Euratom Framework Programme research in reactor safety
main achievements of FP-4 (94-98), preliminary results of FP-5 (98-02)
and prospects for beyond 2002

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Abstract

In this paper an overview is given of the most important aspects of the research activities organised by the European Union (EU) in the area of reactor safety under both the past 4th and the current 5th Euratom Framework Programmes (FP). This research consists of the following 4 areas: reactor safety; waste management; future systems; and radiation protection. Under FP-4 (94-98), the particular area of reactor safety was focusing on “Severe Accident Analysis”, whereas under FP-5 (98-02) it is focusing on "Operational Safety of Existing Installations”.

In the introductory Section, a short description is given of the “nuclear needs” in the EU and the main stakeholders of nuclear fission research (i.e. regulatory and industry organisations), faced with new targets (e.g. minimisation of operating and environmental costs in a deregulated market) and new feedbacks (e.g. public perception of reactor safety and acceptance of the waste issue). In the next Section, a brief description is given of the main facts of FP-4 and FP-5 with emphasis on the clustering approach of research projects in the same field.

In the next seven Sections, attention is drawn to a series of technical and socio-economical facts of interest to regulatory and industry organisations (i.e. mainly utilities and vendors). They are the main end-users of the results of international nuclear fission research, financed by either governments, industries or Euratom. The following “nuclear needs” have been identified at EU level and are proposed for discussion: to ensure flexibility in energy supply by maintaining the nuclear option open; to contribute to health and safety as well as to non-proliferation by a better co-ordination of European research and training activities; to maintain industrial competitiveness by preparing the next generation of reactors; to maintain broad nuclear expertise for non-energetic applications; to develop sustainable solutions for fuel cycle management and waste disposal (emphasis on front-end issues); to share the same nuclear safety culture amongst the EU and the applicant Central and Eastern European Countries (CEECs); and finally, to improve the impact of Euratom research actions by enhancing their public benefit and their added European value. In the following Section then, a brief overview is given of the European response offered under FP-4 and FP-5 - in terms of co-operative research in reactor safety – as a response to some of the “nuclear needs”.

As far as the future beyond 2002 is concerned, the challenge to Euratom research is to reorganize itself in line with the European Research Area concept (ERA), using the proposed tools, for example, by developing networks of excellence, bringing together private and public resources. Finally conclusions are drawn on the main achievements of framework programme research hitherto and on new stakeholders in European research in the “changing world”.

Preparatory paper for FISA-2001 (Luxembourg, 12-14 November 2001)
1 - Introduction

“Nuclear needs” in the EU and main stakeholders of nuclear fission research

Reactor safety is still perceived as a concern by the public at large: it remains directly linked to public confidence. As a consequence, in particular in the EU, it remains a key issue for international research - in line with general safety principles established on a world scale more than 10 years ago /1/. Reactor safety, however, is not an objective per se: it should be optimised together with other requirements, such as health protection, plant economics (technical performance) and environmental protection. Improvement of nuclear power plant (NPP) performance means, amongst other things, increasing plant availability, controlling operation and maintenance costs, and improving the fuel cycle as well as optimising the whole plant organisation. This is the subject of the current Euratom research activities devoted to modernisation of materials and equipments in existing installations. Understanding and developing mitigation measures for (highly unlikely) severe accidents is another area of current Euratom research. Also of interest for Euratom research are advanced reactors of the evolutionary type: their prime objectives are to simplify plant operation and inspection, to extend the service life of systems and components, and to reduce capital cost in general.

![Figure 1 - Role and priorities of the main stakeholders in Euratom FP-4 and FP-5 (centralisation of research within the framework programmes)](image)

The traditional stakeholders of research programmes in nuclear fission have not changed over the last decades. They are the regulators and the industries (mainly utilities and vendors) as well as the research organisations themselves, whether governmental or industrial – see above Figure 1. Note that these traditional stakeholders are interacting actively and are involved in many international research programmes, in particular, Euratom FP actions.

Euratom research under FP-4 and FP-5 used to be somehow “centralised”, as it is tentatively illustrated in the centralised triangular picture of above Figure 1. The centralised approach is symbolised by the links between stakeholders at the 3 tops and Euratom actions at the centre.
In rough summary, the following can be said about the research priorities of the three traditional groups of stakeholders:
- for the regulatory authorities: safety
- for the utilities and the services sector: safety and performance
- for the vendors and the designers: safety, performance and innovation.

The research organisations (especially those involved in Euratom research) are expected to maximise mutual benefit of all stakeholders. Therefore they deal with all above-mentioned priorities (i.e. safety, performance and innovation), while satisfying their own general principles, such as subsidiarity and sustainability in the particular case of Euratom research.

The “nuclear needs” of the main stakeholders have not changed either over the last decades. They are the following: to ensure flexibility in energy supply by maintaining the nuclear option open; to contribute to health and safety as well as to non-proliferation by a better co-ordination of European research and training activities; to maintain industrial competitiveness by preparing the next generation of reactors; to maintain broad nuclear expertise for non-energetic applications; to develop sustainable solutions for fuel cycle management and waste disposal (emphasis on front-end issues); to share the same nuclear safety culture amongst the EU and the applicant CEECs; and finally, to improve the impact of Euratom research actions by enhancing their public benefit and their added European value.

What have changed recently are the boundary conditions for the nuclear industry and for the relevant research actions. For all stakeholders, the enlargement of the EU towards the CEECs, in particular, requires new co-operation modes to integrate a variety of scientific research traditions and safety cultures across the various countries concerned. In addition, for industry both in the EU and in the CEECs, return on investments becomes the main consideration in the broadly liberalized and competitive electricity market. How to optimise plant safety and economics, while gaining public acceptance, is one of the new challenges to Euratom research in the "changing world" (that is, currently within the EU: deregulated electricity market, mergers of large companies, low growth for electricity demand, general public mistrust with respect to nuclear energy, privatisation of research, and outside the EU: enlargement towards the CEECs and world-wide globalisation). In this “changing world”, the regulatory and industrial budgets for nuclear fission research have also been drastically reduced.

2 - Euratom research in nuclear fission under FP-4 and FP-5

Strategic goals, implementation instruments and clustering of projects

At EU level, a large part of the research in nuclear fission safety is carried out through multi-partner projects under multi-annual Euratom Framework Programmes, co-funded and co-ordinated by the European Commission / Directorate General (DG) Research (responsible for the "indirect actions") in co-operation with DG Joint Research Centre (responsible for the "direct actions").

The strategic goal of the specific 4th Euratom Framework Programme (FP-4, 1994-1998) was “to stimulate closer collaboration amongst all parties involved in nuclear energy, to reach a common understanding and to find solutions to open questions” (see Workprogramme of “Nuclear Fission Safety”, 1994). Under the “indirect actions” of FP-4, the objectives of “Nuclear Fission Safety” were thus essentially knowledge-driven. Research consisted of 4 areas, namely: reactor safety (EU budget of EURO 42 Million); waste management (EU budget of EURO 42 Million); future systems (EU budget of EURO 5 Million); and radiation protection (EU budget of EURO 57 Million). Research in reactor safety addressed primarily severe accident analysis, focusing on the prediction of timing and mode of failure of the main barriers. The variety of projects in this area started from early accident progression in the primary coolant system and
went up to severe damage to the containment integrity, under the very unlikely assumption that the safety systems are not working satisfactorily. A smaller part of research was devoted to other areas, such as: plant modernisation with emphasis on the prediction of safety margins for existing installations, and advanced safety concepts with emphasis on passive decay heat removal systems for evolutionary reactor designs.

