Gesellschaft für Anlagen-
und Reaktorsicherheit
(GRS) mbH

Assessment of the Situation of Centres of Competence in the Fields of Nuclear Fission and Radiation Protection

Final Report

in co-operation with

Institut de Radio-
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Situation of Centres of Competence in the Fields of Nuclear Fission and Radiation Protection

Final Report

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Table of Contents

Executive Summary

Introduction

An assessment of the present situation concerning centres of competence in the fields of Nuclear Fission and Radiation Protection has been carried out with the intention to draw strategic conclusions as regards further needs in these fields, based on the actual situation and perceived future developments. This study was initiated by the programme committee for the Euratom research and training programme in the field of Nuclear Energy (1998 – 2002).

To carry out this exercise, a Panel of four independent experts had been set up. The Panel had prepared a questionnaire comprising a comprehensive set of questions aiming at the acquisition of the information needed to carry out the assessment exercise. The questionnaire consisted in ten different form sheets and had been put on the Internet in order to ease the access and offer a comfortable way of filling in the form sheets.

Out of 420 organisations invited to participate in the exercise, 293 organisations from EU member states, Central and Eastern European Accession Countries (CEEC) and from Norway and Switzerland, had responded and registered for participation. Finally, 218 organisations have participated in the exercise. In spite of all efforts undertaken, several known main European nuclear research actors from different European countries have not participated in the exercise.

Specific Aspects

a) Establishment (Mapping) of Present Situation

In Europe there is a large number of institutions with top know-how and highly qualified personnel, qualifying these institutions as **Centres of Competence** having a leading role in nuclear competence world-wide. There is also a number of unique experimental facilities, which are well instrumented and operated allowing to cover research needs for current and new nuclear technologies as well as for radiation protection.

It can be stated that the **actual nuclear competence** in Europe is generally consolidated, with sufficient human and technical resources and financial backing to meet existing economically related needs and basic requirements for safe and peaceful utilisation of nuclear energy.

The Exercise results show that a large and topically structured set of **Co-operations and Networks** already exists or is under preparation and represents excellent and sound link-ups of the scientific community with the European Commission bodies. These Networks are considered the key tool of European research area.

The results of the assessment of the Centres of Competence situation provided a unique spectrum of information which convincingly document the **capability of European institutions to ensure a dynamic development** in the activity fields of Nuclear Fission and of Radiation Protection, including their industrial and socio-economic applications.

All data collected via the filled-in Form sheets of the Questionnaire and stored in a **Database System** for evaluation, represent a very comprehensive and important set of information on the situation of competence in the fields of Nuclear Fission and Radiation Protection across Europe allowing the identification of areas of common interests and actions, as well as the identification of organisations for co-operation or for creation of European networks.

b) Needs, Issues, Problems, and Related Recommendations

The **downward trend** in numbers of newly educated specialists in Nuclear Fission and Radiation Protection areas, together with the ageing and not replacing of retired experts, ageing and closing of experimental facilities, decrease of analytical capabilities in nuclear science as well as much reduced funding of R&D in these areas, give rise to serious concerns.

There is also widespread understanding that **European competence** in nuclear technology and radiation protection has to be maintained (also in a decreasing nuclear market in Europe). Both experimental basis and analytical competence are required to solve actual scientific-technical issues and for being prepared in case of emerging urgent new questions in the future. Networks of competence/excellence should be established/reinforced in the European countries, based on test facilities and research activities.

Young scientists and engineers with an adequate education in nuclear disciplines (e.g. reactor physics, nuclear engineering) and radiological sciences are required to replace the experts who will retire in the near future. A nuclear perspective in the medium and long term, attractive research projects, and networks with ambitious research programmes would clearly help to motivate young scientists for research activities in the nuclear fields.

The operation of **training and research reactors** and other nuclear experimental facilities is seen as a prerequisite for maintaining the required competence in the field of nuclear and health physics, nuclear chemistry. A European strategy for the most efficient application of those installations in the medium term and for the construction of new facilities in the long term should be developed.

The production of **radioactive waste** will continue, independently of the evolution of nuclear power production. Research in the field of radioactive waste management and waste disposal is therefore a must in the short medium and long term in Europe.

The drastic reduction of **nuclear sciences oriented chairs** at European Universities is being seen with profound concern. An education system based on a network of European Universities with the aim of granting a degree of a "European Master in Nuclear Engineering" is being proposed. The introduction of a "European Certificate in Health Physics" is being recommended.

With a view to improve **public confidence** in nuclear safety, waste management and disposal, and medical use of radiation, better and open information of the public on the results of research in the fields nuclear energy and radiation protection is requested.

The exercise carried out shows that the creation of the **European Research Area** with intensified networking across Europe, included the Association Countries (CEEC), and the creation of (virtual) Centres of Competence, as proposed by Commissioner P. Busquin, is strongly supported.

The participants in the exercise are missing in most of the European countries a convincing **perspective** for the nuclear power production in the medium and long term.

1 Introduction

Article 6 of the Council Decision of 25 January 1999, adopting a Specific Research and Training Programme (Euratom) in the field of nuclear Energy (1998 to 2002)[1], stipulates that the European Commission (EC) shall be responsible for the implementation of this Specific Programme. For the purposes of implementing this programme the Commission is being assisted by a Consultative Committee, the so-called Consultative Committee Euratom - Fission (CCE-FISSION).

Article 5 (1) of the Council Decision, adopting the Euratom Fifth Framework Programme (1998-2002)[2], provides that the EC should continually and systematically monitor implementation of the framework programmes and their specific programmes with the help of independent qualified experts.

In this context, and with a view to the relevance of present programme's activities, the EC, supported by the Consultative Committee Euratom - Fission (CCE-FISSION), had decided in the first half of 1999:

- to assess the present situation of centres of competence in the fields of nuclear fission and radiological sciences (as being covered in the Euratom FP5 Work Programme by the "Key Action 2 - Nuclear Fission" and "Research and Technological Development Activities of a Generic Nature / Radiological Sciences"), and
- to draw strategic conclusions as regards further needs in this field, based on the actual situation and perceived future developments.

To carry out the assessment exercise, a Panel comprising the following four experts has been set up:

- Dr. Klaus Wolfert (Chairman); "Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH", Garching;
- Prof. Dr. Henri Métivier; "Institut de la Protection et Securité Nucléaire (IRSN)", Paris;
- Dr. Ivo Vasa; "Nuclear Research Institute (NRI)", Prague;
- Dipl.-Ing. Willi Riebold; "International R&D Project Consultancy (IRPC)", Munich.

[1] Council Decision N°1999/175/Euratom (OJ N° L 64, 12.03.1999, p.142)

[2] Council Decision N°1999/64/Euratom (OJ N° L 26, 01.02.1999, p.34)

2 Objectives of the Assessment Exercise

The objectives of the work carried out under the assessment exercise were:

- To establish ("mapping”) the **present situation** of the centres of nuclear competence in the fields of nuclear fission and radiological sciences;
- To establish the **present and future needs** for research, training, industry at large, medical purposes etc.;
- Identifying the **issues and problems** to be addressed in this area in the short, medium and long term;
- Making recommendations for actions by the Member States and the European Commission (concerning FP5 and beyond), taking also into account the new approach described in the Communication on a European Research Area[3] and supported by the Council resolution of 16th June 2000.

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[3] Towards a European Research Area. Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions. January 2000

3 Work Carried Out under the Assessment Exercise

The work carried out encompasses the following four tasks:

a) **Establishment ("mapping") of the present situation** of research in the fields of nuclear fission (reactor safety, reactor development, waste management and disposal, radiation protection (Key Action)) and radiological sciences by describing activities and competencies, installations and facilities, staffing issues, funding sources etc.

   The "mapping" exercise covered EU Member States as well as the Candidate Countries. It encompassed European Universities, research institutions and industry. Existing networks and co-operations across Europe or even the world are also highlighted.

   This part of the study provides, by European Regions (EU, CEEC, "Others" (CH, NO)), a synthesis of useful information for decision-makers concerning important issues linked with the present status of research activities and centres of competence in Europe, such as e.g. expertise and scientific specialisation of research teams, capabilities of existing facilities and installations, possible gaps and shortcomings.

   The establishment of the present situation builds upon existing documentation for nuclear fission (e.g. OECD/NEA etc), and radiation protection and radiological sciences. The main input, however, has been achieved through a targeted questionnaire. This questionnaire was intended to give the respondents the opportunity to provide information covering the present situation of their organisation, present and future needs, issues and problems, and recommendations for actions.

b) **Establishment of present and future needs** of nuclear competence for research, training, industry at large, medical purposes etc.

   A forward-looking approach was adopted, taking into account at least two different possible scenarios for the next 20 years (for example: no change in the use of nuclear energy versus phase-out scenario) as regards nuclear energy in Europe.

c) **Identification of the issues and problems** to be addressed in this area in the short, medium and long term, resulting from the comparison between:

   – the present (and foreseeable) situation of research activities in Europe, and
   – the present and future needs (as described in 3(b)).

d) **Drawing recommendations for actions** to be undertaken by Member States, the European Commission, centres of competence etc., concerning for example:

   – evolution of European research infrastructure,
   – maintenance of nuclear knowledge base in Europe (resources management, training etc.),
   – management of nuclear facilities (networking, sharing of resources etc.),
   – impact on nuclear research programmes.

4 Methods of Work Applied under the Assessment Exercise

4.1 Evaluation of Existing Documents and Reports

Existing reports and other documents provide only a partial insight into the situation of centres of competence, mainly in the field of nuclear fission. Some examples are presented in this section below.

In 1996, the NEA/CSNI Senior Group of Experts on Nuclear Safety Research Capabilities and Facilities identified a number of facilities and programmes that were judged to be important for continuing research needed by the safety community during the coming decade. Their findings have been published in reports on nuclear safety research in [2] and [3]. A follow-up report [4] has been issued

- to address the immanent loss of Facilities and Programmes (FAP), which may be considered to be at risk and which are crucial to nuclear safety research, and
- to recommend actions required.

Strategic recommendations and specific recommendations to near-term actions on facilities and programmes with respect to thermal-hydraulics, severe accidents, as well as to integrity of equipment and structures have been discussed. Longer-term actions have been identified too, covering issues like thermal-hydraulics, fuel and reactor physics, severe accidents, human factors, plant control and monitoring, integrity of plant and structures, seismic analysis, risk assessment, and fire risk assessment.

Descriptions of existing experimental facilities for investigating thermal-hydraulic behaviour of reactor systems have been compiled in three reports [5], [6] and [7].

Valuable information and statements on the preservation of nuclear safety competencies have also been provided in an OECD report published recently [8].

An Evaluation Commission has been convened by the German Federal Minister of Economics and Technology (BMWi) to establish German priorities in the field of nuclear safety and repository research with special regard to tight funding, to establish the medium-term staffing and technical co-operation between the institutions engaged in these fields, to consider the medium-term financial planning, to identify special efforts in the framework of research policy so that scientific skills pertaining to nuclear reactor safety and waste disposal be maintained, and to recommend ways of closer co-operation between the research institutions by establishing a so-called Competence Pool. The results and recommendations of the Evaluation Commission have been published in [9].

The present assessment provides complementary and more comprehensive information than was available until now, on the present situation of competent organisations and their research activities in the fields of "Nuclear Fission" and "Radiation Protection and Radiological Sciences".

4.2 The Questionnaire Forms and Actions

To collect the information needed in a most speedy and efficient way, a targeted questionnaire has been developed and put in a Web site.

The organisations to be invited to participate in the assessment exercise had been identified in a first step, before its launch, by the different Delegations of CCE-FISSION. Based on this input the assessment Panel reviewed in a second step the organisations put forward by the Delegations and complemented the proposals accordingly.

420 organisations from EU Member States, Central and Eastern European Accession Countries (CEEC) and from Norway and Switzerland have finally been invited to participate in the exercise and to fill in the questionnaire electronically.

Out of these 420 organisations, 218 organisations have participated in the exercise. In spite of all efforts undertaken, several known main European nuclear research actors from different European countries have not participated in the exercise. This did, however, not affect seriously the assessment exercise, as the Panel could make up, based on their own expertise, for the important information not directly provided via the questionnaire.

A set of questions has been prepared to gather the information needed to carry out the assessment exercise. To facilitate the answering of these questions and in order to simplify the handling of the questionnaire, the questions have been structured into 6 categories and put on six different form sheets:

Form Sheet 0: General Information on Organisation and Organisational Unit

Form Sheet 1: Experimental Facilities

Form Sheet 2: Particular Features of Experimental Facilities

Form Sheet 3: Experimental and Non-experimental Activities

Form Sheet 4: Particular Features of Experimental and Non-experimental Activities

Form Sheet 5: General Comments of the Participants

Due to inherent technical differences and to different objectives in the two Activity Fields of "Nuclear Fission" (NF) and "Radiation Protection and Radiological Sciences" (RP), two different sets of the Form sheets 1 to 4 have been prepared: **NF1 to 4** for "Nuclear Fission" and **RP1 to 4** for "Radiation Protection and Radiological Sciences".

The resulting ten types of form sheets have been optimised for comfortable electronic filling in.

Significant efforts were undertaken to ensure high security for the filled-in data. This was achieved by assigning unique usernames and passwords to all participants thus allowing each respondent to see only his own filled-in form sheet.

In total, 1742 form sheets have been filled in and submitted under the exercise by a total of 335 organisational units of 218 organisations. All data collected via the filled-in questionnaires and stored in a database system for evaluation, represent a very comprehensive and important set of information on the situation of centres of competence in the fields of nuclear fission and radiation protection across Europe.

4.3 Response to the Assessment Exercise; Evaluation Methods Used

The amount of information obtained through the filling in of the questionnaire was by far more comprehensive than expected at the beginning of the exercise. As a consequence, only a part of the information received could be evaluated in the framework of the present exercise which has concentrated on the overall assessment of the situation of the competence existing in the fields of nuclear fission and radiation protection across Europe. More detailed information is contained in the database.

Two different evaluation procedures have been applied under this exercise:

A **statistical** evaluation of some selected responses of the Technical form sheet sheets aimed at providing a more general overview of the present situation of research activities (Centres of Competence) across European regions (within EU, CEEC and "Others" (CH, NO)). A breakdown of the results down to individual countries within these regions would certainly be highly interesting, but could not be carried out under this exercise. The results of this statistical evaluation is summarised in Annex 1 and presented as bar charts in the "Mapping Diagrams" D-1 to D-13 in Annex 2.

A evaluation of the **text comments** has also been carried out to provide information on "unique experimental facilities", "outstanding expertise" and "present and future networks", as well as on "present and future needs", on "issues and problems to be addressed", and on "recommendations for actions". The results of this evaluation are also presented in Annex 1. More details of these comments are given in Annexes 4 to 7.

The **response to the assessment exercise** was far beyond expectations and the Form sheets have been filled in with considerable effort. However, it should be mentioned that several participants have complained about the too short time available for the filling-in work.

5 Assessment and Recommendations of the Panel Regarding the Situation of Competence in the Fields of Nuclear Fission and Radiation Protection

5.1 Present Situation of Competence in Nuclear Fission and Radiation Protection

Research activities in the field of “"Radiation Protection and Radiological Sciences” originate from the discovery of radioactivity at the end of the 19th century and they are going on since then. They have accompanied the research activities in the field of “"Nuclear Fission” " which are primarily linked to the exploitation of nuclear energy, under development since the discovery of nuclear fission in the late thirties of the 20th century. During the last decades, radiation protection activities have become more and more independent from nuclear applications. They have been concentrating more and more on applications of X-rays or accelerated particles in medicine and on natural irradiation affecting the public, e.g. by cosmic radiation during air transportation, or by telluric irradiation, e.g. from radon.

In Europe there is a large number of institutions with top know-how and highly qualified personnel, qualifying these institutions as Centres of Competence having a leading role in nuclear competence world-wide. There is also a number of unique experimental facilities, which are well instrumented and operated allowing to cover research needs for current and new nuclear technologies as well as for radiation protection,

The present status of competence in “"Nuclear Fission” " and “"Radiation Protection and Radiological Sciences” varies from country to country; it is strongly influenced by different national approaches as regards the future use of nuclear energy. Nevertheless, it can be stated that the actual nuclear competence in Europe is generally consolidated, with sufficient human and technical resources and financial backing to meet existing economically related needs and basic requirements for safe and peaceful utilisation of nuclear energy. Those requirements follow directly from a number of international agreements (e.g. Convention on Nuclear Safety).

In some Candidate Countries however, the situation is more difficult. In these countries the operation of nuclear power plants relied in the past on technical support from foreign vendors and has to be built up there now step-by-step.

As a consequence of cuts in the national research budgets across Europe, experimental installations are going to become closed. Activities directed to improving or developing nuclear application oriented software are going to become drastically reduced.

Therefore, in the short to medium term, nuclear knowledge is increasingly getting lost. In addition, shortages in nuclear competence are caused by

- ageing and retiring of experts;
- not replacing of retired experts;
- diminishing interest of young scientists and engineers in seeking a profession in the nuclear field;
- decreasing nuclear education due to strong reduction of lectures offered at Universities, and to loss of University chairs.

5.2 Assessment and Recommendations of the Panel

In this chapter, the assessments of the Panel regarding the situation of the competence in the fields of Nuclear Fission and Radiation Protection are described in several sub-chapters. The assessments are presented in standard text, and the related recommendations follow in indented paragraphs headed by a dash.. More detailed information is given in Annex 1.

Nuclear perspective and competence preservation

A clear and convincing perspective for nuclear electricity production share in the medium and long term is missing in most of the European countries. Approaches addressing only short-term economic aspects in the definition of nuclear technology related key problems are counterproductive for long-term research in this field in Europe.

Irrespective of current views on future use of nuclear energy in different countries, sufficient knowledge must be available for both industry and regulatory bodies.

Concerns have to be expressed about the preservation of the existing level of competence in the fields of nuclear fission and radiation protection, especially with a view to the wide range of nuclear applications. An appropriate approach for achieving and ensuring this preservation consists in maintaining existing experimental and analytical capabilities, enhancing the young generation's interest in the nuclear field and assuring the necessary quality of the nuclear education offered, securing adequate levels of funding for research and development at national and international levels, and last but not least – improving and demonstrating safety, reliability, environmental sustainability and economical competitiveness of nuclear energy generation.

The downward trend in numbers of newly educated specialists in Nuclear Fission and Radiation Protection areas, together with the ageing and not replacing of retired experts, ageing and closing of experimental facilities, decrease of analytical capabilities in nuclear science as well as much reduced funding of R&D in these areas, give rise to serious concerns. Those concerns regard not only the maintaining of competence and the preservation of a critical mass of knowledge but also (if this trend is going to continue) the capability to preserve all nuclear safety and radiation protection related prerequisites in the necessary scale and quality.

Education & training

Young scientists and engineers with an adequate education in nuclear disciplines (e.g. reactor physics, nuclear engineering) and radiological sciences are required to replace the experts, which will retire in the near future. Scientific-technical expertise must be maintained in all disciplines, which are specific to “"Nuclear Fission” " and “"Radiation Protection and Radiological Sciences”. A nuclear perspective in the medium and long term, attractive research projects, and networks with ambitious research programmes would clearly help to motivate young scientists for research activities in the nuclear fields.

The discrepancy between the actual utilisation of nuclear power and its public and political acceptance, and uncertainties regarding the long-term use of fission reactor technology in many European countries, cause a diminishing interest of young scientists and engineers in seeking a profession in the nuclear field.

– For bringing back the young generation's interest in nuclear professions to past-required levels and for assuring the necessary quality of the related nuclear education requires increases in funding of research and development at national and international levels beyond present levels.

– The European Commission shall draw the attention of the Governments of the EU Member States on the necessity and on their responsibilities to take care of the education and training of people capable of fulfilling, in the future, the operational duties resulting from nuclear energy production, and from radiation protection in nuclear industry as well as in medicine.

The drastic reduction of nuclear sciences oriented chairs at European Universities and the resulting decrease in nuclear education is being seen with profound concern.

– An education system based on a network of European Universities with the aim of granting a degree of "European Master in Nuclear Science" and the introduction of a "European Certificate in Health Physics" should be promoted by the Governments and the EC.

Public confidence

Public confidence in nuclear safety, waste management and disposal, and medical use of radiation is not on an adequate level and needs to be improved. A better and open information of the public on results of research in the fields of nuclear energy and radiation protection is indispensable.

– Development of common approaches and views, and homogenising of safety practices at European level with inclusion of the Candidate Countries may contribute to a strengthening of public confidence.

– Research on the long-term behaviour of radionuclides in different geological environments could contribute significantly to improve public confidence, which is a prerequisite for the licensing of underground repositories as well as of new nuclear power plants.

– In this regard, credibility of scientific expertise in the public and the existing diversity of institutes in the fields of nuclear energy and radiological sciences should be preserved.

Safety of present and future reactors

An adequate experimental basis and sufficient analytical capabilities are indispensable to give answers to actual safety questions and to be prepared for responding to problems emerging in the future, which may originate e. g. from the operation of the current reactors.

– Experimental facilities (e.g. design basis, beyond design basis and severe accident test facilities, and hot cells) have to be maintained to elucidate basic physical phenomena, to give an insight to the interrelation of these processes during accident sequences and to provide the data base required for model and code validation. To optimise the benefit of all the experimental investigations, adequate networks should be established based on test facilities in the European countries.

– Experimental research should not only be concentrated at research centres but also at the Universities where such support can play an important role in the process of young scientists' education.

– Analytical tools and techniques must be maintained and further enhanced taking into account new requirements originating from the application of “"Best Estimate (BE)-Codes” with quantification of uncertainties, used in the licensing process to better quantify safety margins.

– Networks directed towards the development of advanced accident codes should be supported. Such international networks with an ambitious research programme will also contribute to motivate young scientists for research in the nuclear fields.

– Experimental respectively analytical efforts are required in particular regarding
    - ageing of plant components, life extension of plants

  - high burn-up, mixed oxide fuels, increased power level, extension of operating cycle
  - advanced information technologies, instrumentation & control systems,

- Development of advanced PSA methodologies (e.g. dynamic PSA) dealing with combined cost and safety optimisation of plant design and operation is recommended.

- New experimental facilities as well as the development of advanced analytical tools are required in the case of expected long-term nuclear option with the development of new reactors with enhanced inherent safety. Investigations are required in particular for
  - high enrichment, very high burn-up,
  - advanced LWR technology with passive safety features,
  - high temperature gas reactor technology,
  - new fuel cycles and processes.

- The European nuclear knowledge base must be sustained in the short, medium and long term through sufficient public support to nuclear education, training and research.

- The European Commission should actively support the development of a clear and convincing European strategy regarding the medium- and long-term nuclear electricity production.

Some leading and motivating projects at European level with long-term objectives (similar for instance to the US Generation IV Initiative) would be well suited to maintain and develop the European research infrastructure.

Research reactors

Independently of nuclear energy production, the operation of training and research reactors is indispensable to maintain the competence in nuclear science, in particular in nuclear physics and nuclear chemistry, neutron scattering techniques and nuclear analytical techniques, such as neutron activation analysis, which are applied in an increasing degree in medical and health areas, environmental and industrial applications. Co-ordination on a European level regarding the utilisation of existing research and training reactors and the planning of new such facilities is missing and should be arranged.

- A European strategy for the most efficient application of existing training and research reactors in the medium term and for the construction of new facilities in the long term should be developed, taking into account the future needs in nuclear and medical applications.

- Improving the efficiency of the use of training and research reactors can be best achieved by international collaboration and creation of Centres of Competence with the best facilities existing in Europe.

Radioactive Waste

The production of radioactive waste will continue, independently of the evolution of nuclear energy production. Research in the field of radioactive waste management and waste disposal is therefore a must in the medium and long term in Europe. Although conditions (e.g. geological formations) are different in individual countries, there are common points in the R&D related to this problem.

- The establishment of a multinational network with the aim to combine the efforts of underground laboratories as Centres of Competence is strongly recommended.

- Formation of Centres of Competence comprising a number of institutes working on the radio-/geo-chemical issues is highly desirable and would be of great value for the elaboration of a consistent data base, which is of interest to every national waste disposal programme.

Partitioning & transmutation

Partitioning and transmutation represent potential techniques for reducing the amount of long-lived radioactive waste resulting from the application of nuclear technologies and radiological sciences.

– The potential of partitioning and transmutation should be assessed and an appropriate experimental and analytical research programme should be set up.

Radiation Protection

In respect to the field of "Radiation Protection and Radiological Sciences", the following actions are recommended:

– The European Commission shall remind the Governments of the EU Member States on the necessity to keep the diversity of radioprotection institutes with the aim to ensure the credibility of expertise.

– To encourage actions suited for enhancing the confidence of public opinion in activities involving radiation in both areas, nuclear industries and medical applications.

– To encourage the national Health Authorities to maintain centres of specialised medical care for the treatment of severely irradiated workers.

– To maintain the efficient association EURADOS for supporting metrological and dosimetrical laboratories. This could avoid the disappearance of national facilities, which are not sufficiently funded by a national effort in spite of their importance for research, and the implementation of new requirements in radiological protection.

– To initiate programmes such as the FASSET programme for evaluating the effects of radiation on the environment; for marine radio-ecology the European Commission should organise a coherent access to boats for scientists.

