 1995) and by supporting publication (see, for instance, Helbig, 1994).

Finally, one can also recognize had Joule also has a slight impact on the labour volume for R&D in the E&P sector. Within the E&P projects approved from the first Joule III call, including related TMR grants, additional staff represented 44% of the labor cost. By definition, those staff, about 800 man-months, would not have been employed without the Joule funding.

6 IMPACTS THROUGH "THERMIE"

Because of its demonstration projects, Thermie had more direct relationships and impacts within the industry than Joule (see, for instance, EC, 1997). The Thermie program and its predecessors financed more than 800 projects from 1975 to the present, providing more than 700 MEcu of support. Several projects provided innovative technologies which have been subsidized and are now widely used, the most famous being the "horizontal drilling", or the slim-hole technology (see, for instance, *Eurogif*, 1997 for a review of Thermie benefits). Thermie seems, therefore, to be a logical extension for Joule results, providing an additional toward the market. That is actually why the two elements were amalgamated to form the Joule-Thermie program in 1994 under the fourth Framework Program.

However, very few Joule projects have been tracked from Joule to Thermie in the past. The reason is that there was a gap between Joule, which required pre-competitive projects, and, hence, no prototype at the end, and Thermie, which required demonstration, with some kind of prototype. When comparing the subjects of projects supported within Joule in the past, one may note that the share of topics was significantly different than in Thermie (Fig. 3), emphasizing the misfit for project transfer. In addition Joule and Thermie continued to be formally administered and managed by DG XII and DG XVII respectively and to have separate management committees in 4FP. De facto, they operate largely as two separate programs, and it was difficult to fund projects containing both research and demonstration (Kinsella *et al.,* 1997). Results from Joule could, however, be passed to Thermie especially if the gap between the pre-competitive stage and the demonstration stage is filled by bringing in results developed outside Joule.

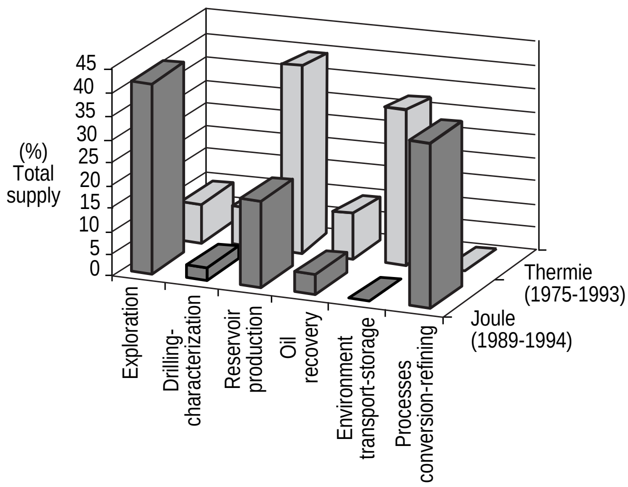

Figure 3

Distribution of Joule and Thermie support over the whole oil and gas sector (*Joule I*, 1993, *Joule II*, 1994, *Thermie*, 1994).

Sometimes Joule results were only integrated to complement a major Thermie development. This was the case for projects related to the Heresim software for geostatistical reservoir description (Ravenne *et al.,* 1997). Basically, the development started in 1986 at *IFP* and the École des mines de Paris. Thermie project [9], 1986-89, was devoted to the elaboration of a software prototype and a second Thermie project [10], 1990-1994 enabled the demonstration of the validity of the software on an actual field case and started the industrialization of the software. Within a part of the Joule project [11], 1990-93 and within the Topic 2 of the Reservoir Engineering project [12], 1993-1996, some attempts were made to identify the ways to enable Heresim to cope with non-stationary fields and fault architectures. At this time, a third Thermie project, "Quantitative Reservoir Modelling Constrained by Wells and Seismic Data" (1996-1998), demonstrates a Heresim version that accounts for non-stationary fields and for constraints from seismic data. The Heresim package is one of the few geostatistical software packages for reservoir characterization to have reached a complete commercial and industrial status. It has been licensed to about 30 oil companies, including *Agip, PetroCanada*, *JNOC, PDVSA, Intevep* and *Pemex.*

Joule has provided a greater contribution to the development of deterministic stratigraphic forward modeling of fluviodeltaic environments for reservoir characterization. This kind of modeling was initiated in the Geoscience I project [13], Joule I-1990, by modeling Roda sand bodies (Spain). This approach has proved to be more relevant than geostatistical approaches, for instance. It was then developed as a software, Dionisos, within the reservoir engineering project [12], Geoscience II, Joule II. The validation stage is now in progress with:

– different 2D and 3D case studies that have been carried out in agreement with industrial partners;
– a patent has been taken in the EU and will be extended abroad;
– a consortium of oil companies is going to be formed for the industrialization;
– one 3D full case study (Brent) is included in a Thermie project [14].