Under FP-4, the "indirect actions" in reactor safety consisted of a total of 67 multi-partner projects (shared-cost and concerted actions), focusing on severe accident phenomenology and structured in 7 clusters, each devoted to one key safety issue. These 7 key issues were: materials ageing (AGE), in- and ex-vessel corium behaviour (INV and EXV), radiological source term (ST), containment integrity (CONT), accident management measures (AMM) and innovative safety concepts (INNO). All 67 projects were presented, cluster by cluster, at the conclusion symposium FISA-99 (EC Luxembourg, 29 Nov. – 1 Dec. 1999). The total cost of these 67 projects in reactor safety research was EURO 62.8 million, out of which EURO 34.2 million was contributed by the EU budget. Another EURO 7.8 million was added for support to the PHEBUS-FP programme (see Section 10.1) and for accompanying measures.

The strategic goal of the current specific 5th Euratom Framework Programme (FP-5, 1998-2002) is “to help exploit the full potential of nuclear energy in a sustainable manner, by making current technologies even safer and more economical and by exploring promising new concepts” (see Workprogramme of “Nuclear Energy, 1998). Under the “indirect actions” of FP-5, the objectives of “Nuclear Fission” are thus more end-user-driven. Research consists of the same 4 areas of FP-4, but with different budgets, reflecting the new trends, namely: reactor safety (EU budget of EURO 38 Million); waste management (EU budget of EURO 59 Million); future systems (EU budget of EURO 12 Million); and radiation protection (EU budget of EURO 49 Million). Research in reactor safety under FP-5 addresses primarily the optimisation of both plant safety and performance: it is planned to give almost equal weight to research in plant modernisation (with emphasis on plant life extension and management or PLEM) and to research in severe accident management (SAM), whereas the weight on evolutionary concepts (EVOL) is increased, as compared with FP-4.

Under FP-5, until now, the "indirect actions" in reactor safety consist of a total of 41 multi-partner projects, structured in 3 clusters (PLEM, SAM and EVOL) and worth a total amount of approximately EURO 50 million, out of which approximately EURO 27 million will be contributed by the EU budget. From now on until 2002, another series of project proposals related to reactor safety research are expected for a total EU budget contribution of approximately EURO 9 million, to be submitted to the Commission by January 2001 or January 2002. Another EURO 2 million should be added for support to the PHEBUS-FP programme and for accompanying measures.

The clustering approach of the FP-5 projects in reactor safety is best illustrated in Tables 1, 2 and 3 at the end of this report. The PLEM cluster (Table 1) consists currently of 3 fields (namely: integrity of equipment and structure; on-line monitoring and maintenance; organisation and management of safety) and 6 items (namely: materials embrittlement; materials corrosion; fracture mechanics; NDT inspection of components); water hammer loads; safety culture). The SAM cluster (Table 2) consists currently of 2 fields (namely: assessment of severe accident risk; severe accident measures) and 6 items (namely: corium behaviour; reactor pressure vessel; source term – with PHEBUS playing a key role; hydrogen; by-pass sequences; code development). The EVOL cluster(Table 3), finally, consists currently of 2 fields (namely: evolutionary safety concepts; high burn-up and MOX fuel) and 3 items (namely: analytical tools / codes; methodologies; operational practices and design improvement; databases).
The main implementation instruments of the “indirect actions” under FP-4 and FP-5 are the cost-shared and concerted actions, which represent more than 90 per cent of the total research budget. Thereby come also the accompanying measures (useful, for example, to support specific training and education activities) and the Marie Curie individual fellowships (useful for the mobility of researchers across the Member States) - see web site of the COmmunity R&D Information Service CORDIS at http://www.cordis.lu/improving.

What will happen beyond 2002 to Euratom research in nuclear fission (FP-6, 2002-2006) is currently under discussion: prior to fixing the contents, a thorough analysis is needed of the various “nuclear needs” (see Sections 3 to 9) and of the existing competences in the EU research community to respond to these needs (see Section 10). The ERA concept and a list of proposed tools are discussed in Section 11. General conclusions about Euratom research in nuclear fission are given in Section 12.

3 - Nuclear electricity industry in the EU

The need to ensure flexibility in energy supply by maintaining the nuclear option open


The starting points are:
- If no measures are taken, in the next 20 to 30 years, about 70 per cent of the Union’s energy requirements will have to be covered by imported products (today 50 per cent). The energy dependence of the Union will be increasingly alarming. This will affect all sectors of the economy.
- The fight against the climate change is difficult: inversion of the trends is more difficult than it appeared to be three years ago. Thus, while the Union stabilised its emissions of greenhouse gases in 2000, the forecasts of the European Environment Agency consider that they will increase by 5.2 per cent between now and 2010.

The Green Paper offers for discussion a plan for a long-term energy strategy, in 5 main fields:
1 - a genuine change in consumer behaviour and energy consumption
2 - a truly alternative transport policy
3 - doubling the share of renewable energies from 6 to 12 per cent in the energy balance between now and 2010 (financial measures)
4 - solutions at the Community level (e.g. reinforced strategic oil and gas stocks, a fiscal policy for energy to steer towards more environmentally friendly sources)
5 - to analyse the medium-term contribution of nuclear power taking into account the phasing out decisions of the majority of the Member States and issues related to waste management, global warming, security of supply and sustainable development.

In this Green Paper, it is proposed, in particular, that the European Union retains its leading position in the field of civil nuclear technology, in order to retain the necessary expertise and develop more efficient fission reactors and enable fusion to become a reality.

In most countries where it is generated, it is clear that nuclear power has a significant role in providing the base load to the electricity grid. Moreover, as a consequence of the broad deregulation and internationalisation of the electricity market, nuclear power is often shared with neighbouring countries - especially within Europe. Within the EU in 1999, nuclear power accounted for approximately 35 per cent of all the electricity production - from more than 75 per
cent in France to just under 4 per cent in the Netherlands. For comparison, world-wide the contribution of nuclear power to the production of electricity is about 17 per cent. Worth noting is also the fact that eight of the fifteen Member States of the EU produce nuclear power (amongst which five are in a moratorium situation !). In 1999 in the EU, a total of 147 reactor units were in operation with a total capacity of 125 net GWe and a total gross generation of 825 TWh, representing a cumulated experience of more than 3700 reactor-years.

As far as the future enlarged EU is concerned, it is also worth recalling that four of the applicant countries that are particularly active in European co-operative research – namely: the Czech Republic (CZ), the Slovak Republic (SK), Hungary (HU) and Slovenia (SI) - are operating NPPs, providing all together approximately 30 per cent of their electricity in 1999, namely: four VVERs-440 model 213 of Russian design in Dukovany (CZ), two in Bohunice and two in Mohovce (SK), and four others in Paks (HU) as well as two VVERs-440 model 230 in Bohunice (SK) and one PWR (660 MWe) of Western design in Krsko (SI).

An interesting figure for the EU, as a result of using nuclear energy, is the avoidance of potential emissions of approximately 10 million tons of NOx, 20 million tons of SOx and 300 million tons of CO\textsubscript{2} per year - equivalent to removing approximately 75 million cars from the roads for a year (or 7 per cent of the total greenhouse gas emissions in the EU).

Despite a continuous improvement in the safety and performance of nuclear power plants and their zero contribution to greenhouse gas emissions, current and future applications of nuclear power continue to be a source of lively political debate within the European Union. Nuclear energy, actually, is still perceived by a majority of people in the EU as a non environmentally-friendly and non sustainable technology. There is a significant body of opinion amongst the Member States, which is totally opposed to this form of electricity generation and takes tough positions at the Council of the EU, at the various Councils of Ministers and at the European Parliament. It is worth recalling that similar differences of opinion also exist in the CEECs and in the rest of the world.