– To encourage research activities focussing on genetic susceptibility, genetic instability and genetic predisposition and last but not least, on effects of molecular basics as bystander effects.

– To encourage new programmes for radio-toxicology after chronic internal contamination linked to waste management.

Networks and research

The exercise results show that a large and topically structured set of co-operations and networks already exists or is under preparation and represents excellent and sound link-ups of the scientific community with the European Commission bodies. These networks are considered the key tool of European research area and hence, are essential for the further long-term development of both Nuclear Fission and Radiation Protection Technologies.

– The efforts undertaken by many European organisations to set up new networks and co-operations deserve to being fully supported.

– Networks of competence/excellence should be established/reinforced in the European countries for both test facilities and research activities.

The Panel supports strongly the further development of the European Research Area in the fields of Nuclear Fission and Radiation Protection as well as all efforts by the EC directed towards strengthening the co-operation and networking in Europe including the EU Member States and the Candidate Countries.

- Efficient and flexible mechanisms for establishing, financing and controlling of networks should be created, having in mind also the possibility of a potential participation of organisations e.g. from the USA, Japan and Russia.

Calls for proposals – research management

- Regarding future calls for research proposals, the Panel shares the participants' suggestion that issues not strictly limited to the nuclear field (e.g. Instrumentation & Control, radiological sciences, common strategy for environmental protection), should be opened/extended to beyond the nuclear community with a view to reaching also scientists outside the field of nuclear fission and radiation protection and to achieving a better cross-fertilisation.
- A more lean project management (administrative and organisational) should be established by the EC for EC funded research projects, carrying from the calls for proposals over the selection of projects to be funded through to the assessment of their results.

Database

The database resulting from the present exercise comprises a huge amount of valuable information on experimental facilities, research activities and the related competencies of EU and CEEC organisations in the fields of nuclear fission and radiation protection.

- The results of the Questionnaire database should be further elaborated such as to become easily accessible to all EU Member States and CEEC countries; a web side should be established allowing the identification of areas of common interests and actions, as well as the identification of organisations to be considered for co-operation or creation of European networks.
- The European Commission and the EU Member States should take care of a periodical actualisation of the database generated in the framework of this exercise.

6 Literature

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[7] "Validation Matrix for the Assessment of Thermal-Hydraulic Codes for VVER LOCA and Transients"; NEA/CSNI, R(2001)4, April 2001.

[8] "Assuring Future Nuclear Safety Competencies", OECD, 2001

[9] "Nuclear Reactor Safety and Repository Research in Germany"; January 21, 2000

ANNEX 1: Results of the Evaluation of the Responses to the Questionnaire

1. Exercise Results Regarding the Competence in the Fields of Nuclear Fission and Radiation Protection

We should emphasise that concerns expressed in the Questionnaire regard primarily the preservation of the existing level of competence, especially with a view to the wide range of nuclear applications. The respondents agree on the approach to be followed for addressing future, possibly unfavourable development in this respect.

Nuclear Fission and Radiation Protection related sciences have found application in a number of industrial branches and activities serving to improve the human life quality (for instance – medicine), and it is evident that they in principle will continue to exist. However, it remains questionable which share of human, technical and financial resources will remain available in the medium and long term (exchange of generations); this share will depend, above all, on whether the "nuclear" development strategy or the phase out strategy will prevail in the EU.

The results of the assessment of the Centres of Competence situation are providing a unique spectrum of information which convincingly documents the capability of European institutions to ensure a dynamic development in the activity fields of Nuclear Fission and Radiation Protection, including their industrial and socio-economic applications.

Responses to the Questionnaire for both activity fields - Nuclear Fission (NF) and Radiation Protection (RP) - provide detailed information on the present orientation of the research and development activities and on the intensity of the manpower efforts assigned to individual branches. In addition, information is provided on the funding structure for research activities and facilities, on the topic of international co-operation and on networking, on experimental facilities and other technical and organisational details. Information is also being provided on future trends to be expected in the orientation of nuclear research efforts and their distribution on individual areas and branches.

This chapter illustrates the results of the evaluation of the filled-in Questionnaire either in graphic or tabular form, accompanied by related comments. However, the results of the statistical and textual evaluation performed and presented so far represent only a limited selection of the numerous responses to the Questionnaire. This selection comprises responses which provide a global overview of the present situation of the research facilities and activities ("Centres of Competence") in the two fields "Nuclear Fission" (NF) and "Radiation Protection and Radiological Sciences" (RP).

It should be mentioned in this context, that (1) the ensemble of organisations from the European Regions considered under this exercise does not comprise all major research actors in the fields of Nuclear Fission and Radiation Protection, and (2) the form sheets of the questionnaire have not in all cases been filled in completely, and sometimes also not correctly. As a consequence, the **quantitative results** presented in diagrams D-1 to D-13 (Annex 2) may not be considered as completely and perfectly reflecting the present overall scenario. This did, however, not affect seriously the overall result of the assessment exercise, as the Panel did its best to make up, based on their own knowledge and expertise, for the important information not directly provided via the Questionnaire.

2. Results of the Statistical Analysis

In this chapter the main results will be summarised of a first statistical analysis of the responses for those quantities of the Questionnaire which may be considered as representative within the scope of the present exercise, and which may provide a first insight into the large amount of information collected.

In Annex 2, the results of the statistical analysis – presented in the form of bar charts in the Diagrams D-1 to D-13 - are being commented in some detail, first with respect to "experimental facilities", and then with respect to "experimental and non-experimental activities".

In these bar charts shown in Annex 2, the "independent variable" (X-axis) is listed and described in a separate table next to the graph on the same page. The notion "frequency" in the bar charts, and in the following comments means "number of the quantity" presented as "dependent variable" (e.g. number of experimental facilities).

The results regarding "**experimental facilities**" for "nuclear fission" (NF) and for "radiation protection and radiological sciences" (RP), presented in the Diagrams D-1 to D-7, can be summarised as follows:

- In total, 353 **experimental facilities** (204 for NF, 149 for RP) are operated in Europe; about 3/4 of them (269 = 160 NF + 109 RP) are run within the EU (see D-1).
- NF related experimental **facility types** operated in Europe are primarily used for "material investigations" (D-2.1); of the RP related facilities the majority is used for "radiological metrology" investigations (D-2.2). (Please take notice of the footnote given in Annex 2 regarding the Diagrams D-2.1 and D-4.1).
- **Funding** for the construction, operation and maintenance of the experimental facilities in both fields NF and RP, results to about equal shares of 40 – 50% from public and own/internal sources; industry funding ranges between 10 and 20% only (D-3).
- In "Europe", the total **manpower** (academic and non-academic) assigned to the operation of experimental facilities amounts to about 3.000 men-years/year (my/y) is in the field of NF, and to about 1.400 my/y in the field of RP. In both fields, more than 80% of these manpower efforts are spent within the EU (D-4.1 and 4.2).
- The **dedication** of the experimental facility design to real plant types is most frequently directed towards investigations for "nuclear power plants" in the case of NF related facilities, and towards investigations for "artificial radio-nuclide sources" in the case of RP related facilities (D-5.1 and 5.2).
- The **degree of use** of the facilities in both activity fields, NF and RP, is the highest (50-70%) for research and much less (20-30%) for commercial services (D-6).
- The **orientation** of the research activities performed on the facilities is in either activity field, NF and RP, primarily directed towards "adding value to knowledge" (D-7.1 and 7.2).

The results regarding **"experimental and non-experimental activities"** (in the following called "research activities") in the fields of "nuclear fission" (NF) and of "radiation protection and radiological sciences" (RP), shown in the Diagrams D-8 to D-13, can be summarised as follows:

- **Research activities** in the field of NF are predominantly directed towards the investigation of "system technology and behaviour" (D-8.1), and in the field of RP, they are predominantly directed towards the investigation of "radiation exposure of humans" (D-8.2).
- Of the **nature of research activities** in both fields NF and RP, the single activity performing "operation and safety evaluation" is the most frequent one (D-9.1 and 9.2). Considering all possible combinations of each one of the 4 activities, the combinations of the "code development and validation" activity are prevailing for both fields NF and RP.

- **Funding** of the research activities in both fields NF and RP, is performed primarily (50 – 70%) from public sources; own/internal and industrial funding range between 15 and 30% each (D-10).
- In Europe, a total **manpower** (academic and non-academic) of about 8.300 men-years/year (my/y) is assigned to NF related research activities; the share of the EU is almost 90% (D-11.1). For RP related activities in Europe the total manpower efforts amount only to about 2.400 my/y, with a slightly less big share of 85% for the EU. (D-11.2).
- In Europe, the **dedication** of the research activities to real plant types in the field of NF is to the vast extent (82%) directed towards investigations for "nuclear power plants" (D-12.1), and in the field of RP primarily (31%) towards investigations on "natural radiation" (D-12.2). Of this total frequency of activity dedication in Europe, the EU share amounts to 72% for NF and to 62% for RP.
- The **orientation** of the research activities is primarily directed towards "adding value to knowledge" (D-13.1 and 13.2), similar to the situation for activities performed on facilities (D-7.1 and 7.2).

Interesting **differences** can be stated from the comparison between the two areas "experimental facilities" and "research activities" regarding especially the quantities "manpower", "funding sources" and "dedication":

- The **manpower** effort assigned to "research activities" (D-11) is considerably higher (by a factor 2,8 for NF, and 1,7 for RP) than that assigned to the operation of "experimental facilities" (D-4).
  In the field of NF, there is an apparent discrepancy: the highest manpower allocation is with "nuclear and non-nuclear facilities" as a whole (D-4.1), whereas the highest number of facilities is with those used for "material investigations" (D-2.1).
  In the field of RP, the by far highest manpower effort is allocated to facilities for investigating "environmental transfer of radioactive substances" (D-4.2), whereas the number of facilities is highest for "radionuclide metrology" (D-2.2).
- For "research activities", the **funding** occurs primarily (50-70%) from public sources. For "experimental facilities", industry funding is surprisingly low (10-20%) compared to the almost equal share of 40-50% for each, public and own/internal sources.
- In the field of NF, the frequency for the **dedication** of "facility design" (D-5.1) and of "research activities" (D-12.1) is in good agreement.
  In the field of RP however, the facility design is primarily dedicated to the investigation of "artificial radio-nuclide sources" (D-5.2), whereas the "research activities" are primarily dedicated to investigating "natural radiation" (D-12.2).

More details are presented in Annex 2.

3. Results of the Textual Evaluation

3.1 Unique Research Facilities

3.1.1 Unique Facilities for Nuclear Fission

The question on "Unique or outstanding design or performance features of experimental facilities" (Form sheet NF1) as well as on "Unique facility(ies)/capabilities for being or becoming considered a Centre of Competence" (Form sheet NF2) has been answered by listing specific features of available experimental facilities. The information provided was, however, not homogeneous and complete. Facilities listed cover research reactors, facilities for two-phase flow investigations, for full scale thermal-hydraulic testing of BWR fuel assemblies, for investigating dynamic loads within pressure vessels, passive containment cooling, aerosol behaviour, for non-destructive testing, for investigating waste disposal in deep geological formations, nuclear chemistry, for radioactivity measurements, etc.

Details regarding unique facilities for nuclear fission could be found in the database of the questionnaire.

3.1.2 Unique Facilities for Radiation Protection and Radiological Sciences

Answers in the Questionnaire show many "unique" facilities for Radiation Protection and Radiological Sciences. However, based on own judgement, only the following ones qualify as unique facilities: laboratories for the calibration of measurement devices for different sorts of ionising radiation or radon (in Germany and France), ion accelerators (in Germany and Italy), chambers for inhalation of aerosols, facilities for neutron irradiation and calibration (CEZANNE, SILENE in France). These facilities have to be exempted from cuts in national research budgets.

Facilities, which allow studying the impact of chronic exposures at low levels of radiation in different parts of the environment, are very important. This issue has been brought up by the media in the public debate, and addresses the protection of the environment against radiation. For these activities, controlled greenhouses in hot cells permitting studies of transfer of radionuclides are scarce in Europe and should be preserved too.

3.2 Unique Performance of Activities / Tasks, and / or Unique Expertise / capabilities

3.2.1 Unique Performance of Nuclear Fission Related Activities / Tasks and / or Unique Nuclear Fission Related Expertise / Capabilities

The question on whether the "performance of activities/tasks reveals unique characteristics" had to be answered on Form sheet NF3. The questions on whether there exist "unique expertise/capabilities qualifying activities for being or becoming considered a centre of competence (C. o. C.), or part of centre of competence within a network", and on the related "justification" had to be answered on Form sheet NF4. The majority of respondents gave general information about their main activities, specialisation and expertise of their organisations. As a consequence, these answers cover a broad spectrum. Any selection or highlighting of unique activities/tasks/expertise/capabilities in different organisations would be arbitrary and difficult to defend. Details of the answers on these uniqueness aspects as well as information about the "European added value of activities" could be found in the database of the questionnaire.

In broad terms, most answers to "unique performance of activities/tasks" are addressing the fields system technology and behaviour, fundamental investigations, component technology and behaviour, material technology and behaviour, reactor core technology and behaviour, and risk. The highest numbers of responses as regards "unique expertise/capabilities" were made in connection with: system technology and behaviour, waste, material technology and behaviour, risk, fundamental investigations, and decommissioning of nuclear plants and facilities.

Figure D-14.1 in Annex 3 shows the distribution of the answers given to the two above-mentioned questions in relation to the different fields of specialisation.

3.2.2 Unique Performance of Radiation Protection Related Activities/Tasks, and/or Unique Radiation Protection Related Expertise/Capabilities

Almost all respondents presented detailed answers concerning the outstanding activities of their laboratories. To summarise the answers, categorise and evaluate them and draw useful conclusions turns out to be a rather complex task. The term "outstanding activity" is understood differently from the individual respondents. Some of them pointed to the availability of a specific instrumentation (whole body counters, neutron spectrometers, mobile radiological laboratories etc.), others mentioned personal skills (knowledge of languages or teaching capabilities). Among the answers were also some more exotic or only locally important and applicable topics (behaviour of alpine ecosystem, the group Radiation Ecology of Nord-Cotentin although it is considered by NEA/CRPPH as a laboratory activity for stakeholders involvement). Some other respondents indicated as an "outstanding activity" rather routine work (the use of etched track detectors; spectrometers of gamma radiation; tritium measurements; environmental monitoring programmes). The information gathered and compiled under this exercise may be utilised in the future for elaborating revised and verified data that could be useful for extending bilateral or multilateral contacts and for organising networks with broad participation.

For the purpose of the evaluation of the Questionnaire it is, however, important to identify areas of strategic significance and to identify the laboratories or group of laboratories, which cover these areas. Most important in this context are areas in which unique opportunities for research exist, which might disappear in the future.

Typical and important examples in this respect are studies on *radon exposure and its late effects*, especially epidemiological investigations of uranium miners that include the groups exposed in the past. There exists a co-ordinated research programme with the participation of European laboratories from EU and CEEC. Considerable effort is devoted in this context also to improving the dosimetric methods used with emphasis on retrospective dosimetry.

In the last years, the ongoing studies of radon exposure have been extended to cover also the exposure of man in buildings. In many countries, both in EU and CEEC, houses are being monitored to identify those in which inhabitants are most exposed to radon, and a number of laboratories have developed significant expertise in dealing with the complex behaviour of radon and radon decay products in indoor environments. These studies are being complemented by epidemiological research programmes in Europe, trying to evaluate the impact of radon exposure in buildings. The ongoing efforts to improve and specify standards for the protection of workers and the public and to develop effective countermeasures is another important activity complementary to the before-mentioned studies.

Another category of "outstanding activities" seems to be the *experimental investigations of the biological effects of ionising radiation.* These studies are important because they could contribute in a longer perspective to verify or falsify the linear threshold hypothesis, which is the key for today's enacted radiation protection measures. The competent authorities in Europe should be aware of the necessity to preserve basic research in this field, even if the research boom of the sixties and seventies in this domain is over. It should be appreciated that small research groups are still continuing this work. The European Commission should support studies of biological effects of radiation through internal contamination at low dose and low dose rate that address public exposure to natural radionuclides or radionuclides released either during routine operation of nuclear facilities or in the context of waste management and disposal.

A lot of work remains still to be done with regard to *emergency preparedness and related topics.* Many institutions and laboratories in Europe are involved in investigating particular facets of this issue. These investigations are closely linked to studies on nuclear fission and reactor safety, and are e.g. related to the modelling of the consequences of nuclear accidents. Other laboratories in Europe deal with the environmental transfer of the radioactive material, develop software for estimating consequences of nuclear emergencies or are investigating and setting up decision support systems or are oriented towards elucidating the role of the human factor in radiation safety. Problems related to the medical handling of radiation accidents are dealt with also in a few European countries.

3.3 Existing Research Co-operations and Networks

Research networks and co-operations exist normally only over limited periods of time. Reasons behind this are quite often time limited funding and clarification of the underlying scientific and technological issues.

3.3.1 Existing Research Co-operations and Networks in the Field of Nuclear Fission

To ease the task of the respondents to answer correctly the questions on co-operations and networking, a definition of the two notions was given. **Co-operation** has been defined as being a bi- or multilateral agreement, not necessarily contractual, to co-operate on a formal basis with the aim to exchange scientific information and/or results. Scientific **networking** has been defined as a bi- or multilateral contractual agreement to co-operate on a formal basis with the aim to share work and costs, to better use synergies (instruments and resources) and to avoid unnecessary duplication, by using new interactive communication tools. The responses received did, however, not always respect these definitions.

As regards networks between experimental facilities, only the following ones have been identified: ECOSTAR (**E**x-vessel **CO**re melt **ST**abilisation **R**esearch), the EUI (**EU I**nterlaboratory radiochemical analysis comparison on primary waste flux), and ENTRAP (**E**uropean **N**etwork of **T**esting facilities for the quality checking of **RA**dioactive waste **P**ackages). All three are being funded under the 5th Euratom Framework Programme.

Approximately 100 projects related to co-operations and networks were formulated in 14 activity areas, predominantly for "system technology and behaviour", "material technology and behaviour", "component technology and behaviour", "waste" and "fundamental investigations".

The frequency of nuclear fission research activities is shown in Diagram D-8.1 (Annex 2); the corresponding manpower for nuclear fission research activity areas is shown in Diagram D-11.1 (Annex 2).

3.3.2 Existing Research Co-operations and Networks in the Field of Radiation Protection

Many international co-operations exist already between different laboratories in the field of radiation protection, but other potentially interested laboratories do not generally know about their existence. Therefore, the database established under this exercise should be used in the future as a tool to make the existence of these co-operations and networks widely known and to extend them to other European partners and laboratories.

A good example in this respect is the work on *radon exposure and on its late effects*. Very important are in this respect the epidemiological investigations of uranium miners that include the groups exposed in the past. There exists a co-ordinated research programme with participation of NRPI in the Czech Republic, IRSN in France, GSF in Germany and others. A considerable effort is being devoted in this context to the improvement of the dosimetric methods with emphasis on retrospective dosimetry. In the last years, the ongoing studies of radon exposure have been extended to cover also the exposure of man in buildings. In many European countries, houses are being monitored to identify those in which inhabitants are being exposed most to radon, and a number of laboratories have developed significant expertise in dealing with the complex behaviour of radon and radon decay products in indoor environments (for example SCK-CEN in Belgium). These studies are being completed by epidemiological research programmes, trying to evaluate the impact of radon exposure in buildings (e.g. STUK in Finland and NRPI in the Czech Republic). The ongoing efforts to improve and specify standards for the protection of workers and the public and to develop effective countermeasures is another important activity complementary to the before-mentioned studies.

Another example is the work related to radiation effects on the environment.

The existing international networks described by the participants under this assessment exercise have mainly the following roots:

- The research projects funded under the 4th and 5th Euratom Framework Programmes;
- The three associations funded by the European Commission: EURADOS, EULEP and IUR, with more emphasis for the two first associations, and
- Bilateral agreements between Members States. These agreements constitute very often the hard core of future networks.

The frequency of radio-protection activity areas is presented in Diagram D-8.2 (Annex 2). The larger share belongs to the activities on "radiation exposure of humans", "environmental transfer of radioactive substances", "characterisation of irradiation by natural sources" and "emergency preparedness". The corresponding manpower allocation is presented in Diagram D-11.2 (Annex 2).

3.4 Present and Future Needs, Issues and Problems

Overall, the Panel and the participants in the exercise underline that meeting the present needs constitutes a prerequisite for meeting the future needs. Preservation and further development of competence in the fields of Nuclear Fission and Radiation Protection are indispensable for ensuring the conditions required for the safe and efficient operation of existing nuclear power plants and facilities. Young scientists and engineers with an adequate education in nuclear disciplines (e.g. reactor physics, nuclear engineering) and radiological sciences are required to replace the experts who will retire in the near future. To achieve this, a convincing nuclear perspective in the long term and attractive research projects are needed.

There is also widespread consensus amongst the participants that more flexible mechanisms should be found than in the past for setting up, financing and controlling of networks at European level. In this context, the possibility should be foreseen to accept in cases of mutual interest also the participation of important organisations from other countries, such as USA, Canada, Japan, Korea, Russia, etc.

3.4.1 Needs not Exclusively Dependent on the Nuclear Electricity Production

At present, radiological and to some extent also nuclear energy related sciences and technologies have already gained an important position in many **non-energy areas**, such as medicine or mechanical engineering. Therefore, their development depends in many respects not only on the actual development of nuclear energy production itself (if we disregard the synergy effects). This holds in particular for research in the fields of "Radiation Protection and Radiological Sciences", "Waste Management and Deposition" and "Training and Research Reactors".

Obviously, the same is true in the other direction: the development in the fields of Nuclear Fission and Radiation Protection is being greatly stimulated by the developments in other fields like Engineering, Instrumentation and Control and Microbiology.

3.4.1.1 Radiation Protection and Radiological Sciences

Many areas of radiation protection are independent of nuclear applications, and an increasing interest is given to medical application of X-rays, accelerated particles in medicine, and natural irradiation affecting the public, e.g. by cosmic radiation during air travel or telluric irradiation by radon.

A more detailed list of the research needs in the fields of Radiation Protection and Radiological Sciences can be found in Annex 6.

3.4.1.2 Waste Management and Disposal

Radioactive waste has already been produced in significant quantities. The rate of increase depends strongly on the evolution of nuclear power production.

The needs in R&D in this field, as put forward by the participants in the exercise can be summarised as follows:

- Minimisation of radioactive waste production, safety of waste processing and safety of waste and spent fuel disposal.
- Safety criteria for long-term disposal and behaviour of engineering and natural barriers of the waste repositories.
- Development of nuclear power technologies generating less long-lived radioactive waste.

A more detailed list of the research needs in the fields of Waste Management and Disposal can be found in Annex 5.

3.4.1.3 Training and Research Reactors

Independently of nuclear energy production, competence in nuclear science is needed for medical and industrial purposes as well as for research on nuclear interactions.

Many participants in the assessment exercise have underlined that the operation of research reactors is a prerequisite for maintaining in Europe the required competence in fields like:

- nuclear physics and nuclear chemistry;
- neutron scattering techniques;
- isotope production for medical, industrial and research applications;
- performance of materials under irradiation conditions and irradiation-induced modifications of their properties;
- nuclear analytical techniques, such as neutron activation analysis, which are applied in an increasing degree in medical and health areas, environmental and industrial applications;
- nuclear interactions and transmutations, methods of the corresponding measurements;
- neutron radiography for material research.

The expertise in these fields has to be maintained and new ideas on instrumentation and applications have to be developed.

Improving the efficiency of the use of training and research reactors can be achieved at best by international collaboration and creation of Centres of Competence with the best existing facilities in Europe.

3.4.2 Needs Originating from Nuclear Electricity Production, Independent of the Nuclear Electricity Share Scenario

Regardless of a supposed future decrease or increase of the "nuclear electricity production share" in Europe, it is vital to preserve all activities and professions connected with the safe and efficient operation of nuclear power plants, fresh fuel manufacturing, spent fuel reprocessing or fuel disposal, and radioactive waste disposal. In respect to maintaining safe nuclear electricity production, the technical and organisational needs for present and future research, industry, medical and biological purposes, education, decision-making, etc., as identified by the participants in the exercise, are being summarised below.

The following general needs have been put forward by the participants:

- Even in case of a supposed decrease in nuclear electricity production in Europe, the competence in nuclear technology and nuclear safety has to be maintained over the next decades. Taking into account the resulting decreasing perspectives for young scientists and engineers in this field, particular efforts would be needed to still attract a sufficient number of them to the nuclear field.
- The experimental basis in the field of reactor technology and reactor safety (nuclear facilities, non-nuclear facilities, hot cells) has to be maintained; it is required to solve actual scientific-technical issues and for being prepared in the case of new questions which may emerge in the future. Networks, based on test facilities in the European countries, have to be established.
- Concentration of efforts on the support of experimental research not only at research centres but also at the Universities where such support can play an important role in the process of young specialists' education.
- To maintain the analytical competence in Europe, networks directed to the development of advanced accident codes should be supported. Such international networks with an ambitious research programme will contribute to motivate young scientists for research in the nuclear fields.
- In the EU's co-ordinated research, more space should be dedicated to the topics related to safety of reactors operated in the candidate countries, i.e. VVERs and to some extent also CANDU (under construction in Romania).