The process should end in 2000, showing again that ten years is needed to go from the first development to the industrial tool.

Joule has also provided a significant contribution within the project "3D Asymptotic Seismic Modelling" [15], 1994-1996. Efficient procedures for quantitative prestack reconstruction of 3D "preserved amplitude" seismic images and for seismic velocity estimation were developed and tested on actual data. These are now extensively used within *NorskHydro* and *Elf*, for instance. Various asymptotic modeling software and models were also implemented. This project was extended with another Joule project [16], 1996-1997, for adapting inversion procedures at the reservoir-well scale and for completing the forward modeling and by the Thermie project [17], 1996-1997. It aims to demonstrate the efficiency of the prestack processing by applying it to the 3D Marmousi[6] synthetic overthrust seismic data. It is a major step forward for a large industrial use of these procedures.

Other Joule contributions to Thermie can be identified through the Framework Programs. They were more numerous in the recent past. Proposals were more and more often submitted for Thermie support as an extension of existing Joule projects. The proposal on "Modelling Two-Phase Flow in Fractured Carbonate Reservoirs" [18] is a demonstration of innovations from the Joule II and III projects [19, 20] on the modeling of dual porosity and dual permeability fractured reservoirs, complemented by the use of a new downhole tool of the S&S industry. Another project on "Advanced Tracer Stimulation" [21] will also use results from the Joule III project [22] on enhanced oil recovery by diffusion in fractured reservoirs. Basically by the end of 4FP, Thermie was becoming a more and more natural continuation for Joule projects.

7 THE FUTURE

The future impact of DG XII funding will depend on its level within the next Framework Program, 5FP, which itself depends on the interplay between society, market, industry and R&D policies.

From the European industry point of view, one can recall that North Sea is today only one third of the way through its production life. As stated above, it provides a large opportunity for the EU industry to optimize and market new European oil and gas-related technologies, that can be exported world-wide. Beside the security of supply issue, there is, therefore, a major economic and employment challenge to maintain activities in this area. On the society side, the most noticeable tendency is a willingness to accept people-friendly and environment-friendly development, for clean technology, in general. To assist in this, gas production and development of the remaining resources, such as marginal fields or hydrocarbons still in place in existing production areas, will continue to be targeted. Looking to the past, one can see that new production targets defined new well technology developments. In the 1950s, a production of 10 000 bbl/d required 100 production wells to be produced (onshore Oklahoma), in the 1970s it could be done with ten wells (offshore), in the late1990s one to two multibranch wells are used for marginal fields or in deeper off-shore. It is, therefore, quite obvious that there are production R&D needs and that they will concentrate first on well technology, such as placement, monitoring, equipment, multi-branch well completion, smart well, smart drilling and smart rig concepts

(6) Marmousi is made of complex sets of synthetic seismics data computed on an Overthrust model by the *DOE* and *IFP* for the *SEG* and *EAGE*. It is, with another "Salt-dome" set, the main reference data set.

On the other hand, the opening of new E&P areas will also remain a main concern, because oil and gas consumption is large and global, and will continue to grow in the future. As reported by Michaux (1994) “...the best substitute for oil (and gas) is simply more oil (and gas)”. It is, therefore, useful to recall that the share of hydrocarbons in European non-nuclear primary energy consumption is 72%, or 60% of total nuclear and non-nuclear energy consumption, and that oil consumption for transport (50%) is relatively unresponsive to changes in the market and prices. The deep sea will have the main share in these new areas. At least 200 basins in the world are partially explored, and the deep sea represents about 50 Mkm^2, while only 2 Mkm^2 have been explored for the moment in the Gulf of Mexico, West Shetlands, Norway offshore, Barents Sea, West Africa and Asia. Developing deep water production may also have a positive impact on public opinion, as most of the production facilities are floating or under-water systems, which create few decommissioning problems. Therefore, exploration R&D needs certainly exist too, at a level comparable to production R&D needs.

