IAEA Nuclear Energy Series

No. NG-T-6.1

Status and Trends in Nuclear Education

Basic Principles

Objectives

Guides

Technical Reports

IAEA

International Atomic Energy Agency

IAEA NUCLEAR ENERGY SERIES PUBLICATIONS

STRUCTURE OF THE IAEA NUCLEAR ENERGY SERIES

Under the terms of Articles III.A and VIII.C of its Statute, the IAEA is authorized to foster the exchange of scientific and technical information on the peaceful uses of atomic energy. The publications in the **IAEA Nuclear Energy Series** provide information in the areas of nuclear power, nuclear fuel cycle, radioactive waste management and decommissioning, and on general issues that are relevant to all of the above mentioned areas. The structure of the IAEA Nuclear Energy Series comprises three levels: **1 — Basic Principles and Objectives; 2 — Guides; and 3 — Technical Reports.**

The **Nuclear Energy Basic Principles** publication describes the rationale and vision for the peaceful uses of nuclear energy.

Nuclear Energy Series Objectives publications explain the expectations to be met in various areas at different stages of implementation.

Nuclear Energy Series Guides provide high level guidance on how to achieve the objectives related to the various topics and areas involving the peaceful uses of nuclear energy.

Nuclear Energy Series Technical Reports provide additional, more detailed, information on activities related to the various areas dealt with in the IAEA Nuclear Energy Series.

The IAEA Nuclear Energy Series publications are coded as follows: **NG** — general; **NP** — nuclear power; **NF** — nuclear fuel; **NW** — radioactive waste management and decommissioning. In addition, the publications are available in English on the IAEA's Internet site:

http://www.iaea.org/Publications/index.html

For further information, please contact the IAEA at PO Box 100, Vienna International Centre, 1400 Vienna, Austria.

All users of the IAEA Nuclear Energy Series publications are invited to inform the IAEA of experience in their use for the purpose of ensuring that they continue to meet user needs. Information may be provided via the IAEA Internet site, by post, at the address given above, or by email to Official.Mail@iaea.org.

STATUS AND TRENDS IN NUCLEAR EDUCATION

The following States are Members of the International Atomic Energy Agency:

AFGHANISTAN
ALBANIA
ALGERIA
ANGOLA
ARGENTINA
ARMENIA
AUSTRALIA
AUSTRIA
AZERBAIJAN
BAHRAIN
BANGLADESH
BELARUS
BELGIUM
BELIZE
BENIN
BOLIVIA
BOSNIA AND HERZEGOVINA
BOTSWANA
BRAZIL
BULGARIA
BURKINA FASO
BURUNDI
CAMBODIA
CAMEROON
CANADA
CENTRAL AFRICAN REPUBLIC
CHAD
CHILE
CHINA
COLOMBIA
CONGO
COSTA RICA
CÔTE D'IVOIRE
CROATIA
CUBA
CYPRUS
CZECH REPUBLIC
DEMOCRATIC REPUBLIC OF THE CONGO
DENMARK
DOMINICAN REPUBLIC
ECUADOR
EGYPT
EL SALVADOR
ERITREA
ESTONIA
ETHIOPIA
FINLAND
FRANCE
GABON
GEORGIA
GERMANY
GHANA
GREECE
GUATEMALA
HAITI
HOLY SEE
HONDURAS
HUNGARY
ICELAND
INDIA
INDONESIA
IRAN, ISLAMIC REPUBLIC OF
IRAQ
IRELAND
ISRAEL
ITALY
JAMAICA
JAPAN
JORDAN
KAZAKHSTAN
KENYA
KOREA, REPUBLIC OF
KUWAIT
KYRGYZSTAN
LATVIA
LEBANON
LESOTHO
LIBERIA
LIBYAN ARAB JAMAHIRIYA
LIECHTENSTEIN
LITHUANIA
LUXEMBOURG
MADAGASCAR
MALAWI
MALAYSIA
MALI
MALTA
MARSHALL ISLANDS
MAURITANIA
MAURITIUS
MEXICO
MONACO
MONGOLIA
MONTENEGRO
MOROCCO
MOZAMBIQUE
MYANMAR
NAMIBIA
NEPAL
NETHERLANDS
NEW ZEALAND
NICARAGUA
NIGER
NIGERIA
NORWAY
OMAN
PAKISTAN
PALAU
PANAMA
PARAGUAY
PERU
PHILIPPINES
POLAND
PORTUGAL
QATAR
REPUBLIC OF MOLDOVA
ROMANIA
RUSSIAN FEDERATION
SAUDI ARABIA
SENEGAL
SERBIA
SEYCHELLES
SIERRA LEONE
SINGAPORE
SLOVAKIA
SLOVENIA
SOUTH AFRICA
SPAIN
SRI LANKA
SUDAN
SWEDEN
SWITZERLAND
SYRIAN ARAB REPUBLIC
TAJIKISTAN
THAILAND
THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA
TUNISIA
TURKEY
UGANDA
UKRAINE
UNITED ARAB EMIRATES
UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND
UNITED REPUBLIC OF TANZANIA
UNITED STATES OF AMERICA
URUGUAY
UZBEKISTAN
VENEZUELA
VIETNAM
YEMEN
ZAMBIA
ZIMBABWE

The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world''.

IAEA NUCLEAR ENERGY SERIES No. NG-T-6.1

STATUS AND TRENDS
IN NUCLEAR EDUCATION

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2011

Marketing and Sales Unit, Publishing Section
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria
fax: +43 1 2600 29302
tel.: +43 1 2600 22417
email: sales.publications@iaea.org
http://www.iaea.org/books

Printed by the IAEA in Austria
March 2011
STI/PUB/1475

IAEA Library Cataloguing in Publication Data

Status and trends in nuclear education. — Vienna : International Atomic Energy Agency, 2011.
p. ; 30 cm. — (IAEA nuclear energy series, ISSN 1995–7807 ; no. NG-T-6.1)
STI/PUB/1475
ISBN 978–92–0–109010–2
Includes bibliographical references.

1. Nuclear physics – Study and teaching. 2. Education. 3. Nuclear engineering – Study and teaching. 4. Iaea. 5. Member states. I. International Atomic Energy Agency. II. Series.

IAEAL 11–00680

FOREWORD

The important role which the IAEA plays in assisting Member States in the preservation and enhancement of nuclear knowledge and in facilitating international collaboration in this area has been recognized by the General Conference in resolutions GC(46)/RES/11B, GC(47)/RES/10B, GC(48)/RES/13, GC(50)/RES/13 and GC(51)/12. These resolutions request the IAEA to assist Member States in their efforts to ensure the preservation of nuclear education and training in all areas of nuclear technology for peaceful purposes, which is a necessary prerequisite for succession planning.

Recently, the IAEA has been working with universities to address future workforce demand and the quality and quantity of nuclear education. IAEA activities focused in particular on curriculums, networking universities and internet platforms for nuclear education. University networks supported include the World Nuclear University (WNU, of which the IAEA is also a founding supporter), the European Nuclear Education Network and the Asian Network for Education in Nuclear Technology, and also other national and regional initiatives.

At recent international meetings, the IAEA's role in assisting Member States in manageing nuclear knowledge has been clearly defined. This is reflected in the recommendations of two technical meetings on the Role of Universities in Preserving and Managing Nuclear Knowledge held in 2007 and 2008 and the Meeting of Senior Officials on Nuclear Knowledge Management — Cooperation for Development, May 2008. The IAEA has been asked by Member States to support the development of policies and strategies in nuclear education.

This report is in response to the request of Member States. Its purpose is to support the development of policies and strategies in nuclear education. It provides a review of the status of nuclear education in over 30 Member States and educational networks while consolidating the best practices in nuclear education. The publication also provides recommendations which could facilitate benchmarking, and improvements in and formulation of strategies, particularly for newcomer countries.

This publication is applicable to decision makers from governments, academia, regulators, facility owners and operators and private industry. In addition, it is intended for practitioners in nuclear education in newcomer, 'young' and mature categories of countries in terms of the extent of nuclear power development.

Appreciation is expressed to all participants who contributed to the drafting of this report. Particular thanks are due to J. Roberts (United Kingdom) for his assistance in consolidating the good practices in nuclear education.

The IAEA officers responsible for this report were A. Kosilov, M. Saidy and Y. Yanev of the Department of Nuclear Energy.

EDITORIAL NOTE

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

The Atoms for Peace initiative presented to the United Nations by President Dwight D. Eisenhower in December 1953 led to the introduction of peaceful uses of nuclear technology around the world. In many nations, the establishment of specialized educational programmes and institutions soon followed with the aim of, to producing a well educated and highly trained workforce for the safe and successful application of this technology.

Today, many countries have a strong nuclear programme while others are looking at creating a national nuclear programme for the first time. There are around 440 nuclear power plants operating in 30 countries [1]. Additionally, nuclear reactors have also been used to power over 400 ships and there are nearly 300 research reactors operating in 50 countries. These provide radioisotopes for medical diagnosis and cancer therapy, serving as a source of neutrons for researchers and as a training facility for students. Some observers point to the beginnings of a worldwide nuclear renaissance currently under way with approximately 55 new plants under construction and 110 planned. Some in countries with very nascent nuclear programmes.

Throughout their career, nuclear workers (in industry, government and universities) must have access to the appropriate level of education and training to perform competently. The level and type of work will determine the amount of training and education required for each worker. This is necessary to maintain competence, to ensure the safe use of nuclear applications and for the protection of workers, the public and the environment. Furthermore, training and education is required to enable new techniques to be learned. It is also recognized that non-nuclear specialists working in the nuclear industry need some nuclear training and education. Competency is defined as the appropriate level of knowledge and skills along with the correct professional attitude to perform work effectively and safely.

A simple model can be derived based on the involvement of government, academia, and industry. It is important that close cooperation among education, industry and government exists. This model also reflects the fact that a significant proportion of the nuclear workforce comes to industry through the vocational route, from local/national training schools and technical colleges. Although this report, and its annexes, focuses on education rather than training, it recognizes the importance of cooperation/coordination between the education and training sectors, to ensure an adequate supply of workers.

The role of government is to provide policies and funding supporting the development and operation of industry and academia. The interaction of government policies with universities and industries may vary from country to country but it must be acknowledged that government policy will have an overarching influence on the decision of universities to provide nuclear orientated courses.

Figure 1 depicts the interdependencies among these elements. Academia is primarily charged with increasing the knowledge of students through education. Successful students graduate with certificates, diplomas, or degrees and can be hired by the industry or other organizations. The industry is charged with training that produces capable workers through the development of appropriate skills. Competent workers often receive recognition of their skills through qualification cards or licences.

Close cooperation between the industry, universities and government has been recognized by most countries as a vital factor in both improving nuclear education and in attracting young talent. The communication between academia and the industry is beneficial for both partners in several ways. First, the knowledge and skills of the students graduating from university are better matched to the needs of the industry, and therefore industrial training can be more focused on specific industry needs. Second, the possible areas of cooperation can be better defined. This cooperation can manifest itself in such industry actions as: student placements, joint research projects, visiting professors, and by providing advisory information to the nuclear university staff that design and teach the curriculum.

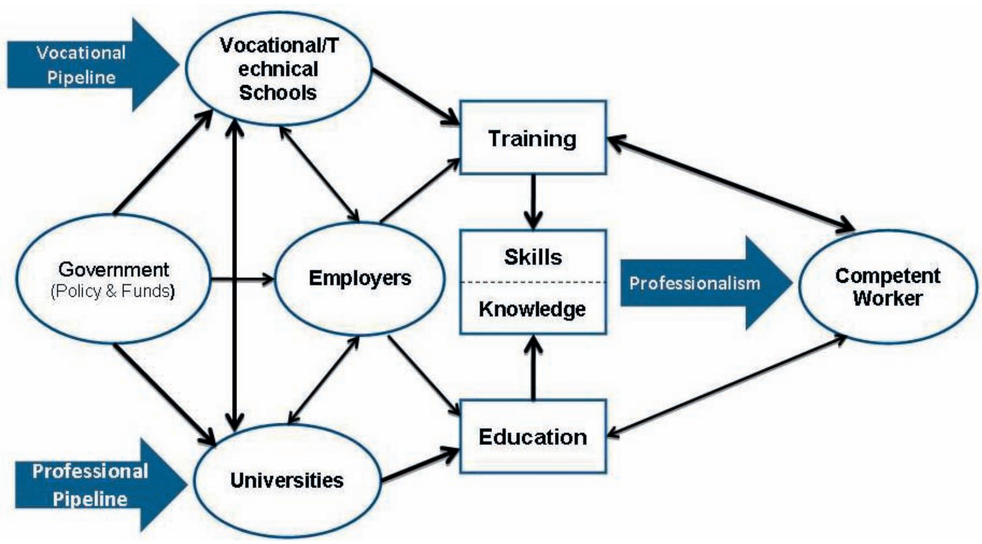


FIG. 1. Government–university–industry interaction to produce competency.

Exposure to some nuclear content in science and engineering degrees will also increase the numbers of students opting to work in the nuclear industry or study nuclear courses at Masters and PhD level. This basic understanding will also underpin the view of nuclear energy by the general public.

Education is necessary to sustain and develop the peaceful utilization of nuclear technology by providing qualified nuclear specialists for:

— The operation of (and specialist technical support for) existing facilities;
— Construction and development of new facilities;
— Research and development for the (current and) next generation of facilities;
— Regulatory authorities;
— Medical and other industrial applications.

1.2. OBJECTIVES

The purpose of this report is to support the development of policies and strategies in nuclear education as part of the overall activities on nuclear knowledge management. This includes: key issues of nuclear education and national and regional needs and expectations; fostering strong regional or inter-regional nuclear education networks; promoting the harmonization of curricula in nuclear education and training programmes; addressing the use of nuclear facilities to enhance education, research, and to maintain capability; addressing national best practices in nuclear education; and analysing and sharing information to facilitate the further development of nuclear education.

1.3. SCOPE

The following main issues are addressed in this report:

— Background/history of nuclear education in Member States;
— Needs for nuclear engineers, including statistics (industrial demands for nuclear expertise compared to what the educational system is able to produce, trends over the past few years);
— Educational systems and educational institutions involved in nuclear education;
— Foreign student enrolments;
— The role of research and experimental facilities (such as research reactors, accelerators, etc.);
— Cooperation/collaborations of academia with industry and government;

— National and international cooperation and educational networks;
— Role of the IAEA and activities supporting nuclear education.

This publication is applicable to decision makers from governments, academia, regulators, facility owners and operators and private industry as well as to practitioners in nuclear education.