It is expected, however, that the world demography and consequently the overall demand for energy will experience unprecedented growth in the coming decades. At the same time, the global climate change and ecological consequences of emissions (especially CO\textsubscript{2}) from energy production and use will cause increasing concern and attention from government and policy makers internationally.

Closing the nuclear option, however, can also have tough economic and social consequences. Worth mentioning here is the premature closure of Sweden's Barsebäck-1 reactor (600 MWe, operated since 1975, 4 TWh per year) in November 1999 under a Swedish Crowns 5.9 billion (= EURO 0.7 billion) compensation deal with Sydkraft. At the same time, surprisingly, opinion polls in Sweden show that 80 per cent of the public want the continued operation of the 11 remaining reactors.

Whether one agrees with nuclear power or not, as a matter of fact it seems unlikely that all the EU countries will abandon this form of electricity production. It is even more unlikely that nuclear power generation will cease on a world scale. For the long-term, it is generally accepted that the choice of energy supply strategies should remain as wide as possible for satisfying in a flexible way the world's growing energy requirements. Therefore the nuclear option should remain open.
The need to contribute to health and safety as well as to non-proliferation by a better co-ordination of European research and training activities

Monitoring and improving health and safety practices amongst the Member States are at the heart of the Euratom Treaty (1957). During the pioneering 1950s, the original six Members of the European Community established the European Atomic Energy Community (EAEC), with the task of «contributing to the raising of the standard of living in the Member States ... by creating the conditions necessary for the speedy establishment and growth of nuclear industries...» (excerpt from Title I - see the EUROPA web site http://europa.eu.int/abc/obj/treaties/en/entoc.htm). Within this Treaty, provision was also made to «establish uniform safety standards to protect the health of workers and of the general public and ensure that they are applied». As a consequence, the European Commission has devoted much effort to the harmonisation of safety requirements and safety criteria for nuclear installations. Part of Euratom research, in particular, has been used to support this European harmonisation process as well as some of the safeguards techniques aimed at ensuring non-proliferation.

Although the existing European Union legislation is based on international standards, the decision-making processes regarding the technical safety of nuclear installations continue to lie with the Member States. Each country follows its own code of conduct, not only to select nuclear power as a particular form of electricity generation but also to establish the technical safety rules deemed appropriate for the chosen technology. At European level, however, there are ongoing consultations and discussions, especially amongst the regulatory bodies, about the need of mandatory requirements for all nuclear installations and other facilities handling radioactive materials. These common requirements should govern nuclear safety, the design, construction and operation of nuclear reactors, reprocessing of spent fuel, decommissioning, waste management and the transport of all radioactive materials. No firm general conclusion has been drawn yet at EU level.

Title I of the Euratom Treaty states further that « in order to perform its task, the Community shall (a) promote research and ensure the dissemination of technical information, (b) ... » : this is actually the legal basis for Euratom research activities and, in particular, for the “research and training programmes in the field of nuclear energy” (FP-4 and FP-5). Diffusion of the scientific findings amongst the Member States, accompanied by an efficient exchange of nuclear practices and experiences, contributes effectively to improve both the safety (and often also naturally the performances) of nuclear technologies in a variety of areas, such as reactor operation and maintenance, spent fuel and waste treatment, radiation protection or emergency measures as well as non-energetic applications of growing interest to industry and medicine. Dissemination is done in particular through the publication of a final report for each reactor safety project and through exchanges at workshops, Eurocourses and symposia like FISA organised by DG Research (see http://www.cordis.lu/fp5-euratom/home.html).

All nuclear operations need to be approached with the highest degree of safety, not only for the people who are employed in those activities, but also for the general public and for the environment. This must also take into account the needs of neighbouring countries, since the impact of a nuclear accident is not limited by considerations of national boundaries. In particular, (highly unlikely) severe accidents with potentially large radioactive releases are still a matter of concern for the public at large, especially since the Chernobyl accident of 1986. Therefore, it is necessary to continue to investigate the material behaviour of both the reactor pressure vessel and the containment in case of severe accident in order to optimise the crisis management process under these extreme conditions. Under FP-5, this is the purpose of the specific SAM cluster,
which contains 16 projects devoted to phenomenological analysis and practical measures for Severe Accident Management.

Besides reactor safety in general, another matter of concern for the public at large is the misuse of fissionable material for military purposes: fissionable radioactive material (uranium and plutonium) should never be diverted from civil to military purposes. Therefore international bodies have established strict control rules in a number of countries to ensure peaceful applications of nuclear power world-wide. As far as nuclear safeguards in the EU are concerned, the Euratom Treaty also deals with the need to control the handling of spent nuclear fuel and nuclear waste.

Whatever is the decision taken for the next generation of reactors, the handling of nuclear materials, the running of nuclear power plants and associated installations such as fuel manufacturing, spent fuel reprocessing and waste disposal as well as the development of advanced safeguards techniques will continue to require highly skilled people and well trained workers in order to ensure maximum plant safety and health protection.

Euratom research is needed to cope with the above-mentioned long-term objectives of common European interest, whereas specific commercial research (for example, directly connected to reactor design and operation) should remain a matter for industry (and not for Community) funding. In addition to research activities, European activities of education and training are needed to improve continuously the scientific and technical competence, while creating the conditions for young people to innovate in these areas.

Worth mentioning here are the education and training activities organised by DG Research like the Eurocourses in nuclear fission. The most recent Eurocourse was devoted to advanced reactor safety concepts (Eurocourse-99 “Advanced Nuclear Reactor Design and Safety” in GRS Garching/Munich, 17-21 May 1999 – see http://www.cordis.lu/fp5-euratom/home.html). The next Eurocourse will be devoted to risk-informed decision making (Eurocourse-2001 “Probabilistic safety assessment and risk-informed decision making” in GRS Garching/Munich, 5-9 March 2001 – see http://www.grs.de/psarid). There is a clear demand for more measures at EU level for improving research, training and education in nuclear fission areas of generic interest.

5 - Nuclear performance in the EU

The need to maintain industrial competitiveness by preparing the next generation of reactors

Maintaining industrial competitiveness within the EU is at the heart of the Amsterdam Treaty (1997 – see same web site as for the Euratom Treaty) and EU research has to play a role in this context. Title XV "Research and technological development", which also provides the legal basis for Community research in general, states the following in its Articles 163 and 164 : « The Community shall have the objective of strengthening the scientific and technological bases of Community industry and encouraging it to become more competitive at international level, while promoting all the research activities deemed necessary by virtue of other Chapters of this Treaty. » and « In pursuing these objectives, the Community shall carry out the following activities, complementing the activities carried out in the Member States: a) implementation of research, technological development and demonstration programmes, by promoting co-operation with and between undertakings, research centres and universities; b)...; c)...etc. ».

During the last decade, a number of changes have taken place in the European electricity market. Generation, transmission (over long distances), distribution (over short distances) and marketing
(to final consumers) are becoming separate entities. Improving the performance of the present generation of reactors, while maximising their safety, is a natural goal for the nuclear utilities and the service sector – see Figure 1 - in the current highly competitive context: each component, be it generation, transmission or distribution, needs special attention from the points of view of safety and performance. For this purpose, two essential factors - and their interaction - are to be considered, which will become even more important in the next generation of reactors, namely: the technological factor and the organisational (or human) factor.