A more detailed list of specific research needs can be found in Annex 4.

3.4.3 Additional Needs in the Case of "Growth of the Nuclear Electricity Production Share" Scenario

In the mind of the participants, a future increase in the production of nuclear electricity may not be achieved without the development of new, advanced nuclear power plant concepts, which would meet future more stringent requirements as regards inherent safety, reliability, high-level radioactive waste reduction and socio-economic competitiveness (compared with other energy sources). Assuming that nuclear fission will be utilised in the long term to produce electricity, increased research efforts would have to be made today, comprising amongst other things the setting-up of new experimental facilities as well as the development of advanced analytical tools.

Projects that would be required in this context and that have been put forward by the participants in the assessment exercise were related to:

- MOX fuel and very high fuel burn-up.
- Advanced LWR technology.
- High temperature gas cooled reactor technology.
- Lead-bismuth cooled reactor technology.
- Fast breeder reactor technology.
- New (reactor) concepts with reduced production of high-level waste (ADTT – molten salt systems).
- Closed fuel cycles based on thorium or plutonium fed reactors.

3.4.4 Education and Training

Some of the participants underlined specific needs in education and training in connection with radiation protection. Generally, a concern was expressed about declining numbers of students in nuclear branches, and about the possible loss of highly qualified teachers (no or nearly no replacement of the retiring generation). The individual issues most frequently stressed were:

- The greatest concern expressed in this exercise is related - irrespectively of any supposed future nuclear energy scenario – to the clearly visible decrease in interest in nuclear engineering (and supporting technical areas) education which is to be considered an alarming sign. The necessity to replace also in the future retiring nuclear specialists has been underlined by respondents from all over Europe.
- To ensure continuity of nuclear research, significant and unique experimental facilities and capabilities to operate them should be preserved. One way to achieve this could be increased EC support for their utilisation within international co-operations and networks.
- Besides relying on the national governments and international organisations, it is necessary to find ways for increasing the financial involvement of the nuclear industry in the nuclear education process.
- Nuclear branches may become attractive for the young generation again only if there will be a reliable and sustainable basis for financial support to Universities and research centres.
- Efficient education and training is impossible without qualified teachers with sound professional background.

3.4.5 Strengthening of Public Confidence

The general impression among the participants seems to be that until now this issue has not been a priority, neither for the general public, nor for the decision-making bodies. To strengthen the public confidence it is essential that information on the effects of radiation on human health and on the environment is provided to the general public in understandable form by trustworthy authorities. Misunderstanding of possible biological effects of radiation could bias the public opinion against nuclear energy and its applications. Participants emphasised the need to co-operate at international level to create a demonstrable and understandable basis of information and arguments which would be suited to support the "nuclear energy” option as a principal instrument capable to meet world-wide increasing energy demands over the next fifty years to come. Additional points mentioned in this context were:

- For increasing public confidence in nuclear safety, waste management and waste disposal, for informing better and in a transparent way on nuclear matters and for developing even safer new plant designs, ongoing nuclear research activities and new research results are required. Homogenising of safety strategies across Europe should be aimed at, too.
- To intensify research on the safety of existing reactors with the aim to ensure their reliable, qualified and cost effective operation, is being seen at present a prerequisite for gaining public acceptance of nuclear energy in Europe.
- Research on the long-term behaviour of radionuclides in the geological environment may be one of the possible options to improve public confidence, which is required for the licensing of underground repositories as well as for public acceptance of nuclear energy as such.

3.5 Considered New Activities

3.5.1 Considered New Nuclear Fission Activities

Some answers to the question regarding new activities in the field of nuclear fission are the continuation of former actions. Most respondents did not answer here in case of continuation of their activities. Some new activities are given in the field of accelerator driven systems (ADS) and transmutation. Surprisingly, only a limited number of new activities with regard to future reactor concepts were mentioned. Identification, assessment, and development of new nuclear energy systems are the aim of the "U.S. Department of Energy Generation IV Initiative”.

A detailed list of considered new work, as described by the respondents is given in Annex 4.

3.5.2 Considered New Radiation Protection Activities

The table in Annex 6 gives an overview of the considered new activities in the field of radiation protection as described by the participants. It clearly appears that there is a continuous shifting of activities from radiological protection to radiological sciences and more and more to a pure medical research. This shift has to be controlled, but it seems that a part of fundamental research projects could attract some new young scientists in the field of radiological sciences and radiation protection of tomorrow. In this context, the European Commission should seriously check the whole objective of the new Euratom Framework Programme (2002-2006) with a view to the preparation of a new generation of radiation protection specialists because the Member States are expecting this from activities laid out in the Euratom Treaty.

Some considered new activities are a continuation of previous actions, others are genuinely new ones like research on bio-accumulation which should be encouraged, because it is linked to the problems of chronic contamination of humans and environment, that are not well appreciated to day. Unfortunately, many of new activities described by the participants are only new for their own laboratories.

The Panel has realised, that interest in decontamination seems to be going down, and warns that under this trend no more experts would be available in this field in 5 to 10 years from now. Moreover, the Panel has observed that research on novel treatment of irradiated people is not adequately covered in the different European countries. This could lead to difficult situations not only in the nuclear, but also in the medical field where irradiation accidents cannot be excluded. Recently, there have been three occurrences of this kind in the world, one in Europe (Saragossa, ES).

New projects are rare. One is devoted to the problem of bio-accumulation, which constitutes a specific problem regarding the "disposal of nuclear waste", in spite of the general assumption made by several laboratories that "waste management" is the critical point of the nuclear energy.

Some new other projects, like the one on the synthesis of molecules for nuclear medicine, would fall outside of the new Euratom Framework Programme and have to be shifted to other programmes. For listing the proposed new activities, the same structure has been used as for the description of the present activities. The Panel has noted that eight intended new projects address the issue of environmental transfer of radioactive substances, in spite of the ongoing activities in this field since the beginning of the radiation protection programmes. But only one proposal is being considered to address the new issue of radiation effects on environmental ecosystems. The European Commission has, however, already launched the FASSET project in this field. Another major issue for future work could be radiological risk management applied to contaminated sites and territories. It would be necessary to attract new experts to this field of socio-economic relevance. A detailed list of future activities in the field of radiation protection, considered by the participants in the exercise can be found in Annex 6.

3.6 Considered Networks

3.6.1 Considered Networks for Nuclear Fission "Experimental Facilities" and "Experimental and Non-experimental Activities"

A significant number of participants have answered the questions on planned networking activities in the field of nuclear fission. Even if all possible fields of co-operation seem to be covered, the answers show, nevertheless, the following two trends:

Networking activities regarding activities linked to specific and narrow issues like source terms seem to be limited in scope and number.

- Networking activities aiming at more fundamental and broader issues like "system technology and behaviour in general", "waste issues" and "fundamental investigations" seem to be more attractive to researchers.

The TACIS and PHARE Programmes have initiated networking with Central European and Eastern European Countries (CEEC countries) and with the countries of the former Soviet Union, and INTAS has clearly also contributed to insert a co-operative working style in European laboratories.

Annex 4 and 5 shows the considered networking activities in the field of Nuclear Fission.

3.6.2 Considered Networks for Radiation Protection "Experimental Facilities" and "Experimental and Non-experimental Activities"

The intention to participate in European networks is obviously strong in the field of Radiation Protection. This is possibly the result of the actual and previous Euratom Framework Programmes under which only multi-national research with a strong European added value are being or have been funded. As in the case of nuclear fission, the TACIS and PHARE Programmes have initiated networking with Central European and Eastern European Countries (CEEC countries) and with the countries of the former Soviet Union, and INTAS has clearly also contributed to insert a co-operative working style in European laboratories.

In Europe, some associations sponsored at European level have played an important role for networking: EULEP, EURADOS and IUR. It is obvious that EURADOS is a model of a European network, EULEP doesn't seem very efficient actually, and the role of IUR needs to be revisited.

Annex 6 shows the considered networking activities in the field of Radiation Protection.

3.7 Recommendations for Actions

In the context of this assessment exercise, the majority of the participants have made use of the opportunity offered to them to make recommendations as regards for example the evolution of the European research infrastructure, the maintenance of the nuclear knowledge base in Europe or the management of nuclear research facilities in Europe. Even if some of the recommendations go beyond the scope of this exercise, they give in their totality a quite good impression into which directions the thinking is actually evolving in the research community in the fields of Nuclear Fission and Radiation Protection.

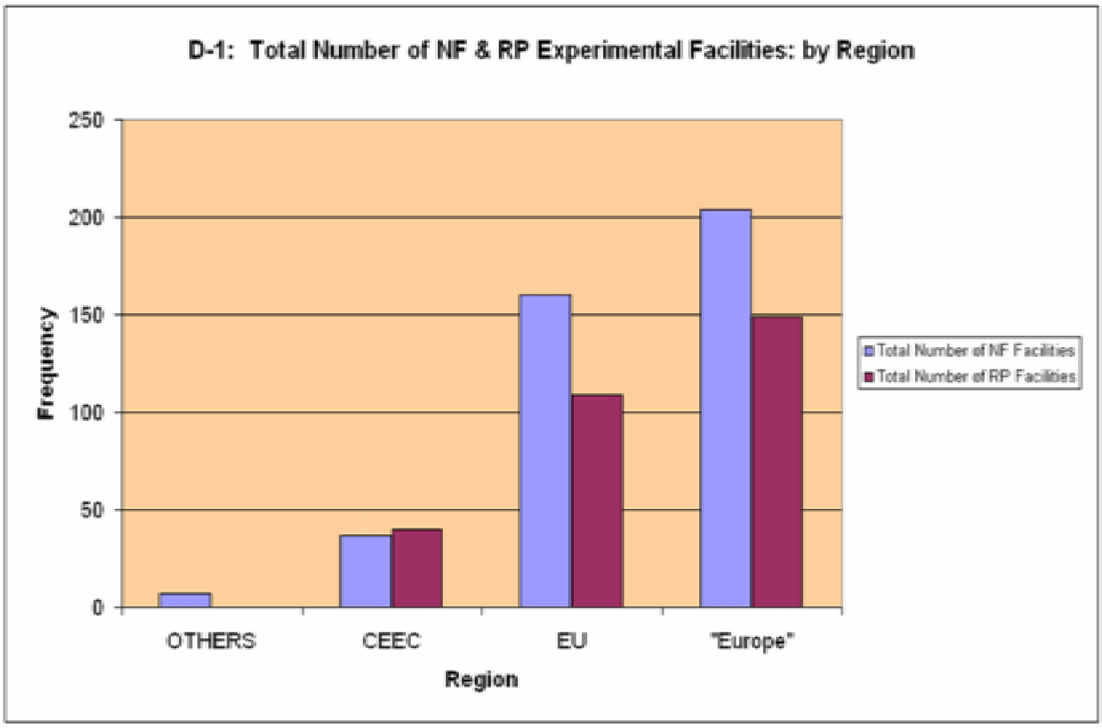
The recommendations made are listed in Annex 7, according to the three categories:

- Recommendations for actions to be taken by the European Commission;
- Recommendations for actions to be taken by the European Countries;
- Recommendations for actions to be taken in common by European Countries and the European Commission.

The recommendations cover practically all important aspects of research, education, training and maintenance of competence in and around the nuclear field.

ANNEX 2: Diagrammatic presentation of results with Specific Comments (Diagrams D-1 to D-13.2)

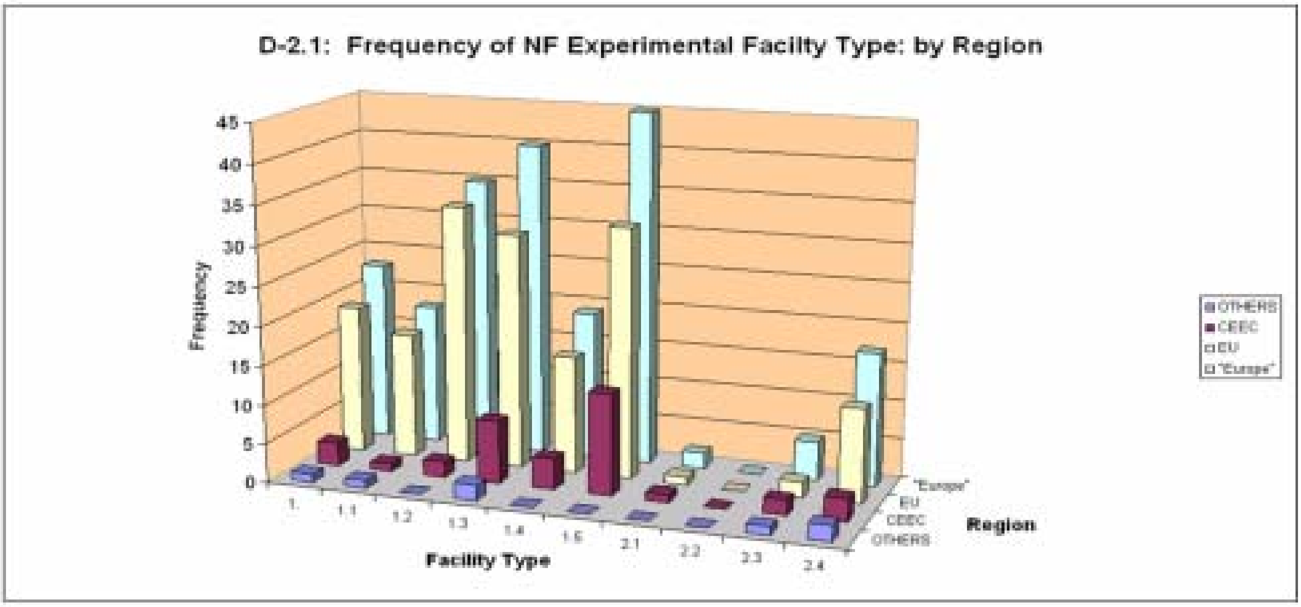
Region	OTHERS	CEEC	EU	"Europe"
Total Number of NF Facilities	7	37	160	204
Total Number of RP Facilities	0	40	109	149
Sum	7	77	269	353



Frequency of **NF & RP** Experimental Facilities: **D-1**

- the total number of experimental facilities in all three European Regions considered (EU, CEEC and Others; in this report referred to as "Europe") amounts to about 350, of which
- the majority of 270 (77%) is located in the EU;
- more than half of them - 204 or 58% - are NF related facilities, and 149 or 42% are RP related facilities,
- within "Europe" as well as within the EU, the ratio between the number of NF and of RP facilities amounts to about 1,5, whereas for the CEEC this ratio is close to 1.

Region	1.	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	Sum
OTHERS	1	1	0	2	0	0	0	0	1	2	7
CEEC	3	1	2	8	4	13	1	0	2	3	37
EU	19	16	33	30	15	32	1	0	2	12	160
"Europe"	23	18	35	40	19	45	2	0	5	17	204

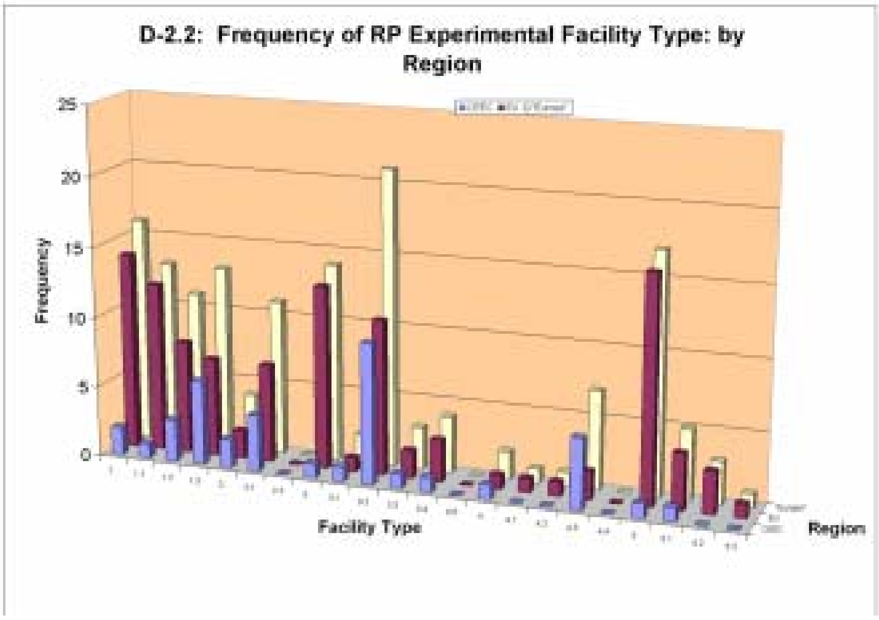


Facility Type	
1. Nuclear & Non-nuclear Experimental Facilities	**2. Nuclear Facility**
1.1 Plant System Investigation - Nucl. & Non-nucl. Fac.	2.1 Medical Investigation - Nuclear Facility
1.2 Plant Component Investig. - Nucl. & Non-nucl. Fac.	2.2 Biological Investigation - Nuclear Facility
1.3 Physic. Phenomena Investig. - Nucl. & Non-nucl. Fac.	2.3 Critical Experiments - Nuclear Facility
1.4 Phys./Chem. Property Investig. - Nu. & Non-nu. Fac.	2.4 Hot Laboratory - Nuclear Facility
1.5 Material Investigation - Nucl. & Non-nucl. Fac.	

- Frequency of **NF** Experimental Facility Types [4] **D-2.1**
  - the 10 different (experimental) facility types are listed in the table next to the graph in D-2.1,
  - among the various facility types, facilities for "Material Investigations (1.5)" represent the majority, followed by facilities for "Physical Phenomena Investigations (1.3)" and "Plant Component Investigations (1.2)";
  - the number of NF-related "Hot Laboratories (2.4)" is remarkably high;
  - apparently, no facilities exist for NF related "Biological Investigations (2.2)", and only 2 for NF related "Medical Investigations (2.1)".

[4] For the facility types 1.1 to 1.5 in the diagrams D-2.1 and D-4.1, the responses for the frequency of nuclear and of non-nuclear facilities have been summed up because evidently the respondents have interpreted the notions nuclear facility and non-nuclear facility in a different and hence, not consistent way.

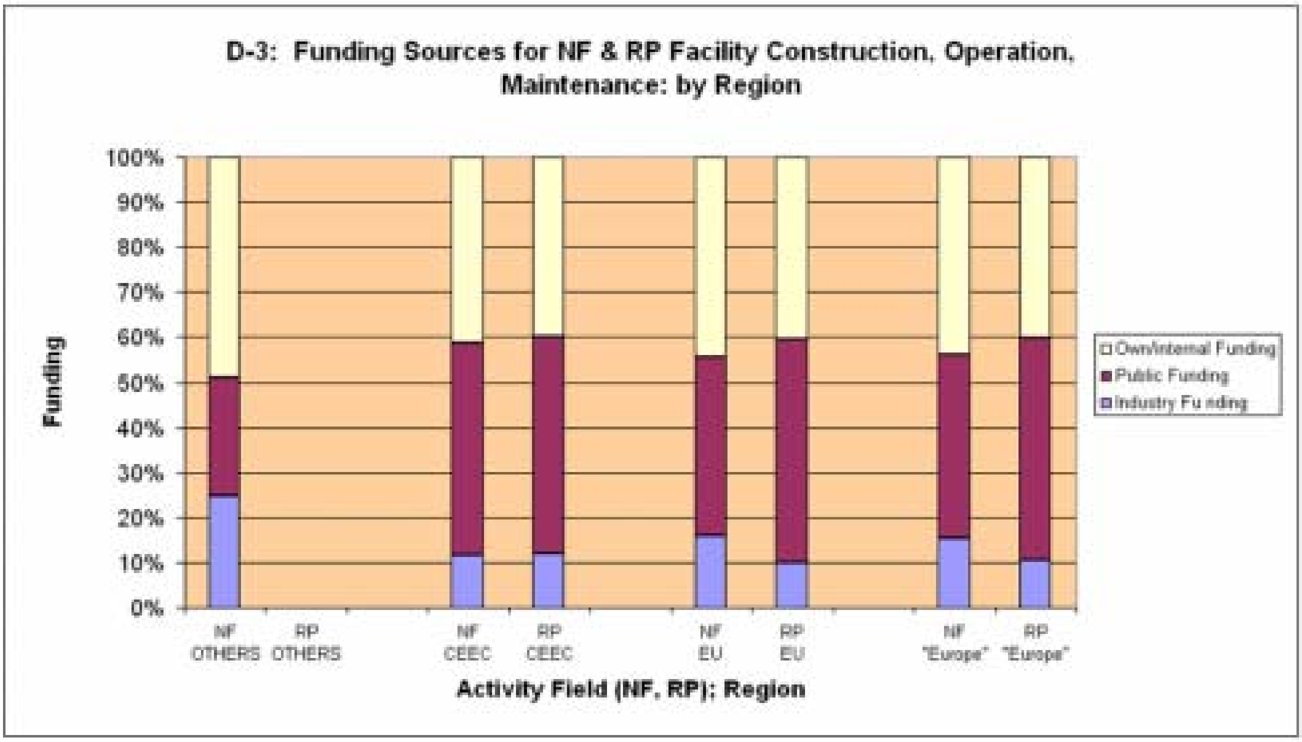
Region	1.	1.1	1.2	1.3	2.	2.1	2.2	3.	3.1	3.2	3.3	3.4	3.5	4.	4.1	4.2	4.3	4.4	5.	5.1	5.2	5.3	Sum
CEEC	2	1	3	6	2	4	0	1	1	10	1	1	0	1	0	0	5	0	1	1	0	0	40
EU	14	12	8	7	2	7	0	13	1	11	2	3	0	1	1	1	2	0	16	4	3	1	109
"Europe"	16	13	11	13	4	11	0	14	2	21	3	4	0	2	1	1	7	0	17	5	3	1	149



Facility Type
1. Irradiation Exposure Estimation of Humans
1.1 External Exposure
1.2 Internal Exposure
1.3 Calibration of Radiation Protection Dosimeters
2. Characterisation and Calibration of Natural Irradiation
2.1 Equipments for Radon Measurement and Calibration
2.2 Cosmic Radiation, including Associated Organisations
3. Environmental Transfer of Radioactive Substances
3.1 Network for Atmospheric Nuclides Measurement
3.2 Radionuclide Metrology
3.3 Equipment devoted to Speciation, incl. Equip. in Assoc. Universities
3.4 Hot Cells and Contamination Facilities
3.5 Access to Boats Facilities for Marine Research incl. Assoc. Organisations
4. Emergency Preparedness
4.1 Technical Support Center
4.2 Emergency Operating Facility
4.3 Radiological Environmental Monitoring Center
4.4 Emergency Training Center
5. Biological Effects of Radiation
5.1 Sources of External Exposures
5.2 Installations for Internal Exposures
5.3 Species; Hosting Numbers for Acute and Chronic Exposures

- Frequency of **RP** Experimental Facility Types: **D-2.2**
  - the 5 categories and their related sub-categories of facility types are listed in the table next to the graph in D-2.2.
  - no responses have been provided from the "others" countries (CH, NO);
  - it should be pointed to the interesting result that within "Europe" no facilities have been reported for "Cosmic Radiation (2.2)" and "Access to Boat Facilities for Marine Research (3.5)" investigations, and for "Emergency Training Centre (4.4)";
  - Within "Europe", a clear majority results for facilities for "Radio-nuclide Metrology (3.2)" investigations, followed in decreasing order by facilities for "Biological Effects of Radiation (5.)" investigations, "Irradiation Exposure Estimation of Humans (1.)", "Environmental Transfer of Radioactive Substances (3.)" and - in parity - "External Exposure (1.1)" and "Calibration of Radiation Protection Dosimeters (1.3)" investigations;
  - The profile for the frequency distribution of facilities as function of the facility types is quite different for "Europe", the EU and the CEEC and elucidates the differences in emphasis placed on the individual facility types:
    - in the EU, emphasis is apparently placed on facilities for "Biological Effects of Radiation (5.)" investigations, followed by facilities for "Irradiation Exposure Estimation of Humans (1.)", "Environmental Transfer of Radioactive Substances (3.)", "External Exposure (1.1)" and "Radio-nuclide Metrology (3.2)" investigations,
    - whereas in the CEEC, emphasis is placed on facilities for "Radio-nuclide Metrology (3.2)" investigations, followed by facilities for "Calibration of Radiation Protection Dosimeters (1.3)" investigations and "Radiological Environmental Monitoring Centres (4.3)".