1.4. STRUCTURE

The first part of this report provides background for nuclear education activities, summary of good practices and conclusions and recommendations, the second part presents country reports on the status of nuclear education in the Member States. Those reports include a description of the educational system of Member States, universities offering courses in nuclear education and some statistics on the courses and trends over the past few years. The country reports also address partnerships between educational institutions and the nuclear industry as well as cooperation with Government and research organizations.

2. GOOD PRACTICES IN NUCLEAR EDUCATION

Good practices in nuclear education have been identified and are summarized under the following subcategories:

(1) Human resource development;
(2) Cooperation between education and training institutions;
(3) Networks;
(4) Quality of education and training;
(5) Use of technology;
(6) Outreach.

2.1. HUMAN RESOURCE DEVELOPMENT

Most of the IAEA Member States are facing an increasing demand to recruit nuclear engineers and scientists. Therefore, nuclear technology development requires and fosters human resource development (HRD). A continuous, consistent and well managed HRD programme is crucial for each Member State:

— To ensure continuity over time in the capacities needed, skills and knowledge;
— To establish and maintain a pool of manpower variously trained in different nuclear-related skills and educated in nuclear relevant fields.

In the context of industry, the role of educational institutions is to supply an educated and skilled workforce. HRD, and its management, is a long term process that balances the dynamics of supply and demand with respect to the education, recruitment, and training needed for industry operations as well as innovation. Regarding HRD in nuclear technology, the following points are emphasised:

(1) Technological development is a continuous process, needed to maintain NPPs and other facilities in good operational conditions;
(2) A supply of nuclear specialists will always be required for the safe operation of NPPs and other facilities;

(3) Maintaining knowledge and competences in currently available technologies will be an important item of education in the forthcoming decades leading to the development of improved and new applications of nuclear technology.

It is also suggested that basic nuclear knowledge should be included in secondary level education. This would have the following benefits:

- It is easier to attract young people to nuclear education when they already have some fundamental nuclear knowledge;
- There are a large percentage of students that decide their future career as they complete their secondary education. Exposure to nuclear technology could help them chose a nuclear related career;
- It would be beneficial to careers indirectly associated with the nuclear industry; such as politicians, economists, journalists etc. at national and international levels, if they have some basic nuclear technology knowledge.

Maintaining a qualified, competent workforce is a critical element in the safe and efficient operation of nuclear power plants and other nuclear R&D organizations. Many countries, for example Canada, USA, and some European countries, will be facing a significant challenge over the next few years due to workforce demographics and the potential for a substantial loss of core expertise and knowledge. This is further supported by the fact that, over the past two decades the nuclear industry, including government and universities, has not been hiring many new graduates and there has not been a significant investment in university-based education and research nor in nuclear component manufacturing or other aspects of nuclear infrastructure. A reversal of this trend is now occurring in many countries which must be maintained.

For example, in Canada, to address this potentially serious gap, the nuclear industry has placed a high priority on establishing and maintaining meaningful and active partnerships with industry, government and universities. The University Network of Excellence in Nuclear Engineering (UNENE) [2] is a leading example of these partnerships. The UNENE government and industry representatives have committed a significant level of funding and other support to ensure that the primary objectives of this partnership are successfully met, namely:

- To provide a sustainable supply of qualified staff to meet current and future industry needs;
- To promote university-based research in topics of significance to the nuclear industry;
- To create a stronger, wider base of nuclear expertise for industry and public consultations.

The UNENE organization has made significant progress towards establishing its research and education programmes. It is the collective responsibility of all participants in this partnership to ensure that the practical focus of this initiative is maintained and that the benefits to the nuclear industry as a whole are sustained in the long term.

2.2. COOPERATION BETWEEN EDUCATION AND TRAINING INSTITUTIONS

The differences between education and training are subtle but important. Education encompasses the need to maintain completeness and continuity of knowledge across generations. It is essentially a knowledge driven process, involving academic institutions as suppliers, and students as customers. Training is generally understood to refer to learning of a particular skill which, when applied with the requisite knowledge, will deliver the required result. It is essentially an application driven process, primarily involving training organizations, which can also be higher education institutes (HEIs), as suppliers and workers as customers.

Maintaining a high level of nuclear competencies is required for the safe use of current nuclear applications and to ensure the protection of workers, the public and the environment. Up to date nuclear knowledge is also required in R&D for the optimization of current and the development of future technologies. An essential component in ensuring a high level of expertise in the future is a sustainable education and training infrastructure.

The traditional view is that ‘formal’ education ends for most workers after secondary education or after higher education, unless a decision is taken to re-enter academia as a mature student. However, workers can opt to study part-time courses at HEIs supported by their employer or, increasingly, they may attend HEIs for continuous professional development (CPD) stand alone modules.

Training is an ongoing process within industry and is required for both vocationally qualified and graduate workers. An academic degree provides the student with the basic knowledge of general subjects such as physics, mathematics and computer science etc. These subjects will be a prerequisite requirement for much industry advanced training. HEIs can collaborate with technical/vocational schools, industry and government to provide advanced training.

Cooperation between education institutions is evident at international levels leading to the concept of national and international networks. For example the objective of the European Nuclear Education Network (ENEN) was realized through the cooperation of European universities involved in education and research in nuclear disciplines, nuclear research centres and the nuclear industry. At the same time, cooperation between education and training institutions should be significantly improved.

2.2.1. Common course contents

Nuclear energy is a global industry with the movement of materials and workers between countries a common occurrence. Awareness, of course, content and commonalities between universities, training courses and countries is required to allow this movement without a requirement for re-testing. Ideally, the curricula of each course at each university should be made publically available, allowing the courses to be recognized as providing the required content for each level of attainment. The Bologna agreement to use of European Credit Transfer System (ECTS) is an excellent example of this requirement.

Also, the Asian Network (ANENT) has developed reference curricula for education and training in key nuclear areas to facilitate the mutual recognition of credits, degrees, qualifications etc. In the USA, the Institute for Nuclear Power Operations and the Nuclear Energy Institute, representing the entire nuclear reactor community, have collaboratively produced a unified curriculum which can be used to educate and train potential workers in the nuclear field.

2.2.2. Education and training needs

There are several key aspects that will allow the provision of education and training necessary for a nuclear workforce. These can be broadly categorized as funding support, facilities and suitably qualified educators. Funding support either from governments or industries is required with parliamentary cross-party consensus wherever possible. This will allow the long term planning required in the nuclear industry. As stated previously, there is now a growth in the number of universities offering nuclear related courses as well as the number of courses. This is the case in the UK where universities are either restarting or providing nuclear related courses for the first time [3]. Investment in facilities are also taking place that will allow for this increase in student numbers. This reflects clear government statements concerning the role of nuclear energy in their respective countries. In the workplaces, there is an age profile of nuclear workers skewed towards the end of the career timescale. This has been recognized for several years and industry has been relaying this message to the HEIs which, together with the government statements, allows the universities to invest in new nuclear courses or the expansion of existing courses.

Schemes are also starting that will capture the senior nuclear specialists expertise and knowledge before they retire. These allow for the senior nuclear specialists to contribute lectures to nuclear courses that provide added value to the curricula by providing real life examples of nuclear processes and technologies.

2.2.3. Government, academia and industry

Governments can act to support certain areas of research and education by making money available via research initiatives or government departments. Government funding of HEIs also allows educational courses to be established and maintained.

In some areas of nuclear technology, a level of understanding is required that is only available via tertiary education. As nuclear technology is utilized in the power sector, as well as in areas such as medicine, agriculture and national security, it is vital that each government supports nuclear education at HEIs. The safe and efficient utilization of nuclear technology requires a certain number of experts in nuclear specific areas i.e. nuclear reactor engineering, reactor physics, health physics, radiochemistry, nuclear materials, nuclear instrumentation and controls, radiation detection and radiation protection. The required number of experts in these disciplines may be small in some countries so it is the government's role to maintain educational provision to continue the supply of qualified nuclear specialists.

For example, the Argentine Government established strong cooperation with academia whereby the government provides 40% of the operating budget, scholarships for students plus infrastructure costs. Similarly, in India, the Department of Energy (DAE) provides funding support to the Bhabha Atomic Research Centre (BARC) so that it meets national demands. With this significant funding more programmes can be offered to meet demand.

In the USA, the Department of Energy Office of Nuclear Energy, Science and Technology (DOE-NE) is the main federal funding agency for universities to increase its nuclear education level. DOE-NE has several different programmes for university infrastructure and uses a considerable amount of their funds for R&D and university research reactors support. There is also funding for university researchers and graduate students that aligns with the DOE-NE's programmatic research programmes in areas such as GEN IV reactor development. There is ample evidence showing the important role of government support in fostering the growth in student enrolments and in the creation of new nuclear academic programmes which is essential in order to provide the necessary amount of new workers needed by the nuclear industry.

This close cooperation between industry, universities and government has been recognized by most countries as a vital factor in improving nuclear education and training and in attracting young talent. For example, the close interaction between educational institutions and large nuclear facilities achieved by the Russian system of science towns consisting of national research centres side by side with high technology organizations and educational institutions, was recognized as the principal strength of the nuclear education system and was continued in the Russian Federation. Following the Chernobyl accident and subsequent public loss of confidence in nuclear energy, financial support for all nuclear R&D was reduced with the consequent loss of half the staff of the Kurchatov Institute, and the disappearance of some scientific institutions. However, due to the strength of industry — university cooperation, along with strong governmental support, the Russian nuclear complex survived the crisis decade. Currently, scholarships, grants, governmental support to scientific schools, etc., are attracting the younger generation back to the nuclear sector.

The nuclear industry does not always recognize the important role they have in supporting nuclear education within HEIs. There are two common reasons put forward by industry:

(1) Industrial partners sometimes consider education to be wholly the responsibility of government;
(2) Industry provides in-house training for their employed workforce and therefore do not see the value in engaging with the HEI sector.

Both of these approaches deny industry the following advantages of collaborating with universities:

— Industry can provide scholarships for students studying nuclear subjects. This motivates the best students to choose nuclear options and establishes early contact between students and the industry;
— Students can apply for an internship and get hands-on experiences with a nuclear company possibly at a nuclear licensed site, or they can be assigned diploma work which requires industry involvement;
— Practicing professionals can participate in the development and/or delivery of courses and lectures at universities, sometimes as a visiting professor/lecturer/researcher. This practice is found in several countries. It has the advantage that not only explicit, but also implicit and tacit knowledge is transferred;
— Industry can send employees to universities to provide educational advances. For example, employees can attend short courses or day release courses for continuous professional development or attend part-time to obtain a formal qualification.

It is also fair to say that academic institutions sometimes resist the 'too-close' involvement of industry, not necessarily wanting too much input on the development of curricula, for example. Educational institutions can also gain much from effective interaction with industry, such as:

- ‘Customer’ input to discussions on programme/course curricula;
- Industry contact/experience for lecturers to enhance their understanding of the industry;
- Developing networks, which can be exploited to find placements for students, support for research, obtaining teach materials/aids, etc.

2.2.4. Governmental administrative support

Governments generally regulate national education through legislation. For example, in China, the Academic Degree Committee of the State Council and Ministry of Education are the governmental authorities responsible for education in China.

A government needs to engage itself in strategic energy planning, including consideration of education, manpower and infrastructure requirements. It needs an integrated plan to ensure that human resources are available to meet necessary obligations and address outstanding issues. It should support, on a competitive basis, young students and provide adequate resources for nuclear research and development programmes including modernization of facilities. Government administrative and funding support to develop ‘educational networks or bridges’ between universities, industry and research institutes have been very successful and should be encouraged in countries without such networks. For example, UNENE in Canada, CIRTEN (Consortium Interuniversitario per la Ricerca Technologica Nuclear) in Italy, BNEN (Belgian Nuclear Education Network) in Belgium and NTEC (Nuclear Technology Education Consortium) in the UK are good initiatives toward enhancement of the supply of highly qualified graduates in nuclear engineering and technology.

2.2.5. Student and workforce exchanges

Student exchange and development creates a win-win situation through the transfer of knowledge as well as developing transnational networks.

This is evident from the numerous network reports included in various country reports, which are part of this publication. In the USA and other developed countries, student and workforce migrations can open the doors to multifaceted benefits for both the sending and receiving States or countries. There might be concerns regarding security and industrial secrecy between the countries involved, but the advantages far outweigh the disadvantages for the exchange of students and work force for the generation and preservation of knowledge in the field of nuclear education.

2.3. NETWORKS

The establishment of networks is being used as a tool to exchange experts and information as well as facilitating the full utilization of facilities. Networking through educational institutions has been widely recognized as a key strategy for capacity building and better use of available educational resources. In the field of nuclear knowledge management (NKM), networks have become an important element of nuclear education and training with networks being established on all levels i.e. national (e.g. CIRTEN, UNENE, NTEC), regional (e.g. ANENT, ENEN) and global (e.g. World Nuclear University (WNU)). Networks can initially be established through partnership agreements.

Through these networks, universities are collaborating to establish common platforms for education at a master’s degree level. Establishing and supporting similar education networks is considered essential for other world regions, such as Latin America and Africa. The founding of the WNU was a positive development in this regard.

Strengthening and growth of existing nuclear educational networks is recommended and support for the establishment of networks where none exist is encouraged.

2.4. QUALITY EDUCATION AND TRAINING

High quality nuclear education and training is required to provide the workforce of today and tomorrow. A national system of accreditation should be in place to ensure that the curriculum of each course is of sufficiently high standard to allow the qualification to be awarded. Whether this accreditation is provided by national governments, as is the case in the Russian Federation, Learned Societies or by the Accreditation Board for Engineering and Technology (ABET) as in the UK and USA, respectively, or by some other means (e.g. Washington Accord status) it is important that the required high standard is maintained and consistently applied. With increased worker mobility it is now emerging that an international approach is required to assure the employer that qualifications are of a similar standard of knowledge and expertise wherever they are gained. The IAEA has established meetings to review national curricula and standards and ensure they are comparative. This review can also be used by emerging nuclear nations for their nuclear course content and standard.

For example ANENT, in cooperation with MEPhI (Moscow Engineering Physics Institute), ENEN, and the Dalton Nuclear Institute of the UK, established a standard curriculum for its master’s degree in nuclear engineering. This consists of five courses with 39 subjects. Another good example of standard integrated curricula is ENEN. The Nuclear European Platform of Training and University Organizations (NEPTUNO) [4] programme, under the sixth European Framework for funding, integrates European education and training in nuclear engineering, nuclear safety and other nuclear fields with the major objective to secure qualified curricula in the nuclear disciplines at European universities. It also aims to harmonize both the courses to ensure mutual recognition according to the Bologna declaration, and professional training and accreditation schemes.