In addition, the sector also needs to pursue changes in its organization and work methodology. The E&P concept is evolving. The most common visions for the future of field development are related to the reduction of the time to first oil. Appraisal and development of a field will be shortened to less than two years, while the production plateau will be extended as far as possible. The ultimate objective will be the ability to convert any exploration well into a production well. The need for integration and cooperation will still be there.

How this situation will be taken into account within the DG XII R&D program is still a matter of speculation. The objectives for 5FP have yet to be finalized, but it must be assumed that they will be broadly consistent with those of 4FP, basically related to employment and competitiveness of European industry, environmental protection and security of supply. An oil and gas program could be supported because it supports all these objectives by developing efficient, safe and clean exploitation as well as competitive and sustainable employment growth in European Services and Supply (S&S) companies of the oil and gas sector. However, whatever the necessity for an E&P program, the most foreseeable future is that the E&P related budget will remain fairly limited in the 5FP. In short, therefore, focusing on priority topics will be necessary in order to meet both industry's and society's needs and to prevent spreading.

Such a focus will lead again to consider the production side first. The oil companies will continue to run long-term R&D activities on their core exploration activities. One may also note that a lot of innovation in exploration has been, and will be, related to rapid development of computer and communication capabilities, such as computing power, visualization, imaging, data acquisition and treatment and transport. This kind of development is going to happen in sectors other than oil and gas, that are actively supported by other industries. Accordingly, it would be more efficient to focus on reservoir/well technologies, i.e. on appraisal and production rather than on basin scale modeling or large scale 3D survey technologies. It is in this sector that SMEs may need greater support. This will also support the current trend, which is that the most efficient recent developments—multilateral wells and 3D seismic—are now going to be combined, merging in a single step reservoir appraisal and development. As to demonstration and dissemination, one may note that technology related to reservoirs will be more rapidly demonstrated and disseminated in the market place by S&S companies, because it is their economic interest. Comparing to Thermie, one may also recall that Thermie has included many reservoir oriented projects, including reservoir, drilling, production and recovery, showing that this sector is actually more appropriate for rapid demonstration (Fig. 3). Increasing the reservoir-related projects in the R&D side Joule will then allow more efficient impact on demonstration, especially in the frame of a global program. An additional reason for focusing on the production side is that a number of environmental legal requirements must be met there, especially those related to the Osparcom 92 (Paris agreement of 1992 applying to the North Sea since 1996), those for reduction for hydrocarbon content in water, in mud and in cutting releases, those for gas release or flaring or those for CO_2 release or those for platform decommissioning. Finally, production is also the sector where common industry priority R&D topics may be easier to define. Exploration addresses the core business of oil companies, which may be driven by different priorities.

The effects on future impacts may be as in Table 3.

In the short term, a more direct impact of DG XII support on technology will be obtained because a first focus on the production side has begun within 4FP (Table 2). The view was that future production technologies require further developments in well drilling and completion technology, and in enhanced methods for interpreting 3D seismics, which can derive images ahead of the drill bit almost in real time. This is supported in the present Joule III projects and will ensure technological impact within a few years (see, for instance, existing projects on drilling mud, bits for slim-hole drilling, remote control for reservoir management, detection of overpressure zones, well treatment, carbonate scaling, mechanical behavior of chalk, seismic imaging, etc.). Impact on technology is also expected to be more rapid, mainly because the need will become increasingly urgent. As stated above the optimization of existing technologies presupposes the existence of technologies to be optimized, and they are going to be scarce on the production side, if new developments are not actively sustained over the coming years.

As for R&D impact, the support for partners’ R&D budgets will continue not to be the main reason for joining an EU supported project. It will, in fact, become even less

TABLE 3

Impacts of DG XII support to the E&P oil and gas sector

	Present	Future trend
Direct impact, (Fig. 2 (4a))	Exploration technologies Production technologies from a ten years process	– + By a shorter process
Impact on research, (Fig. 2 (4b))	Support to partner R&D budgets Preventing duplication Attracting of companies to production R&D topics Improving R&D partnerships and collaboration Support for training competent industry staff Disseminating results, publications, conferences Support for R&D manpower	– = + = – – –
Impact through Thermie (Fig. 2 (4c))	*Transfer of Joule results for demonstration	+

important because the focus on integration, collaboration and introduction of SMEs will significantly increase the organization and coordination costs.

Preventing duplication will continue to be a main impact because it makes the whole R&D process more effective from a technical and cost point of view. As stated above, however, one must be careful not to become too focused. Past experience shows that unexpected spin-offs are sometimes very important and valuable. One should learn from *Nasa*'s experience. The general opinion is that one of the main benefits of the Apollo and Space Shuttle programs was non-stick frying pans and portable electric screw-drivers.