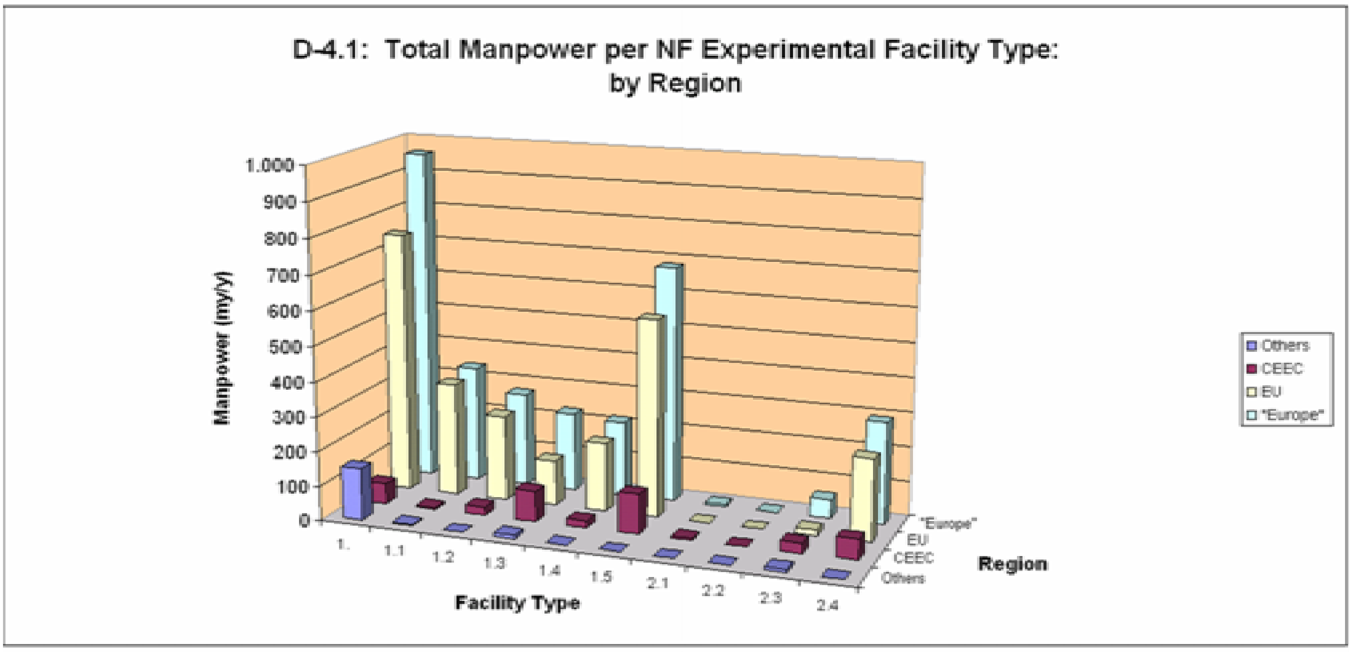
Region	OTHERS NF	OTHERS RP	CEEC NF	CEEC RP	EU NF	EU RP	"Europe" NF	"Europe" RP
Industry Fu nding	25%	0%	12%	12%	16%	10%	15%	11%
Public Funding	26%	0%	47%	48%	40%	50%	41%	49%
Own/internal Funding	49%	0%	41%	40%	44%	40%	44%	40%



Funding Sources for **NF & RP** Experimental Facilities (construction, operation, maintenance): **D-3**

- The four different funding sources are listed in the table next to the graph in D-3.
- Within "Europe", as well as within the EU and the CEEC, the share of "own/internal" and "public" funding is more or less equal and ranges between 40 – 50%;
- For NF, the "own/internal" funding prevails on the "public" funding in "Europe", except in the CEEC;
- For RP, this order is inverted: "public" funding prevails on "own/internal" funding;
- "Industry" funding holds a share of only 10-15%, except in "Others" countries where it amounts to 25%.

Region □	1.	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	Sum
Others	150	4	0	10	0	0	0	0	9	0	173
CEEC	59	6	24	88	20	114	5	0	30	59	405
EU	751	327	248	130	198	568	0	0	16	236	2.474
"Europe"	960	337	272	228	218	682	5	0	55	295	3.051

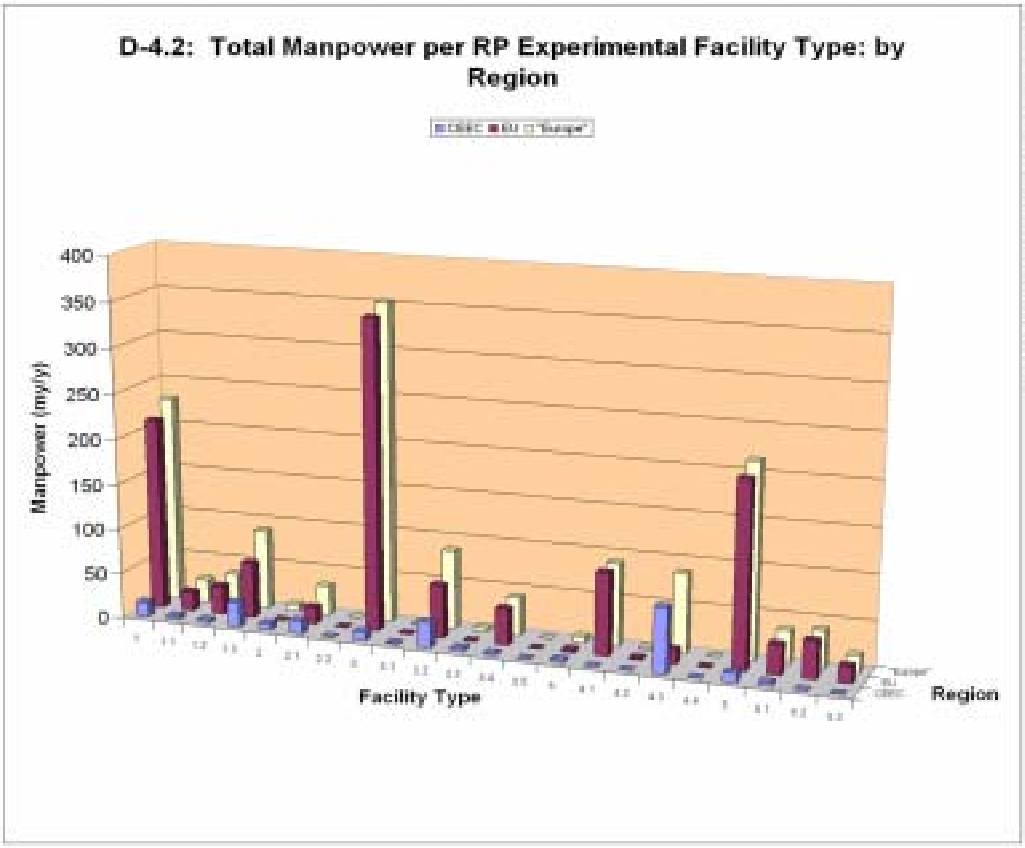


Facility Type	
1. Nuclear & Non-nuclear Experimental Facilities	**2. Nuclear Facility**
1.1 Plant System Investigation - Nucl. & Non-nucl. Fac.	2.1 Medical Investigation - Nuclear Facility
1.2 Plant Compononent Investig. - Nucl. & Non-nucl. Fac.	2.2 Biological Investigation - Nuclear Facility
1.3 Physic. Phenomena Investig. - Nucl. & Non-nucl. Fac.	2.3 Critcal Experiments - Nuclear Facility
1.4 Phys./Chem. Property Investig. - Nu. & Non-nu. Fac.	2.4 Hot Laboratory - Nuclear Facility
1.5 Material Investigation - Nucl. & Non-nucl. Fac.	

Manpower assigned to the operation of **NF** Experimental Facility Types: **D-4.1**

- The Questionnaire database contains results for the total as well as for the academic manpower involved in the facility operation. In the present report only the results for the total manpower are considered.
- The 10 different (experimental) facility types are listed in the table next to the graph in D-4.1
- The total manpower effort assigned to NF facilities operation amounts to 3051 my/y (c.f. manpower effort for RP facilities of 1402 my/y, see D-4.2);
- The major part of it is assigned to the sum of unspecified "Nuclear and Non-nuclear Facilities (1.)";
- Broken down on specified facility types, the majority of manpower effort is assigned to facilities for "Material Investigations (1.5)", which are followed, in decreasing order, by facilities for "Plant System Investigations (1.1)", by "Hot Laboratories (2.4)", and by facilities for "Plant Component Investigations (1.2)", "Physical Phenomena Investigations (1.3)" and "Physical and Chemical Properties Investigations (1.4)";
- The overall manpower effort assigned to NF experimental facilities is a much higher in the EU than in CEEC (factor 4 to over 10); however, in the CEEC, the manpower assigned to facilities for "Physical Phenomena Investigations (1.3)" and for "Critical Experiments (2.3)" amounts to 60% and 200% of that in the EU, respectively;
- Within "Europe", no manpower at all is assigned to facilities for NF related "Biological Investigations (2.2)".

Region	1.	1.1	1.2	1.3	2.	2.1	2.2	3.	3.1	3.2	3.3	3.4	3.5	4.	4.1	4.2	4.3	4.4	5.	5.1	5.2	5.3	Sum
OTHERS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CEEC	[illegible]	4	[illegible]	27	1	14	0	10	1	[illegible]	4	2	0	0	0	0	72	0	[illegible]	4	0	0	206
EU	213.2	21.1	[illegible]	61.4	[illegible]	[illegible]	0	340	[illegible]	58.5	[illegible]	40	0	0	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	41	[illegible]	1196
"Europe"	229.2	[illegible]	[illegible]	88.4	[illegible]	[illegible]	0	350	[illegible]	87	[illegible]	42	0	0	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	41	[illegible]	1402

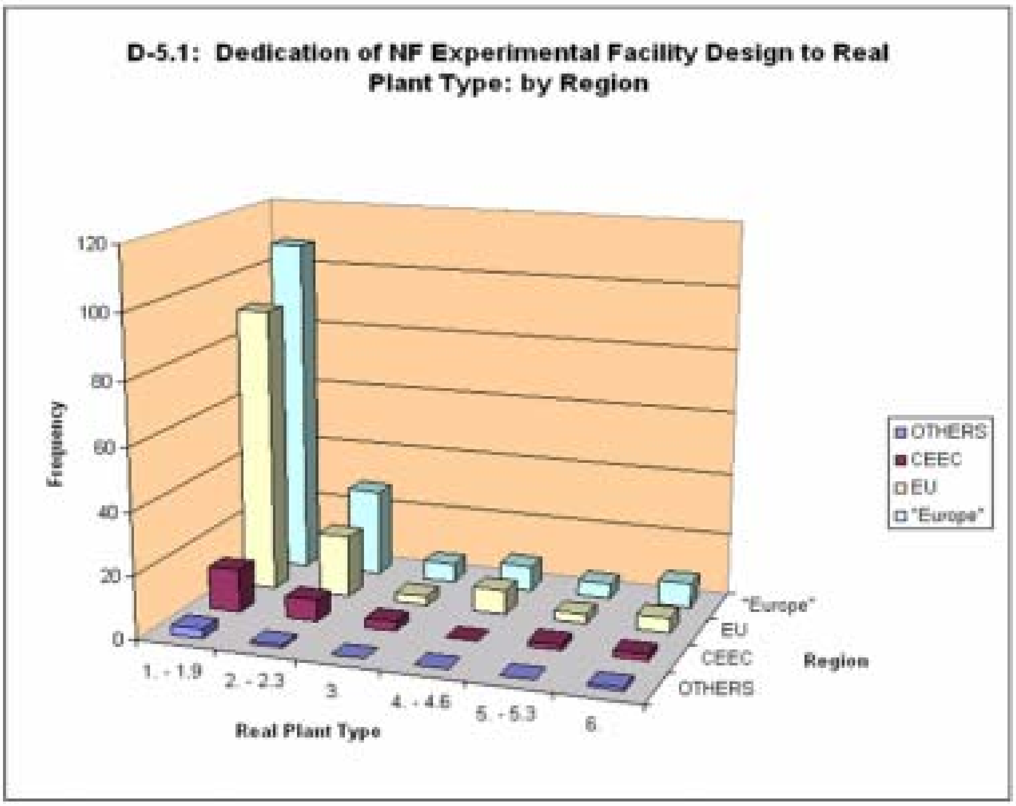


Facility Type
1. Irradiation Exposure Estimation of Humans
1.1 External Exposure
1.2 Internal Exposure
1.3 Calibration of Radiation Protection Dosimeters
2. Characterization and Calibration of Natural Irradiation
2.1 Equipments for Radon Measurement and Calibration
2.2 Cosmic Radiation; including Associated Organisations
3. Environmental Transfer of Radioactive Substances
3.1 Network for Atmospheric Nuclides Measurement
3.2 Radionuclide Metrology
3.3 Equipment devoted to Speciation, incl. Equip. in Assoc. Universities
3.4 Hot Cells and Contamination Facilities
3.5 Access to Boats Facilities for Marine Research; incl. Assoc. Organisations
4. Emergency Preparedness
4.1 Technical Support Center
4.2 Emergency Operating Facility
4.3 Radiological Environmental Monitoring Center
4.4 Emergency Training Center
5. Biological Effects of Radiation
5.1 Sources of External Exposures
5.2 Installations for Internal Exposures
5.3 Species; Hosting Numbers for Acute and

Manpower assigned to the operation of **RP** Experimental Facility Types: **D-4.2**

- The Questionnaire database contains results for the total as well as for the academic manpower involved in the facility operation. In the present report only the results for the total manpower are considered.
- The 5 categories and their related sub-categories of facility types are listed in the table next to the graph in D-4.2.
- No responses have been provided from the "Others" countries (CH, NO);
- The total manpower effort within "Europe" assigned to RP facilities (construction, operation, maintenance) amounts to 1402 my/y, (it represents hence, about 45% of the 3051 my/y for NF facilities, see D-4.1);
- The CEEC countries hold a relatively small share of 206 my/y or about 15% of the total for "Europe"; the major part of 1196 my/y or about 85% falls to the EU countries;
- Within "Europe" as well as within the EU, the vast majority of manpower effort is assigned to facilities for "Environmental Transfer of Radioactive Substances (3.)" investigations, followed by "Irradiation Exposure Estimation of Humans (1.)" and "Biological Effects of Radiation (5.)" investigations;
- Within the CEEC, emphasis of manpower effort is placed on facilities for "Radiological Environmental Monitoring Centres (4.3)", followed by facilities for "Radio-nuclide Metrology (3.2)" and "Calibration of Radiation Protection Dosimeters (1.3)" investigations;
- Within "Europe", no manpower is assigned to facilities for "Cosmic Radiation (2.2)" investigations, "Access to Boats Facilities for Marine Research (3.5)" and "Emergency Training Centres (4.4)".

Region	1. - 1.9	2. - 2.3	3.	4. - 4.6	5. - 5.3	6.	Sum
OTHERS	3	1	0	0	0	1	5
CEEC	14	7	3	0	2	2	28
EU	91	20	3	8	3	5	130
"Europe"	108	28	6	8	5	8	163

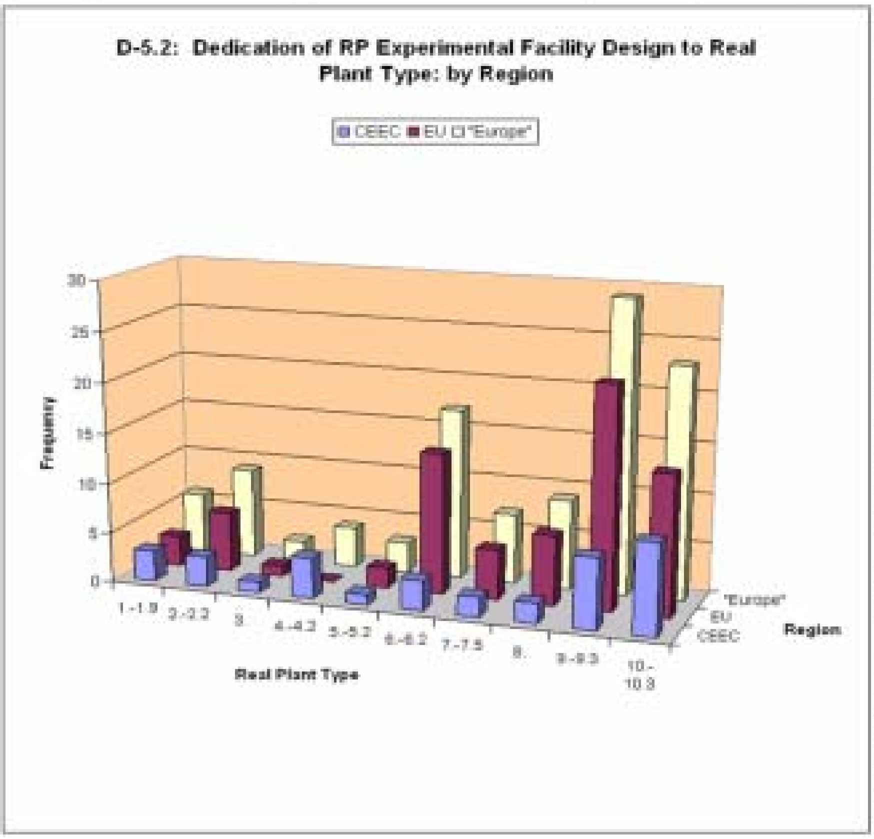


Real Plant Types
1. NuclearPower Plants (NPP)
1.1 Boiling Water Reactors (BWR)
1.2 Pressurized WaterReactors (PWR)
1.3 High Performance Light Water Reactors (HPLWR)
1.4 PWR of Russian Design (WWER)
1.5 Graphite Moderated BWR of Russian Design (RBMK)
1.6 Heavy Water Reactor (HWR)
1.7 Gas Cooled Reactor (GCR)
1.8 High Temperature Reactor (HTR)
1.9 Fast Breeder Reactor (FBR)
2. Research Plants/React.
2.1 Research Reactor
2.2 Test Reactor
2.3 Training Reactor
3. Accelerator Driven System (ADS)
4. Nucl. Fuel Cycle Facilit's.
4.1 Enrichment Facility
4.2 Manufacturing Facility
4.3 Reprocessing Facility
4.4 Interim Storage Facility
4.5 Final Deposit Facility
4.6 Transport Container
5. Waste
5.1 Waste Conditioning Facility
5.2 Waste Deposit Facility
5.3 Waste Transport Container
6. Hot Cells

Dedication of **NF** Experimental Facilities to Real Plant Types: **D-5.1**

- The 6 different categories of real plant types are listed in the table next to the graph in D-5.1.
- The design of NF Experimental Facilities is, for all European Regions, to a predominant majority dedicated to "Nuclear Power Plants (1.)", followed by "Research Plants (2.)";
- Interesting is the almost equal number of facilities designed to "ADS (3.)" and "Waste (5.)” in the EU and the CEEC.

Regions	1.-1.9	2.-2.2	3.	4.-4.2	5.-5.2	6.-6.2	7.-7.5	8.	9.-9.3	10.-10.3	Sum
OTHERS	0	0	0	0	0	0	0	0	0	0	0
CEEC	3	3	1	4	1	3	2	2	7	9	35
EU	3	6	1	0	2	14	5	7	22	14	74
"Europe"	6	9	2	4	3	17	7	9	29	23	109

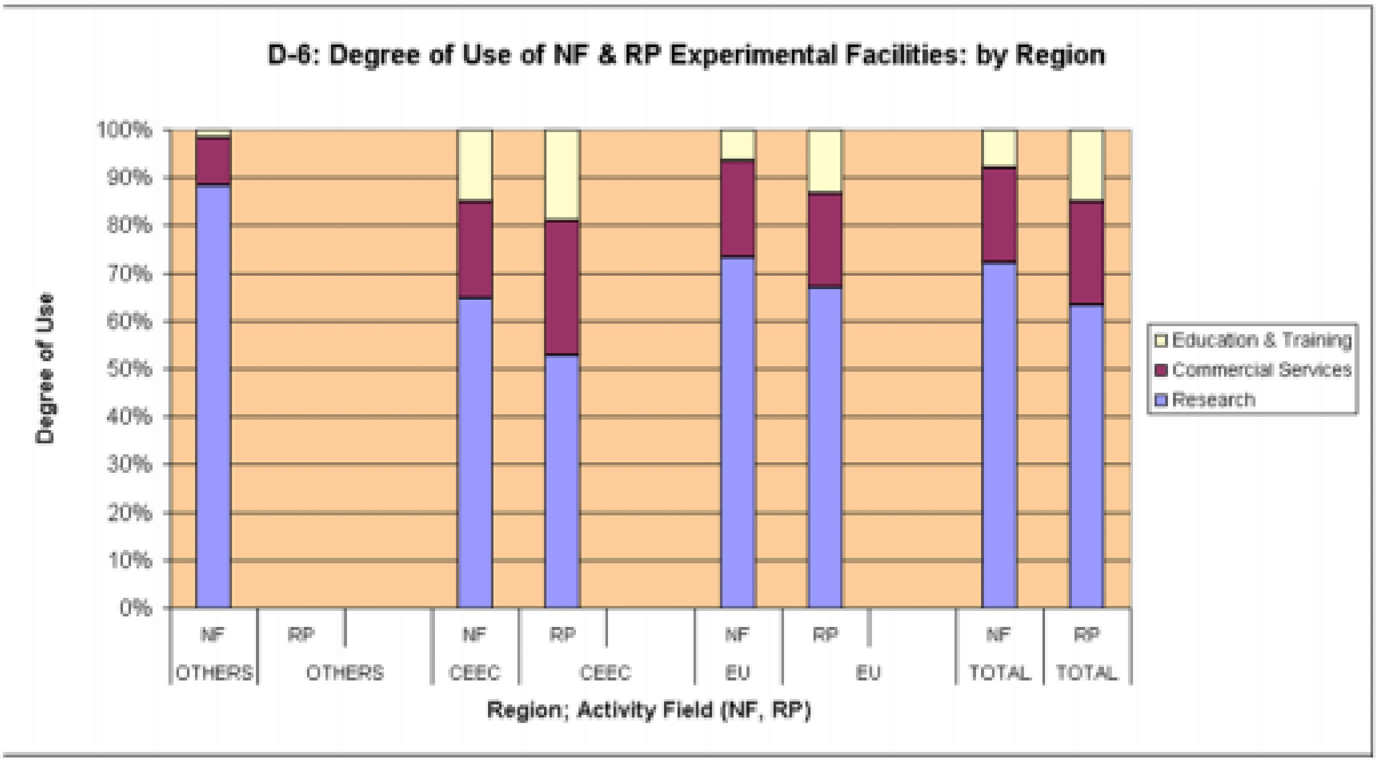


Real Plant Type
1. Nuclear Power Plants (NPP)
1.1 Boiling Water Reactors (BWR)
1.2 Pressurized WaterReactors (PWR)
1.3 High Performance Light Water Reactors (HPLWR)
1.4 PWR of Russian Design (WWER)
1.5 Graphite Moderated BWR of Russian Design (RBMK)
1.6 Heavy Water Reactor (HWR)
1.7 Gas Cooled Reactor (GCR)
1.8 High Temperature Reactor (HTR)
1.9 Fast Breeder Reactor (FBR)
2. Research Reactors
2.1 Test Reactors
2.2 Training Reactors
3. Accelerator Driven System (ADS)
4. Nuclear Fuel Cycle Plants
4.1 Fuel Manufacturing Plant
4.2 Fuel Reprocessing Plant
5. Radioactive Waste Plants
5.1 Waste Repository "temporary"
5.2 Waste Repository "final"
6. Hot (radioactive) Installations
6.1 Hot Cells
6.2 Hot Laboratory
7. Accelerators
7.1 Cyklotron
7.2 Linear Accelerator
7.3 Synchrotron
7.4 Mikrotron
7.5 Neutron Generators
8. X-Ray Source (Roentgen)
9. Artificial Radionuclide Sources
9.1 Open Sources
9.2 Neutron Sources
9.3 Isotopes
9.3.1 Co-60
9.3.2 Ir-192
9.3.3 Cs-137
9.3.4 I-131
10. Natural Radiation
10.1 Radon
10.2 Cosmic Radiation
10.3 Naturally Occurring Radiactive Materials

Dedication of **RP** Experimental Facilities to Real Plant Types: **D-5.2**

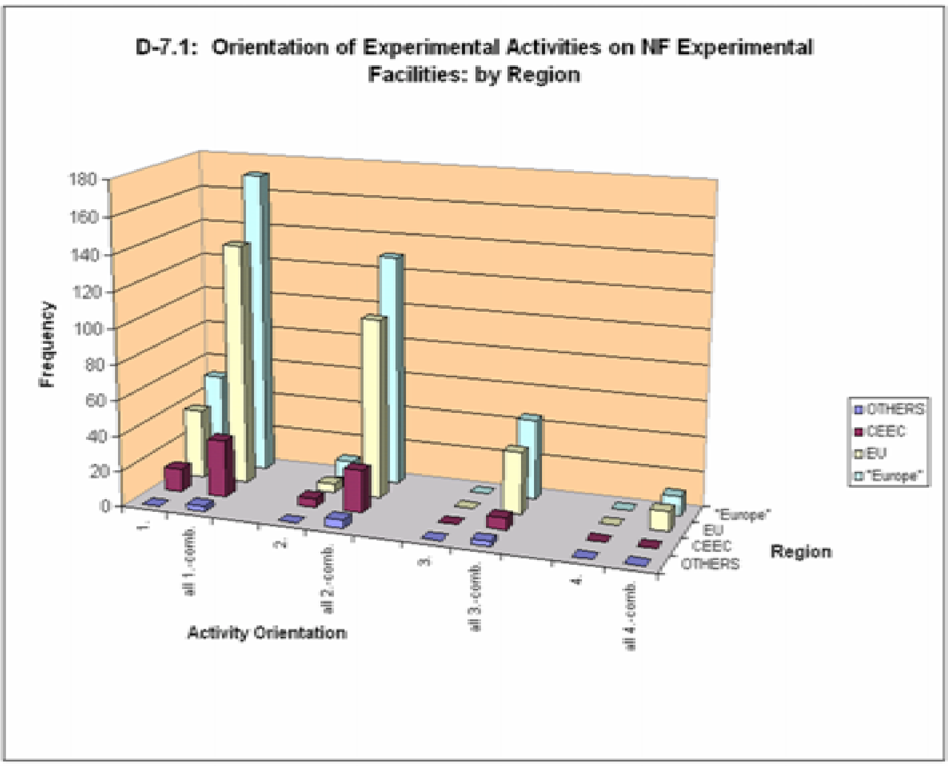
- The 10 different categories of real plant types are listed in the table next to the graph in D-5.2.
- No responses have been received from the "Others" countries;
- The design of RP Experimental Facilities is, for "Europe" as well as for the EU countries, primarily dedicated to the real plant type category of "Artificial Radio-nuclide Sources (9.)", followed by "Natural Radiation (10.)" and "Hot Installations (6.)";
- For the CEEC countries, this order is different: majority is held by the real plant type category of "Natural Radiation (10.)", followed by "Artificial Radio-nuclide Sources (9.)" and "Nuclear Fuel Cycle Plants (4.)";
- It is surprising that within the EU there would not exist experimental facilities designed to "Nuclear Fuel Cycle Plants (4.)"; this result is to be attributed to incomplete entries into the Questionnaire.