Recently, there were also organisational changes in the nuclear industrial landscape: for example, Framatome and Siemens announced a joint entity for their nuclear activities, whereas British Nuclear Fuels plc was purchasing ABB nuclear power operations while consolidating their links with Westinghouse Atom. The driving force behind these changes on the side of vendors and designers is usually the need to join resources (i.e. funding and manpower) to develop innovative systems for the NPPs with higher performances and lower costs, while maximising their safety – see Figure 1.

As 2010 approaches, numerous Member States, as well as applicant countries, will have to make choices regarding energy investment, primarily in the electricity sector. In the particular area of electro-nuclear energy, one of the main concerns of industry (i.e. mainly utilities and vendors) is naturally the question of end-of-life: what are the technical-economical criteria to decide to go for plant life extension or for a new generation of reactors?

In the first case – go for plant life extension -, which is to be validated by the regulatory bodies, it is necessary to organise research programmes aimed at deepening our understanding of material ageing processes and quantifying with greater precision the end-of-life safety margins. That is the purpose of the specific cluster PLEM under FP-5, which contains 16 projects devoted to Plant Life Extension and Management.

In the second case – go for a new generation of reactors -, which is also to be validated by the regulatory bodies, research is needed to reduce capital cost in general, extend service life of systems and components, and improve the organisational aspects of plant safety (for example, by simplifying plant operation and inspection). That is the purpose of the cluster EVOL under FP-5, which contains 9 projects devoted to advanced “EVOlutionary” safety concepts. Research on advanced “innovative” concepts for the long term is conducted in other areas of the Key Action Nuclear Fission. Research on high temperature reactors (HTRs) is performed in the area of future systems, i.e. “Safety and Efficiency of Future Systems”, whereas accelerator driven systems (ADSs) are investigated in the area of waste management, i.e. “Safety of the Fuel Cycle”.

6 - Nuclear applications other than electricity production

The need to maintain broad nuclear expertise for non-energetic applications

Nuclear industry is interested in manufacturing components not only for electricity generation in NPPs but also for advanced (present or future) energetic applications - such as co-generation plants (for example, for district heating and/or desalination of sea water) as well as for non-energetic applications of nuclear energy. Examples of such applications are: advanced measurement and gamma imaging techniques in the process industry, irradiation applications to the food industry (note: a total of more than 250 000 tons of irradiated food was produced in 34 countries world-wide in 1999 !), as well as production of radioisotopes and radiological equipment in the medical area for prevention, diagnosis and therapy. Nuclear instrumentation is also an area of rapid innovation: for example, room temperature radiation detectors, in
particular, for monitoring radioactive and non-radioactive pollutants, and for developing nuclear safeguards techniques.

Radioisotopes meant for medical, agronomic, environmental or industrial purposes are produced in reactors or accelerators and processed in hot cell facilities. The medical uses of sources of radiation and more generally the processes of assessment/management/regulation of the radiation risks are treated under FP-5 in the area of radiation protection (i.e. “Radiation Protection and Health” of the Key Action Nuclear Fission and “Radiological Sciences” under Generic RTD Activities). As a consequence of the increasing number of non-energetic applications of nuclear fission technologies, there is a need to maintain a broad nuclear expertise, also in this lesser known area, for further improvements and innovations in technological developments and risk management measures.

7 - Nuclear wastes in the EU

The need to develop sustainable solutions for fuel cycle management and waste disposal (emphasis on front-end issues)

The treatment of spent fuel and nuclear wastes is connected to the back-end of the fuel cycle. This is still a matter of concern for the public at large: disposal of high-level waste, in particular, which accounts for 5 per cent of the total volume of nuclear waste and 95 per cent of its total radioactivity, is an important factor for the public acceptance of nuclear energy. Some countries have opted for direct disposal of spent fuel, while others prefer to re-utilise the fissile material of the spent fuel after reprocessing. Whatever option is chosen, in view of the number of nuclear facilities now in operation, it is particularly important to avoid, whenever possible, or to reduce the production of radioactive waste and to reduce their radiotoxicity in the long term. In the case of re-utilisation of fissile material, research is conducted, in particular, on the possibility of recycling for actinides and long-lived fission products, for example, using advanced partitioning and transmutation techniques, as they are investigated in the innovative long term research about ADSs, as mentioned in Section 5).

Research in the area of waste management should consider the entire fuel cycle, that is: from the fuel behaviour in the reactor at the front-end up to the treatment of spent fuel and wastes at the back-end, including geological disposal.

In this paper, the emphasis is obviously on the front-end of the fuel cycle, apparently far away from any waste management strategy: attention is devoted to the feasibility and the behaviour of high burn-up and MOX fuels, in particular, in the above mentioned EVOL cluster. Many efforts in reactor safety research are focusing on the following items: the increase of the burn-up and the increase of the fuel cycles in the reactor with the aim to reduce ultimately the total volume of spent fuel on one side; and the recycling of plutonium in reactors, on the other side, by using mixed oxide fuels (MOX), thereby taking most advantage of all available fissile materials. The knowledge of the behaviour of high burn-up fuels and the integrity of the cladding is of foremost importance to optimise both the performance and the safety of the fuel assemblies. MOX studies also are important to optimise the fuel management in the core of the reactor (percentage, core configuration, rotation time, ...etc). In the current holistic approach for fuel cycle research, there are naturally some connections between advanced fuel research activities and waste management strategies.

More generally, the big challenge for fuel cycle management and waste disposal is to develop sustainable solutions, acceptable by the public at large, thereby opening the way to possible future generations of NPPs, once the current generation has come to its end of life (i.e. approximately in
The closing of the nuclear fuel cycle, in particular, is an objective yet to be achieved, especially if fully-operational commercial-scale techniques are to be developed for the treatment of high-level and long-lived type wastes.

8 - Nuclear power in the applicant countries

The need to share the same nuclear safety culture

The largest current challenge to the EU is the enlargement towards a number of applicant CEECs in the coming years. In the Communication "Agenda 2000: For a stronger and wider Union / The Challenge of Enlargement’’, (COM(97)2000) issued in July 1997, the Commission presented proposals for the future developments of the Community including, in particular, one section on nuclear safety in the enlargement process. In this section, Agenda 2000 emphasises that applicant countries "should co-operate fully in efforts to bring their levels of nuclear safety up to international standards" in accordance with the approach of the G7 since 1992 and that “the Union should co-operate closely with the safety authorities of the countries concerned to create a climate favourable to nuclear safety” (see http://www.cc.cec/sg_vista/textes/repository/rep_rech.htm).

Some of the reactors in the CEECs are of rather old design or in poor conditions, sometimes lacking confinement buildings of proven efficiency. The enlargement process, initiated in 1997, has led the EU to stress repeatedly the importance of high levels of nuclear safety in central and eastern Europe. It is clear also that technical assistance and/or scientific co-operation are more appreciated than advice or comments. That is the main lesson learnt from a series of contacts with representatives of the nuclear industry and governments in the CEECs.

“Commission support to nuclear safety in the Newly Independent States and Central and Eastern Europe” has been the subject of a recent Communication of the Commissioners Messrs C. PATTEN (External Relations) and G. VERHEUGEN (Enlargement) – in agreement with Ms L. DE PALACIO (Transport and Energy), namely: document COM(2000) 493 (September 2000 - see http://europa.eu.int/search/s97.vts). The Commission’s approach to nuclear safety in the CEECs and NIS is recalled in this document. It is based on two main objectives:

* in the short term, to improve operational safety; make near term technical improvements to plants based on safety assessments and to enhance regulatory regimes;

* in the longer term, to examine the scope for replacing less safe plants by the development of alternative energy sources and more efficient use of energy and to examine the potential for upgrading plants of more recent design.