The new program will probably try to increase companies' involvement in longer term R&D for production. It is seen as a good way to attract end-users to participate in R&D and then to ensure future technological impact. It is also an appropriate way to leverage the amount of R&D able to serve other EU policies, such as those related to environmental protection.

The impact on the R&D partnerships and collaboration will continue to be a major concern. However, one can notice that partnerships now need to bring together teams from different countries throughout the world, not only from the EU countries. Thomas *et al.* (1997), for instance, recognized that trans-European research is not enough, that competition is global and that research networks, training and mobility must be global, too. However, as DG XII funding for E&P is not going to be directed to non-EU or non-associate members, it is unlikely that this impact will increase. Some other external organizations like *CMPT* and *Energ* are more likely to take the lead as world-wide R&D brokers.

The support for training of appropriate and competent staff for the industry may, on the other hand, increase. The introduction of new production technologies and of computer and telecommunications technologies will make the need even more acute in the future. In the collaborative projects the young staff are also going to learn teamwork and international relationships, a feature that will become increasingly necessary.

Impact on dissemination will probably not be addressed, because dissemination is supported by the market. Since, the oil and gas service market is very mature and efficient, and a proprietary technology cannot actually be protected from general use. Therefore, the best economical use of technology is obtained by promoting rapid diffusion. Diffusion gives managers confidence in technology and makes them regard it as a valuable asset. Diffusion also makes it possible to perform parallel tasks, parallel engineering, permanently sharing up-to-date information, that is understandable by everyone involved. It changes the methodology and leads to high economic benefits. Parallel engineering is going to shorten field development significantly, for instance. Basically, most oil and gas companies have an interest in dissemination. It will occur without the need for public support. Additionally, DG XII funding for dissemination through symposia, publication support, etc., will certainly be reduced, as the funding level seems to be too low to have a significant impact.

Impact on available R&D manpower is not expected to evolve significantly, mainly because it is linked to the level of funding.

Finally impact through a demonstration program, is certainly expected to increase due both to improved future integration within the R&D and demonstration program and a better fit between topics supported within these two programs. Improved integration between Joule and Thermie must certainly be achieved in the future, especially in the area of providing continuous support from research to demonstration, comparable with the *DOE* program for United States companies. *DOE* achieves continuous funding from research, through development, including prototype development, to demonstration phases (phases 1, 2 and 3) with a level of funding up to 100%, 75% or 50%, respectively (IRW, 1997). A better fit between R&D and demonstration project topics will allow most of the Joule partners to anticipate proposals for demonstration which will fit into a future demonstration technical program. Both are certainly a concern for R&D efficiency and for rapid and competitive development of R&D products. They are on the horizon, and, at the moment, more than half the Joule III projects which are approaching completion have submitted, or are preparing, a proposal to demonstrate their results.

CONCLUSION

The share of funding devoted to the exploration and production of oil and gas within the European Commission R&D programs was low and primarily located in the Joule-Thermie program. The funding for R&D (Joule) was even more limited, corresponding to only 0.13% of the 4FP budget.

The Joule E&P projects have an impact on oil and gas E&P, however, through three "first level pathways", technology, R&D and Thermie. Technology itself impacts security of supply, employment, competitiveness of the S&S industry, and the environment, which are the main EU policy concerns. It is of high economic interest for the industry. R&D basically impacts technology development, even though the whole process may require several years. The Thermie program has an impact on the use of new technologies by supporting demonstration and transfer to the market.

First level major impacts of E&P Joule projects can, therefore, be summarized as follow:

– On the technology side, they provide new techniques or new data sets which have sometimes been successfully transferred to oil companies and to the S&S market and have impacted employment and the economy.
– On the R&D side, their larger impacts occurred in R&D organization and methodologies. They were mainly effective for supporting R&D efforts, preventing duplication, encouraging oil and gas companies to support more long-term R&D topics and to share field data, improving the R&D partnership and collaboration, supporting training of staff and dissemination of results.
– On the demonstration side, Joule project results have sometimes been demonstrated in Thermie. It is, however, a trend which has been difficult to track in the past.