To standardize the European academic education system, many European countries (mostly ENEN members) are adopting the ‘Bologna-process’. This scheme is based on the European credit system (ECTS), which needs three years (180 ECTS) for the first level degree (bachelor’s degree), two years (120 ECTS) for the second level degree (master’s degree) and three years for the PhD degree [ENEN].

To ensure the high quality of the courses, ENEN has a quality assurance committee as one of its five committees. This committee examines the quality assurance practices adopted in partner institutions. It collects information about rules and practices such as selection, training and certification of teachers, and proposes a scheme for their harmonization. The European Master of Science in Nuclear Engineering (EMSNE) certificate is awarded to students who have obtained a Master’s Degree in Nuclear Engineering, or equivalent, that meets the objectives and quality standards set by the ENEN Association. This certificate is a guarantee that the masters education received is of the highest quality in Europe.

2.5. USE OF TECHNOLOGY

The development of web technologies coupled with increased broadband availability has allowed the development of new education and training methods. These are termed distance learning where the student or employee does not need to attend the training institute or HEI but accesses the course material online. A variant of this is termed blended learning where some of the learning is done online but integrated with traditional classroom, tutorial or laboratory teaching at the training institute or HEI.

Successful distance learning courses deliver the same course content at the same standard as the traditional method. This is achieved by a combination of presentations with audio commentary by the lecturer, video recordings of lecturers and online assignments. In parallel with this, online forums are established that allow communication between the lecturers and students as well as student to student discussions. This is the model that was used for the successful adaptation of the NTEC master’s programme in the UK.

Another method, as adopted by Georgia Institute of Technology in the USA, is the approval of remote facilities around the country where students can access their medical physics programme. These remote facilities can be used by distance learning medical students to meet the clinical rotation requirements in the curricula.

With access to reactor laboratories becoming more difficult in some countries, the creation of virtual reactor laboratories allows far greater access. The University of Massachusetts at Lowell (USA) has developed a system for making real time and archived research reactor data available via a standard web browser. This capability is available online to facilitate various remote learning activities and training exercises via the web site [5]. The system offers nearly all the same real time and archival data acquisition capability as available to the

UMass–Lowell Research Reactor (UMLRR) control room operators, and gives the remote user nearly the same look and feel as if the person were actually present in the control room. This remote accessibility uses a standard personal computer to act as a web server along with the use of a special purpose software package that receives data from the control room computers and distributes it in a web-based format.

Several databases and teaching materials are also available electronically. For example in Canada, CANTEACH [6] is a database of reference and teaching materials on CANDU reactors.

2.6. OUTREACH

Outreach is the process where universities, HEIs, training institutes, nuclear licensed sites and companies, learned societies, etc. reach out to the local community and in particular to secondary level teaching establishments. This outreach has the goal of increasing the number of students that opt for nuclear courses or science, technology, engineering and mathematical courses at the tertiary level. The outreach process recognizes the fact that many pupils make their career choice whilst at school therefore greater exposure to nuclear technologies at that time will enhance the possibility of the pupil considering the nuclear sector for their career. In its simplest form, outreach is done by a nuclear specialist visiting a school to give a presentation but this can be enhanced in many ways. Pupils in groups can be invited to visit university campuses for tours of facilities such as university reactors. Nuclear licensed sites with visitor centres can invite school groups or local science-focussed societies to visit.

It is also good practice to engage with teachers. In the USA, specialized teacher workshops are held by professionals from academia and industry. Organizations such as the American Nuclear Society (ANS) and Health Physics Society (HPS) put on these events either at local schools or as part of regional and national conferences. The DOE-NE has also produced the ‘Harnessed Atom’ curriculum as a key nuclear teaching resource.

In Hungary, the basics of nuclear and radiation physics have been introduced in high school curricula since the 1970s. Since then the universities, with the help of the nuclear industry, have put a large emphasis on outreach activity. University professors regularly attend annual meetings of high school physics teachers and deliver lectures to them; they are also invited to ‘school days’ to talk about nuclear subjects. Many thousands of pupils visit the different nuclear installations (Visitor Centre of the Paks NPP, Training Reactor and Research Reactor in Budapest, and the Radioactive Waste Depository in Bátaapáti). ‘Nuclear summer camps’ are organized by the Hungarian Nuclear Society for talented high school pupils. A nationwide physics competition named after Leo Szilárd is organized annually with the main emphasis on nuclear physics (and modern physics). Every year a group of about 40 Hungarian high school teachers visits CERN for a week. This visit, which is led by a university professor, also reinforces the contact between academia and school teachers. Young professionals of the Hungarian Nuclear Society go annually to represent the nuclear community at a summer youth festival in Budapest (The Sziget), which is the largest festival of this kind in Europe. As an international recognition of their achievements the young generation of the Hungarian Nuclear Society won the first Communication Award of the European Nuclear Society in 2005.

3. CONCLUSIONS AND RECOMMENDATIONS

The nuclear power sector is faced with significant and potentially growing demands for qualified personnel. This is due to the simultaneous necessity for plant refurbishments and new nuclear power plants to meet increased energy needs. Additional expertise will be needed to cope with the growing number of decommissioning projects to retire the ageing fleet of existing plants. Unless this situation is carefully managed, the nuclear industry is potentially at risk of serious consequences. In this context, knowledge management is a key factor in assuring the sustainability of existing nuclear facilities. Moreover, the effective application of current knowledge to new design and construction projects, and development of innovative new technology for future nuclear sector needs is essential. The building and maintaining of nuclear expertise and competence, obtained through *education and* *training*, is a critical aspect of knowledge management. This is crucial in ensuring the capabilities necessary for the safe and successful application of nuclear technology are sustained.

At the IAEA Technical Meetings on Nuclear Education held in 2008 and 2009, the assembled representatives of the nuclear community identified several common 'best practices' in nuclear education that are consolidated and presented below:

— The *involvement of industry* in the education process is very important. It cannot be denied that it is in the interest of the industry that a sufficient number of workers be provided with a sufficient level of competence at the right time. However, companies and utilities do not always recognize that they should help universities and other educational institutions in achieving this goal (and universities and other educational institutions have not always welcomed the involvement of industry). Several good practices can be recommended as to how the industry can provide help to support academic nuclear education:
  - Industry can *provide scholarships* for students studying nuclear subjects. This motivates the best students to choose the nuclear option and establishes early contacts between the students and the industry;
  - Industry can also be *directly involved* in the education of students in several ways. Students can go for an *internship*, and get hands-on experiences on site in an NPP, or they can be assigned to *diploma work* which needs industry involvement;
  - Another way of involving industry is when *practicing professionals participate in the development and/or delivery of courses* and lectures at universities; sometimes as visiting professors. It has the advantage that not only explicit, but also implicit and *tacit knowledge* is transferred;
  - Industry can request the universities to provide *educational upgrade for the personnel*, as a service. There are good practices where not only reactor operators are obliged to regularly upgrade their knowledge and skills, but also other workforce members, including the managers.

— There are several good practices for *governments* that can be recommended. Education — being a long return investment — is usually a national duty, financed by the state (government). In many countries nuclear education has to compete for funding with other subjects. One risk for the government is not recognizing that a good science and engineering education requires significant investment. It should be recognized that comprehensive nuclear knowledge and skills underpin safety, and the lack of them may compromise nuclear safety and create risk at a national level. Therefore it is recommended that nuclear education and training should be treated with utmost attention by governments.

— *Networking* (national and international) can also be considered as a good practice. It has several beneficial effects. It facilitates sharing of information and good practices between the members; it provides an enabling environment to complement each other's possible lack of expertise in certain fields (not all expertise is available at every place), it makes possible that the students get the information from the best professors or the best expert of the special subject. There are several good examples of networking in education:
  - There are several large international networks: ANENT (Asia), ENEN (Europe), WNU (worldwide) etc. Joining these networks is really beneficial to countries/universities;
  - There are good examples of national networks as well: BNEN (Belgium), CIRTEN (Italy), NTEC (UK) etc. In Canada the University Network of Excellence in Nuclear Engineering (UNENE), the Natural Science and Engineering Research Council (NSERC), and the CANDU Owners Group (COG) have come together to focus resources on building capacity in nuclear engineering education in the universities;
  - In the USA, the Nuclear Engineering Department Heads Organization (NEDHO) is composed of the leaders of all the academic programmes in the country;
  - In the Russian Federation, the recently established National Research Nuclear University MIPhI has united five specialized universities, three regional branches and 13 colleges, with more than 30 thousand students on total to enhance the effectiveness of nuclear education and provide sufficient number of engineers for nuclear sector needs.

— Besides 'networking', *international* (bi- or multilateral) *cooperation* in specific projects is also a good practice to recommend. Several examples can be mentioned:
  - A course for nuclear managers is being organized jointly by Finland, the Russian Federation and Sweden;
  - Several courses are being conducted by Austria and its neighbouring partners (Hungary, Slovakia, and Czech Republic). The examples are: Eugene Wigner Course for Reactor Physics Experiments, EERRI course for nuclear candidate countries etc.;

- Lithuanian nuclear education institutions make use of international (Russian) experimental facilities and MSc courses of Russian universities delivered for Lithuanian students before they established their own Member State programmes;
- Students from different countries go to the USA, Switzerland, France, and Belgium for foreign field experiences. This is beneficial not only from the point of view of their technical knowledge, but also from the point of view of their language skills;
- The IAEA promotes international cooperation by supporting the exchange of professionals.

— When considering future workforce needs, there is a tendency that only higher nuclear education is considered. However, to 'fill the pipeline' talented high school students should be persuaded to select nuclear subjects at universities. Therefore *outreach activity* toward secondary school and/or secondary school teachers is an important and good practice to recommend.

- In the USA and Canada, outreach to high schools is very active. This includes visits to describe nuclear engineering and nuclear energy to high school students. Other approaches include participation in high school college days and career fairs. There is a similar focus on teachers. Specialized workshops for teachers are held by specialists from academia and industry. Professional organizations such as the American Nuclear Society and Health Physics Society put on these events either at the local schools or during meetings. These organizations and others such as the Nuclear Energy Institute, the NRC and US DOE have resources available for teachers. The Canadian Nuclear Society provides workshop material and Geiger counters to high school teachers, and prizes for student projects at science fairs. All these activities provide a strong basis for outreach to teachers and students.

— In Hungary, the basics of nuclear and radiation physics had been introduced in the high school curricula in the 1970s. Since then, the universities — with the help of the nuclear industry — put a large emphasis on outreach activity. University professors regularly attend annual meetings of high school physics teachers, and deliver lectures to them; they are also invited to school days to talk about nuclear subjects. Many thousands of pupils visit the different nuclear installations (Visitor Centre of the Paks NPP, Training Reactor and Research Reactor in Budapest, and the Radioactive Waste Disposal Facility in Bátaapáti). Nuclear summer camps are organized by the Hungarian Nuclear Society for talented high school pupils. A nationwide physics competition named after Leo Szilárd is organized annually with the main emphasis on nuclear physics (and modern physics). Every year a group of about 40 Hungarian high school teachers visit CERN for a week. This visit, which is led by a university professor, also reinforces the contact between academia and school teachers.

— The use of *new media and electronic methods* is certainly a good practice in nuclear education:

- Several projects of distance learning (e-learning, cyber-learning) can be mentioned. Probably the most recent development is the Asian Network for Education in Nuclear Technology;
- To fill the gap of providing educational experiences with a reactor to universities that do not have their own facilities, North Carolina State University has created a 'virtual' reactor laboratory;

— Several databases and teaching materials are also available electronically. The large international networks (ENEN, ANENT etc.) maintain and update their own databases. In Canada, CANTEACH is a database of reference and teaching materials on CANDU reactors. The IAEA has a long tradition of maintaining nuclear databases (e.g. INIS), and other nuclear educational tools (e.g. reactor simulators, video recorded lecture courses, etc.) which are freely available for users of Member States. This is certainly a good practice and it is recommended to use these in nuclear educational institutions.

International cooperation is recognized as an effective mechanism to present and discuss the role of nuclear higher education in the development of human resources for building a national infrastructure for nuclear power and non-power applications. The following key issues and activities are recommended for further common efforts by Member States:

(a) Work together to improve processes for disseminating information about national activities to ensure Member States are fully aware of those of interest to them;
(b) Increase national contribution and participation in international conferences on nuclear education and training e.g. NESTet, CONTE, etc.;
(c) Initiate the establishment of international requirements and guidelines for nuclear education and benchmarking for evaluation of national nuclear education;

(d) Carry out a comparison of accreditation standards of nuclear engineering national programmes to identify similarities and differences in the various criteria used;
(e) Establish national networks in nuclear education and training for strengthening cooperation or join international networks;
(f) Support the development of learning materials on nuclear education;
(g) Ensure the promotion of national and international activities at different meetings related to nuclear education.

REFERENCES

[1] World Nuclear Association, http://www.world-nuclear.org/info/reactors.html
[2] http://www.unene.ca
[3] See http://www.nuclearliaison.com
[4] http:// www.enen-assoc.org/data/document/neptuno-final-activity-report.pdf
[5] http://nuclear101.com
[6] http://www.canteach.ca/

ABBREVIATIONS

ABET	Accreditation Board for Engineering and Technology
ANENT	Asian Network for Education in Nuclear Technology
ANS	American Nuclear Society
BARC	Bhabha Atomic Research Centre
BNEN	Belgian Nuclear Education Network
CANDU	Canada deuterium–uranium reactor
CIRTEN	Consortium Interuniversitario per la Ricerca Technologica Nuclear
COG	CANDU Owners Group
CONTE	Conference on Nuclear Training and Education
CPD	Continuous professional development
DOE	Department of Energy (USA)
DOE-NE	Department of Energy Office of Nuclear Energy, Science and Technology
ECTS	European Credit Transfer System
EERRI	Eastern European Research Reactor Initiative
EMSNE	European Master of Science in Nuclear Engineering
ENEN	European Nuclear Education Network
HEI	Higher education institutes
HPS	Health Physics Society
HRD	Human resource development
NEDHO	Nuclear Engineering Department Heads Organization
NEPTUNO	Nuclear European Platform of Training and University Organizations
NKM	Nuclear knowledge management
NSERC	Natural Science and Engineering Research Council
NTEC	Nuclear Technology Education Consortium
UMLRR	University of Massachusetts–Lowell Research Reactor
UNENE	University Network of Excellence in Nuclear Engineering
WNU	World Nuclear University

Annex I

ARGENTINA[1]

I–1. BACKGROUND

The history of Argentina nuclear development can be summarized into two periods: ‘splendour’ and ‘stand-by’. The former starting in the decade of the 1950s until the late 1970s while the latter period goes from the late 1970s to 2006. The first period (1950–1980) was characterized by a national policy of scientific and technological development; State intervention in the area of industrial production. The military aspects, if any, were marginal in the context of the overall development. During this period, important public scientific technological projects were carried out: the production and sale of experimental reactors, nuclear plants (Atucha I and Embalse), and some projects aimed to developing national industry. The stimulus experienced in the country in this period accompanied the role of nuclear technology worldwide due to the Cold War and the persuasion factor among the main powers. However, during the 1970s and 1980s the whole world started questioning these technologies which ran parallel to the liberalization of the countries economies.