Technical assistance in the field of nuclear safety is being implemented mainly through the European Union programmes PHARE for the CEECs (total budget committed for nuclear safety from 1990 to 1999 = EURO 193 million) and TACIS for the Newly Independent States (total budget committed for nuclear safety from 1991 to 1999 = EURO 532 million). Worth mentioning here - in connection with the NIS - are the activities of the ISTC (International Science and Technology Centre), in particular in the area of plutonium research (e.g. utilisation of weapons grade Pu as MOX fuel for Russian nuclear reactors).

The activities proposed by the PHARE programme can be broadly classified as follows: support for nuclear regulators; safety improvements of specific power plants; research (see excerpt from the Communication: “The candidate countries will be increasingly involved in research co-operation with the Member States under the 5th framework programme’’); off-site emergency preparedness; radioactive waste and spent fuel; and finally safeguards projects. More generally, it is believed that, in addition to scientific co-operation amongst research experts, a fair exchange of
industrial and regulatory practices amongst the EU and the CEECs can greatly contribute to harmonising and globally improving the nuclear safety culture throughout Europe.

Under FP-5, scientific co-operation in nuclear fission research with the CEECs is starting, in particular, through research projects connected to the « Operational Safety of Existing Installations » and making use of eastern European resources (e.g. outstanding experts and experimental facilities) - see for example the concerted action VERSAFE /3/. Research is needed, in particular, to increase the safety of some equipment and to improve the experimental validation of numerical simulation tools aimed at predicting materials and systems behaviour under abnormal conditions. Other topics in reactor safety research are related to the demonstration of the efficiency of possible improvements of the confinement buildings and the understanding of the results of the reactor vessel annealing.

9 - Nuclear scientific co-operation in Europe

The need to improve the impact of Euratom research actions by enhancing their public benefit and their added European value

As a preliminary conclusion of the above Sections 3 to 8, it can be said that, despite the impressive record for the safety of nuclear operations in the European Union, it is clear that the system can be further improved, in particular, through reinforced co-operation amongst all European nuclear stakeholders and scientific experts concerned.

The European policy for energy supply brings with it the concern of maintaining all options open, including the nuclear option (see Section 3). For the public at large, the generation of electricity by nuclear power brings with it essentially three types of fears: (1) the (highly unlikely) possibility of severe accidents with potentially large radioactivity releases - see Section 4, (2) the misuse of material for military purposes - see also Section 4, and (3) the concerns about waste disposal - see Section 7.

A key lesson learnt from discussions with safety experts at the power plants is that safety is primarily a matter for plant operators. It is not something that can be imposed from a distance. Quite often, organisational (human) questions at plant level raise more concern than technical questions, as it is also demonstrated by international statistics on operational incidents. This must come as a surprise to those who see nuclear safety in terms of a technological fix. The organisational (or human) factor - associated with the above-mentioned technological aspects - is a new challenge to reactor safety research (see Section 5).

The ultimate objectives that the nuclear power industry organisations – both the utilities and the vendors - have in mind, are that the nuclear power plants should be able to operate both safely and economically (i.e. competitively against other electricity generation technologies) and that they should re-conquer public confidence (i.e. be accepted as a sustainable energy source amongst other sources). Also worth considering are the marketing opportunities offered to the European industry by the non-energetic applications of nuclear energy and ionizing radiations - see Section 6.

It is generally believed that international applied research - and in particular research of a European co-operative nature - together with feedback of operational experience and better communication outside the circle of experts - can contribute to the solution of the technological and organisational (human) aspects associated with the fears of the public at large, as discussed above. It is also obvious that co-operative research with the CEECs concerned is of mutual benefit - see Section 8: their expertise and some of their experimental facilities are key
components in a number of shared-cost and concerted actions of the 5-th Euratom Framework Programme.

Activities of future Community research programmes will be based on two main selection criteria (see Communication COM(2000)612, discussed in Section 11): the “public benefit” and the “European added value”. This new approach is expected to improve the impact of European research on real life, be it in private industries, in public administrations (including regulatory bodies) or more generally in citizen’s daily life.

First and foremost, public funding itself requires justification. Public authorities can legitimately support research activities where the results generated are of "public benefit" in addition to the direct benefit to whoever is carrying out the research. This is the case with basic research, but also with many examples of targeted research. Public funding is legitimate and necessary where the research in question may make a contribution to, or is essential for, the implementation of public policies. This is also true where it helps to resolve problems confronting society and increases European competitiveness, by encouraging businesses to carry out risky or long-term research which is not immediately cost-effective, and where it helps to increase the transparency of the knowledge market.

The second aspect is the justification for support at European level, and more particularly at Community level. The key concept here is that of “European added value”. European added value is first and foremost connected with the specific form that EU research activities must take, that is: in accordance with Articles 163 and 164 of the above-mentioned Amsterdam Treaty, they are designed to complement Member States' activities.

In the past, a list of criteria enshrining this principle has been drawn up on several occasions in different forms, in particular in the Decisions adopting the earlier Framework Programmes. It covers the following aspects:
- the cost and scale of research above and beyond the possibilities of a single country, and the need to assemble a critical mass of financial and human resources;
- the importance in economic terms of working jointly (economies of scale) with beneficial effects on private-sector research and industrial competitiveness as a result;
- the need to combine complementary expertise in the different countries, particularly in the case of interdisciplinary issues, and to carry out comparative studies on a European scale;
- the links with EU priorities and interests and with Community legislation and policies, in particular in the fields of enterprise, the information society, agriculture, environment, energy, transport, health and consumers, employment and social affairs, education, justice and internal affairs, as well as external relations, trade and development;
- the necessarily trans-national nature of the research, given the scale on which the issues arise (environment) or for scientific reasons (comparative studies, epidemiology).

Once the priorities and themes are selected for a given research area, a call-for-proposals is issued by the Commission. Project proposals are then submitted to the EC and evaluated by groups of independent external experts on the basis of the following criteria: Scientific/technological (S/T) quality and innovation (that is: scientific excellence, which remains by far the most important criterion to select or reject a proposal !); European added value and contribution to EU policies; Contribution to Community social objectives; Economic developments and S/T prospects; and finally Resources, partnership and management. Once a project proposal has been selected, it is subject to contract negotiations with the EC, taking into account constraints of the EC budget and recommendations made previously by the independent external evaluators.

In the following Section 10, more information is given about the rationale for selecting priorities in the particular area of reactor safety research under the key action Nuclear Fission. Some
examples also are given of how results of Euratom research under FP-4 had a real impact on the decision making process of regulatory and industry organisations.

10 - The response of European research up to 2002 to the above-discussed “nuclear needs”

Impact of Euratom research on the decision-making process of regulatory bodies, utilities and vendors

10.1 - Regulatory-driven research priorities

Emphasis on safety

Safety authorities in OECD countries have warned that cut-backs in nuclear safety research can have an adverse impact on the ability to fulfil safety responsibilities. Speaking collectively through the Committee on the Safety of Nuclear Installations (CSNI) of the Nuclear Energy Agency (NEA), they are particularly concerned by the shutdown of large research facilities and the break-up of experienced research teams, as funding for government programmes is continuously reduced. The CSNI report /2/ identified in 1996 a total of 13 priority areas for further research, namely: (1) Steam generator and pressure vessel integrity ; (2) Component ageing ; (3) Human factors ; (4) Computer-based control and safety systems ; (5) Validation of fire simulation codes and active fire protection measures ; (6) Extended applications of thermal-hydraulic codes ; (7) Fuel damage limits at high burn-up ; (8) Further development of probabilistic safety analysis tools ; (9) Fission product release in relation to containment leak-tightness ; (10) Better understanding of steam explosions ; (11) Development of models and a data base on core debris coolability ; (12) Hydrogen combustion and mitigation techniques ; and finally (13) the Effects of ageing on containment integrity.