For the future one expects more significant and rapid impact on production technologies, on the contribution of oil and gas companies to long-term R&D topics, on staff training and on the transfer of results to a demonstration program. Other impacts, such as preventing duplication or improving partnerships and collaboration are still major concerns, because they can not be addressed at a national or private level. However, they are expected to keep a constant level. A higher impact may be achieved by increasing the EU support for E&P and/or by funding world-wide collaboration, but neither is likely to occur soon. At the bottom of the scale, the level of R&D budgets, of R&D manpower and dissemination through conferences and publications will not be the main focus for funding and, therefore, will not have an increasing impact.

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GLOSSARY

Agip	A subsidiary of the *Italian Energy Group ENI*
AMJIG	*Atlantic Margin Joint Industry Group*
Arco	*The Atlantic Richfield Company*
Brite Euram	Industrial and Material Technology Programme
CGG	*Compagnie générale de géophysique*
CMPT	*The Centre for Marine Petroleum Technology*
Crine	Cost Reduction Initiative for the New Era
CSM	*Camborne School of Mines*
CSMA	*Camborne School of Mines Associates*
Cordis	The European Commission data base
DG III	The European Commission Directorate for Industry
DG XII	The European Commission Directorate for Science, Research and Development
DG XVII	The European Commission Directorate for Energy
DOE	The *United Kingdom Department of Energy*
DTI	The *United Kingdom Department of Trade and Industry*
E&P	Exploration and production
E&P Forum	the *Oil Industry International Exploration and Production Forum*
EC	European Community
Ecu	European Currency Unit - Now Euro: 6.56 F
Energ	The *European Network for Research in Geo-Energy*; an association of about 30 European research groups in the oil and gas sector
Esprit	The Information Technologies Programme

Eurogif	The *European Oil and Gas Innovation Forum*; an alliance of over 2650 companies in the engineering, supply and service sector of the oil and gas industry
FP	Framework Programs
FTP	File Transmission and Storage System
Gerth	*Groupement européen de recherches technologiques sur les hydrocarbures*
HDR	Hot Dry Rock
IFP	*Institut français du pétrole*
Intevep	R&D affiliate of *Petróleos de Venezuela*
JNOC	*Japan National Oil Corporation*
Joule	Joint Opportunities for Unconventional or Longer-Term Energies
Marmousi	Consists of complex sets of synthetic seismic data computed on an overthrust model. It is computed by the *DOE* and *IFP* for the *SEG* and *EAEG*. It is the main reference data set, along with another “salt-dome” set
Mast	The Marine Science and Technology Programme
NMR	Nuclear Magnetic Resonance
NNE	Non-Nuclear Energy Program
Norsok	*Norsk Sokkels Konkuranseposisjon*, the Competitive Standing of the Norwegian Offshore Sector
ODS	The *Danish company Odegaard* and *Danneskrold-Samsoe*
Opec	*Organization of Petroleum Exporting Countries*
Osparcom 92	The Convention for the Protection of the Marine Environment of the North-East Atlantic, September 22, 1992
PDVSA	*Petróleos de Venezuela, SA*
Pemex	*Petróleos Mexicanos*
PSTI	The *Petroleum Science and Technology Institute.*
R&D	Research and Development
RTD	Research, Technological Development
SME	Small and Medium Enterprise
Thermie	Technologies européennes pour la maîtrise de l’énergie
TMR	Training and Mobility of Researchers.

UNITS

bbl/d	Barrel per day
kEcu	Thousand Ecus
kF	Thousand French Francs
Mbbl/d	Million barrels per day
Mboe/d	Million of oil equivalent barrels per day
MEcu	Million Ecus
MF	Million French Francs
M$/y	Million US dollars per year
Gbbl	Billion barrels
GF	Billion French Francs
G$	Billion US dollars
G£	Billion GB pounds

REFERENCES TO EUROPEAN PROJECTS MENTIONED IN THE TEXT

1	SRT 0640 95 FR	12	JOU2-CT92-0182
2	EN3G-0003-UK	13	JOUF-CT90-0034
3	OF3-CT97-0032	14	OG/148/97
4	JOF3-CT97-0027	15	JOU2-CT93-0321
5	JOF3-CT95-0009	16	JOF3-CT95-0019
6	JOF3-CT95-0006	17	OG/110/95
7	JOF3-CT97-0038	18	OG/173/97
8	JOF3-CT95-0014	19	JOF3-CT95-0015
9	TH01.070, 1986-89	20	JOF3-CT93-03
10	OG/097/89, 1990-9434	21	OG/007/97
11	JOUF-CT90-0037	22	JOF3-CT95-0008

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