Region	OTHERS NF	OTHERS RP	CEEC NF	CEEC RP	EU NF	EU RP	TOTAL NF	TOTAL RP
Research	88%	0%	65%	53%	73%	67%	72%	63%
Commercial Services	10%	0%	20%	28%	20%	19%	20%	22%
Education & Training	2%	0%	15%	19%	6%	13%	8%	15%



- Degree of Use of **NF & RP** Experimental Facilities: **D-6**
  - The 3 different categories of use are listed in the table next to the graph in D-6,
  - All NF and RP Experimental Facilities within "Europe" are primarily (53-73%) used for "Research" purposes, with NF facilities showing a higher percentage than RP facilities, and with the highest value of 88% for NF facilities in the "Others" Region.
  - For NF and RP facilities, in all Regions an almost equal use of about 20% results for "Commercial Services", with the highest value of 28% for RP facilities in the CEEC.
  - The use for "Education and Training" purposes holds a share of 6-19%, with a higher share for RP than for NF facilities.

Region	1.	all 1.-comb.	2.	all 2.-comb.	3.	all 3.-comb.	4.	all 4.-comb.
OTHERS	0	3	0	5	0	3	0	0
CEEC	13	32	5	24	0	7	0	0
EU	39	136	5	101	0	35	0	11
"Europe"	52	171	10	130	0	45	0	11

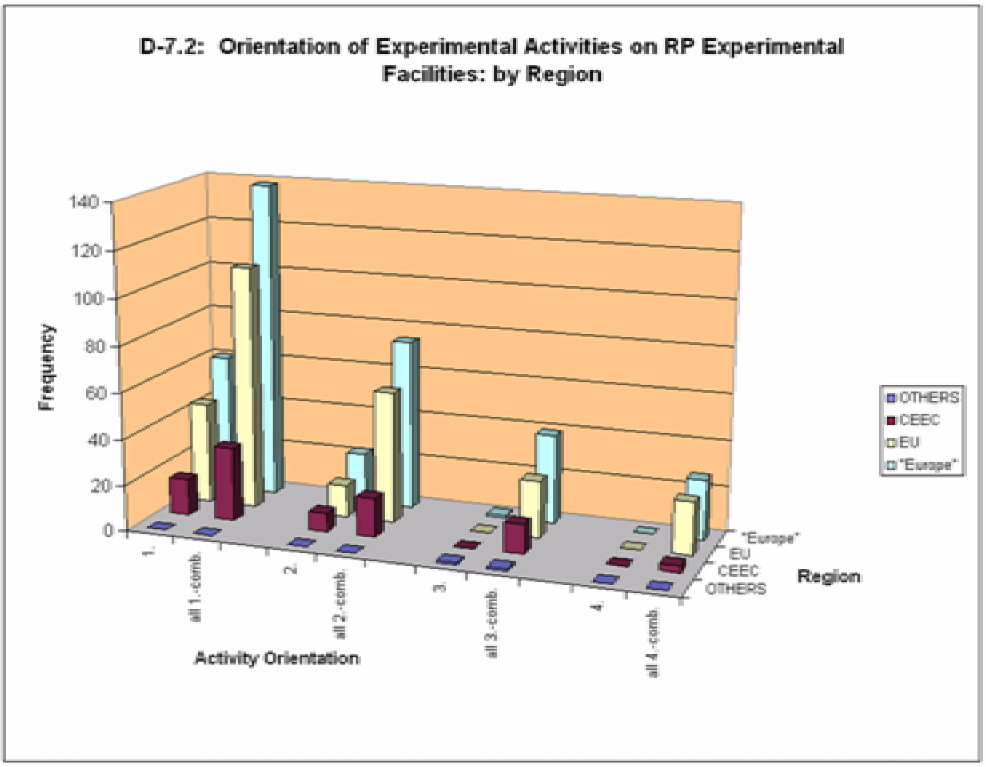


Activity Orientation
1. Adding Value to Knowledge
2. Industry Oriented
3. Regulation Oriented
4. Policy Making Oriented

"all x.-comb." =
all combinations with "x" incl. "x" alone

- Orientation of Experimental Activities performed on **NF** Experimental Facilities: **D-7.1**
  - The four different activity orientations are listed in the table next to the graph in D-7.1.
  - The experimental activities performed on facilities have in the large majority of cases more than one single orientation; the x-axis distinguishes between orientations alone and in combination with other orientations;
  - The activity orientation profiles for EU and for CEEC are similar to each other.
  - "Regulation Oriented (3.)" and "Policy Making Oriented (4.)" activities occur only in combination with other activity orientations, and never as single activity orientation;
  - The activity orientation is in the majority of cases focused on "Adding Value to Knowledge (1.)", as a single activity orientation as well as in combination with one or more other activity orientations;
  - The second frequent activity orientation exists for "Industry Oriented (2.)" followed by "Regulation Oriented (3.)";
  - Activities comprising the orientation towards "Policy Making (4.)" have been reported only in the EU.

Region	1.	all 1.-comb.		2.	all 2.-comb.		3.	all 3.-comb.		4.	all 4.-comb.
OTHERS	0	0		0	0		1	1		0	0
CEEC	16	32		8	17		0	13		0	3
EU	44	106		14	57		0	25		0	23
"Europe"	60	138		22	74		1	39		0	26



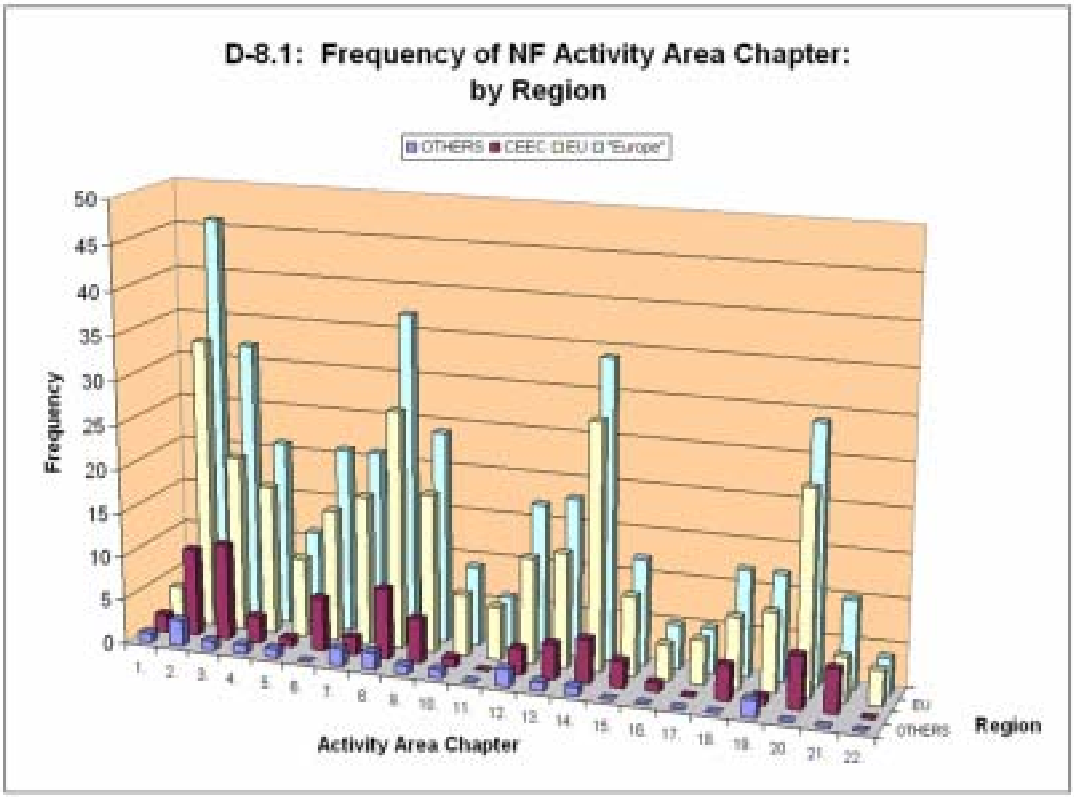
Activity Orientation
1. Adding Value to Knowledge
2. Industry Oriented
3. Regulation Oriented
4. Policy Making Oriented

"all x.-comb." = all combinations with "x" incl. "x" alone

- Orientation of Experimental Activities performed on **RP** Experimental Facilities: **D-7.2**
  - The four different activity orientations are listed in the table next to the graph in D-7.2.
  - The results for the orientation of activities performed on RP experimental facilities are quite similar to those for NF reported in the previous section, see also D-7.1: this observation holds for the frequency profile as well as for the differences between "Europe" as a whole and the three individual "Regions"; noteworthy is the exception, that the frequency of activities oriented to "Policy Making (4.)" combined with other orientations, is remarkably higher in the field of RP than in the field of NF, c.f. D-7.1.
  - Note: The numbering sequence in the table for the "Activity Orientation" has to be inverted as follows: 2. Industry Oriented; 3. Regulation Oriented.

- Orientation of Experimental Activities performed on **RP** Experimental Facilities: **D-7.2**
  - The four different activity orientations are listed in the table next to the graph in D-7.2.
  - The results for the orientation of activities performed on RP experimental facilities are quite similar to those for NF reported in the previous section, see also D-7.1: this observation holds for the frequency profile as well as for the differences between "Europe" as a whole and the three individual "Regions"; noteworthy is the exception, that the frequency of activities oriented to "Policy Making (4.)" combined with other orientations, is remarkably higher in the field of RP than in the field of NF, c.f. D-7.1.
  - Note: The numbering sequence in the table for the "Activity Orientation" has to be inverted as follows: 2. Industry Oriented; 3. Regulation Oriented.

Region	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	Sum
OTHERS	1	3	1	1	1	0	2	2	1	1	0	2	1	1	0	0	0	0	2	0	0	0	19
CEEC	2	10	11	3	1	6	2	8	5	1	0	3	4	5	3	1	0	4	1	6	5	0	81
EU	4	33	20	17	9	15	17	27	18	7	6	12	13	28	9	4	5	8	9	23	5	4	293
"Europe"	7	46	32	21	11	21	21	37	24	9	6	17	18	34	12	5	5	12	12	29	10	4	393

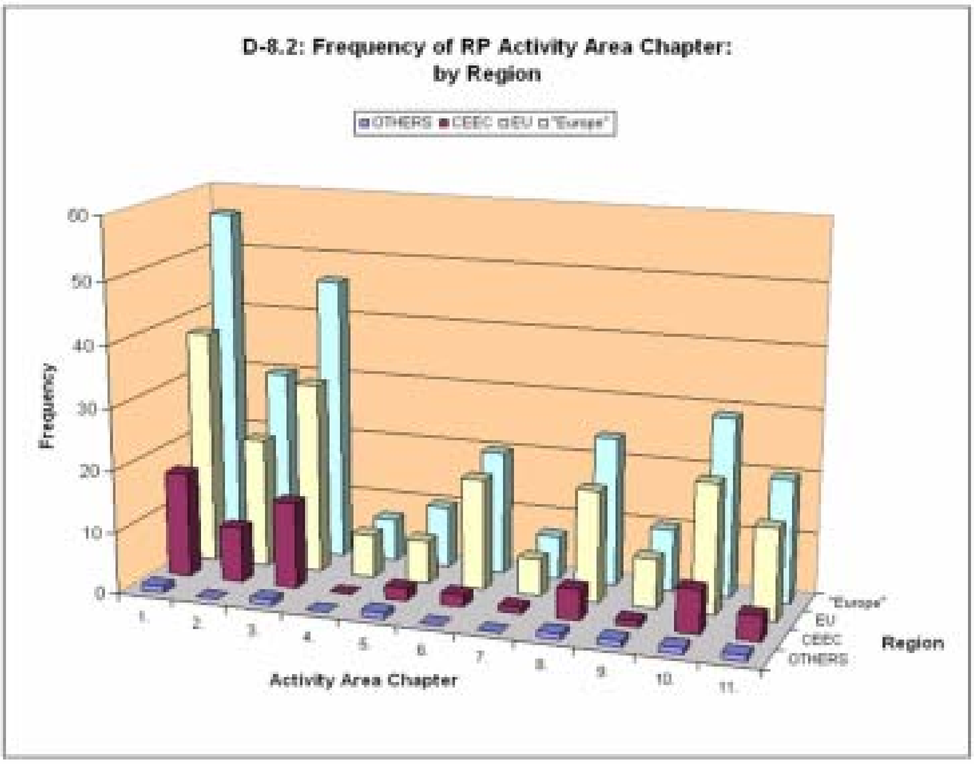


Activity Area Chapter
1. Project Management & Coordination
2. System Technology &Behaviour
3. Component Technology & Behaviour
4. Nuclear Fuel Technology & Behaviour
5. Nuclear Fuel Cycle Facilities
6. Reactor Core Technology & Behaviour
7. Decommissioning of Nuclear Plants
8. Material Technology & Behaviour
9. Risk
10. Radiation
11. Electricity
12. Instrumentation & Control
13. Spent Fuel
14. Waste
15. Partitioning & Transmutation
16. Particular Investigations
17. Emergency Plans
18. Experimental Investigations
19. Human Factor
20. Fundamental Investigations
21. Education & Training
22. Legal Framework & Standards

Experimental and Non-experimental Activities (Form Sheets NF3 and RP3)

- Frequency of **NF** Activity Area Chapters: **D-8.1**
  - The 22 different activity area chapters are listed in the table next to the graph in D-8.1.
  - "Experimental and Non-experimental Activities" are primarily concentrated on the Activity Area Chapter " System Technology & Behaviour (2.)" showing the highest frequency of occurrence, followed, in decreasing order, by activities related to " Material Technology & Behaviour (8.)", "Waste (14.)", "Fundamental Investigations (20.)" and "Component Technology & Behaviour (3.)";
  - The activities dedicated to the Chapters "Risk (9.)", "Nuclear Fuel Technology & Behaviour (4.)", "Reactor Core Technology & Behaviour (6.)" and "Decommissioning of Nuclear Plants and Facilities (7.)" show nearly the same frequency;

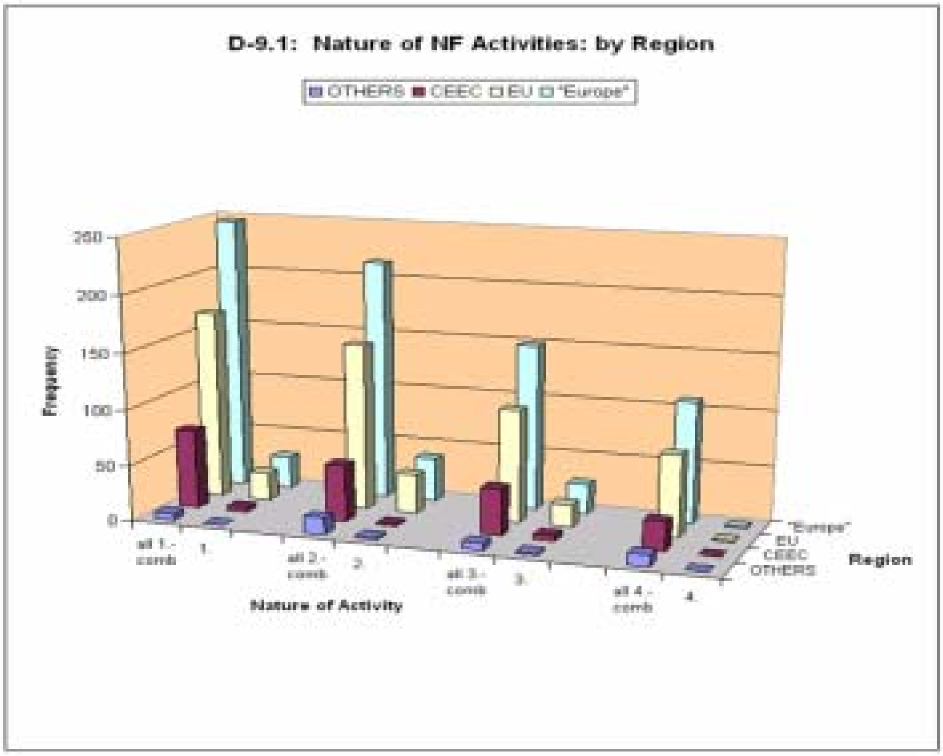
Regions	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sum
OTHERS	1	0	1	0	1	0	0	1	1	1	1	7
CEEC	17	9	14	0	2	2	1	5	1	7	4	62
EU	38	21	31	7	7	18	6	18	8	21	15	190
"Europe"	56	30	46	7	10	20	7	24	10	29	20	259



Activity Area Chapter
1. Radiation Exposure of Humans
2. Characterization of Irradiation by Natural Sources
3. Environmental Transfer of Radioactive Substances
4. Radiation Effects on Environmental Ecosystems
5. Restoration
6. Biological Effects of Radiation
7. Epidemiology
8. Radiological Risk Assessment & Management; Feed Back Analysis
9. Radiological Risk Governance
10. Emergency Preparedness
11. Education & Training

- Frequency of **RP** Activity Area Chapters: **D-8.2**
  - The 11 different activity area chapters are listed in the table next to the graph in D-8.2.
  - Within "Europe" as well as within the EU and the CEEC, "Experimental and Non-experimental Activities" are primarily concentrated on the Activity Area Chapter of "Radiation Exposure of Humans (1.)", followed, in decreasing order by "Environmental Transfer of Radioactive Substances (3.)", "Characterisation of Irradiation by Natural Sources (2.)", "Emergency Preparedness (10.)", "Radiological Risk Assessment & Management; Feed Back Analysis (8.)", "Biological Effects of Radiation (6.)" and "Education & Training (11.)"; noteworthy is the frequency for "Education & Training (11.)" which is definitely higher in the field of RP than in the field of NF.

Region	all 1.-comb	1.	all 2.-comb	2.	all 3.-comb	3.	all 4.-comb	4.
OTHERS	8	0	15	2	8	2	10	0
CEEC	71	4	51	2	42	6	26	0
EU	169	25	149	35	101	20	73	1
"Europe"	248	29	215	39	149	27	109	1



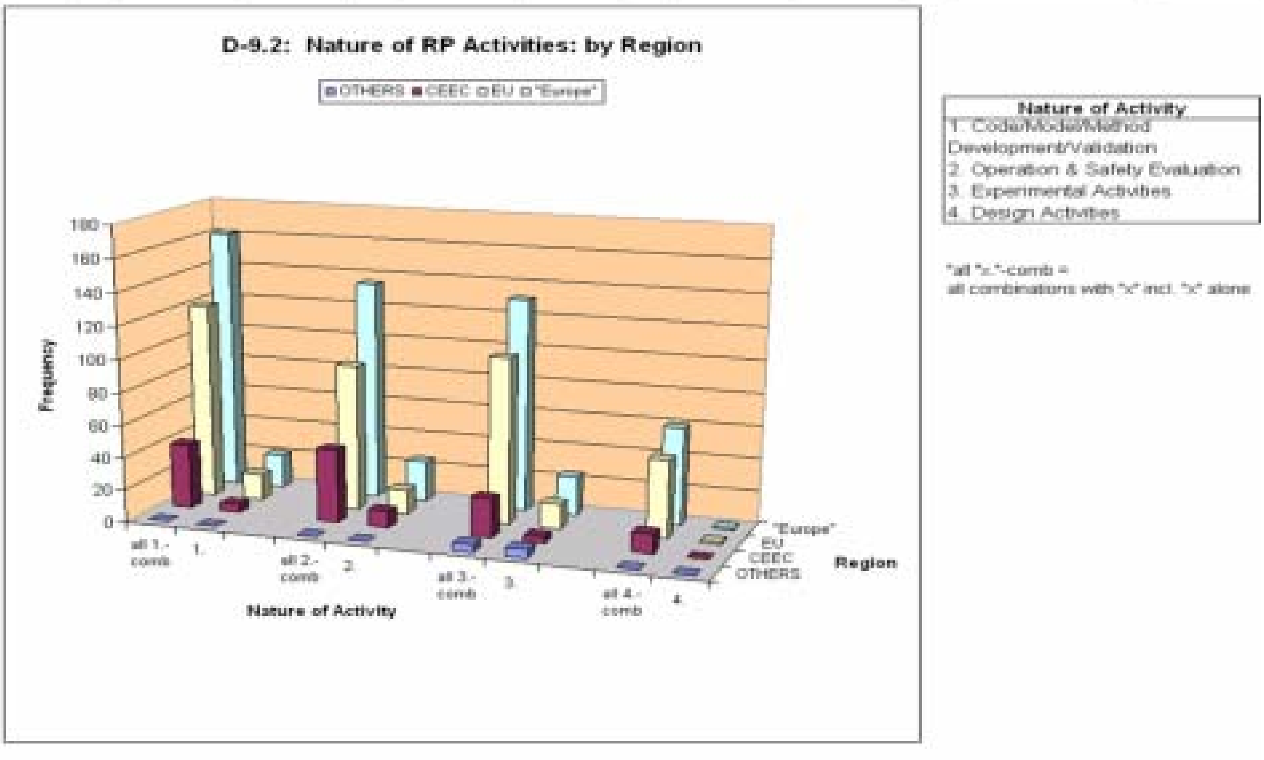
Nature of Activity
1. Code/Model/Method Development/Validation
2. Operation & Safety Evaluation
3. Experimental Activities
4. Design Activities

"all "x."-comb =
all combinations with "x" incl. "x" alone

Nature of Activities in **NF** Activity Area Chapters: **D-9.1**

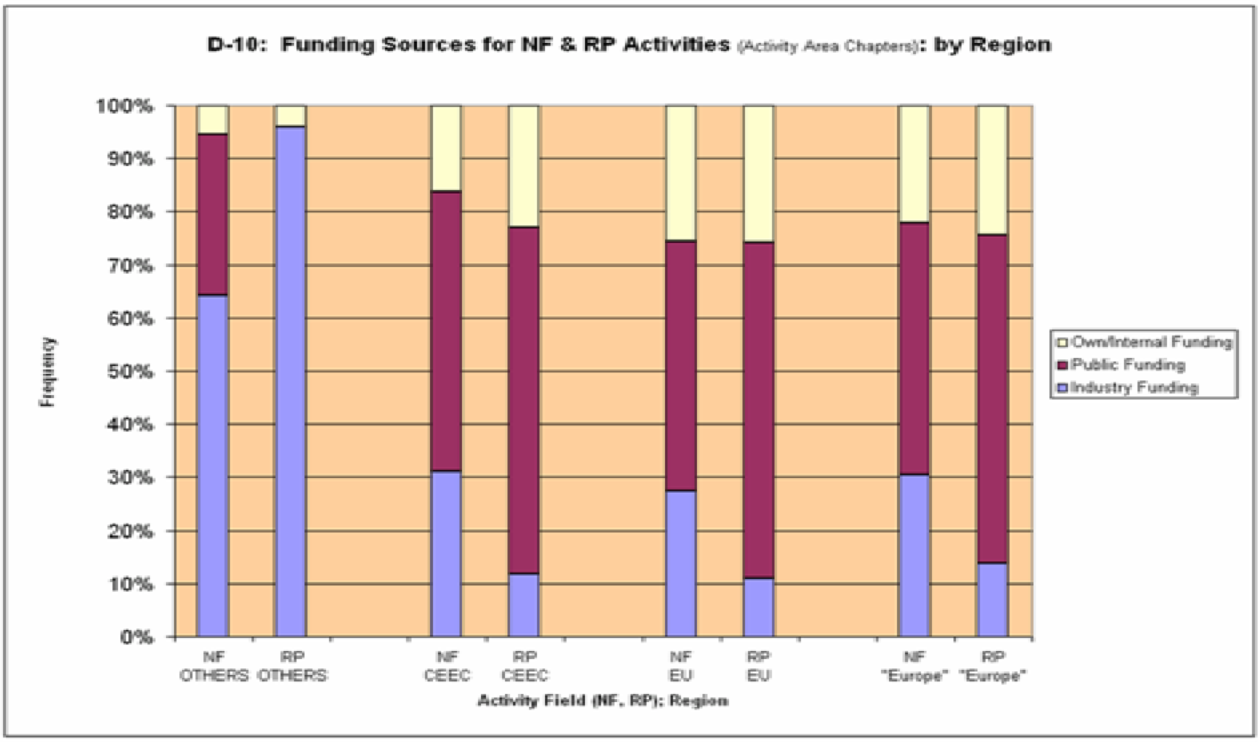
- The four different natures of activities are listed in the table next to the graph in D-9.1.
- Within "Europe" as well as within the EU and the CEEC, combinations of all four activity natures evidently are much more frequently occurring (up to more than an order of magnitude) than single activity natures;
- As a single activity nature, emphasis is on "Operation and Safety Evaluation (2.)", followed rather closely by "Code/Model/Method Development/Validation (1.)" and "Experimental Activities (3.)";
- In the combination with other activity natures, "Code/Model/Method Development/Validation (1.)" precedes, in decreasing order, "Operation and Safety Evaluation (2.)", "Experimental Activities (3.)" and "Design Activities (4.)".