Since the Euratom programme committees are working in close co-operation with CSNI and other international bodies, it is no wonder that some of the above research areas became priorities in the strategy of the Euratom Framework Programmes. For example, 6 out of the 13 priorities of the above CSNI report were selected for Euratom research under FP-4 and FP-5 (namely : numbers 2, 8, 9, 10, 11 and 12). Component ageing (priority 2), in particular, is the main subject of the PLEM cluster. Due to their own priorities (based on a mixture of European regulatory and industry interests - see next sub-Section 10.2), the Euratom committees decided to introduce the 2 following new topics in FP-4 and FP-5 : « severe accident management measures» (e.g. advanced decision support tools - see SAM cluster) and « innovative safety concepts » (e.g. passive decay heat removal systems - see EVOL cluster).

In the particular area of severe accident management, it is well known that designs and operating procedures need to satisfy increasingly stringent rules which, in many countries, are enforced by national regulatory bodies. Research in nuclear safety, thus, has often a strong regulatory component. Worth mentioning here is the central role of the EC co-sponsored programme PHEBUS-FP, managed by IPSN and run at CEA Cadarache, which brings essential contributions to the issues of severe core degradation and source term and thereby enables technical safety organisations to validate numerical prediction tools needed for the development of severe accident management guidance (SAMG) strategies. The link with the relevant Framework Programme activities is ensured through a series of supportive actions, such as the concerted action PHEBEN in FP-4 /4/. Finally, the relationship between organisational factors and reactor safety, which is playing an increasing role in the global plant safety assessment, is investigated in the shared-cost action ORFA in FP-4 /5/.
Talking about real impact of Euratom research, it is worth mentioning here the following study made by an international group of regulatory experts: the concerted action ISARRP in FP-4, aimed at assessing the regulatory decisions taken on the basis of international research (including Euratom research) in the particular area of SAM /6/. For operating plants, for example, there is a general consensus – based amongst others on results of projects in the INV cluster - that no backfits are needed to ensure containment integrity against the alpha (steam explosion) failure mode and that for low power reactors (in particular in Loviisa/Finland) core coolability through in-vessel melt retention is possible in case of severe accident. Passive autocatalytic recombines for hydrogen risk management have been installed in many European NPPs; their installation on the industrial side and their assessment on the regulatory side have benefitted from many research projects - amongst others in the cluster CONT. Revision of radiological source term specifications is underway in many countries: this is based amongst others on results of the international programme PHEBUS-FP in connection with the cluster ST. Probabilistic safety assessment techniques were improved – amongst others in the cluster AMM – especially for beyond design basis events and human factors. For advanced evolutionary plants, containment coolability through melt spreading was investigated and assessed from a regulatory point of view – based amongst others on results of the projects in the EXV cluster.

10.2 – Utilities-driven research priorities

**Emphasis on safety and performance**

Utilities have their own experts circles, such as WANO (World Association of Nuclear Operators) for reactors in operation world-wide. More specifically within Europe, as far as the next generation of reactors is concerned, a very interesting harmonisation effort is underway in the European Utility Requirements (EUR) group /7/. In addition to legitimate commercial interests depending on plant performance, the utilities and the associated services naturally share the same safety concerns as the above-mentioned regulatory bodies. Their research programmes usually contain the following two separate functions : (1) safety and reliability and (2) operability and availability.

**Safety and reliability.** Safety and health requirements are to be satisfied both on an individual and collective level, through on-going improvements in radiological protection (e.g. dose reduction or ALARA programmes). Also needed are a better knowledge of the mechanisms that cause the materials to deteriorate and of the properties of new materials that may be used to replace them, as well as the development of new testing and analysis techniques. The safety and reliability are further increased through advanced interactive information and communication systems, with a rapid response when confronted with an emergency situation. To ensure maximum reliability of the various systems, a safety and quality culture programme has to be implemented throughout the managerial chain within the plant organisation, in close co-operation with other NPPs on a national and/or international scale.

**Operability and availability.** Robotics and automation help improve the operability, for example, by introducing mobile robots into the processes and monitoring process variables in a local and remote real-time manner. In addition, nuclear fuel management should be optimized in terms of burn-up, technical/economic analysis of multi-cycle management of reload batches, back-end of the cycle, storage, sample taking and sample preparation and quality assurance programmes. Finally, the fuel supply should be ensured in the plant, in terms of quality, quantity, safety, price and delivery periods.

Talking about real impact of Euratom research, it is worth mentioning here the following study made by an international group of industry experts (representing both the utilities and the
vendors): the concerted action MICA in FP-4, aimed at assessing technical decisions taken by the industry on the basis of international research (including Euratom research) /8/. For operating plants, for example, improved in-service inspection and repair techniques have been developed using non-destructive testing techniques – based amongst others on results of projects in the AGE cluster. Similarly, improvements of industrial significance were brought to dosimetry and reconstitution techniques qualification to monitor reactor pressure vessel degradation – also investigated in the AGE cluster.

For obvious reasons, Euratom research in reactor safety is inclined to privilege actions related to function (1) of the above list, namely: “safety and reliability”, as this topics fits best the two previously discussed criteria of “public benefit” and “European added value”.

10.3 Vendors-driven research priorities

**Emphasis on safety, performance and innovation**

In order to optimize plant safety and performance, the vendors and designers naturally are interested in innovations in view of the next generation of reactors. In addition to the above-mentioned functions “safety and reliability” and “operability and availability”, their research programmes usually contain the following two separate functions; (1) maintainability and constructability and (2) new materials and economics.

**Maintainability and constructability.** For maintenance purposes, the state of the existing installations and their components should be permanently monitored, with a view to being able to make technical and economic decisions at any time. Advanced maintenance strategies should be developed such as integrated maintenance management systems. Constructability of any new design feature (be it hard- or software) is another important requirement in plant management practice.

**New materials and economics.** New materials with improved features and characteristics should be developed and used, with the aim of saving raw materials and power, thereby making the company become more competitive. In addition, new opportunities and products should be acquired, with a view to improving technological diversification and to optimize the entire fuel cycle. More generally, new technologies should be applied to achieve a greater net power production or to optimize quality, thereby contributing to a better and more rapid response from the power plant to face rapidly changing demands from the electricity system.

Talking about real impact of Euratom research, it is worth mentioning again the concerted action MICA in FP-4, aimed at assessing technical decisions taken by the industry on the basis of international research (including Euratom research) /8/. For advanced evolutionary plants, for example, steam injectors and passive cooling systems (for both the pressure vessel and the containment) were developed – on the basis amongst others of projects in the cluster INNO. For advanced innovative plants, such as high temperature reactors, preliminary conclusions were drawn – in the same cluster INNO - for new materials with high resistance to radiation damage and high temperature conditions and with reduced activation.

For obvious reasons, Euratom research in reactor safety is inclined to privilege actions related to function (2) of the above list, namely: “new materials and economics”, as it is long term oriented, with a view to contribute ultimately to the competitiveness of European industry in general.
10.4 – Indirect and direct actions under Euratom FP-4 and FP-5

Emphasis on safety, performance and innovation to maximise mutual benefit

The three general objectives - reactor safety, plant performance and innovation (from both the technological and the organisational points of view) - are closely associated and any modification of an existing installation or any new concept for advanced reactors, whether evolutionary or innovative, must be thought of in those terms. This fact has led the Commission, in co-operation with the European nuclear regulatory and industry organizations to propose in the nuclear energy field a work programme for FP-5 that is based on a strong partnership of research and industry, aimed at maximising mutual benefit by improving further the safety and competitiveness of nuclear installations in Europe. It is worth stressing here that, besides “hard” research on reactor safety, plant performance and innovative systems, many of the Euratom actions are also touching upon “soft” issues such as public acceptance and sustainability of new concepts. Many of the risk management related research activities are touching upon these “soft” aspects, directly or indirectly. Risk governance (assessment/management/regulation), in particular, is playing an increasing role in the public debate and in the general decision process for future energy policies.