The second period (1980s onwards) was characterized by many economic problems and the consequent transitory stop of national nuclear projects; e.g. Argentina transitory stopped its third nuclear plant (at present under construction). At that moment, neoliberal politics were aimed at reducing the role of the State and promoting privatization, separating nuclear projects from governmental control, trying to privatize the nuclear plants, and cutting scientific budgets.

Argentina has two nuclear power plants in operation providing 8.6% of the total country’s electricity. A third one, 692 MW(e) power reactor PHWR Atucha-2 construction was stopped in the 1990s and re-started in 2007 (it is expected to be in commercial operation by 2011).

Argentina nuclear power plants utility, NA S.A. is preparing the refurbishment of its CANDU-6 reactor.

Argentina Atomic Energy Commission (CNEA) has a prototype of its CAREM nuclear power plant (25 MW(e)) under construction.

With all these nuclear projects going on in Argentina, the demand for qualified nuclear engineers has increased during the last years; but even during the years of nuclear stagnation worldwide, those graduating from Balseiro Institute have never had problems in getting a good job. Graduates from Balseiro Institute have played an important role in the design and construction of research reactors Argentina built in Peru, Algeria, Egypt, and Australia.

Furthermore, Balseiro Institute alumni have also played a key role in some of the most important technological achievements in Argentina.

I–2. INSTITUTO BALSEIRO

The Institute of Physics in Bariloche was established in 1955 (at present named Balseiro Institute — Instituto Balseiro (IB)), when the CNEA and the youngest of the six national universities in the country at that time, Universidad Nacional de Cuyo (UNCu), signed an agreement. The meritorious and motivated students are selected once a year by written examinations and a personal interview. The successful students are provided with a creative educational environment with state of the art research facilities. These students are awarded all-round scholarships which ensure their exclusive dedication to study.

IB runs three degree programmes: Nuclear Engineering, Mechanical Engineering and Physics; and seven post-graduate levels: Post-graduate Certificate in Technological Applications of Nuclear Energy, MSc in Physics, MSc in Medical Physics, MSc in Engineering, PhD in Physics, PhD in Engineering Sciences, and PhD in Nuclear Engineering. Due to the strict correlativity system, groups do not disperse. IB students must complete their studies

[1] Prepared by J. Lolich, Director, Balseiro Institute, Bariloche, Argentina.

in the established period of time, i.e. one year for the Postgraduate Certificate in technological applications of nuclear engineering, one and a half years for a master's degree.about four years for a PhD.

Applicants for a degree programme must have successfully completed two years of study in Science or Engineering at other universities; the career duration is two and a half years for the Physics Degree and three years for the Engineering Degrees.

The teaching staff is comprised of active researchers with part time dedication to teaching in different fields of knowledge.

IB alumni had played a significant role in the construction and commissioning of two nuclear power plants during the Argentina Nuclear Programme of the 1960s and 1970s. During the stand-by period, i.e. for the past 20 years when the country was facing an economic crises that seriously affected nuclear development, IB was successful in getting alternate sources of funding from private sectors interested in its graduates.

IB graduates played an important role in the design and construction of research reactors by INVAP — an Argentina based company, that were exported to Peru, Algeria, Egypt, and recently to Australia (OPAL research reactor). At present, INVAP, which is mostly run by IB's alumni, is the world leader in research reactor design and construction.

Furthermore, IB alumni have also played a key role in some most important technological achievements in the country:

— Uranium enrichment demonstration plant;
— Design, construction, and operation of scientific satellites;
— Design, construction, and operation of research reactors;
— Nuclear medical equipment;
— Airport radar systems, etc.

At present, IB alumni are playing an important role in two nuclear projects going on in Argentina:

— Completion of Atucha-2 nuclear power plant;
— Construction of the Argentina design small nuclear power plant prototype CAREM reactor.

IB accepts students from all Latin American countries for degree and post-degree courses. In most cases, CNEA awards them a fellowship; others receive an IAEA fellowship. The most common are students from Chile, Peru, Colombia, Bolivia, Ecuador and Brazil (the MSc in Medical Physics course usually has a significant amount of students from Central American countries).

IB has special agreements with the most important technological companies of Argentina (nuclear and not nuclear). Some of these companies offer fellowships to IB students (approximately 10% of the total).

Recently, IB was nominated as an IAEA Collaborating Centre for human resources for nuclear technology.

In Argentina, there are some other institutions in the country which are contributing to nuclear education by offering some courses relevant to nuclear engineering.

TABLE I–1. EDUCATIONAL PROGRAMMES OFFERED AT INSTITUTO BALSEIRO

University	Faculty	Degree	Post-graduate
Cuyo University	Instituto Balseiro	Physics Nuclear Engineering Mechanical Engineering	Post-graduate Certificate in technological applications of nuclear energy MSc Engineering MSc Physics MSc Medical Physics PhD Physical Sciences PhD Nuclear Engineering PhD Engineering Sciences

I–3. INSTITUTO SABATO

Instituto Sabato (IS) was the result of an agreement signed in 1993 between the CNEA and the Universidad Nacional de San Martín (UNSAM).

The Institute is located in the Centro Atómico Constituyentes (CAC), province of Buenos Aires, Argentina, close to Buenos Aires city. The IS orientation is the training of students in materials science and technology.

The academic activities are a natural consequence of the long tradition in human resource formation carried out in the Materials Department of CAC-CNEA since July 1955.

These courses started when Professor J.A. Sabato, in charge of organizing the Materials Department, found that the professionals of the local national universities had no training in metallurgy or materials science. The professionals from Sabato´s courses were responsible for the manufacturing of the fuels elements for the first research nuclear reactor in Latin America, the RA-1, inaugurated on 20 January 1958. The 'know how' for the manufacture of the fuel elements was later sold by the Materials Department to Degussa-Leybold (Germany), in an unprecedented transfer of technology.

For more than three decades (1962–1996), the different courses on materials science and technology, like the well known Pan-American Course of Metallurgy, were partially supported by the Organization of American States (OAS), allowing the training of hundreds of professionals from Argentina and many other Latin American countries. In the case of Argentina, those professionals were, and are, the heart of several technical departments of the CAC, like the Materials Department, the Department of Non-Destructive Testing and the Department of Nuclear Fuel Elements. Professionals in these departments give permanent support in non-destructive testing, corrosion consulting and failure analysis to the two power reactors presently active in Argentina.

They are also very active in nuclear enterprises like Combustible Nucleares Argentinos (CONUAR) established for the manufacture of nuclear fuel elements and FAE (Fábrica de Aleaciones Especiales) in charge of the manufacture of Zircaloy tubes for the fuel elements. Furthering this long tradition of organizing and teaching courses on science and technology of materials, the IS was created with the purpose of establishing an efficient mechanism for the technology transfer and the supply of specialists to institutions and companies involved in research and development as well as in the production of technological goods.

IS offers one degree programme, Materials Engineering, four post-graduate levels: MSc in Materials Science and Technology, PhD in Science and Technology — Materials, PhD in Science and Technology — Physics, Post-graduate Certificate in Non-Destructive Testing, and Special Courses.

Applicants for Materials Engineering are selected once a year by a written examination and a personal interview. To ensure their exclusive dedication to study, all of them are awarded all-round scholarships, provided by local enterprises related to materials activities, as well as UNSAM and CNEA. Applicants must have successfully completed two years of study in Science or Engineering at other universities; the career duration at the IS lasts four more years. Following the same policy of that of IB, the students must complete their studies in the established period of time and, due to the strict correlative system, groups do not disperse.

To complete the MSc in materials science and technology, graduates are required to work during the two years in the IS. In the first year, they take 20 intensive courses on materials science and technology, and in the second they carry out thesis work.

The PhD typically requires four years in which the students have to pass the courses, selected according to their background, and carry out the thesis. The post-graduate certificate in non-destructive testing lasts one year. Special courses are frequently offered to professionals in order to update their knowledge in materials science.

Since its creation, in 1993, the IS has produced 80 materials engineers, 115 MSc, 38 PhD and 20 certificates in non-destructive testing. Around 75% of these graduates are working in Argentina, in different companies, universities, and in CNEA. The remaining 25% are completing studies or working abroad.

In CNEA, IS graduates entered many research groups, like mechanical properties, irradiation damage, hydrogen damage, diffusion, electron microscopy, corrosion, phase transformation, defect theory and continuous mechanics among others. Materials engineers from IS are also working for, Embalse, Atucha II and FAE.

I–4. INSTITUTO DE TECNOLOGÍA NUCLEAR DAN BENINSON

Instituto de Tecnología Nuclear Dan Beninson was created at the end of 2006 in order to put, within an adequate institutional and academic frame, a long tradition of courses, both on radiochemistry and nuclear reactor theory, that were taught in the past to fill the needs brought forth by different projects where the development of nuclear technology was involved. These courses trained a relevant number of engineers later engaged in important nuclear projects: Atucha I, Embalse and Atucha II power plants as well as research reactors: Ra-1, RA-3 and the Peruvian RP-10 reactor.

The Institute has the purpose of promoting an appropriate interdisciplinary exchange to make possible the integration of academic, scientific, and technical personnel, and the development of human resources specializing in the nuclear field. Degrees offered by Instituto Beninson are:

(a) Graduate degrees:
— Post-graduate certificate in radiochemistry and nuclear applications;
— Post-graduate certificate in nuclear reactors and its fuel cycle.

(b) Graduate courses:
— Methodology and applications of radio nuclides;
— Radiotherapy dosimetry;
— The physics of radiotherapy;
— Introduction to nuclear technology I and II (for technicians);
— Training courses on PET/CT.

I–5. FUNDACIÓN ESCUELA DE MEDICINA NUCLEAR

Fundación Escuela de Medicina Nuclear (FUESMEN) was formally created in 1991, with the main objective to achieve excellence in the practice of medicine. Additionally, offering people the possibility to access first class assistance in image diagnostics and in medical treatment through nuclear technology. To this purpose, FUESMEN has last generation technological equipment, highly trained human resources, as well as engaging in research and development; all these activities have contributed to its position as an innovative institution. It offers an MSc in Physical Medicine (jointly with Instituto Balseiro).

I–6. FUNDACIÓN CENTRO DIAGNÓSTICO NUCLEAR

Fundación Centro Diagnóstico Nuclear (FCDN) was created in 2004 by CNEA and FUESMEN to make available to the public access to highly complex equipment using nuclear technologies for the diagnosis and treatment with radiation therapy and chemotherapy using PET technology. FCDN fabricates, distributes, and commercializes its own radioisotopes, and performs research for the production of new radioactive tracers for their use in PET or similar equipment. FCDN was officially opened in May 2007 and offers training courses with the academic support of Instituto de Tecnología Nuclear Dan Beninson.

I–7. INSTITUTO DE ENERGÍA Y DESARROLLO SUSTENTABLE

Instituto de Energía y Desarrollo Sustentable (IEDS) promotes, incubates, and conducts, engineering projects in the frame of a definite policy of environmental conservation, geared to the formation of human resources in the vast field of energy generation and conservation. To this end, IEDS gets support, both in technical and scientific aspects, from different groups at CNEA.

The activity of the Institute concentrates mainly in the organization of courses, conferences, and technical and scientific workshops, and in the promotion of technological projects, research, development, and transfer of results directly related to energy in general. IEDS areas of interest are: energy and environment, hydrogen and fuel cells, waste management studies, biomass, fuels, etc.

I–8. EXPERIMENTAL FACILITIES

Most of CNEA Atomic Research Centre holds an Education Institute:

- Bariloche Atomic Centre holds Instituto Balseiro;
- Constituyentes Atomic Centre holds Instituto Sabato;
- Ezeiza Atomic Centre holds Instituto Beninson.

Students have access to all experimental facilities and laboratories of their respective Atomic Centre (research reactors, accelerators, etc.).

FUESMEN activities are carried out in its facility at Mendoza State, with last generation technological equipment and highly trained human resources.

I–9. ADDITIONAL INFORMATION

http://www.cnea.gov.ar/xxi/primeras/institutos.asp;
www.ib.edu.ar;
http://www.isabato.edu.ar/;
http://www.cnea.gov.ar/institutobeninson/;
http://www.fuesmen.edu.ar/;
http://www.cab.cnea.gov.ar/ieds/.

Annex II

AUSTRIA[2]

II–1. BACKGROUND

Austria does not operate any nuclear power plants. Thus, its interest in the safety of nuclear facilities relates primarily to environmental, health and safety concerns arising from nuclear power plants in neighbouring countries. In November 1978, legislation prohibiting nuclear power plants on Austrian territory was adopted as a result of a referendum, rejecting the almost finished nuclear power plant Zwentendorf. The events at Chernobyl in 1986 reinforced this parliamentary decision and further strengthened public opposition to nuclear power. Confirming this policy, on 13 August 1999 the Parliament adopted the Federal Constitutional Act for a Nuclear-Free Austria.

II–2. NEEDS FOR NUCLEAR ENGINEERS

The country has practically no nuclear industry therefore there are no urgent demands of skilled nuclear manpower. Nuclear manpower is only needed in the following cases:

- Several neighbouring countries operate nuclear power plants and discussions on an international or bilateral level demands educated experts in this field;
- The future of Austria’s power supply may require a revision of its antinuclear policy and therefore also long term knowledge management is necessary;
- Nuclear knowledge has many other applications beyond power production such as in industry, medicine and agriculture, etc.

Currently, the Atomic Institute of the Austrian Universities (ATI) is a major contributor to the preservation of nuclear skilled manpower in Austria. Its nuclear education is not only fulfilling the national demands of nuclear graduates but also supplying its graduates to other European countries like Germany, France, etc.