Region	all 1.-comb	1.	all 2.-comb	2.	all 3.-comb	3.	all 4.-comb	4.
OTHERS	0	0	0	0	5	5	0	0
CEEC	40	5	45	10	24	4	12	0
EU	121	16	90	15	102	15	48	1
"Europe"	161	21	135	25	131	24	60	1



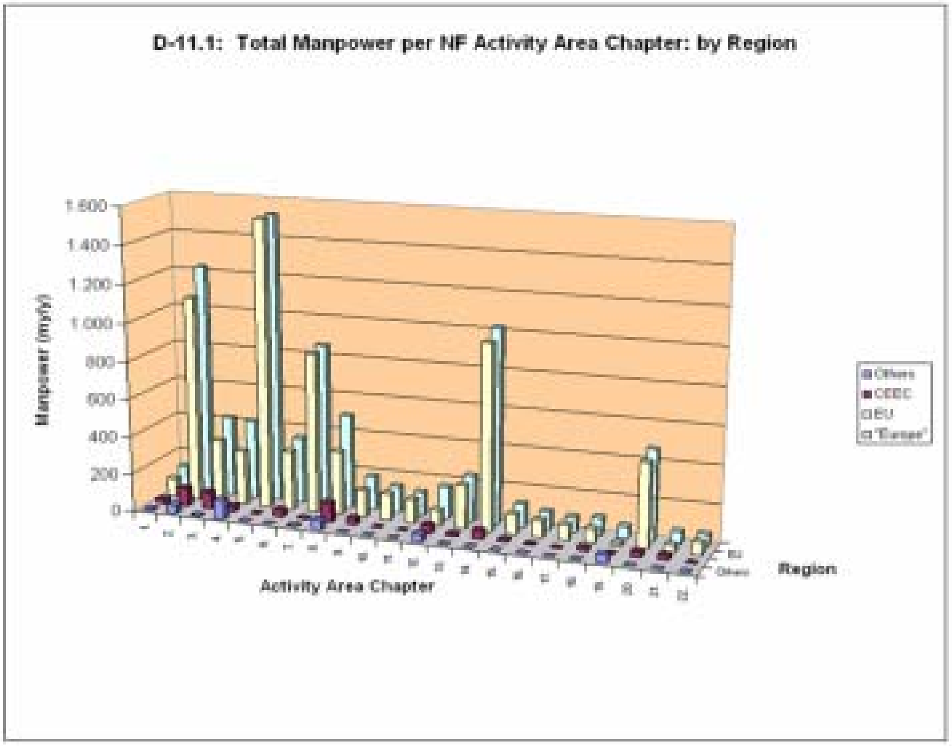
- Nature of Activities in **RP** Activity Area Chapters: **D-9.2**
  - The four different natures of activities are listed in the table next to the graph in D-9.2.
  - The overall results for RP are quite similar to those for NF in D-9.1;
  - As in the case of NF, combinations of all four activity natures evidently are much more frequently occurring (up to more than an order of magnitude) than single activity natures;
  - Of the single activity natures, emphasis is on "Experimental Activities (2.)", followed by " Operation & Safety Evaluation (3.)" and "Code/Model/Method Development/Validation (1.)" which are in a quite different order compared to NF in D-9.1;
  - Within "Europe", in the combination with other activity natures, "Code/Model/Method Development/Validation (1.)" precedes "Experimental Activities (2.)", "Operation & Safety Evaluation (3.)" and "Design Activities (4.)" in decreasing order, however with "Operation & Safety Evaluation (3.)" much closer to "Experimental Activities (2.)" than in the case of NF in D-9.1;
  - This sequence is different for the EU and for the CEEC: in the EU, "Code/Model/Method Development/Validation (1.)" prevails "Operation & Safety Evaluation (3.)" and "Experimental Activities (2.)"; in the CEEC, "Experimental Activities (2.)" shows the highest frequency followed by "Code/Model/Method Development/Validation (1.)" and "Operation & Safety Evaluation (3.)".
  - Note: The numbering sequence in the table for the "Nature of Activity" has to be inverted as follows: 2. Experimental Activities; 3. Operation & Safety Evaluation

Region	OTHERS NF	OTHERS RP	CEEC NF	CEEC RP	EU NF	EU RP	"Europe" NF	"Europe" RP
Industry Funding	64%	96%	31%	12%	27%	11%	30%	14%
Public Funding	30%	0%	53%	65%	47%	63%	47%	62%
Own/Internal Funding	6%	4%	16%	23%	26%	26%	22%	24%



- Funding Sources for **NF & RP** Experimental and Non-experimental Activities: **D-10**
  - The four different funding sources are listed in the table next to the graph in D-10.
  - "Public" funding clearly precedes "Industry" and "Own/Internal" funding in the case of NF related activities, whereas in the case of RP related activities, it precedes "Own/Internal" and "Industry" funding and is hence, in the inverse order;
  - "Public" funding is by 23-34% higher for RP than for NF related activities;
  - In the "Others" Region, and for RP related activities, there is 96% "Industry" but no "Public" funding; NF related activities have only a 30% "Public" funding, and the smallest "Own/Internal" funding.

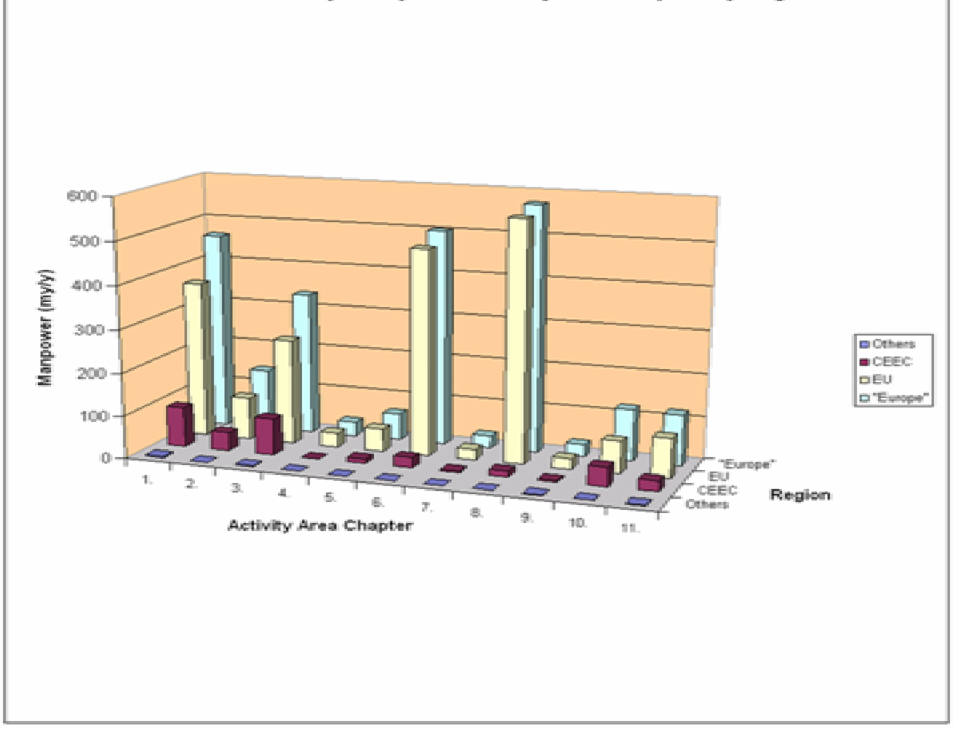
Reg.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	Sum
Others	10	44	4	100	0	0	8	50	0	0	0	39	0	0	0	0	0	0	43	0	0	0	298
CEEC	23	98	88	28	0	37	7	106	36	2	0	47	13	47	16	5	0	18	2	31	27	0	628
EU	97	1.086	334	288	1.621	314	843	340	145	140	123	82	230	976	104	88	81	73	16	443	36	66	7.423
"Europe"	130	1.227	426	416	1.621	351	858	496	181	142	123	168	243	1.023	120	93	81	91	60	473	62	66	8.347



Activity Area Chapter
1. Project Management & Coordination
2. System Technology & Behaviour
3. Component Technology & Behaviour
4. Nuclear Fuel Technology & Behaviour
5. Nuclear Fuel Cycle Facilities
6. Reactor Core Technology & Behaviour
7. Decommissioning of Nuclear Plants
8. Material Technology & Behaviour
9. Risk
10. Radiation
11. Electricity
12. Instrumentation & Control
13. Spent Fuel
14. Waste
15. Partitioning & Transmutation
16. Particular Investigations
17. Emergency Plans
18. Experimental Investigations
19. Human Factor
20. Fundamental Investigations
21. Education & Training
22. Legal Framework & Standards

- Manpower assigned to **NF** Activity Area Chapters (22 Chapters): **D-11.1**
  - The 22 different activity area chapters are listed in the table next to the graph in D-11.1.
  - Within "Europe" and the EU, the manpower effort assigned to the different "Activity Area Chapters” is clearly the highest for activities related to "Nuclear Fuel Cycle Facilities (5.)”, followed, in decreasing order, by that for activities related to "System Technology & Behaviour (2.)”, "Waste (14.)”, "Decommissioning of Nuclear Plants and Facilities (7.)”, ”Fundamental Investigations (20.)" and "Material Technology & Behaviour (8.)”; this order for the manpower effort is quite different from that for the frequency of the "Activity Area Chapters” shown in D-8.1!
  - Within the CEEC, the highest manpower effort is assigned to "8. Material Technology & Behaviour", followed by "System Technology & Behaviour (2.)” and by "Component Technology & Behaviour (3.)";
  - The total manpower effort assigned to all "Activity Area Chapters” in the CEEC amounts to only 1/10, and in the EU to considerable 9/10 of the total manpower effort in "Europe”;
  - The total manpower effort in "Europe” assigned to "Experimental and Non-experimental Activities” amounts to 8345 my/y, and is hence, nearly three times higher than the manpower effort assigned to "Experimental Facilities”, c.f. D-4.1.

Regions	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sum
Others	3	0	3	0	0	0	0	1	2	1	2	12
CEEC	93	43	85	0	10	24	4	15	3	45	25	347
EU	366	99	246	34	53	479	25	558	25	75	92	2 049
"Europe"	462	142	334	34	63	503	29	574	29	121	119	2 408

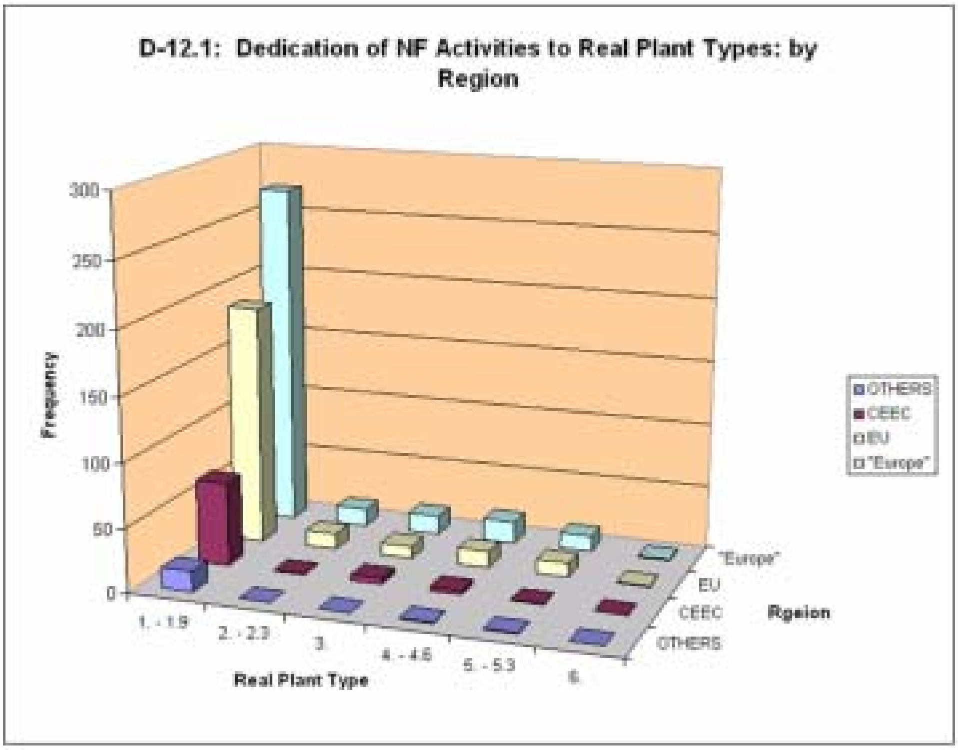


D-11.2: Total Manpower per RP Activity Area Chapter: by Region

Activity Area Chapter
1. Radiation Exposure of Human
2. Characterization of Irradiation by Natural Sources
3. Environmental Transfer of Radioactive Substances
4. Radiation Effects on Environmental Ecosystems
5. Restoration
6. Biological Effects of Radia
7. Epidemiology
8. Radiological Risk Assessment & Management; Feed
9. Radiological Risk Governanc
10. Emergency Preparedness
11. Education & Training

- Manpower assigned to **RP** Activity Area Chapters: **D-11.2**
  - The 11 different activity area chapters are listed in the table next to the graph in D-11.2.
  - Within "Europe" and the EU, the frequency distribution profiles are very similar: the majority of manpower effort is assigned to activities related to "Radiological Risk Assessment & Management; Feed Back Analysis (8.)", followed by "Biological Effects of Radiation (6.)" and "Radiation Exposure of Humans (1.)";
  - Within the CEEC, this frequency distribution profile is completely different showing the maximum of manpower effort assigned to activities related to "Radiation Exposure of Humans (1.)", followed by "Environmental Transfer of Radioactive Substances (3.)" and "Emergency Preparedness (10.)";
  - These differences in the frequency distribution between the CEEC and the EU are significant and indicate the different importance allocated to the individual Activity Area Chapters in these two Regions.

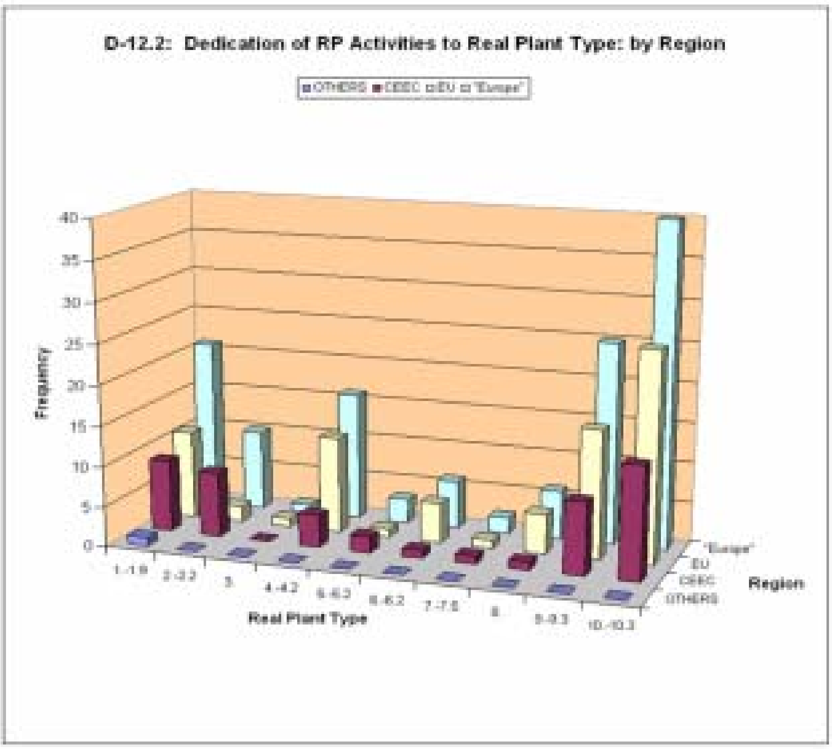
Region	1. - 1.9	2. - 2.3	3.	4. - 4.6	5. - 5.3	6.	Sum
OTHERS	16	0	0	1	1	0	18
CEEC	66	1	5	3	1	0	76
EU	188	13	10	13	11	1	236
"Europe"	270	14	15	17	13	1	330



Real Plant Types
1. Nuclear Power Plants (NPP)
1.1 Boiling Water Reactors (BWR)
1.2 Pressurized WaterReactors (PWR)
1.3 High Performance Light Water
1.4 PWR of Russian Design (WWER)
1.5 Graphite Moderated BWR of
1.6 Heavy Water Reactor (HWR)
1.7 Gas Cooled Reactor (GCR)
1.8 High Temperature Reactor (HTR)
1.9 Fast Breeder Reactor (FBR)
2. Research Plants/React.
2.1 Research Reactor
2.2 Test Reactor
2.3 Training Reactor
3. Accelerator Driven System (ADS)
4. Nucl. Fuel Cycle Facilit's.
4.1 Enrichment Facility
4.2 Manufacturing Facility
4.3 Reprocessing Facility
4.4 Interim Storage Facility
4.5 Final Deposit Facility
4.6 Transport Container
5. Waste
5.1 Waste Conditioning Facility
5.2 Waste Deposit Facility
5.3 Waste Transport Container
6. Hot Cells

- Dedication of **NF** Activity Area Chapters to Real Plant Types (6 categories): **D-12.1**
  - The 6 categories of real plant types are listed in the table next to the graph in D-12.1.
  - About 82% of all NF related "Experimental and Non-experimental Activities" are dedicated to " Nuclear Power Plants (1.)"; the remainder is nearly equally distributed on the other 5 categories of Real Plant Types;
  - The share of activity dedication to "Nuclear Power Plants (1.)" amounts in the CEEC to about 20%, and in the EU to about 70% of that in "Europe".

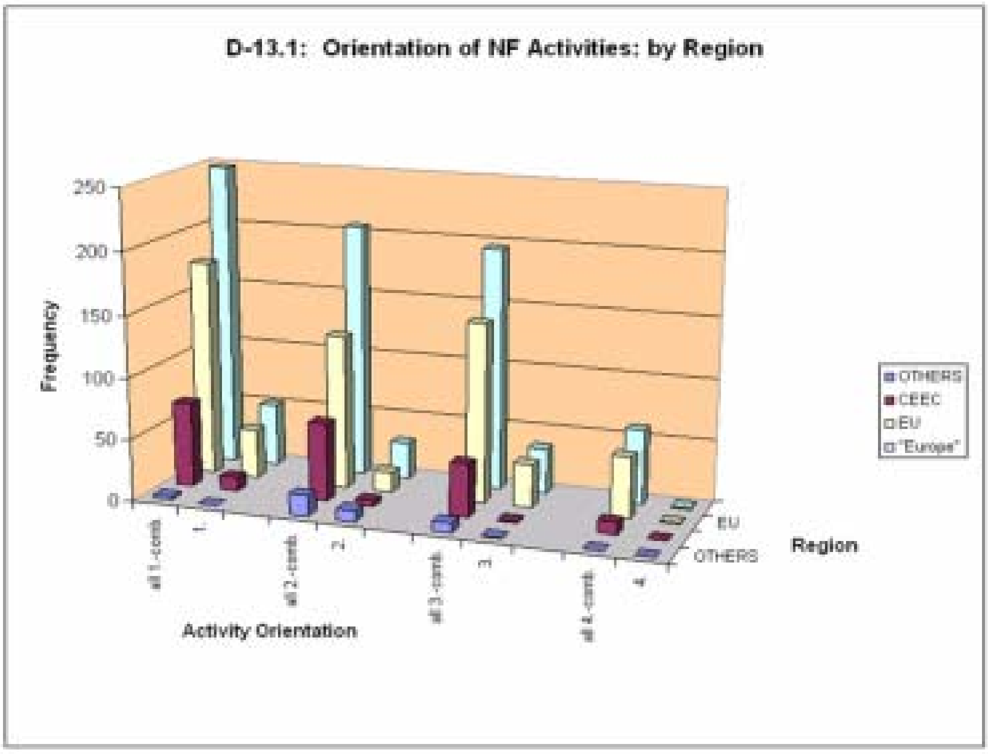
Regions	1.-1.9	2.-2.2	3.	4.-4.2	5.-5.2	6.-6.2	7.-7.5	8.	9.-9.3	10.-10.3	Sum
OTHERS	1	0	0	0	0	0	0	0	0	0	1
CEEC	9	8	0	4	2	1	1	1	9	14	49
EU	11	2	1	12	1	5	1	5	16	26	80
"Europe"	21	10	1	16	3	6	2	6	25	40	130



Real Plant Type
1. Nuclear Power Plants (NPP)
1.1 Boiling Water Reactors (BWR)
1.2 Pressurized WaterReactors (PWR)
1.3 High Performance Light Water Reactors (HPLWR)
1.4 PWR of Russian Design (WWER)
1.5 Graphite Moderated BWR of Russian Design (RBMK)
1.6 Heavy Water Reactor (HWR)
1.7 Gas Cooled Reactor (GCR)
1.8 High Temperature Reactor (HTR)
1.9 Fast Breeder Reactor (FBR)
2. Research Reactors
2.1 Test Reactors
2.2 Training Reactors
3. Accelerator Driven System (ADS)
4. Nuclear Fuel Cycle Plants
4.1 Fuel Manufacturing Plant
4.2 Fuel Reprocessing Plant
5. Radioactive Waste Plants
5.1 Waste Repository "temporary"
5.2 Waste Repository "final"
6. Hot (radioactive) Installations
6.1 Hot Cells
6.2 Hot Laboratory
7. Accelerators
7.1 Cyklotron
7.2 Linear Accelerator
7.3 Synchroton
7.4 Mikrotron
7.5 Neutron Generators
8. X-Ray Source (Roentgen)
9. Artificial Radionuclide Sources
9.1 Open Sources
9.2 Neutron Sources
9.3 Isotopes
9.3.1 Co-60
9.3.2 Ir-192
9.3.3 Cs-137
9.3.4 I-131
10. Natural Radiation
10.1 Radon
10.2 Cosmic Radiation
10.3 Naturally Occurring Radiactive Materials

- Dedication of **RP** Activity Area Chapters to Real Plant Types: **D-12.2**
  - The 10 categories of real plant types are listed in the table next to the graph in D-12.2.
  - Within "Europe", the EU and the CEEC, the majority of activities are dedicated to "Natural Radiation (10.)", followed by "Artificial Radio-nuclide Sources (9.)", "Nuclear Power Plants (1.)" and "Nuclear Fuel Cycle Plants (4.)";
  - Within the CEEC, and compared to the EU, relatively high emphasis is placed on activities related to "Research Reactors (2.)", and low emphasis on "Nuclear Fuel Cycle Plants (4.)".