For specific information about the achievements of Euratom FP-4 research in reactor safety, one can consult the proceedings of the already mentioned FISA-99 symposium (EC Luxembourg, 29 November – 1 December 1999 / EUR 19532 - ISBN 92-828-9588-2 – published in April 2000) and reference /9/ for a summary. For general information about national research activities in reactor safety and performance within Europe, one can consult the Joint Safety Research Index (concerted action JSRI in FP-4 and FP-5) /10/.

Here is a very short comparative summary of the three main topics (symbolised by the three acronyms PLEM, SAM and EVOL) treated by the “indirect actions” of Euratom research in reactor safety under both FP-4 and FP-5:

* topic (1) PLEM: ageing of the multiple barriers (especially the structural components) for the confinement of radioactive materials, with emphasis on the prevention of deviations from normal operation and the prediction of margins to failure. Under FP-5, the EU budget spent hitherto for all 16 projects of the cluster PLEM amounts to EURO 9.2 million, which represents approximately half of the total project value – see Table 1. This might be compared to the EU budget spent under FP-4 for all 11 projects of the AGE cluster, which was EURO 2.1 million.

* topic (2) SAM: improvement of the defence-in-depth approach, by introducing a 4th level of defence for the mitigation of severe accident consequences, as it will be required in countries which are "practically" prohibiting large-scale evacuation and long-term land contamination. Under FP-5, the EU budget spent hitherto for all 16 projects of the cluster SAM amounts to EURO 12.8 million, which represents approximately half of the total project value – see Table 2. This might be compared to the EU budget spent under FP-4 for all 45 projects of the clusters INV, EXV, ST, CONT and AMM, which was EURO 27.3 million.

* topic (3) EVOL: development of innovative safety concepts for the next generation of NPPs, aimed at maximising the defence-in-depth, while optimising the cost/benefit ratio and simplifying reactor design and operation. Under FP-5, the EU budget spent hitherto for all 9 projects in the cluster EVOL amounts to EURO 4 million, which represents approximately half of the total project value – see Table 3. This might be compared to the EU budget spent under FP-4 for all 11 projects of the INNO cluster, which was EURO 4.8 million.

Besides the "indirect actions" described previously and co-ordinated by DG Research, it is worth recalling the "direct actions" in nuclear fission carried out by DG Joint Research Centre (5
establishments in 5 countries) under the common Euratom umbrella. The following web site provides useful information about JRC activities: http://www.jrc.cec.eu.int/.

One of the main actions of JRC in reactor safety research consists in operating European networks in the field of structural integrity for nuclear components The network on Ageing Materials Evaluation and Studies (AMES), the European Network for Inspection Qualification (ENIQ) and the Network for Evaluating Structural Components (NESC) each deal with a specific aspect of fitness for service of materials in structural components. These “networks for mutual benefit” have developed co-operative programmes, bringing together several European institutions and organisations including utilities, manufacturers, engineering companies, research and development laboratories, regulatory bodies and the JRC Institute for Advanced Materials (Petten, NL). Of particular interest to both regulatory and industry organisations is the work performed on risk-informed in-service inspection in the concerted action EURIS of FP-4 /11/ in close co-operation with the ENIQ experts (see “handbook of recommended practice for inspection qualification” in http://www.jrc.nl/).

11 - Challenge to Euratom research for beyond 2002

Build the European Research Area (ERA), using the proposed tools (e.g. networks of excellence)

The concept of the European Research Area (ERA) was launched in January 2000 by Research Commissioner Mr. P. BUSQUIN in Communication COM(2000)6, entitled "Towards a European research area" (see http://europa.eu.int/comm/research/area.html). Recently, in October 2000, another Communication, COM(2000)612, was published with the title « Making a reality of the European Research Area : Guidelines for EU research activities (2002-2006) » (same homepage), taking into account the results of the evaluation of the previous Framework Programmes carried out by an Independent Expert Panel as well as the many comments received regarding the first Communication.

Here is an excerpt from COM(2000)6 that indicates the intentions of the Commission for future Community research in general: « In form as in content the Sixth Framework Programme will have to be thoroughly rethought out in the light of the project to develop the European research area. An extra effort must be made on issues that need to be tackled at European level. The methods of operating and assistance with the Framework Programme will also have to be re-examined and new means of action based on greater decentralisation of programme implementation need to be introduced after being studied and tested. ».

The Commission is indeed proposing a radical change of approach for the next (6th) Framework Programme 2002-2006, based on the following principles discussed in COM(2000)612:
- focusing on areas where Community action can provide the greatest possible « European added value » compared with national action
- closed partnership with the Member States, research institutes and companies in Europe by networking the main stakeholders
- greater efficiency by channelling resources to bigger projects of longer duration.

In concrete terms, arrangements of the following types are proposed :
- networking of national research programmes through support for the mutual opening-up of programmes and EU participation in programmes carried out in a co-ordinated fashion;
- creation of European networks of excellence by networking existing capacities in the Member States around « joint programmes of activities »;
- carrying out large targeted research programmes conducted by consortia of companies, universities and research centres on the basis of overall financing plans;
greater backing for regional and national efforts in support of innovation and research conducted by SMEs;
more diversified action in support of research infrastructures of European interest;
increase and diversification of mobility grants not only for EU researchers but also for researchers from third countries;
action to strengthen the social dimension of science, in particular in matters concerning ethics, public awareness of science and giving young people a taste for science.

The Commission is not at this stage proposing priorities for research in Europe. These will be fixed after wide-ranging consultation with the various programme committees and with the main research stakeholders in Europe, in line with the above-discussed criteria of public benefit and European added value (see Section 9). An example of a priority area might be research in support of European policymaking in areas where there are great uncertainties and risks. Other areas of interest could be the development of a sound economy, health protection, environmental protection and/or security against external threats.

In the particular case of Euratom research activities, the Scientific and Technical Committee Euratom (STC – based on Article 134 of the Euratom Treaty) has issued a strategic report in May 2000, proposing some preliminary ideas. Here is an excerpt: “a key R&D objective should be to ensure that future generations have a real selection of available technologies to chose from, when they have to decide on the energy supply systems that would best suit their needs and acceptance criteria” – see http://europa.eu.int/comm/research/pdf/eur19150en.pdf.

This new approach consists to some extent in decentralising Framework Programme research management. It also opens the door of Community research to matters that are basically political or administrative (as opposed to the traditional approach focused on the scientific infrastructure) but that are significantly dependent on technical factors. One of the big challenges (not the least one !) is to convince public and private sponsors to work together, joining their resources (i.e. manpower, experimental installations and funds) to carry out research of mutual interest and of European value. In this new approach, science should become more oriented towards the solution of real policy issues (for instance, policies for industrial safety standards or for disarmament) or at least towards supporting various decision-making processes. This is also widely debated in the current political-scientific discussions about « Science and Governance in the EU », raising in particular a number of new ideas about “risk governance” (assessment/management and regulation) in our societies.