II–3. EDUCATION SYSTEM

The Federal Ministry for Education, Science and Culture is the responsible body for higher education in Austria. It supports and regulates the educational institutions (i.e. universities, R&D organizations, etc.) in the country. Universities, through their faculties and institutes, precede the objective oriented education. There is no university or institute offering a nuclear engineering degree in Austria, but there are several nuclear courses (i.e. nuclear engineering, reactor physics, reactor experiments, dosimetry and radiation protection, etc.) offered to BSc, MSc and PhD students in the physics curricula of Austrian universities. The following are the main institutions that are involved in nuclear education.

II–3.1. Vienna University of Technology

The Vienna University of Technology manages five faculties. The faculty of Science and Informatics administers physics, chemistry, informatics, geophysics departments and the Atomic Institute of the Austrian Universities. Here the role of ATI in regional and international efforts of nuclear knowledge management activities has been highlighted.

Following are the main programmes through which ATI contributes to nuclear education at national, regional and global level.

---

[2] This report was prepared by H. Böck, Technische Universität Wien, Atominstitut.

(a) Academic programmes

The Atomic Institute graduates about 20 master’s and 5 PhD students per year in the following subjects:

— Neutron- and solid state physics;
— Nuclear technology;
— Radiation protection;
— Radiochemistry;
— Low temperature physics;
— X ray physics;
— Nuclear- and astrophysics.

(b) Training programmes

Being the closest nuclear research facility to the IAEA, ATI organizes the following activities in cooperation with the IAEA:

— Development of safeguards instrumentation;
— Prevention of illicit trafficking;
— Storage of special nuclear material;
— Training courses for junior inspectors;
— Since 1992 more than 100 IAEA fellows from developing countries participated in training courses at ATI;
— Customer designed training courses;
— Irradiation and test of safeguards instrumentation;
— Calibration of nuclear instrumentation.

(c) Organizing practical courses

The ATI organizes practical courses in the field of reactor physics and kinetics, reactor instrumentation and radiation protection. About 30 different practical exercises are available in German and English supported by textbooks which can be combined according to the special interest of the participants. For a few years, the interest in these courses from national and international users has been steadily increased.

II–3.2. University of Vienna

Within the academic curricula of the University of Vienna, several courses related to atomic and nuclear physics are offered. However most of the courses at the Atomic Institute can also be taken by students from the University of Vienna.

II–3.3. Austrian Research Centre Seibersdorf

Although the 10 MW MTR type ASTRA research reactor was shut down in July 1999, nuclear competence in fields such as radiation safety, health physics, and waste management continues to be available. The waste storage facility, together with related waste treatment facilities, is operated by the Seibersdorf Austrian Research Centre to meet the radioactive waste management needs of Austrian industry, hospitals, other medical institutions and research institutes. The storage facility has a design capacity of 15 000 barrels containing 200 litres each.

II–3.4. University of Salzburg

The division of physics and biophysics has five research groups. Two of the groups i.e. Environmental Radioactivity, Radioecology, Risk Assessment and Dosimetry, and Modelling groups are focussing their research on environmental radioactivity, neutron activation analysis, radioecology risk assessment, dosimetry and modelling aerosol research cell biology and tumour research experimental physics.

II–3.5. Demonstration PWR facility

The Austrian nuclear power plant at Zwentendorf is a unique PWR facility which is now being used for practical training of international nuclear customers to train staff in a non-radiation environment, especially in non-destructive inspection methods and for demonstration purposes for students in this field.

II–4. FOREIGN STUDENTS ENROLMENT

Foreign students are admitted to the ATI programme, presently students participate mainly within the ERASMUS programme in several courses, and in addition the ATI is a member of the ENEN Association which allows easy access for foreign students to any of the ATI courses. In addition the ATI contributes to the Eugene Wigner Course.

II–5. RESEARCH AND EXPERIMENTAL FACILITIES

ATI operates the only nuclear facility in Austria, the TRIGA Mark II research reactor with a maximum thermal power of 250 kW. This reactor is equipped with nuclear experimental facilities as a neutron interferometer, neutron activation system, and experimental irradiation channels in the core, etc. (www.ati.ac.at).

II–6. COOPERATION/COLLABORATION WITH INDUSTRY AND GOVERNMENT

Cooperation in the nuclear related fields exists with very few national industries as there is practically no nuclear industry in Austria. Some of the developed nuclear methods are being utilized in conventional industry; however there are mainly international partnerships with ILL, FRM-2, CEA-Cadarache, ITER, University of Manchester, and Technical Universities of Bratislava, Budapest and Prague, Institute Josef Stefan of Ljubljana, etc.

II–7. NATIONAL AND INTERNATIONAL COOPERATION AND EDUCATIONAL NETWORKS

ATI plays an active role in the performance of international networks of nuclear education such as European Nuclear Education Network (ENEN) and Nuclear Technology Education Consortium (NTEC). ATI is an active member of the ENEN association and participates in the ENEN training programmes like Eugene Wigner courses, NEPTUNO, and MTR+3I programmes. In cooperation with NTEC, a one week training course on reactor physics and kinetics, radiation protection and I&C systems has been carried out since 2007. Each group consists of six students. This two week course, per year, is a part of the NTEC MSc Programme in Nuclear Science and Technology. Being that thia is the closest operating nuclear (TRIGA Mark II) research reactor to the IAEA, ATI facilitates the IAEA through safeguard training courses.

Figure II–1 reflects the trend of students in nuclear subjects offered at ATI. These graphs show that the enrolment trend of students in favour of nuclear technology is increasing. The ostensible reason for this growing trend may be the awareness level of the public in general and of students in particular, regarding the potential of safe usage of nuclear energy in the coming future.

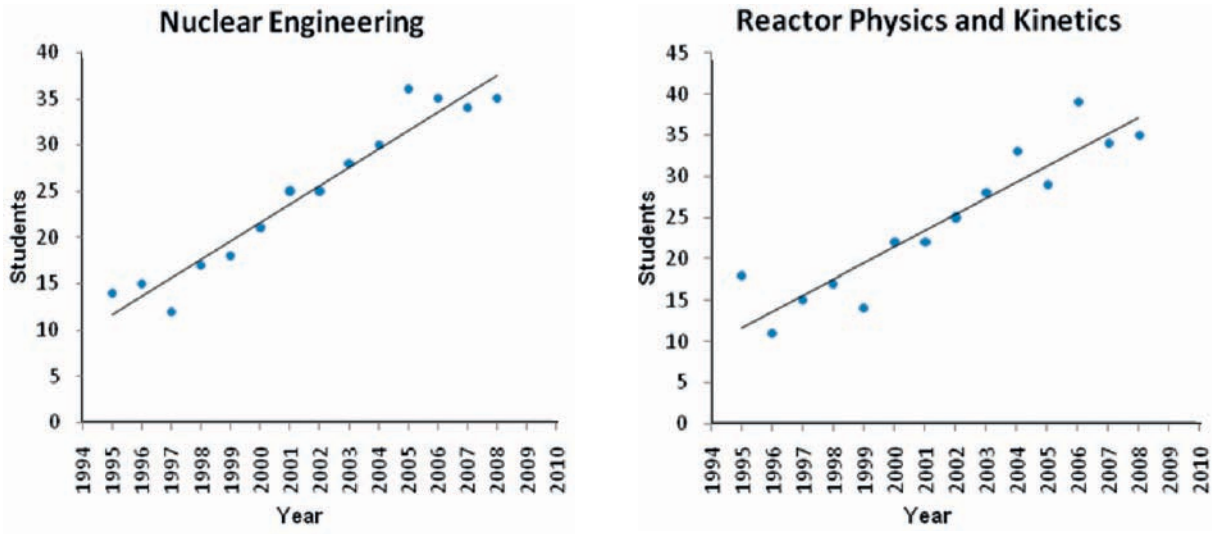


FIG. II–1. Nuclear education trends at ATI since 1995.

BIBLIOGRAPHY

BÖCK, H., VILLA, M., Management of Nuclear Knowledge on an international scale using small university research reactor, IAEA publication, www.ati.ac.at.

A consortium of UK universities and other institutions providing post-graduate education in Nuclear Science and Technology, ‘Nuclear Technology Education Consortium NTEC’, http://www.ntec.ac.uk/.

ENEN Association, ‘European Nuclear Education Network’,www.enen-assoc.org.

Annex III

BELGIUM

III–1. BACKGROUND

To maintain and further develop the high quality of nuclear engineering education, a network of five Belgian universities and Belgian nuclear research centre (SCK CEN) were created in 2001 with the title of ‘Belgium Nuclear Higher Education Network BNEN’. Public authorities, regulators and industries supported this initiative due to the need of well educated and trained nuclear manpower. It introduced a new programme of higher education under the name of 60 ECTS programme ‘Master of Science in Nuclear Engineering’. To join this new master’s programme, students must already hold a university degree in engineering or equivalent. This programme aims to deliver a considerable number of highly qualified engineers for the safe and economic operation of nuclear power plants, not only in Belgium, but worldwide as well.

The BNEN consortium organizes several courses for a significant number of foreign students under the ENEN project. This creates good international exposure for European students. The master’s programme is a demanding programme whereby students with different high level backgrounds in engineering have to go through highly theoretical subjects like neutron physics; fluid flow and heat transfer modelling, and apply them to reactor design, nuclear safety and plant operation and control. As a more interdisciplinary level, the programme includes some important chapters of material science, with a particular interest in the fuel cycle. Radiation protection belongs also to the backbone of the programme. All subjects are taught by academics appointed by the partner universities, whereas the practical exercises and laboratory sessions are supervised by researchers of SCK CEN. The final thesis offers an opportunity for internship in industry or in a research laboratory.

III–2. OBJECTIVE

III–2.1. Consortium objective

The main objective of the BNEN consortium that organizes the BNEN programme is to become a European pole of reference for education in nuclear engineering. This is the main justification of the interuniversity character of the programme.

A secondary objective of the BNEN consortium is to maintain, in Belgium, an *academic* pole of competence, meaning that:

- Universities involved in academic nuclear education have to pursue research in the related areas;
- The recruitment for Belgian nuclear power plants can continue to rely, at least partially, on locally educated people since safety culture is dependent among others on local cultural factors.

III–2.2. BNEN programme objective

The main objective of the BNEN programme is to provide holders of a Master’s in Science degree (MSc) in an engineering discipline with a second MSc specialized in nuclear engineering (Master after Master). The BNEN programme is open for full time students and for part time students with a professional occupation. After an additional practical training outside the scope of the academic programme, these engineers will have all necessary scientific and technical background and skills to carry out duties at a high level of responsibility in one of the following areas:

- Safe and economical operation of nuclear power plants;
- Regulation and control of nuclear installations;
- Safe and economical dismantling of nuclear installations;

— Design of innovative safety features;
— Design of new systems (e.g. GEN IV).

They will also be able to undertake doctoral studies in the related scientific fields.

The secondary objectives of the BNEN programme are to offer a variety of courses which can be used also for purposes other than the Belgian MSc in nuclear engineering, namely:

— To provide option courses to Belgian students who are specialising in non-nuclear fields (e.g. engineering physics, energy and environment, etc.);
— To provide international courses to European students;
— To provide continuing professional courses to practitioners;
— To provide advanced courses on topics of nuclear sciences and technologies to researchers and/or industry professionals.

III–3. BNEN MEMBERS

BNEN is comprised of the following six universities and SCK CEN. The universities provide the academic framework i.e. the courses, professor and degrees while SCK CEN provides the infrastructure i.e. classrooms, laboratories and exercise sessions:

— Vrije Universiteit Brussel (VUB);
— Universiteit Gent (Ugent);
— Katholieke Universiteit Leuven, (KULeuven);
— Université de Liège (ULg);
— Université Catholique de Louvain (UCL);
— Université Libre de Bruxelles (ULB).

III–4. THE ACADEMIC PROGRAMME

This ‘master’s after master’s’ programme pertains to the study domain of Engineering, corresponding to Applied Sciences of respectively the Flemish and French Community. It covers one year of study and corresponds with 60 ECTS units. After successful completion of the programme, the academic degree of Master of Nuclear Engineering or ‘Diplomé d'études spécialisées en Génie Nucléaire’ will be awarded depending if the student enroled respectively on a Flemish or a Walloon BNEN university. The courses are organized in a highly modular way and are taught in English to facilitate and enhance participation of students coming from other countries. As this programme is a Master after Master programme, the participants are supposed to already have a thorough background in engineering sciences. The course programme is listed in Table III–1.

III–5. INTERNATIONAL PARTICIPATION

As mentioned earlier, the BNEN programme courses are taught in English to facilitate participation of foreign students. In order to qualify for an EMSNE certificate, several students registered at foreign universities taking part in ENEN, participated in modules of the BNEN programme. Figure III–1 provides the overview of foreign students in the BNEN programme.

The BNEN is an active member of the ENEN association, and it also cooperates with the Asian Network for Education in Nuclear Technology (ANENT) as well as with the World Nuclear University (WNU). In the sixth framework programme project EUROTRANS, a challenging programme on accelerator driven transmutation research; the post doctoral research is being coordinated by a BNEN partner.

TABLE III–1. OVERVIEW OF BNEN COURSES

BNEN courses	ECTS
Nuclear energy: introduction	3
Introduction to nuclear physics	3
Nuclear reactor theory and experiments (ENEN)	8
Nuclear thermal-hydraulics (ENEN)	6
Operation and control	3
Reliability and safety	3
Nuclear fuel cycle and applied radiochemistry	3
Nuclear materials I	3
Nuclear materials II	3
Radiation protection and nuclear measurements	6
Advanced topics	4
Master thesis project and internship	15
Total	60

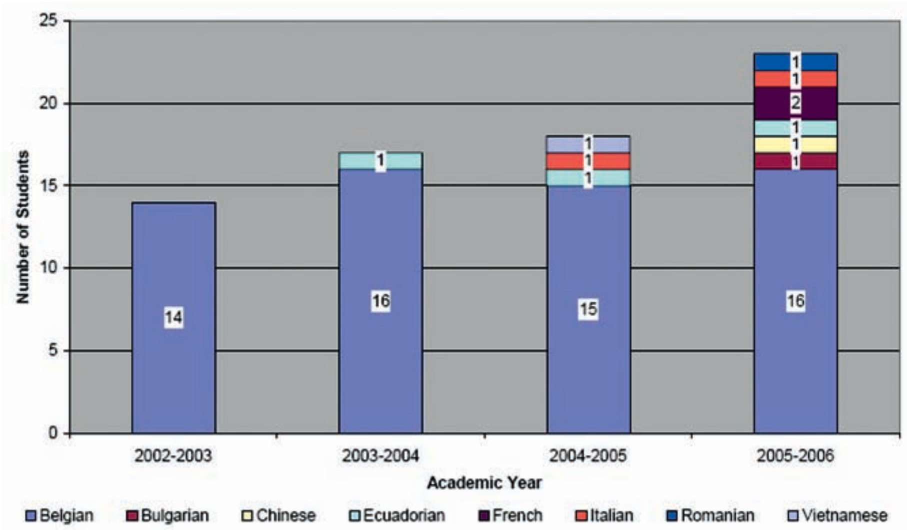


FIG. III–1. Overview of the nationalities of student in the BNEN programme.