Region	all 1.-comb.	1.	all 2.-comb.	2.	all 3.-comb.	3.	all 4.-comb.	4.
OTHERS	3	0	17	9	8	1	0	0
CEEC	69	11	64	5	43	1	10	0
EU	176	40	125	16	145	35	60	1
"Europe"	248	51	206	30	196	37	60	1

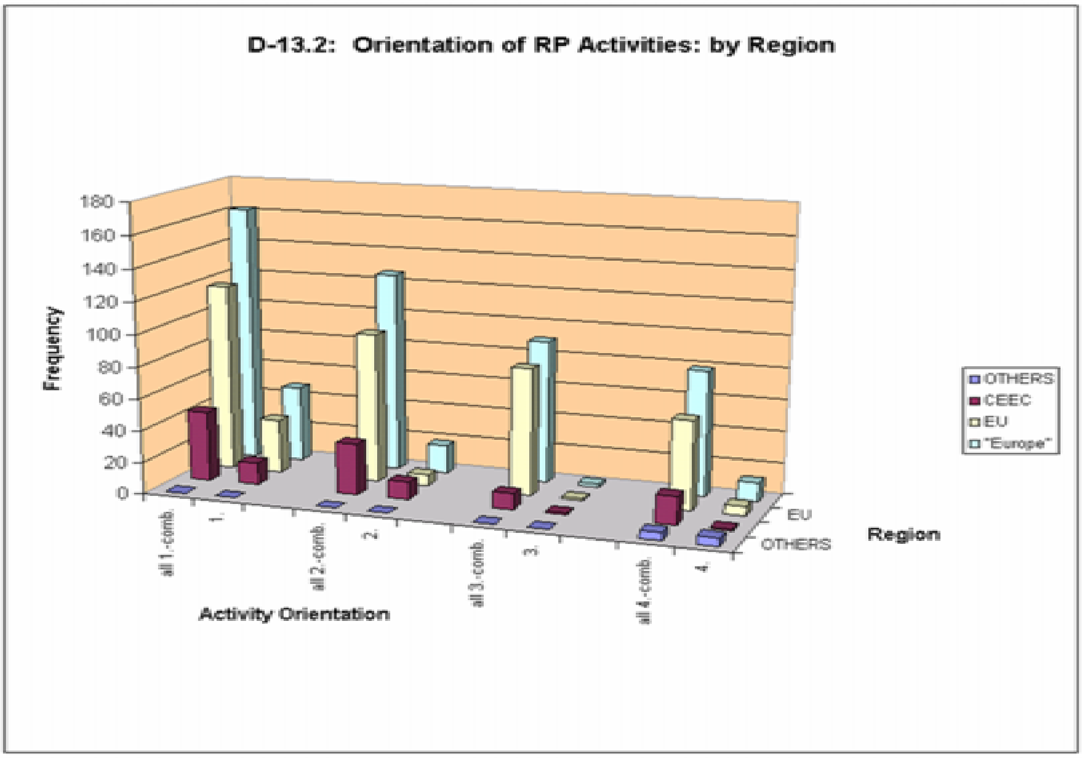


Activity Orientation
1. Adding Value to Knowledge
2. Industry Oriented
3. Regulation Oriented
4. Policy Making Oriented

"all x.-comb." =
all combinations with "x",
incl."x" alone

- Orientation of Activities performed in **NF** Activity Area Chapters: **D-13.1**
  - The 4 categories of activity orientation are listed in the table next to the graph in D-13.1.
  - The NF related "Experimental and Non-experimental Activities" have in the vast majority more than one single orientation;
  - "Policy Making Oriented (4.)" activities nearly never occur as single activity orientation;
  - The orientation of NF related "Experimental and Non-experimental Activities" is in the majority focused on "Adding Value to Knowledge (1.)", as a single activity orientation as well as in combination with one or more other activity orientations;
  - In the EU, the second frequent orientation exists for "Regulation (3.)" followed by "Industry (2.)", and in the CEEC this order is the inverse;
  - Activities comprising the orientation towards "Policy Making (4.)" exist in the EU as well as in the CEEC.

Region	all 1.-comb.	1.	all 2.-comb.	2.	all 3.-comb.	3.	all 4.-comb.	4.
OTHERS	0	0	0	0	0	0	5	5
CEEC	44	14	32	11	10	1	18	1
EU	118	34	94	7	80	1	56	6
"Europe"	162	48	126	18	90	2	79	12



Activity Orientation
1. Adding Value to Knowledge
2. Industry Oriented
3. Regulation Oriented
4. Policy Making Oriented

"all x.-comb." = all combinations with "x", incl. "x" alone

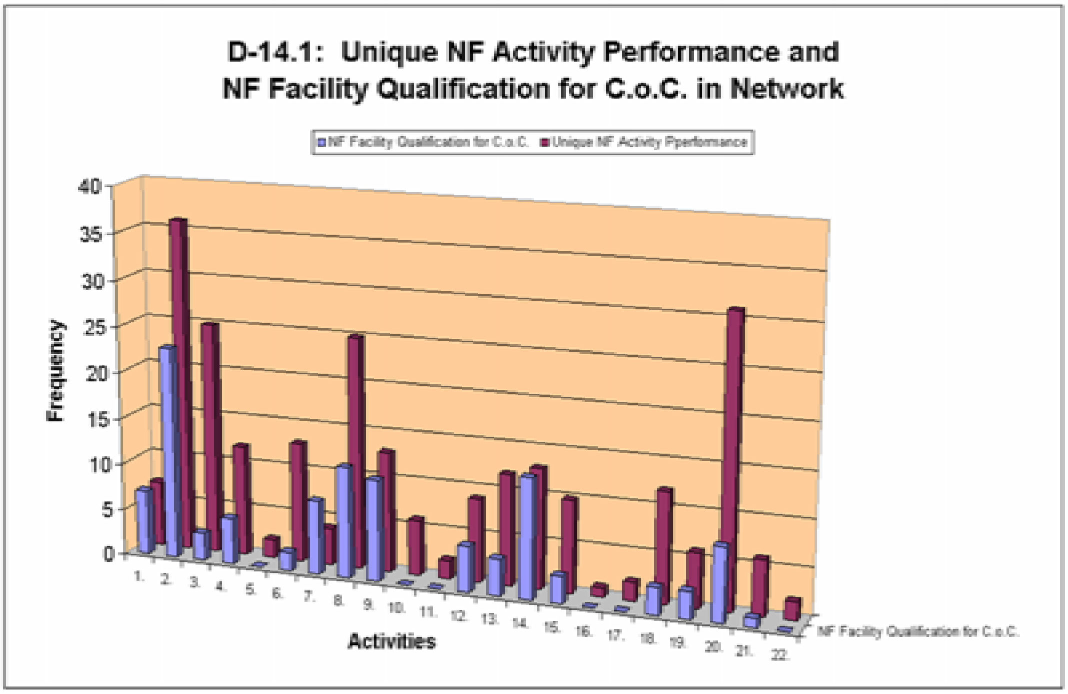
Orientation of Activities performed in **RP** Activity Area Chapters: **D-13.2**

- The 4 categories of activity orientation are listed in the table next to the graph in D-13.2.
- The RP related "Experimental and Non-experimental Activities" have in the vast majority, like in the NF related activities (see D-13.1), more than one single orientation;
- Within "Europe" and the EU, the frequency distribution profile for the activity orientation is quite similar showing a steady decrease from "Adding Value to Knowledge (1.)" down to "Industry Oriented (4.)";
- Within the CEEC, we observe nearly the same profile with one exception: "Industry Oriented (4.)" shows a higher frequency than "Policy Making Oriented (3.)".

Note: The numbering sequence in the table for the "Activity Orientation" has to be inverted as follows: 2. Regulation Oriented; 3. Policy Making Oriented; 4. Industry Oriented

ANNEX 3: Frequency of Responses Regarding "Unique Performance of NF Activities” and "Unique NF Expertise/Capabilities” (Diagram D-14.1)

Activity =>	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	Total
NF Facility Qualification for C.o.C.	7	23	3	5	0	2	8	12	11	0	0	5	4	13	3	0	0	3	3	8	1	0	111
Unique NF Activity Pperformance	7	36	25	12	2	13	4	25	13	6	2	9	12	13	10	1	2	12	6	31	6	2	249



Activities

1. Project Management and Co-ordination
2. System Technology and Behaviour
3. Component Technology and Behaviour
4. Nuclear Fuel Technology and Behaviour
5. Nuclear Fuel Cycle Facilities
6. Reactor Core Technology and Behaviour
7. Decommissioning of Nuclear Plants and Facilities
8. Material Technology and Behaviour
9. Risk
10. Radiation
11. Electricity
12. Instrumentation and Control
13. Spent Fuel
14. Waste
15. Partitioning and Transmutation
16. Particular Investigations
17. Emergency Plans
18. Experimental Investigations
19. Human Factor
20. Fundamental Investigations
21. Education and Training
22. Legal Framework and Standards

Total

ANNEX 4: Comments given by the respondents regarding specific needs and future activities in the field of reactor safety and future systems

The content of this Annex summarizes the input of the participating organisations and has not been examined and evaluated by the Panel

Needs

Specific needs regarding System & Component Behaviour, Materials and Safety

- In the whole ensemble of responses safety related issues are prevailing, especially severe accidents, prevention of such accidents and/or mitigation of their consequences. Emphasised is (as a support for the solution of these problems) the necessity of an extended knowledge database, the capability to utilise currently available databases of the experimental and operational data; severe accidents should be treated as a part of the extended design documentation.
- A strong emphasis has to be put on ageing and, provided it fits to nuclear energy policy, on lifetime extension of existing plants. Recommended is material know-ledge base extension, analyses of components degradation and damage caused by operation (including accident conditions), development of materials resistant in extreme conditions (temperature, pressure, radiation, etc.).
- Special attention should be paid to areas such as:
  - advanced information technologies, instrumentation & control systems,
  - upgrading PSA methodology,
  - development of new advanced computer tools for accidents modelling,
  - research of basic safety barriers integrity, operational reliability,
  - inspection techniques and on-line monitoring.

Successful solution of these problems is a prerequisite for economic, reliable and safe operation, which together with the correct promotion, influences acceptability of nuclear energy for the general public

Specific needs regarding fuel and core

Particular projects are required on

- Enhancement of fuel operational reliability/integrity.
- Research of fuel behaviour in accident conditions.
- Development of new nuclear fuel for high burn-up.
- Fuel reload optimisation methods.
- Advanced information and prediction methods for core behaviour.
- Supporting service and analyses for the complex fuel cycle.

Specific needs regarding Risk and Human Factor

- Risk-oriented approaches (including human factor effects) are generally regarded as efficient tools and therefore their development is considered mandatory for a number of purposes: for NPP design preparation and optimisation, for NPP operation and maintenance, as well as for regulatory related activities.
- Qualified risk assessment is an important tool for arguing and supporting the defence of nuclear power as a present and prospective energy source. Creation of powerful risk assessment methods in shortest possible time is a prerequisite for that purpose; the results will serve as a rational argumentation for the industry, decision-making bodies and the general public.

In the Emergency Preparedness areas the development of decision-making supporting tools for National and NPP Crisis Teams should be promoted.

Future activities

The participants in the exercise are considering the following future activities in the field of nuclear fission:

System Technology and Behaviour

- REDOS: EU 5 FP Project (Reactor Dosimetry) Code development and validation. Procedures preparation. Radiation deposition methodology development and implementation for decommissioning of VVER NPP's. Nuclear fuel behaviour under:
  - Normal operating condition,
  - accident conditions
- 3D calculations for containment hydrogen distribution in the containment to evaluate hydrogen mitigation measures.
- Containment severe accident analyses to support the Level 2 PSA.
- Development of a water hammer code for fast two-phase flow pressure transient analyses.
- Two phase flow investigations in components with large diameter and high pressure tomografic measurement techniques modelling of microstructure property relations Coupling of thermal hydraulics system/ 3D neutron kinetics codes with CFD codes for appropriate consideration of coolant mixing effects.
- Analysis of PHEBUS tests and validation of radionuclide transport models against experimental data.
- Development of new chemical reaction models to account for PHEBUS results
- Application of neural algorithms to source term analysis in support to probabilistic safety assessments.
- Coupling between aerosol transport models and fluiddynamic codes.
- Studies on severe accident phenomenology for a LBE-cooled Accelerator Driven System (ADS).
- Implementation and validation of a 3-D neutronic model coupled to a thermal-hydraulics code for accident analysis of an Accelerator Driven System (ADS).

Component Technology and Behaviour

- High temperature electrodes Radiation technique (gamma, electrons), ageing simulation, DBE-testing, acceptance criteria specification, measurement performance, high dose dosimetry. Electron accelerator, gamma irradiations and DBE-simulator make possible to solve problems connected to evaluation of DBE-simulation tests.
- Enhancement of the computer programs improve the accuracy of failure predictions.

Nuclear Fuel Technology and Behaviour

- Extended burn up fuel behaviour modelling.
- In reactor load following tests in TRIGA material testing reactor (design, data interpretation).
- Development of a new extended burn up fuel bundle design.
- Technologies for manufacturing of advanced CANDU fuel destined for burn up extension.
- Utilisation of Recovered Uranium (RU) and Slightly Enriched Uranium (SEU) for manufacturing of nuclear fuel for extended burnup.
- Accelerator Driven Systems can become an essential and very viable solution to the major remaining problems of nuclear energy production. The MYRRHA system would provide the indispensable first step towards the European XADS. MYRRHA is an innovative project that will trigger different research and industrial activities in fields such as accelerator reliability (mitigation of proton beam trips, nuclear waste management (transmutation), and development of new materials, environmental medicine, structural corrosion and embrittlement (liquid Pb-Bi), and safety of nuclear installations. Increasing knowledge and know-how in these fields will contribute to aspects of sustainable development and offer a potential for industrially applicable spin-offs.

Reactor Core Technology and Behaviour

- Detailed analysis related with advanced reactor concepts and advanced fuel cycle options, in particular for the RU and SEU fuel cycles, applied for the current and for the advanced PHWR cores development of the institute capability to perform accident analysis for the CANDU reactors, including reactor physics (3D-kinetics), thermal-hydraulics for the PHT and other heat transport systems, containment, severe accident (as far as possible) development and validation of an independent reactor physics code system, dedicated to CANDU reactor analysis, based on 1D, 2D and 3D multigroup transport codes and on 3D multigroup diffusion code, including burn up and 3d kinetics module, able to simulate the reactor regulating system actions.
- Neutronics calculations for Accelerator Driven Systems (ADS) safety studies.

Decommissioning of Nuclear Plants and Facilities

- Deactivation of pure metals

Material Technology and Behaviour

- Irradiation facility for testing of structure materials and components behaviour. for ADTT - structure materials and components behaviour under irradiation (eg. mech. properties).
- Molten salts behaviour under irradiation (e.g. stability, chem. composition).
- Compatibility of structure materials with molten salts at high temperature and under irradiation.
- Verification of physical models.
- Advanced Zr-alloy cladding materials studies (corrosion, hydriding, creep, swelling).
- Nuclear fuel behaviour (thermal properties, fission gas release at normal operation).
- Microbial corrosion of CANDU NPP components.
- Long term corrosion surveillance of NPP secondary circuit.
- Mathematical modelling of the impurities concentration and deposition processes.
- Chemical cleaning and passivation technologies of components for steam generator and secondary circuit of NPP.
- Development of testing and analysis methods regarding the nuclear materials behaviour under abnormal condition of operation.
- Modelling of materials fuel channel behaviour under abnormal condition of operation.
- Monitoring of aerosoles - micromachining - time-of-flight spectrometer for RBS and ERDA.
- Instrumentation of nuclear fuel rods for in-pile fuel research.
- Development of Electro Chemical Potential (ECP) reference electrode and typical instrumentation for in-reactor use
- Refinement and further qualification of direct fracture toughness measurement, and further development modelling (mechanistic and computer simulation) of pressure vessel steels irradiation effects
- Laser reconstitution of pressure vessel material samples
- Advanced microstructural investigation techniques (XRD, TEM, XPS) to be applied to irradiated materials
- Fuel zircaloy cladding fracture toughness and microstructural evaluation
- Development of crack-arrest technique, within the frame of pressure vessel steel and fusion materials research
- Research on Thorium and Inert Matrix based fuels
- Hot-cell Slow Strain Rate Test (SSRT) equipment within an autoclave for dedicated IASCC research
- Research on ODS and RAFM materials as candidate fusion reactor materials
- Introduction of lifetime non-destructive tests diagnosis into application

Risk

- Models and software development for risk monitoring:
- develop methods and study cases for different applications of the plant probabilistic model to support the management and decision making process (design evaluation, personnel training, tech specs optimisation, configuration control, licensing decisions based on risk information, inspection prioritisation, operational procedures evaluation, abnormal operation procedures and accident management, etc.),
  - participating in the performance of the CANDU 600, Cernavoda Unit 2 PSA study,
  - application and development of SPSA (Shutdown PSA) methodology and study for CANDU 600,
  - external events modelling -PSA level 2 study and developments for CANDU 600,
  - development of a probabilistic model and risk assessment for TRIGA 14 MW research /testing reactor, non-reactor installations and SCN site.
- Use of emerging information technology (personal computers, communication technologies) for critical automation.
- Integration of automation safety and plant safety operational condition monitoring integrated with advanced maintenance procedures and decision theory.

Instrumentation and Control

- Development, testing and installation of methods and algorithms applicable for on-line process optimisation, early fault detection and root-cause diagnosis in large, complex industrial systems (especially in nuclear power plants).
- Use of operational feedback and data bases to optimise the utilisation of available knowledge in sustained safety management. A large international research project (Euratom funded) will start in mid 2001 on how nuclear management is and should handle deregulation, globalisation, ageing of staff and components, public opinion change, demotivation.
- Increased activities regarding data management with preservation and innovative dissemination of data, including remote calculation ageing of other material than steel components system, process and human aspects of ageing.

Experimental Investigations

- Non-destructive corrosion monitoring at loading conditions by the means of acoustic emission for modification on the active loop.

Fundamental Investigations

- Development of new thermal-hydraulic models, supported by specific separate effects tests, e.g. 3D two-phase CFD.
- Reactor physics analysis of different transmutation concepts (ADS, molten salt reactor). Calculation of the equilibrium isotopic concentrations and dynamic properties of molten salt reactors.
- Installation of a source for ultracold neutrons and studies with this type of neutrons

- Chemical interactions and coupled processes in the near field of the repository. Participation in international large scale near field experiments in rock laboratories. Development of capability to study alpha nuclides in anaerobic conditions.
- Development on speciation techniques and on-lime measurements of chemical parameters.

Education and Training

- Continuation of the present work.
- Development and application of retrospective dosimetry.
- Updating of the Neutron Metrology File (NMF-90) and the International Reactor Dosimetry File (IRDF-90) of IAEA NDS.

Future Networking and need for experimental facilities

The participants in the exercise are considering future networking activities in the following fields:

System technology in general:

- Hydrogen risk management.
- Hydrogen recombiners linked with passive heat removal systems
- Safety analysis for CANDU reactors (thermo-syphoning, void effect reactivity, moderator as cold source, etc.).
- Validation of codes, methodology and actual validation work similar to LWR
- Code application to CANDU reactor thermal-hydraulics, containment and severe accidents, model development and validation.
- Continuation of DEEPSSI (Design and Development of a Steam Generator Emergency Feedwater Passive System for Existing and Future PWRs Using Advanced Steam Injectors) Project; 6 partners proposed.
- Validation of coupled neutron-kinetics and fluiddynamics codes (VALCO); 7 partners proposed.

Normal operation - operational safety:

- THENPHEBISP, Competitiveness and sustainability of nuclear energy in the European Union; 14 partners proposed.
- Michelangelo network; 19 organisations proposed.

Accidents without core degradation:

- Development and validation of the next generation of thermal-hydraulic code (European initiative comprising experimental and analytical efforts); at least 4 partners proposed.
- Development and harmonisation of European safety requirements.

- Accident Analysis Code User Club CENS (Centre of nuclear safety for MEEC and CIS countries), System behaviour and analysis, component behaviour and analysis, accident analysis safety issues, safety improvement programme.

Severe accidents:

- European network for the reduction of uncertainties in severe accident safety issues (EUSAFE); 17 partners proposed and EDO "Gidropress" (Russia).
- Centre of nuclear safety for MEEC and CIS countries, Analysis, safety issues, safety improvement programs, safety research, decommissioning; at least 4 partners proposed plus Eastern TSOs.
- Severe accident modelling code (European initiative comprising experimental and analytical efforts).
- Resolution of hydrogen issue, deterministic and PSA, experimental database for CFD codes for ex-vessel molten corium behaviour, severe accident mitigation strategies, co-operation with OECD MASCA project; 17 partners proposed.
- Melt progression into concrete, experimental large scale MCCI (2D) tests and modelling activities; 4 partners proposed.

Source term:

- ECART code maintenance and development; 2 partners proposed.
- Thermal-hydraulics, Aerosol, Iodine ThAI facility); DE.

Component technology:

- Continuation of Network for Evaluation of Structural Components (NESC).
- Continuation of AMES Thematic Network on Ageing (ATHENA).

Nuclear Fuel Cycle Facilities

- Design/Safety by using Coupled 3D Neutronics Thermohydraulics Models; 6 partners proposed.
- Fuel behaviour modelling for accident conditions - Rapid power transient tests in TRIGA ACPR.

Reactor Core and Technology

- Molten Salt Reactor Revisiting Critical Issues in Nuclear Reactor; 8 partners proposed.

Material Technology and Behaviour, Non-destructive testing

- IASCC study on BWR, RBMK and PWR internals and RPV materials for plant life extension and management; 7 partners proposed.
- New generation of radioactive beam facility (EURISOL), design of second generation radioactive beam facility in Europe; 9 partners proposed.

- Application of ion beam analytical methods for the solution of environmental and industrial problems: "Motion microsensors with ferromagnetic patterns produced by ion beam micro-machining"; 3 partners from SI, IT, USA proposed.
- Reliability studies to residual stress characterisation NDT technology.

Risk Assessment

- Application of neural algorithms to source term analysis in support to probabilistic safety assessments.
- Risk Assessment Methodology for Civil Nuclear Sites (modelling of nuclear installations, accident sequences, reliability databases, human action models, common cause failure and dependencies, consequence evaluation, risk estimation, software tools).
- Dynamic level-2 probabilistic safety assessment programme.

Human factor:

- Workshops of "Inter-University Co-operation on System Safety" under the auspices of the Werner Reimers Foundation and the Maison des Sciences de l'Homme (Paris). TU Berlin, "Research Institution System Safety" will further develop the co-operation with the Safety Units of the universities of Technology in Delft and Budapest with regard to "The Role of Human Factors for Safety in High Hazard Organizations".

Physics:

- Evaluation of the Th-232 resonance cross section structure, Action Plan PECO initiative "Neutron measurement and Evaluation Activities"; 3 partners
- VVER Safety Analysis: -Development of coupled code packages (includes 3D neutron kinetics code and thermal hydraulic system models):
- validation of coupled codes on international benchmarks.
- generation of neutron physical data for such widened area of parameters which is significant during accident processes,
- development and validation of models for dynamic fuel rod behaviour Investigation of the formation of low borated plugs; 7 partners.
- Participation in MICANET, HTR-TN, considered: network on neutron data priorities based on requests from European industry.
- EURISOL European Isotope Separation, On-Line Radioactive Nuclear Beam Facility. The detailed objectives are: to prepare a conceptual layout of the next-generation European ISOL Radioactive Nuclear Beam (RNB) facility, driver accelerator, target/ion-source assembly, mass-selection system, post-accelerator, and instrumentation; to identify the possible synergies with other major European projects and existing laboratory infrastructures; to identify the key technologies involved and the R&D still needed, which would be part of the next step in such a project; to establish a cost estimate of the considered facility, including capital investment and running costs.

Thermal-Hydraulics

- Development of new thermal-hydraulic models, supported by specific separate effects tests (3D two-phase CFD). Follow-up activity to 5th FWP activities, like EUROFASTNET (European Group for Future Advances in Science and Technology for Nuclear Engineering Thermal-hydraulics), ECORA (Evaluation of Computational Fluid Dynamic Methods for Reactor Safety Analysis), ASTAR (Advanced 3D Two-Phase Flow Simulation Tool for Application to Reactor Safety).
- FLOMIX: Coolant mixing and flow distribution simulation in nuclear reactors; at least 6 partners.
- THERMO-NET (Thermal-hydraulics network of laboratories for nuclear reactors studies - design and operational safety): Thermal-hydraulic codes library, open experimental platform, distributed data bases (extended CERTA - Consolidation of the Integral System Experimental Data Bases for Reactor Thermal-hydraulic Safety Analysis), high performance computing and networking; 26 organisations from 13 Eastern and Western European countries may participate.

Divers

- Cable condition monitoring and life extension in NPPs.
- Scaling of containment experiments.
- Continuation of Halden Reactor Project (NO), year 2003 - 2005; 20 countries currently participating.

ANNEX 5: Comments given by the respondents regarding specific needs and future activities in the field of waste management and disposal of radioactive waste

The content of this Annex summarizes the input of the participating organisations and has not been examined and evaluated by the Panel

Needs

The following specific needs in the fields of waste management and disposal of radioactive waste have been highlighted by the participants in the exercise:

- Research in the field of radioactive waste management and waste disposal is a must in the medium and long term in Europe.
- Although geological formations could be different from one country to another, there are common points in the R&D related to this problem. The involvement of the scientific community, decision-makers, and public at the European level will be a decisive point in the decision process.
- Radioactive waste management is a major and common issue in Europe, therefore it is important to set up a European network to allow achieving a common understanding about the possible solutions and their impact on the environment.
- Research and demonstration of the feasibility of spent fuel and high-level radioactive waste final disposal by construction of a monitored, retrievable, limited scale disposal facility. Such a facility could be monitored for a reasonably long period of time to provide assurance of the feasibility of spent fuel and High Level Waste (HLW) final disposal. Beside the scientific use, such a facility could be a key cornerstone in achieving public acceptance.
- The establishment of a multinational network with the aim to combine the efforts of underground laboratories as Centres of Competence is strongly recommended.
- Formation of Centres of Competence comprising a number of institutes working on the radio-/geo-chemical issues is highly desirable and would be of great value for the elaboration of a consistent database, which is of interest to every national waste disposal programme.
- Transmutation (development and testing of new technologies in order to explore the possibility to eliminate part of the waste produced in the nuclear plants; in so doing shedding a new light on the issue of nuclear waste treatment and storage, presently one of the most difficult issues to be understood and accepted by the vast public due to the "multi-century solutions" it requires to deal with)
- Projects are required on:
  - spent fuel behaviour,
  - fuel reprocessing and demonstration of fuel cycle back-end feasibility,
  - spent fuel storage/disposal,
  - waste conditioning and treatment,
  - new engineering barriers for new type of high-level waste,

- waste disposal,
- long-lived waste repository issues,
- decommissioning and site rehabilitation,
- radiation monitoring,
- elaboration of comprehensive data sets for the various disposal options in granite, argillaceous formations and rock salt. This has to be achieved by site specific investigations as well as by non-site specific research in underground rock laboratories,
- emergency response capabilities,
- non-site specific research, mainly on basic nuclear physics, radiochemistry, geochemistry, applied geology.