12 - Conclusions

Main achievements of framework programme research hitherto and new stakeholders in European research in the “changing world”

In this overview paper, a series of EU needs in the area of nuclear fission energy have been identified and discussed, namely: to ensure flexibility in energy supply by maintaining the nuclear option open; to contribute to health and safety as well as to non-proliferation by a better co-ordination of European research and training activities, to maintain industrial competitiveness by preparing the next generation of reactors; to maintain broad nuclear expertise for non-energetic applications; to develop sustainable solutions for fuel cycle management and waste disposal (emphasis on front-end issues); to share the same nuclear safety culture amongst the EU and the CEECs; and finally, to improve the impact of Euratom research actions by enhancing their public benefit and their added European value.
It has been shown also how Euratom research has been able hitherto to respond in part to these needs and how things could be further improved. In addition, the benefits of strong co-operation between private (e.g. industrial) and public (e.g. governmental) organisations in the nuclear area have been illustrated by describing some remarkable results obtained from Euratom FP-4 research actions where all nuclear actors were involved. A simple look at the bibliographic references of this report gives an idea of the diversity of organisations and countries that are involved in joint co-operative “indirect” and “direct” Euratom research actions. More information about the current FP-5 Euratom research activities in reactor safety will be given at the FISA-2001 symposium (12-14 November 2001, Brussels or Luxembourg), free of charge and open to all persons interested: the co-ordinators of the current 41 projects of FP-5 will present the state of their project and discuss their views on further developments.

The nuclear industry has reached a mature stage. However, in some aspects, it remains a young industry and many improvements due to technological and organisational progresses are expected in the foreseeable future in the fields of both plant safety and economic competitiveness. Nuclear power also presents unique institutional problems arising from two facts: (1) the public perception of special risks (discussed in this paper), such as nuclear proliferation, severe accidents and high-level wastes, and (2) historical facts, like the original government monopoly in nuclear energy and the complex of international treaties and agreements that have developed in the field. Nowadays the development of nuclear power technologies interacts with public health and safety, the environment, foreign policy and energy security, as well as with the economy. As a result, nuclear programmes are cutting across institutional lines formed traditionally within each EU Member State by ministries, regulatory bodies, industry, electric utilities and research organisations – not to mention the public at large. Moreover, the nuclear programmes are expanding more and more beyond the borders of the EU.

In the framework of this “changing world”, it seems obvious that not only national technical experts and international organisations but also the public at large would like to have their say in the nuclear decision process. Therefore, also a better communication is needed amongst the various circles of (nuclear) experts and the public at large, both within Europe and outside. There is no doubt that this current trend will have an impact on both the contents and the organisation of future Community research, in particular, in the nuclear fission area.

In line with the concept of European Research Area (ERA), Euratom research after FP-5 will be somehow “decentralised” and will count one additional group of stakeholders, as it is tentatively illustrated in the decentralised square picture of Figure 2 hereafter. This will be a real challenge for European research. The decentralised approach is symbolised by the strong links between the four stakeholders on one side and their loose links towards the centre on the other side. The new group of stakeholders, that should take an active part in future Community research programmes, consists of policy makers and opinion leaders. Their priorities are not necessarily of a purely technical nature: they are, for example: human and environmental protection, risk management and communication, etc. The research organisations will be expected again, as in FP-4 and FP-5, to maximise mutual benefit of all stakeholders, while satisfying their own general principles, such as public benefit and European added value in the particular case of Commission co-sponsored research.

New implementation instruments will be proposed for the ERA, in addition to the shared cost and concerted actions of FP-4/FP-5 type, for example: centres of competence, networks of excellence (private/public partnership), sharing of large infrastructures of common interest and greater mobility of researchers and experts.
It is in the interest of the EU countries to let the market take the decisions regarding nuclear power growth and technological advancements, while maintaining for the individual Member States the key role of safety regulatory authority. This does not, however, imply complete private research programmes, in view of the large capital requirements, the technical and economical uncertainties, and historical responsibilities for facilities like uranium enrichment, plutonium reprocessing or waste disposal. Once the discussions about “science and governance” in the EU come to conclusion, Euratom research, in particular, will find its right place amongst the various (inter)national research programmes: it may well change form, as illustrated in Figure 2, but it should anyway continue to play a key role.

In the future, Community research in nuclear fission will continue, in particular, to contribute to offer a response to some of the main concerns raised by the key stakeholders and by the European citizens at large. The task of identifying the new research needs, arising from the present “changing world”, and of programming international research to address the new challenges will require the clear engagement of all actors.

"Helping exploit the full potential of nuclear energy in a sustainable manner", which is the main aim of the current Euratom FP-5, is quite a challenge for now and will remain so in the future. To meet this challenge in the future FP-6, the main actors sharing this aim in the particular field of nuclear fission and radiation protection (i.e. mainly: the regulatory bodies, the utilities and the associated services, the vendors and the designers as well as the research organisations themselves) should propose networks of excellence, bringing together governmental and/or industrial resources with a view to solving problems of mutual interest, thereby making a reality of the European Research Area, in co-operation with the Commission services.

Figure 2 - Role and priorities of the main stakeholders in future Euratom research actions (decentralisation – or networking – of research in the European Research Area)
Table 1: Work programme and main issues of PLEM
Severe Accident Management Research under FP-5 (SAM cluster)

<table>
<thead>
<tr>
<th>Assessment of SA Risk</th>
<th>SAM Measures</th>
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<tr>
<td>Corium</td>
<td>COLOSS ENTHALPY</td>
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<td>Reactor Pressure Vessel</td>
<td>LISSAC</td>
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<td>Source Term</td>
<td>LPP ASTERISM II</td>
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<td>Hydrogen</td>
<td>HYCOM</td>
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<td>By-Pass Sequences</td>
<td>PHEBEN 2</td>
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<tr>
<td>Code Development</td>
<td>EVITA * JSRI *</td>
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</tbody>
</table>

Table 2 – Work programme and main issues of SAM
Evolutionary Safety Concepts

High Burn-up and Mox

Analytical Tools (codes, methodologies)

ASTAR
RMPS
TEMPEST

NACUSP
DEEPSSI

Micromox

Cluster EVOL

Operational Practices and design improvement

Databases

CERTA
EUROFASTNET

* JSRI *

Table 3: Work programme and main issues of EVOL
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6. INTERACTIONS BETWEEN SEVERE ACCIDENT RESEARCH AND THE REGULATORY POSITIONS IN EUROPEAN COUNTRIES (ISARRP), by Raj Sehgal (RIT, Stockholm), S. Chakraborty (SFNSI, Villigen), J. Peltier (IPSN, Fontenay-aux-Roses), J.A. Martin (CSN, Madrid), J. Rohde (GRS, Köln) and A. Hall (HSE, London), FISA-99 symposium


10. JOINT SAFETY RESEARCH INDEX (JSRI), by J. Peltier (IPSN, Fontenay-aux-Roses), G.H. Weimann (FZ Seibersdorf), B. Arien (SCK/CEN, Mol), E. Nonboel (RISOE, Roskilde), T.A. Vanttola (VTT Energy, Espoo), R. Zipper (GRS, Köln), H. Plitz (FZK, Karlsruhe), A. Jones (JRC, Ispra), G. Piolanti (ENEA, Bologna), J. López Jiménez (CIEMAT, Madrid), L. Pettit (SKI, Stockholm), I. Price (Health and Safety Executive, Merseyside), H. Van Rij (NRG, Petten) and P. Hoseman (PSI, Villigen), FISA-99 symposium (NB: in the follow-up project JSRI of FP-5, a number of new organisations from the CEECs are participating, such as CITON in Romania with G. Vladescu, NRI in the Czech Republic with L. Zezula and HUT in Hungary with K. Varga)

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