III–6. MAIN SCK CEN FACILITIES USED FOR THE BNEN PROGRAMME

— Research reactor BR2, 50 MW, beryllium moderated, water cooled, materials testing reactor, with high enriched uranium fuel. It is used for testing and qualification of fuel and materials for different reactor types, as well fission as fusion reactors. It is also used for isotope production for medical and industrial purposes and for silicon doping for the electronics industry;

— Research reactor BR1 is a natural uranium, graphite moderated, air cooled reactor. It is used as a neutron source for activation analysis, dosimetry calibration, neutrography and reference experiments. The reactor is also well suited for educational and didactical purposes. Normally it operates at some 0.7 MW with a neutron flux up to 10^{15} neutrons/m² sec;
— The VENUS zero power critical facility allows detailed analysis of core configurations, including MOX and high burnup fuels. VENUS is intensively used for the validation of reactor core configurations and criticality codes. This facility is also well suited for educational and didactical purposes;
— The laboratory for high and medium level activity examines and models fuels and materials for present-day and future nuclear installations. A wide variety of mechanical, physic-chemical and microstructure research tools in remotely operated hot cells are available. In these laboratories, practical sessions in support of the courses on radiation protection and nuclear measurements are organized: i.e. low level activity measurements, dosimetry calibration, and non-destructive detection of Pu in waste;
— MYRRHA, at this moment a design project, is an accelerator driven sub-critical reactor of some 50 MW. Research items in support of the MYRRHA design are a constant source for master theses and for practical exercises i.e. in support of the course on nuclear thermal hydraulics;
— SCK CEN's Knowledge Centre has the legal obligation to collect and conserve the nuclear scientific, technological and technical documentation. The present day knowledge centre surpasses the classical library function. In order to ensure better retrieval and access of existing data and documentsand tacit knowledge, dedicated web-based portals sustaining interactive research communities are developed;
— SCK CEN has a fully operational conference centre with auditoria, meeting rooms, catering and hotel facilities as well as supporting services such as a printing office, informatics support service, public relations, article lay out, contact data bank, etc.

Annex IV

BULGARIA[3]

IV–1. BACKGROUND

According to the Convention on Nuclear Safety, Bulgaria should ensure that sufficient numbers of qualified staff with appropriate education, training and retraining are available for all safety related activities in or for each nuclear installation, throughout its lifetime.

The development of the nuclear sector is closely related to the education and training of a sufficient number of skilled and qualified specialists in the following directions:

— Fundamental and application nuclear science;
— Nuclear energetic;
— Nuclear I&C industry and microelectronics;
— Civil engineering;
— Nuclear safety and emergency planning;
— Ecology and radioactive waste management;
— Economical aspects of nuclear technology;
— Security of nuclear installations and non-proliferation.

The development and maintenance of a state of the art system for education and training of nuclear installations personnel is crucial for the safety and the reliable and efficient operation of nuclear power plants. The major task of the government, academic community and nuclear industry sector is to preserve existing nuclear expertise and to implement a successive approach to set up a three level qualified personnel — undergraduate education, graduate and post-graduate education and specialized training.

Education in Nuclear Science at university level in Bulgaria exists since 1939, when E. Karamihailova began to teach a course on Experimental Atomic Physics and Radioactivity at the University of Sofia. A few years later (1945) she founded the Department of Atomic Physics. Later, in 1962 K. Kostadinov gave the first lectures in radiochemistry as an optional course at the Faculty of Chemistry.

Specialized education at the MSc level started in 1972: in nuclear engineering at the Faculty of Physics and in radiochemistry at the Faculty of Chemistry, both at the University of Sofia.

Nowadays, there are three departments at the University of Sofia, which, along with the Technical University of Sofia, form the national basis for the nuclear education in Bulgaria (see Table IV–1).

The technical aspects of nuclear power plants are studied at the Department of Thermo- and Nuclear Power Engineering of the Technical University (Sofia). The chair of Atomic Physics at the Plovdiv University is also engaged in the nuclear education process in the country.

TABLE IV–1. DEPARTMENTS AT THE SOFIA UNIVERSITY, PROVIDING NUCLEAR EDUCATION

Department	Faculty	Scope
Atomic physics	Physics	Nuclear and particle physics, Radioactivity, health physics
Nuclear engineering	Physics	Nuclear engineering
Radiochemical laboratory within the Department of general and inorganic chemistry Radio analytical laboratory within the Department of analytical chemistry	Chemistry	Nuclear and radiochemistry, radioecology

[3] Prepared by P. Kovacheva, L. Litov, L. Tsankov, University of Sofia, Sofia, Bulgaria, L. Pironkov, Training Centre, Kozloduy NPP, Kozloduy, Bulgaria.

Research in nuclear science and engineering is performed at the Institute for Nuclear Research and Nuclear Energy of the Bulgarian Academy of Sciences and the above mentioned universities as well.

Ruse University ‘Angel Kantchev’ and the Technical University of Varna do not have departments and academic programmes focused specifically to nuclear technology. However they, together with the Technical University of Sofia, carry out graduation on various engineering specialities and thus ensure the availability of supporting engineering personnel for nuclear industry.

IV–2. NEEDS FOR NUCLEAR ENGINEERS

The first nuclear power unit in Bulgaria was commissioned in 1974 (Kozloduy NPP). At present there are six units (four WWER-440 being prepared for decommissioning and two WWER-1000 in operation). A new NPP in the city of Belene is in an initial stage of construction (two units WWER-1000); it is expected to be commissioned in 2014. Nuclear Power Plants are the most significant industry branch needing nuclear engineers. Besides them, specialists in nuclear engineering and science are employed at the State enterprise for radioactive waste management, the State administration (Nuclear Regulatory Agency, Ministry of Energy, Institute of Metrology and Standardization, Institute of Radiology and Radiation Protection, etc.) and also at some large industrial and medical companies using radioactive sources.

By the end of 2007, the nuclear sector employment is about 7300 persons in total. Most of them (about 65%) are working for Kozloduy NPP, 14% are involved in service and maintenance and 21% are evenly distributed between education institutions, nuclear science and R&D organizations and engineering companies.

About 38% of employees are master’s degree graduates. The average age of the staff is about 50. Industrial demand for nuclear expertise distributed among major nuclear related institutions is presented below. Table IV–2 includes the demand for qualified staff during the period 2009–2013.

Generalized data of personnel need analysis classified by academic or engineering specialties are presented in Table IV–3. The analysis has been carried out on the bases of the static model of estimated student and workforce flow. Taking into account unavoidable fluctuation the number should be increased up to 20%.

TABLE IV–2. NUCLEAR SECTOR EMPLOYMENT DEMAND (2009–2013)

Organization	Demand
Kozloduy NPP	730
Belene NPP	520
State enterprise radioactive waste	35
Nuclear science and R&D institutes and universities	40
Nuclear engineering and consultancy companies	95
Total:	1420

TABLE IV–3. EMPLOYMENT DEMAND DISTRIBUTED ON STAFF WITH NUCLEAR QUALIFICATION

Profession	Persons
Nuclear engineering and nuclear technology (M.S. Physical Science)	39
Nuclear power engineering (MSc, Technical Science)	165
Nuclear chemistry and radiochemistry (MSc, Chemical Science)	67

IV–3. EDUCATIONAL SYSTEM AND EDUCATIONAL INSTITUTIONS INVOLVED IN NUCLEAR EDUCATION

The Bulgarian system for education, training and qualification of nuclear sector personnel follows a multigrade approach. The key pillars of that approach are:

- Undergraduate professional education and vocational training provided by national general education system;
- Graduate BSc (8 semesters), post-graduate education MSc (2–3 semesters) and PhD (3 years) provided by academic educational system;
- Initial and continuous specialized training for specific professional qualification provided by industry.

(1) Undergraduate course offerings;
Two professional schools offer following programmes oriented to nuclear sector:
- Microprocessor technology;
- Nuclear energetic;
- Electrical installations;
- Electrical supply networks;
- Air condition technology;
- I&C technology.

These schools provide also vocational training for apprentices and prequalification courses for adults.

(2) Graduate and post-graduate course offerings.

IV–3.1. University of Sofia

A brief description of curricula in Nuclear Engineering, Nuclear and Particle Physics and Nuclear Chemistry related education is presented below.

IV–3.1.1. Nuclear engineering

(1) BSc curriculum in Nuclear engineering and nuclear technology;
General characteristics:
- Duration: 8 semesters;
- Total number of academic hours (required and optional) — 2835;
- Subjects distribution by topics: 20% mathematics; 29% general (non-nuclear) physics; 11% general engineering, 40% specialized nuclear subjects;
- Number of exams — 42;
- Number of ECTS — 240;
- The final graduation of the students requires a defence of their bachelor thesis.

The average number of incoming students is 15 per year. About half of them successfully complete the curriculum.
Table IV–4 presents the nuclear related courses within the specialty, their academic hours and ECTS.

(2) MSc curriculum in Nuclear engineering
General characteristics:
- Duration: 3 semesters;
- Total number of academic hours (required and optional) — 685;
- Number of exams — 11;
- Number of ECTS — 90;
- The final graduation of the students requires defence of their MSc thesis.

Table IV–5 presents the compulsory courses within the specialty, their academic hours and ECTS.

TABLE IV–4. NUCLEAR-RELATED COURSES IN THE BSc NUCLEAR ENGINEERING AND NUCLEAR TECHNOLOGY

Compulsory nuclear-related courses	ECTS	Total academic hours	Academic hours		
			Lectures	Seminars	Exercises
Atomic physics and interaction of the ionizing radiation with matter	9	105	45	15	45
Nuclear and particle physics	9	105	45	15	45
Neutron physics	5.5	75	45	30	
Reactor physics	3	45	45		
Computational reactor physics	6	75	45		30
Nuclear electronics	7	105	45		60
Dosimetry and radiation protection	8.5	105	45		60
Introduction to nuclear technology	9	120	45	30	60
Experimental nuclear physics	8	105	45		60
Nuclear theory	3	45	45		
Practical training at NPP (2 weeks)	3	60			60

TABLE IV–5. COMPULSORY COURSES IN THE MSc NUCLEAR ENGINEERING

Compulsory courses	ECTS	Total academic hours	Academic hours		
			Lectures	Seminars	Exercises
Operational reactor physics and nuclear safety — 1	6.0	60	45	15	
Heat transfer	4.5	45	30	15	
Technical hydromechanics	6.0	60	45	15	
Reliability in NPPs	6.0	60	45	15	
Radiochemistry	7.5	75	30	0	45
Operational reactor physics and nuclear safety — 2	6.0	60	45	15	
Reactor analysis	9.0	90	45	45	
Ionizing radiation metrology	6.0	60	30	0	30

IV–3.1.2. MSc curriculum in Nuclear and Particle Physics

All students at the BSc level in physics pass, as a part of their general education, two courses on atomic physics and interaction of the ionizing radiation with matter (45+15+45) and on nuclear and particle physics (45+15+45). During the third and fourth years, all BSc students in physics can choose courses according to their interest. Among them are: experimental nuclear physics, theoretical nuclear physics, dosimetry and radiation protection, nuclear electronics, nuclear reactions, radiation biophysics, and introduction to particle physics. These courses form the basis for the students which are going to continue their education in the MSc programme on Nuclear and Particle physics.

During the first two semesters of the MSc curriculum in Nuclear and Particle physics, students should attend optional courses (at least 300 hours per semester, equivalent to 30 ECTS) and successfully take exams. At least four of the courses should be chosen from the list of the required courses. The student may choose to attend one course from another MSc programme (MSc programme in Theoretical and Mathematical physics, Nuclear Engineering or Medical Physics). The total number of the courses for the first and the second semester should be at least ten. The third semester is foreseen for research work under supervision of senior tutors, MSc thesis preparation and participation in scientific seminars (30 ECTS in total).

General characteristics:

— Duration: 3 semesters;
— Total number of academic hours (required and optional) — 900;
— Number of exams — >10;
— Number of ECTS — 90;
— The final graduation of the students requires MSc thesis defence.

Table IV–6 presents the major courses within the specialty, their academic hours and ECTS. Since 2001 the MSc programme has been attended by 38 students.

IV–3.1.3. Bachelor's degree in nuclear chemistry

Students at the BSc level in chemistry pass, as a part of their general education courses, Nuclear chemistry and radiochemistry (compulsory for the students with specialization in inorganic chemistry and chemistry of the solid state), radioecology and radio analytical chemistry (optional).

TABLE IV–6. MAJOR COURSES IN THE MSc NUCLEAR AND PARTICLE PHYSICS

Courses	ECTS	Total academic hours	Academic hours		
			Lectures	Seminars	Exercises
Standard model of strong and electroweak interactions	6	60	60	0	0
Symmetry in particle physics	4.5	45	45	0	0
Nuclear models	4.5	45	45	0	0
Nuclear structure	6	60	45	15	0
Modelling physical processes	6	60	30	0	30
Theory of nuclear reactions	6	60	45	15	0
Environmental radioactivity, radioecology	7.5	75	30	0	45
Nuclear electronics — 2	9	90	45	0	45
Theoretical astrophysics	6.5	60	60	0	0
Introduction to strings and superstrings theory	4.0	45	45	0	0
Physics experiment automation	4.5	45	45	0	0
Radiochemistry	7.5	75	30	0	45
Radiation biophysics	4.5	45	45	0	0
Advanced topics in nuclear physics	4.5	45	45	0	0

The BSc in Nuclear chemistry was established in 2006 at the University of Sofia. Its aim was to:

- — Strengthen nuclear education and training of chemists;
- — Ensure sustainable supply of qualified nuclear chemists to meet the current and future national needs;
- — Provide students with profound fundamental knowledge in chemistry and to assure their professional realization in various branches of the science and the practice.