Future activities

Spent Fuel

- Determination of organic components in waste. Analysis of composite (radioactive and toxical) waste.
- Safety issues of new automation will be studied in the modernisation of current Finnish NPPs, or in connection with future plant concepts. More concentrated effort to study the role of glaciations on the performance of spent fuel repository.

Waste

- Elaboration of QA program for LIL waste final disposal and spent fuel dry storage.
- Elaboration of preliminary and final safety assessment reports for LIL waste final disposal and spent fuel dry storage.
- Equipment design for LIL waste final disposal and spent fuel dry storage
- dissolution and leaching of spent fuel under clay conditions with active samples full scale integrated demonstration tests in the frame of HLW or spent fuel disposal.
- Design, construction and underground testing of fiber optics sensors for repository long-term monitoring. This activity is already started and will be intensified.
- Concentrated effort to study the role of glacial cycle on the performance of spent fuel repository. Automatic integration of various hydrogeological data for site models with their confidence limits, which enables alternative conceptualisations and sensitivity analysis.
- Via its communications policy, NDWMU is implementing the Ispra Site's Decommissioning and Waste Management Programme as transparently as possible to address the needs and concerns of the programme's sponsors.

Partitioning and Transmutation

- Heat transfer molten salt-water/steam -specific components and sensors.
- Modification of the investigated process for the replacement into the hot cell.
- concentration of measurement program on waste transmutation and safety aspects.

- The SPES Project, using the results of TRASCO, will produce accelerator driven high flux neutron fields for the production of radioactive beams using a ISOL source with fissile elements 238U and 232Th. Medical applications (BNCT), solid state and material science applications are also foreseen.
- Design and testing high power spallation target.

Future Networking and need for experimental facilities

Spent Fuel Disposal Technology

- Accelerator driven systems programme under discussion; at lest 5 partners proposed.
- Posiva's research programme on spent fuel disposal.

Design of Waste Deposit Facilities

- Underground research facilities, international collaboration linked to education, training, joint experiments, etc.; co-operation with IAEA, Canada, USA.
- Evaluation and development of concepts of repositories for high-level waste (CROP: The Cluster repository Project is an existing concerted action & thematic network project focussing on the improvement of European repository concepts by evaluating experiences from large-scale underground laboratories); 6 partners and OPG-Canada, USDOE-USA proposed.

Safety and Security of Waste Deposit Facilities:

- Performance assessment of repository systems: creating a quality system for computer models and input data used in the calculations for safety assessment.
- Repository technology: development and testing of techniques for long term monitoring of the waste package and geological environment.
- Waste and spent fuel management and disposal, management strategies: comparison of different storage concepts for high level waste and spent fuel.
- Experiment Modex Repository, geo-mechanical vertical mine test programme, Meuse-Haute-Marne Underground Research Laboratory, France, HADES Underground Repository, Belgium, Aspö Hard Rock Laboratory, Sweden, etc.; co-operation with scheduled IAEA network.
- Gas issues in safety assessment of deep repositories for nuclear waste; 7 partners proposed.
- Development of consistent thermo-dynamical data base universally applicable to different geological environments; 9 partners proposed.
- Elaboration of a European platform for performance assessment for radioactive waste repositories. Based on the experiences gained in the EU-projects PAGIS, PACOMA, EVEREST, SPA, BENOPA and SPIN, establishment of a European network on the harmonisation of performance assessment methodologies and tools; at least 5 potential partners.

Partitioning and transmutation, theoretical and experimental investigations:

- International programme similar to Czech national RTD programme coordinated by Ministry of Trade and Industry and Czech Radioactive Waste Depository Authority.
- Investigation of waste recycling symbiotic nuclear energy systems.
- Assessment of HLW produced in different types of reactors.
- Design, examination of kinetics parameters and associated dynamic behaviour of accelerator driven transmutation systems.
- Design of partitioning procedures fitted to the demands of transmutation; at least 5 potential partners proposed and Kurchatov Institute of Atomic Energy Moscow (USSR), Research Institute of Atomic Reactors Dimitrovgrad (Russia).
- ADOPT - ADS network MOST - molten salt technology network.
- SPIRE - materials for ADS network.

Chemistry

- Research programme on nuclear waste disposal.

Geology

- Posiva's research programme on spent fuel disposal, Public Sector's research programme on nuclear waste management.

ANNEX 6: Comments given by the respondents regarding specific needs and future activities in the field of radiation protection and radiological sciences

The content of this Annex summarizes the input of the participating organisations and has not been examined and evaluated by the Panel

Needs

The following specific needs in the fields of Radiation Protection and Radiological Sciences (RP) have been highlighted by the participants in the exercise:

- Competence in Radiation Protection and Radiological Science has to be maintained with the aim to be capable to answer questions and solve problems in related applications.
- The maintenance of the management of radiation injuries research is needed.
- Further developments in experimental radiobiological research are necessary which seems to be an indispensable basis for progress in the principles of RP (including the approach to the LNT (Linear Non-Threshold) issue).
- Support, to a reasonable extent, the basic research in radiobiology and in epidemiological studies to maintain the theoretical basis for setting criteria and principles of RP.
- Research is required related to
  - biological effects of radiation in epidemiological studies on the effects of radiation and appropriate extension of such studies in exposed groups,
  - development of criteria for managing chronic (continuing) exposures,
  - natural radiation,
  - continuation of evaluating the exposure of the public to radon in dwellings, and suggestion of effective countermeasures,
  - evaluation of natural exposure by cosmic radiation (aircraft travel),
  - environmental transfer of radioactive substances,
  - study of the kinetics of radio-nuclides within the human body,
  - ionising radiation in medicine,
  - up-grading of standards and preparing of new directives.
- The establishment of networks is recommended for a better harmonisation of tasks related to
  - environmental monitoring,
  - effect of radio-nuclides in the environment and environmental preservation,
  - biological and medical effects, medical exposure, further development of concepts and techniques aiming at the protection of professionals and patients in medical use of ionising radiation,
  - harmonisation of measurements and dosimetry, namely personal dosimetry (for this point, EURADOS already exists),

- Europe-wide radiation monitoring network enabling to transfer on-line information on the contamination of the air or of the territory to all participating countries.

- Unique installations in Europe have to be maintained.
- Further progress in the concepts and techniques concerning the protection of the public from radon in dwellings.
- Improvement of physical and medical surveillance of the radiation workers.
- Availability of medical centres and experts for medical handling of radiation accidents.
- Maintaining the basic requirements for emergency preparedness.
- Proposals for up-grading the infrastructure in RP to increase its effectiveness.
- Promotion of the international co-operation in conceptual issues, setting standards and exchange of operational experience. Even in the case of nuclear electricity production decrease, the risk of contamination in case of an accident remains (see Chernobyl effect).
- Maintenance of the indispensable scientific and operational RP capacity for the possible return of the nuclear programmes in the future.
- Increasing concern about education of young scientists and basic research in the fields related to RP.
- Independently on decrease or increase of nuclear electricity production share, the management of nuclear waste and dismantling of nuclear installations will require good radiation protection specialists for at least one generation of scientists, with a greater challenge resulting from a more and more reluctant attitude of the public towards ionising radiations.
- Risk assessment procedures related to nominal operations of NPP and nuclear emergencies.
- Up-grading the conceptual, organisational and technical issues of emergency preparedness including medical handling of radiation accidents.
- Regulations for the transport of spent radioactive fuel; radwaste disposal policy.
- Optimisation of the working regime of the staff of NPP, including reactor operators and managers, according to the principles of behavioural medicine and occupational hygiene.
- Planning and performing programmes and actions aimed at extending knowledge of the public on radiological issues and at clarifying the arguments concerning the acceptance of nuclear power and the use of radiation in medicine.
- Maintaining high competence for the managing of radiation protection related to the final stages of the nuclear fuel cycle (interim repositories, final burying), to further develop the concepts and techniques aiming at the protection of professionals and patients in medical use of ionising radiation.
- To continue the evaluation of the exposure of the public to radon in dwellings and to suggest effective countermeasures.

Future activities

The participants in the exercise are considering the following future activities in the field of radiation protection:

Radiation Exposure to Humans

- Internal exposure of the public by chronic ingestion and research of potential bioaccumulation phenomena after chronic exposure. This research could have an impact on the bio-kinetics of radionuclides and internal dosimetric models.
- External routine exposure of humans in neutron fields. Study and development of spectrometers and neutron field analysis tools, as well as personal neutron dosimeters.
- Development of methods for analysis of long-lived radionuclides, such as, Tc-99, I-129, Np-137, Cs-135 by mass spectrometry.
- The effect of dialysis for elimination of different radionuclides used in nuclear medicine.
- Preparation of registration dossier for clinical trials of H2(O-15)O and subsequently preparation of registration dossier.
- The application of the radiological security standards in the extraction field and uranium ores processing, standards elaborated by the National Commission for the Nuclear Activities Control from Romania. The application of the European methodology concerning the dose calculus and the modelling development.
- Intercomparison new standards regarding the measurement of radiopharmaceuticals in hospitals.
- Development of new spectra evaluation methods.

Characterisation of irradiation by Natural Sources

- Calculation of doses received by aircrew during previous years.
- National Radon Survey in collaboration with many Greek University Departments and Research Institutes.
- Risk Assessment and Environmental Impact of Depleted Uranium containing Munitions.
- Dosimetry of cabin crew, instrumentation for cosmic radiation measurements, modelling with GEANT code.
- Correlation of indoor radon measurements with radon progeny measurements, in soil radon and indoor and outdoor in situ gamma spectrometry measurements.
- Data collection of natural environmental radioactivity data, evaluation of these (with national experts) and publication as Atlas.

Environmental Transfer of Radioactive Substances

- Further code development following the technology advancement in computer sciences towards the direction of convergence of model predictions and reality. Data assimilation and uncertainty analysis on atmospheric dispersion models on complex terrain.

- Further development and coupling of the hydrological and radionuclide transport codes. Uncertainty analysis, calibration and validation of the coupled codes.
- Experimental investigation of the attachment coefficient of radionuclides on aerosols with respect to particle size. Sampling and specialisation of natural and technologically enhanced radionuclides in atmospheric aerosol.
- Application of environmental impact techniques to the data collected (see above) to verify compliance with safety standards.
- Advance Statistical analysis, further development (based on shared cost action CIVERT (Centre for Information and Valorisation of European Radioactive contaminated Territories) of advanced statistical techniques (Bayesian, multivariate analysis,) for evaluating monitoring data from various sources.
- Using top predators for the assessment of the environmental radiological situation.
- Radionuclides speciation from mine and pound waters of the plant for uranium ores processing.
- The identification and characterisation of some other polluting agents found in mine and pond waters.
- The risk assessment for humans and environment affected by the increased number of the pollution agents.

Radiation Effects on Environmental Ecosystems

- Radiation effects in natural populations of aquatic organisms based on the assessment of the distributions of structural chromosome damage.
- Conceptual model of responses of organisms, populations and ecosystems to all possible dose rates of ionising radiation in the environment.

Restoration

- Dose reduction in rural and urban areas, mapping of social and psychological factors of importance for the public acceptance of restoration work.
- The design and development of some efficient equipment for the mining sites cleaning-up, sites affected by the uranium ores extraction and processing.
- Professional reconversion of the former employees from closed uranium mines and their training for clean-up activities.
- The study of chemical processes from waste disposal site.

Biological effects of radiation

- Influence of NIR on activity of neuronal networks in vitro Influence of IR on activity of neuronal networks in vitro.
- Cytogenetics of human lymphocytes.
- Development of new therapeutic approaches. The research carried on to develop therapeutic treatments of haematopoietic syndrome, based on the injection of expanded ex vitro bone marrow cells, is extended to the expansion of mesenchymateous cells. Further investigations are conducted to test new therapeutic agents which act on the recovery of intestinal damage,

such as some cytokines which may induce a therapeutic benefit on GI tract as well as on haematopoietic tissues

- Investigation of these effects in lymphoid cells. Evaluation of the phenomena in relation to radioresistance/radiotolerance of healthy and cancerous cells. Identification of lymphoid subpopulations mediating such phenomena
- Relation of radiation exposure bystander effects to relative effects of chemo-therapeutical agents (e.g. nucleotide analogues).
- Studies of very low-dose effects in mammalian cells. Development of a micro collimated beam apparatus at the CN accelerator for irradiation of a single cell with a single particle or few counted particles.
- Complex investigations of biological factors influencing stochastic effects, Factors like progenitor cell pool, hypersensitivity, geometry of human genome, etc. will be investigated with the aim to put parameters into mathematical model predicting radiation risk.

Epidemiology

- Comparative study of predictive models of radiocarcinogenesis after low doses in the environment.

Radiological Risk Assessment and Management

- Radiological risk assessment from low- and medium-level waste deposits facilities. Studies of long-lived naturally occurring and waste related radionuclides in the environment using mass spectrometry.
- Involvement of the population in the management of radon in houses.
- Application of the ALARA principle for the protection of patients.
- Sponsors involvement in the assessment and management of radiological risks at contaminated sites and in contaminated territories.
- The development of the Probabilistic Safety Assessment, Level 3.

Emergency Preparedness

- Data assimilation systems as prognostic tools. Development of a data assimilation code for implementation in existing decision support systems.
- Completion of the data bases development.
- Development of software tools for the estimates of consequences of nuclear emergencies for Civil Defence purposes.

Future Networking and need for experimental facilities

The participants in the exercise are considering future networking activities in the following fields:

Radiation Exposure of Humans:

- Internal exposure, Bio-kinetics and Dosimetry of Internal Contamination (IRSN, FR), (BIODOS.
- External exposure IRSN FR) IRSN co-ordinator (F) ; Bundesamt für Strahlenschutz BfS (D) ; National Radiation Protection Institute (CZ) ;GSF (D), CEA (F); AEA Technology Plc.(UK); National Radiological Protection Board NRPB (UK); National Institute of Public Health and Environment RIV.
- Evaluation of Individual dosimetry in Mixed neutron photon fields (EVIDOS) (IRSN FR) Physikalisch Technische Bundesanstalt, co-ordinator PTB (D) ; IRSN (F); Universita degli Studi di Pisa DIMNP(I); National Radiological Protection Board NRPB (UK) ; Nuclear Centre of Mol SCK-CEN (B) ; Swedish Radiation Protection Institute SSI (S) ; Paul CH).
- Spectrometry and radiation field analysis (INT-RP, GR) WG3 of European Dosimetry Group EURADOS, Spain (CIEMAT)-Denmark (RISO)-Germany (PTB)-UK-Greece (NTL)List not closed.
- Medical exposure (AKH, DK) Concerted Action on Quality Criteria for CT contract no. FIGM-CT-2000-20078 running until 1 December 2003.
- Radiation metrology (IFIN- HH, RO) Development of radioactive standards for specific types of radiation, intercomparison for beta absorbed dose and neutron fluence rate and equivalent dose.
- Radio-nuclide Biokinetics Database, EU framework programme; (GSF, GE, NRPB, UK, AEA Technology, UK, CEA, FR, IPS, FR Karolinska Institute (SE)) EULEP continued since 1996.
- Workers/activities using radioactive material/sources of ionising radiation IPHB, RO.
- Methodology and measurements techniques(IFIN- HH, RO) Preparation of high precision tritium and radon standards, Installing of a X-ray spectrometric system, Participation in the EC, IDRANAP, WP 7 programs, Improvement of the FMH module (assessment of tritium food chain and dose) and of the geographical and radio-ecological data bases for Romania. (INFIN-HH , RO).
- Safe handling of production targets for high intensity radioactive ion beam facilities (INFN, IT) EURISOL - "SAFERIB" - European Network on safe handling of production targets for high intensity radioactive ion beam facilities LMU (Germany) ISOLDE (CERN) COLRC (UK) GANIL (France) INFN-LNL (Italy) GSI (Germany).

Characterisation of Irradiation by Natural Sources:

- (VKTA, GE) Collaboration of European Low level Underground Laboratories.

Environmental Transfer of Radioactive Substance:

- Environmental transfer of radioactive substances (LWT GE).
- Aquatic systems; lake and rivers (USBG) Austria.
- Studies of long-lived radio-nuclides in the environment using mass spectrometry (RISOE, DK) Nordic Nuclear Safety Research and next European Framework Programme.
- Radionuclides metrology IRMM (BE) EC-FP5.

Radiation effects on Environmental Ecosystems:

- Comparative effects of radiation and chemical pollutants in natural populations of aquatic organisms: An indicator based on analysis of chromosome aberrations (INT-RP, GR) Bilateral Collaboration Greece-Ukraine. Institute of Biology of the Southern Seas, Sebastopol, Ukraine.
- Radiation effects on environmental ecosystems (INT-RP, GR) JRC/ITU, Germany, ANU, Norway, RPI, Ukraine, UCA, Spain, JOGU, Germany, ISS, Italy, UO, Spain, Ministerio De Ciencia e Technologia, Portugal, ARPA, Italy, UNIBO, Italy, DASE - CEA, France.

Biological Effects of Radiation

- Exchange of cell-lines, exposure to short-range particles, determination of cytotoxic and genotoxic endpoints in vitro, biological effects of short-range particles. (GAG, GE), UROS (GE).
- Radio-sensitivity and radioresistance UROS, (GE) CEA (FR), Delft University NL, IRSN (FR).
- Cytogenetics of human lymphocytes - Protein Biochemistry (Markers for radio-sensitivity) BfS; GE, (UROS GE).
- Development of a Radio-pathology centre in Bucharest (IPHB, RO).
- Biological dosimetry (IPHB, RO).
- Retrospective measurement: volume traps; surface traps (GSF, GE). The institute of epidemiology participates in the EU-study (FIGH-CT1999-0008)"Study of lung cancer risk and residential radon exposure". Contribution to a large dataset of about 10 000 cases and their controls for an analysis of lung cancer risk BfS? Ge, NRPB, UK, SSI, SE, KI, SE.

Epidemiology

- Quantification of Lung Cancer Risk after Low Radon Exposure and Low exposure Rate: Synthesis from Epidemiologic and Experimental Data (UMINERS (IRSN-FR) IRSN (FR) IRSN coordinator (F) ; Univ. Salzburg (AU) ; National Radiological Protection Board NRPB (UK) ; Technoorg-Linda Co. Ltd (HU) ;Karolinska Institute (S) ; Swedish Radiation Protection Institute SSI (S); CEA/DSV/DRR - Laboratoire de Radiotoxi-cologie (F); GSF.

Radiological Risk Assessment and Management

- Radiological risk assessment from low- and medium-level waste deposit facilities (RISOE, DK).
- Technologically enhanced naturally occurring radioactive materials (INT-RP, GR) "Risk Assessment and Environmental Impact of Depleted Uranium containing Munitions".
- RADAMES Research proposal coordinated by EC-JRC-ITU, Karlsruhe.

Emergency Preparedness:

- Starting and continuing the European Networks DSSNET, DARMING, SAMEN, DAONEM (SCK-CEN, BE), LWT (GE).
- Participation in European Networks for emergency preparedness planning such as DSSNET, ENSEMBLE etc. Participation in NEA exercises(INEX etc) INT-RP (GR).
- Participation in European Networks for emergency preparedness planning such as DSSNET (IFIN-HH, RO).
- Network between GAEC and Greek Steelwork Industries for supporting in case of a radiological accident involving contaminated scrap metal. INT-RP (GR).
- NRPI (CZ)Common approach development and it's harmonisation with EU practices in the field of emergency preparedness.
- Development of methods and tools for NPP Technical Support Centres and for National Emergency Response Centres: VUJE Trnava (Slovakia), Nuclear regulatory authority of Czech and Slovak Republics.
- Emergency radiation monitoring NRPI(CZ) IAEA Emergency Response Network (ERNET).
- World-wide emergency assistance in situations necessitating rapid response to reduce consequences of a nuclear accident or radiological emergency With the other ERNET member institutions IJS, SL;
- Development of decision support systems (IFIN –IH, RO);
- Development of decision support systems NRI (CZ); Development of the prototype of Decision Support System. Research of human factor in emergency situations;
  OECD Halden Reactor Project Regulatory Framework Review, Institute for Energiteknikk (IFE), Norway;Nuclear Research Centre (SCK CEN), Belgium;Comissao Nacional de Energia Nuclear (CNEN), Brazil;Nuclear Research Institute (NRI), Czech Republic; Risoe National Laboratory (Risoe), Denmark, Ministry of Trade.

Education and Training:

- ULUND, (SE) Training courses and exchange of students. EDUNORDBALT Lund University, Nordic Countries and the Baltic States.
- IJS (SL) Organisation of training courses for determination of natural and man-made radio-nuclides.

ANNEX 7: Recommendations Made by the Participants

The content of this Annex summarizes the input of the participating organisations and has not been examined and evaluated by the Panel

Recommendations for actions to be taken by the European Commission

The following recommendations have been made by the participants for future actions to be taken by the European Commission:

- The European Commission should support the development of a clear and convincing European strategy regarding nuclear electricity production in the long term.
- A strategic European research programme should be developed whose continuity should be assured in the short, medium, and long-term.
- European public funds should be used to sustain the considered new developments in the nuclear field. The private sector will not be in a position to achieve this alone (the EU should support only exploratory, confirmatory and societal research; promotional research should be supported by industry). At the same time the administrative procedures of funding and grants to be followed by the applicants should be simplified for not preventing any potential participant from taking part in the European research programmes.
- As soon as possible, the European Commission should define the mechanisms necessary for the creation, financing and efficient functioning of the envisaged future ERA tools (ERA: European Research Area), especially for the networking of Centres of Competence/Excellence or Virtual Centres. These mechanisms should include the possibility to address not only specific but also strategic and complex issues. The mechanisms should be incorporated into the new Euratom Framework Programme.
- The research projects foreseen under the new Euratom Framework Programme should offer ambitious and attractive challenges for young scientists and should contribute to the preservation and further development of experimental facilities and analytical capabilities in Europe.
- A Joint EC-OECD/NEA Task Group should be set up to define forms of international cooperation which would comprise best practices already used and thus enhance the synergy effects in the topically related, but so far separate activities (designs, networks, EC organisational and financial capability, human potential and Working Groups know-how, NEA projects and organisational capability, including involvement of the organisations from outside the EU).
- Inclusion of Reactor Safety, Radiation Protection, Waste Management and New Reactor Concepts in the new Euratom Framework Programme is of interest for most of the Member States and is strongly recommended.
- A common approach to the needs and funding of unique and large research facilities should be developed and implemented in the EU and the associated countries.
- The Association Countries should by fully integrated in the European Research Area. The creation of Centres of Competence for reactors of Russian design is recommended.

- The foremost condition to maintain a European research infrastructure alive in the field of nuclear fission is to have, at European level, some leading and motivating projects with long-term objectives (similar for instance to the US Generation IV Initiative).
- An education system based on a network of European Universities with the aim of offering a degree of "European Master in Nuclear Science" and the introduction of a "European Certificate in Health Physics" should be promoted.

Regarding the assessment exercise performed, the Panel recommends in addition the following activity:

- The database comprising the responses to Questionnaire should be brought for the benefit of all EU Member States and Association Countries in an appropriate form (this would necessitate e.g. a clearing of confidential information), and uploaded onto a Web side for:
  - Identification of research areas of common interests and actions;
  - Identification of research organisations or organisational units for co-operation or the creation of European networks.

Recommendations for actions to be taken by the European Countries

- Governments should engage in strategic energy research planning, including the aspects of nuclear education, manpower and infrastructure.
- Governments should contribute to, if not take responsibility for, integrated planning to ensure that human resources are available to meet necessary obligations and address outstanding issues in the nuclear field.
- Governments should provide support by developing "educational networks or bridges" in the nuclear field between universities, industry and research institutes.
- Governments should develop and promote a programme of collaboration between the European countries in nuclear education and training.
- Existing capabilities to ensure safe and reliable operation of nuclear facilities, safe storage/disposal of spent fuel and safe processing and disposal of radioactive waste should be maintained.
- Adequate domestic capabilities should be maintained in support of European Governments for evaluating issues linked to nuclear safety, especially for cases of nuclear emergency whose consequences might transgress national borders.
- The European industry should support all activities related to education and preserving of competence in the nuclear field.
- In the frame of international networking, the European countries should open their national research programmes for other European countries.

Recommendations for actions to be taken in common by European Countries and the European Commission

- European Countries and the European Commission should promote the creation of European networks as well as the creation and further development of nuclear Centres of Competence in Europe to optimise resources.
- Co-operation between European nuclear research centres and Universities should be increased, e.g. through European networks.

- Networking under European projects should be increased also with respect to Non-European Countries, for example with USA and Japan.
- Centres of Competence beyond the traditional nuclear areas should be identified and supported, e.g. on:
  - organisational Learning and
  - knowledge Management.
- Support of fundamental research programmes should not be constrained by short-term political views.

A European strategy for the most efficient use of existing training and research reactors in the medium term and for the construction of new facilities in the long term should be developed. The use of these facilities should be optimised at European level, considering the future needs in nuclear and medical applications.

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