General characteristics of the BSc in nuclear chemistry:

- — Duration: 8 semesters;
- — Total number of academic hours of the compulsory courses — 2805;
- — Total number of academic hours of the compulsory and optional courses — 2985;
- — Shares of the subjects by topics: 17% physics and mathematics; 38% general (non-nuclear) chemistry courses; 45% specialized nuclear subjects;
- — Number of exams — 42;
- — Number of ECTS — 240;
- — The final graduation of the students requires defence of their bachelor's thesis.

The average number of students admitted is ten per year.

After their graduation, the bachelors, with a degree in nuclear chemistry, will be qualified to work in the fields of: nuclear energetic; nuclear waste management (nuclear waste treatment/processing and storage); production of radioisotopes and labelled compounds; environmental monitoring and nature conservation; all the branches of medicine, agriculture and industry where radioisotopes are used. They will be able to continue their education in specialized master's programmes in the field of nuclear chemistry, as well as in all the programmes intended for the graduates of university chemistry and industrial chemistry. Table IV–7 presents the nuclear related courses within the specialty, their academic hours and ECTS.

TABLE IV–7. NUCLEAR-RELATED COURSES FOR THE BACHELOR'S DEGREE IN NUCLEAR CHEMISTRY

Compulsory nuclear-related courses	ECTS	Total academic hours	Academic hours		
			Lectures	Seminars	Exercises
Atomic and nuclear physics	9	105	45	15	45
Nuclear chemistry and radiochemistry — I	7	90	45	0	45
Measurement of the ionization radiation	6	75	30	0	45
Radiation protection	4	60	30	0	30
Nuclear chemistry and radiochemistry — II	6	75	30	0	45
Operation and decommissioning of nuclear power plants	6	90	45	0	45
Radio analytical chemistry	6	75	30	0	45
Chemistry of the nuclear fuel cycle and of nuclear reactors	8	105	45	0	60
Water treatment and water purification in the nuclear energetic	4	60	30	0	30
Radioecology	4	60	30	0	30
Production of radioactive isotopes and labelled compounds	5	60	30	0	30
Radioactive wastes	5	60	30	0	30
Nuclear safety. Risk analysis and risk informed decision making	3	60	45	0	15
Fundamentals of radiobiology	4	60	45	0	15
Practical training (4 weeks)	4	140	0	0	140

Optional nuclear-related courses: radiation chemistry, hot atom chemistry, radionuclide methods in medicine, radioisotope dating, exploitation changes in the structure materials of nuclear power plants, X ray fluorescence, Moessbauer spectroscopy, nuclear electronics etc. Four optional courses are to be selected by the students in the eighth semester. Each of the courses (4 ECTS) has 30 academic hour lectures and 15 academic hour exercises.

IV–3.1.4. Post-graduate courses

(1) MSc curriculum in radiochemistry and radioecology;

The programme is designed for bachelors or masters of chemistry, chemical engineering, chemistry and physics, and biology and chemistry.

Properties of radioactive substances, methods for measurement of ionizing radiation, production, analysis and application of radio nuclides and labelled compounds are studied. Knowledge about various problems of the exploitation of nuclear facilities and the monitoring and protection of the environment is also given (see Table IV–8). The curriculum consists of 750 academic hours (lectures — 270, laboratory practice — 480). The variety of optional courses provides the possibility for further specialization in:

— Radiochemical and radio ecological problems of nuclear energy, including fuel processing and management of nuclear wastes;
— Radio analytical chemistry and environmental monitoring;
— Production and application of radio nuclides and labelled compounds.

For five years, only ten students attended the MSc programme in radiochemistry and radioecology. Most of them succeed in finding jobs in the nuclear field.

(2) MSc curriculum in nuclear chemistry:

A new one year master’s programme in nuclear chemistry has been developed (see Table IV–9). It is designed for bachelors of nuclear chemistry and is aiming to give the students’ deeper knowledge and skills in the various applications of the radioisotopes. The offered optional courses provide the students the possibility to get acquainted with the national energy programme and extend their knowledge on the world energy market, radioisotope dating, experimental physics, etc.

The curriculum consists of two semesters, including 735 academic hours: lectures — 195, laboratory practice — 540.

IV–3.1.5. PhD programmes

PhD programmes in nuclear physics, particle physics, neutron and reactor physics and radiochemistry are organized at the University of Sofia. The duration of the programme is three years. The students are performing scientific investigations in the corresponding field of nuclear science and/or engineering under supervision of a qualified university professor. As a rule the students (especially those in nuclear and particle physics) participate in large international collaborations working in the forefront of the field having an access to the world best laboratories and infrastructures (accelerators). The programme is finished by defence of a PhD thesis based on at least two publications in peer reviewed journals. During last years (since 2002) the programme was attended by 22 PhD students.

IV–3.2. Technical University of Sofia

The Technical University of Sofia is the largest higher engineering school in Bulgaria and provides specialists essential for the industrial development, including nuclear industry. It is a major educational, research and development complex, offering qualified staff, with modern laboratory facilities and considerable capacities for experimentation and production. The Chair of Thermal and Nuclear Power at the Technical University of Sofia carries out BSc, MSc and PhD programmes on nuclear engineering (see Fig. IV–1).

TABLE IV–8. CURRICULUM OF THE MSc DEGREE PROGRAMME IN RADIOCHEMISTRY AND RADIOECOLOGY

	Compulsory courses	ECTS	Total academic hours	Academic hours		
				Lectures	Seminars	Exercises
I semester	Radiochemistry	7	90	45	0	45
	Radiometry and dosimetry	6	75	30	0	45
	Fundamentals of radiobiology	3	45	30	0	15
	Optional courses	10	120	45	0	75
	Course project	4	60	0	0	60
II semester	Radioecology	6	75	30	0	45
	Nuclear methods for analysis	6	75	30	0	45
	Optional courses	12	150	60	0	90
	Pre-graduation practice	5	60	0	0	60
III semester	Research practice	11	160	0	0	160
	Master thesis	20	0	0	0	0
I or II semester	Radioactive wastes	4	60	30	0	30
	Regulatory control in the nuclear energetic	4	60	30	0	30
	Decommissioning of nuclear facilities	2	30	15	0	15
	Production of radioactive isotopes and labelled compounds	5	75	30	0	45
	Application of radio nuclides	5	75	30	0	45
	Radioisotope dating	3	45	15	0	30
	Liability in the nuclear energetic	3	45	30	0	15
	Chemistry of the f-elements	2	60	30	0	30
	X ray analysis	3	45	15	0	30
	Nuclear safety. risk analysis and risk-informed decision making	4	60	45	0	15

TABLE IV–9. CURRICULUM OF THE MSc DEGREE PROGRAMME OF NUCLEAR CHEMISTRY

	Compulsory courses	ECTS	Total academic hours	Academic hours		
				Lectures	Seminars	Exercises
I semester	Application of radio nuclides in chemical investigations	5	60	30	0	30
	Chemistry of f-elements and transactinides	3	30	15	0	15
	Radioisotope methods in medicine	3	30	15	0	15
	Materials for the nuclear energetic	5	60	30	0	30
	Liability and resource in nuclear energetic	4	45	30	0	15
	Optional courses	10	150	75	0	75
II semester	Pre-graduation practice	15	360	0	0	360
	Diploma work	15				
	Optional courses					
I semester	World energy market. Bulgarian energy programme	3	45	30	15	0
	Experimental physics and Moessbauer spectroscopy	4	60	30	0	30
	Fundamentals of the physics of nuclear reactors	3	45	30	0	15
	Radioisotope dating	3	45	15	0	30
	Radiation biophysics	4	60	30	0	30
	Hot atom chemistry	2	30	15	0	15
	Metrology of the ionizing radiation	3	45	30	0	15
	Programming in UNIX system	4	60	30	0	30

Additionally, the Technical University of Sofia provides education on nuclear related disciplines through the subsidiary institution College of Energy and Electronics.

Table IV–10 presents five year statistic information for number of students, enroled in nuclear technology related specialties of Technical University of Sofia.

IV–3.3. Plovdiv University ‘Paisii Hilendarski’

The academic and scientific activities at the University of Plovdiv, related to the nuclear application and industry are carried out by the faculties of Physics and Chemistry.

The Faculty of Physics offers BSc, MSc and PhD in engineering physics, as well as a post-graduate degree programme on nuclear physics methods.

The Faculty of Chemistry offers two semesters MSc programme radiochemistry and radioecology.

The average number of students on the above mentioned programmes over the past five years is about 15.

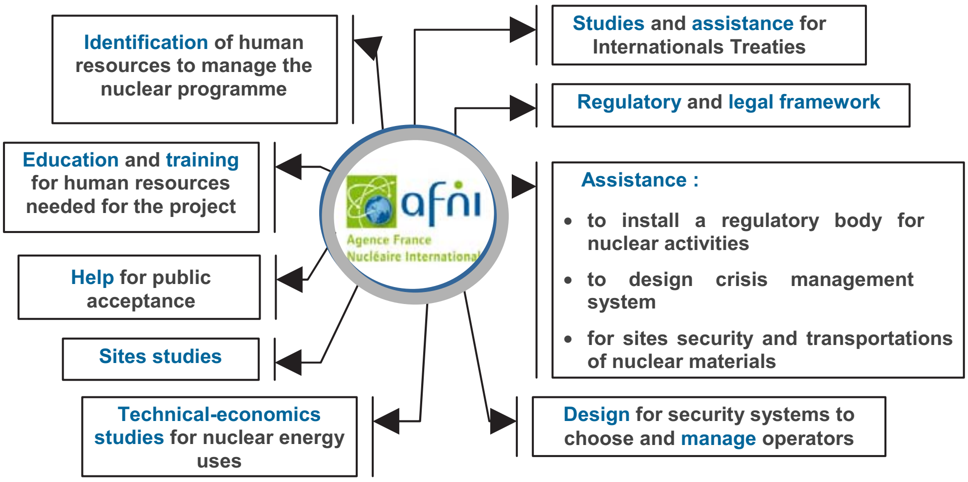


FIG. IV–4.1. Diagram of graduation process.

TABLE IV–10. STATISTIC DATA OF NUCLEAR ENGINEERING PROGRAMMES IN TU-SOFIA

Speciality, degree	Students total	Average input per year	Graduation 2007
Thermal and nuclear power, BSc	210	52	43
Nuclear power, MSc	28	14	12
Nuclear power, PhD	9	3	2

IV–3.4. Institute for Nuclear Research and Nuclear Energy (INRNE)

As part of the Bulgarian Academy of Science, INRNE is the major scientific and research nuclear centre in Bulgaria. Together with scientific and applied investigations, the Institute has a programme accreditation from the National Evaluation and Accreditation Agency and tutors persons working for a doctoral degree in regular, extramural and free manner in the following scientific disciplines:

- Theoretical and mathematical physics;
- Nuclear physics;
- Physics of elementary particles and high energies;
- Neutron physics and physics of nuclear reactors;
- Radiochemistry.

Currently 25 PhD students receive training at the INRNE.

IV–4. FOREIGN STUDENT ENROLMENT

The Atomic Physics Department (Faculty of Physics, University of Sofia ‘St. Kliment Ohridski’) gives various opportunities for the foreign students in the framework of different programmes. The students have an opportunity to choose between two MSc programmes: Nuclear and Particle Physics or Medical Physics.

The Faculty of Chemistry has the capacity to offer foreign students nuclear chemistry education in English at bachelor’s and master’s degree level.

IV–5. AVAILABILITY OF RESEARCH AND EXPERIMENTAL FACILITIES (SUCH AS A RESEARCH REACTOR, ACCELERATORS, ETC.)

Each of the faculties and chairs of the specified universities is equipped with specialized laboratories and workshops, including specific equipment, needed for educational and scientific work.

The University of Sofia, Technical University of Sofia and Plovdiv University have developed organization and administration capacity to perform research activities at contract basis at national and international levels.

The leading complex centre for research and application of the nuclear physics in Bulgaria is the above mentioned Institute of Nuclear Research and Nuclear Energy. It has a highly qualified scientific potential, well developed infrastructure, broad international cooperation and long standing traditions in scientific research. The Institute's staff of about 320 (150 of them are scientific researchers) works in 16 laboratories, 2 scientific experimental facilities including research reactor IRT, currently in a process of reconstruction and modernization.

IV–6. COOPERATION/COLLABORATION WITH INDUSTRY AND GOVERNMENT

The established educational programmes in the nuclear field respond to the national needs of qualified specialists and cover the different fields of the nuclear power and non-power applications.

The curriculum of the specialty in nuclear chemistry is prepared considering the recommendations of: Nuclear Regulatory Agency of Bulgaria, experts in radiochemistry, involved in different branches of the peaceful use of nuclear energy from Bulgarian Academy of Science (BAS), Kozloduy NPP, etc. Experts from the Institute for nuclear research and nuclear energy and Institute of metal science (BAS), Nuclear Regulatory Agency, State Enterprise ‘Radioactive waste’, Kozloduy NPP, Technical University of Sofia, etc. are all involved in the teaching process. Contracts for mutual collaboration in nuclear education, training and research are established with the Institute for Nuclear Research and Nuclear Energy, State Enterprise ‘Radioactive waste’ and Kozloduy NPP. An advisory committee in the specialty nuclear chemistry is set up in order to discuss and respond the problems of the educational process with representatives from the University of Sofia, Nuclear Regulatory Agency, Kozloduy NPP, State Enterprise ‘Radioactive waste’, Institute for Nuclear Research and Nuclear Energy, Ministry of Economy and Energy.

The partnership between educational organizations and nuclear industry has been realized through research and development units. There are several main directions of cooperation:

- Joint research activities and scientific support in the technological process;
- Direct financing through sponsored development programmes, stipends for selected students, development and maintenance of training and research facilities, etc;
- Demand for specialized programmes and courses designed for specific group of personnel;
- Joint education and training activities — cooperation with NPP training centre in area of practical and on the job training of students, conducting of specific lectures or courses.

Table IV–11 presents one of the aspects of collaboration between nuclear industry and major educational organizations. Second column shows the number of students trained in Kozloduy NPP Training Centre during 2007–2008. Besides the data stored into the table a specific training has been additionally requested by other Bulgarian universities and conducted by the training centre.

The Training Centre has also provided training of small groups or single students from some foreign universities: Warsaw University of Technology, Poland; RWTH, Aachen, Germany; Louis Pasteur University, Strasbourg, France; University of Waterloo, Ontario, Canada; Ss. Cyril and Methodius University, Skopje, Former Yugoslav Republic of Macedonia; Hacettepe University, Ankara, Turkey.

TABLE IV–11. STUDENT'S PRACTICAL TRAINING IN THE KOZLODUY NPP TRAINING CENTRE

Educational organization	Students
Professional school 'I. Kurchatov'	375
College of Energy and Electronics — TU Sofia	40
Technical University of Sofia	83
University of Sofia 'St. Kliment Ohridski'	23
Ruse University 'Angel Kantchev'	12

IV–7. NATIONAL AND INTERNATIONAL COOPERATION AND EDUCATIONAL NETWORKS

Bulgarian universities implement international collaboration generally through bilateral agreements and participation in European education and research programmes. Bulgaria is involved in the TC project IAEA RER/0/028 Improving Educational and Training Capabilities in Nuclear Science and Applications. The development of national nuclear knowledge management network has been planned as well as integration into existing European educational networks.

BIBLIOGRAPHY AND ADDITIONAL INFORMATION TO ANNEX IV

MINISTRY OF ECONOMICS AND ENERGETIC, Situation Analysis of Nuclear Power Employment Needs 2009–2013 and prospect to 2020, (2008) (in Bulgarian).

KOVACHEVA, P., TODOROVSKY, D., (Eds), Proceeding of the International workshop Education and Knowledge Preservation in Nuclear Sciences in the Balkan Countries, Theta Consult, Sofia (2004) CD-ROM.

VELEV, V., Education on Nuclear Power — problems and trends, Bulatom International Conference, Varna (2009).

Sofia University, Faculty of Chemistry web address: http://www.chem.uni-sofia.bg

Sofia University, Faculty of Physics web addresses: http://www.phys.uni-sofia.bg

http://ntne.phys.uni-sofia.bg, http://atomic.phys.uni-sofia.bg/atomic-physics-department?set_language=en

Technical University of Sofia web address: www.tu-sofia.bg

Plovdiv University 'Paisii Hilendarski' web address: www.uni-plovdiv.bg

Ruse University 'Angel Kantchev' web address: www.ru.acad.bg

Technical University of Varna web address: www.tu-varna.bg

Institute for Nuclear Research and Nuclear Energy web address: www.inrne.bas.bg

Annex V

CANADA[4]

V–1. BACKGROUND

Nuclear research and development in Canada started in the 1940s as a responsibility of the federal government. An engineering design team was established at Chalk River, Ontario, to carry out research on heavy water moderated lattices. A zero-energy heavy water moderated research reactor, ZEEP, was built and achieved criticality in September 1945; it was in fact the first human-made operating reactor outside the USA. In 1947, the 20 MW heavy water moderated national research experimental reactor (NRX) started up. It served as one of the most valuable research reactors in the world, and provided the basis for Canada's development of the very successful CANDU series of pressurised heavy water reactors (PHWR) for power generation.

Atomic Energy of Canada Limited (AECL) was established in 1952 as a federal Crown Corporation. It has both a public and a commercial mandate. AECL has overall responsibility for Canada’s nuclear research and development programme (its public mandate) as well as for the Canadian reactor design (CANDU), engineering and marketing programme (its commercial mandate). Nuclear energy in Canada is a $5 billion per-year industry, representing about 150 firms, 21 000 direct jobs and 10 000 indirect jobs, and ~$1.2 billion in exports — the value to the country’s economy is much higher than the research and development funding provided by the federal government.

The CANDU nuclear reactor system was developed by AECL in close collaboration with the Canadian nuclear industry, and in particular with Ontario Hydro (now Ontario Power Generation). Currently, Canada operates 17 CANDU reactors, which contribute 16% of the country’s current electricity consumption. There are also 12 CANDU reactors operating abroad (in Argentina, China, India, the Republic of Korea, Pakistan and Romania). See Fig. V–1 — the localities shown in red are where the CANDU plants are situated. AECL is now developing the ‘third generation plus’ Advanced CANDU Reactor (ACR-1000), and also has the leading role internationally in developing the Generation IV Supercritical Water Cooled Reactor (SCWR).

Canada also initiated or contributed to other important applications of nuclear science and technology:

— The cobalt-60 therapy machine was developed in 1952 by J. Harold;
— Canada has for many decades provided the lion’s share of medical radio nuclides to the world market. These have been produced mostly in the National Research Universal reactor (NRU) at Chalk River Laboratories. NRU has served Canada extremely well in this regard;
— NRU has also performed a key role in supporting the power reactor programme for fuel and materials research over the last 52 years.

V–2. DEMANDS FOR NUCLEAR ENGINEERS

The economic health of the nuclear industry has a strong effect on the status of nuclear education in the country. In the 1980s, the number of students studying or graduating with degrees having nuclear content stayed relatively constant, as did the number of teaching staff. But from the early 1990s, for about 15 years, there was not a high level of investment by the nuclear industry in university research, and not a high level of hiring of graduates, which resulted in the near vanishing of nuclear programmes and nuclear engineering professors.

In contrast, in the last few years, with a number of activities to refurbish aging reactors and with the looming renaissance in the nuclear industry, the job market for new graduates with a nuclear engineering background has improved significantly.

[4] Prepared by W.J. Garland, V.G. Snell and B. Rouben, University Network of Excellence in Nuclear Engineering, UNENE.

Fig. V–1. Nuclear reactors in Canada.

- 17 operating CANDU reactors in Canada and 12 abroad
- Provide 16% of Canada's electricity

Current annual demand for new engineers and scientists (of all disciplines) in the Canadian nuclear industry are approximately as follows:

— By the electric utilities, ~250–300;
— By AECL, ~70;
— By mining companies, ~60;
— In total, by all sectors of the nuclear industry, 400–500.

V–3. EDUCATIONAL SYSTEM AND INSTITUTIONS INVOLVED IN NUCLEAR EDUCATION

The list below identifies the main Canadian universities which offer programmes in nuclear engineering or engineering physics, or in closely related disciplines with application in the nuclear industry, such as chemical engineering, mechanical engineering, control and instrumentation, nuclear science and radiation, and health physics. All the universities listed offer bachelor's, master's, and PhD degrees.

— McMaster University (http://www.mcmaster.ca);
— Queen's University (http://www.queensu.ca);
— University of Ontario — Institute of Technology (http://www.uoit.ca);
— University of Saskatchewan (http://www.usask.ca);
— University of Toronto (http://www.utoronto.ca);
— University of Waterloo (http://www.uwaterloo.ca);
— University of Western Ontario (http://www.uwo.ca);
— École Polytechnique de Montréal (http://www.polymtl.ca);
— University of New Brunswick (http://www.unb.ca);
— Royal Military College (http://www.rmc.ca);
— University of Guelph (http://www.uoguelph.ca).

It should also be mentioned that McMaster University and the University of Ontario Institute of Technology have instituted course based Nuclear Technology Diploma programmes for working professionals who want to broaden their knowledge in certain nuclear topics. Areas in which Diploma courses are offered are, for example, reactor physics, thermal hydraulics, fuel, operation and maintenance, safety, radiological applications, etc. The Nuclear Technology programmes confer the Diploma on students who have successfully taken four university based courses on specific topics. The Nuclear Technology Diploma programmes are separate from the more intensive Master's of Engineering offered by the University Network of Excellence in Nuclear Engineering (UNENE) — see below.

The page at http://www.nuclearcanada.ca/nc-wiki/index.php?title=Universities collects links to universities and to professors active in nuclear science and engineering research and education in Canada.

V–4. FOREIGN STUDENTS

All Canadian universities readily accept foreign students — although the registration fees for foreign students are higher than for Canadian students. In the nuclear programmes, foreign students currently represent a small number — perhaps 5% or at most 10% of all students in the programmes.

V–5. RESEARCH AND EXPERIMENTAL FACILITIES

Canada has a large number of research and experimental facilities. The main ones are listed here:

- Research reactors at AECL Chalk River Laboratories:
  - ZED-2 for reactor-physics measurements;
  - NRU for irradiation and testing of nuclear fuel and nuclear materials.
- RD-14M, full-elevation thermal hydraulics loop at AECL Whiteshell Laboratories used for studying loss of coolant accidents and emergency core cooling phenomena, heat transport system stability, and natural-circulation;
- Moderator test facility at Chalk River Laboratories used to measure local moderator temperature and velocity distributions in three dimensions;
- Large scale vented combustion facility at Whiteshell laboratories used to study hydrogen burning and explosions;
- Large scale containment facility at Whiteshell Laboratories used for gas-mixing tests and to simulate aerosol transport in containment;
- Small scale burst test facility at Chalk River Laboratories for research in fuel channel performance;
- Facility at Chalk River Laboratories to study molten fuel moderator interaction, as in a postulated fuel channel rupture;
- Hot cells and other facilities at Chalk River Laboratories used for research on materials and fuel performance;
- Full scale water facility at Stern Laboratories to measure critical heat flux;
- Freon thermal hydraulics test loop at Chalk River Laboratories;
- Five MW nuclear reactor at McMaster University used for neutron activation analysis (NAA), radionuclide production, research and teaching;
- SLOWPOKE nuclear reactor at the Royal Military College used for research and teaching;
- SLOWPOKE nuclear reactor at École Polytechnique de Montréal used for research and teaching;
- SLOWPOKE nuclear reactor at University of Alberta used for NAA and radionuclide production, research and teaching.

V–6. NATIONAL LINKS: UNIVERSITY NETWORK OF EXCELLENCE IN NUCLEAR ENGINEERING — EDUCATION AND RESEARCH NETWORK

To help increase the level of nuclear research in Canadian universities, and provide the nuclear manpower required by the Canadian nuclear industry in the future, the UNENE was established.

UNENE is an industry driven alliance of universities, nuclear power utilities, research and regulatory agencies for the support and development of nuclear education, research and development capability in Canadian universities. UNENE was established as a not for profit corporation by the Government of Canada with Letters Patent issued on 22 July 2002. Collectively supported by industry, governments and universities, UNENE has started an integrated approach to address future workforce needs, create new or strengthen existing university expertise in nuclear technology and promote university based nuclear research in Canada.

V–6.1. UNENE objectives

Nuclear industry, universities and governments (provincial and federal) in Canada have elected to work together through UNENE to ensure that the country continues to be among the world leaders in peaceful and safe application of nuclear technology. UNENE concentrates its efforts to ensure that, in sufficient numbers, bright candidates are attracted, educated and trained as engineers and scientists to advance the state of the art in nuclear technology and find innovative solutions for challenges faced by the industry. In specific terms, UNENE has three distinct objectives:

- Enhance the supply of highly qualified graduates in nuclear engineering and technology;
- Reinvigorate university based research and development in nuclear engineering and technology, focusing primarily on mid to longer term research;
- Create a group of respected, university-based, nuclear experts for public and industry consultation.

V–6.2. UNENE member organizations

(a) Industrial partners:
- Atomic Energy of Canada Limited (http://www.aecl.ca);
- Bruce Power (http://www.brucepower.com);
- Ontario Power Generation (http://www.opg.com);
- Cameco Corporation (http://www.cameco.com);
- Canadian Nuclear Safety Commission (http://www.nuclearsafety.gc.ca);
- CANDU Owners’ Group (http://www.candu.org);
- AMEC-NSS (Nuclear Safety Solutions) (http://www.amecnss.com).

(b) University partners:
- McMaster University (http://www.mcmaster.ca);
- Queen's University (http://www.queensu.ca);
- University of Ontario Institute of Technology (http://www.uoit.ca);
- University of Toronto (http://www.utoronto.ca);
- University of Waterloo (http://www.uwaterloo.ca);
- University of Western Ontario (http://www.uwo.ca);
- École Polytechnique de Montréal (http://www.polymtl.ca);
- University of New Brunswick (http://www.unb.ca);
- Royal Military College (http://www.rmc.ca);
- University of Guelph (http://www.uoguelph.ca);
- University of Saskatchewan (http://www.usask.ca).

V–6.3. UNENE educational programmes

UNENE educational programmes consist of courses for professional development on the one hand and full-time studies/research on the other hand. For professional development, there is a Master’s of Engineering Degree in Nuclear Engineering which is accredited by the Ontario Council of Graduate Studies (OCGS). This is a course based Master’s of Engineering in Nuclear Engineering, offered by McMaster University, University of Waterloo, University of Western Ontario and Queen’s University. University of Toronto will join in the near future. Ten to twelve graduates are expected every year. This programme is designed to provide practicing engineers with enhanced knowledge, tools, and technology, as well as business and management skills necessary to keep them at the forefront of their profession. Uniquely it is offered outside working hours, in order to accommodate people who work in the nuclear industry.

- Through UNENE, the student can take a variety of courses in areas that are fundamental to nuclear power plant design, operation and safety, as well as to the technologies of many industries which use nuclear techniques. The programme provides an overview of the fundamentals in many nuclear areas;
- In order to take any of the UNENE courses the student must be registered as a graduate student at one of the UNENE universities;
- A graduate student registered in a UNENE university is eligible to take all the courses in the UNENE programme and be credited for them at the university where the student is registered;
- The requirement for a Master's of Engineering Degree is ten UNENE courses or eight such courses plus an industrial project;
- Course costs are normally covered by the student's employer, as long as the student has passed the course.

UNENE courses are listed below:

- Nuclear reactor physics;
- Nuclear plant systems and operations;
- Reactor thermal hydraulics;
- Nuclear reactor safety design;
- Project management for nuclear engineering;
- Nuclear materials;
- Radiation health risks and benefits;
- Power plant thermodynamics;
- Engineering risk and reliability;
- Control, instrumentation and electrical systems in CANDU nuclear power plants;
- Reactor chemistry and corrosion;
- Fuel management;
- Nuclear fuel waste management;
- Industrial research project.

Details of course expectations can be found under the web link http://www.unene.ca/courses/coursedescriptions.htm

The student will be granted a Master's in Engineering Degree from the University where he/she is registered upon the completion of ten term courses or eight term courses and an industrial project (equivalent to two term courses) within a five-year period, with a minimum passing grade of B or 70% for each course/project.

Eligibility — applicants must hold an honours baccalaureate (four years) degree in the fields of engineering, science or mathematics, with an acceptable grade point average, set by the university where admission is sought, for entry into a Master's Degree programme in Engineering Physics (B or 75% minimum).

V–6.4. Enrolment in UNENE courses

The total number of students, past and present, in the UNENE Master's of Engineering Programme is now 96.

Of the 96, 31 have graduated from the programme, and 48 are currently active in it. See Figure V–2 below.

The new enrolment in the programme is growing, and this is expected to continue unabated.

Distance learning is being planned and is expected to bring in even more students from remote nuclear sites interested in registering in the programme.

V–6.5. UNENE research programme

UNENE also enhances research and training of highly qualified personnel in CANDU technology by establishing Industrial Research Chairs (IRC) in Ontario universities and funding research at other Canadian

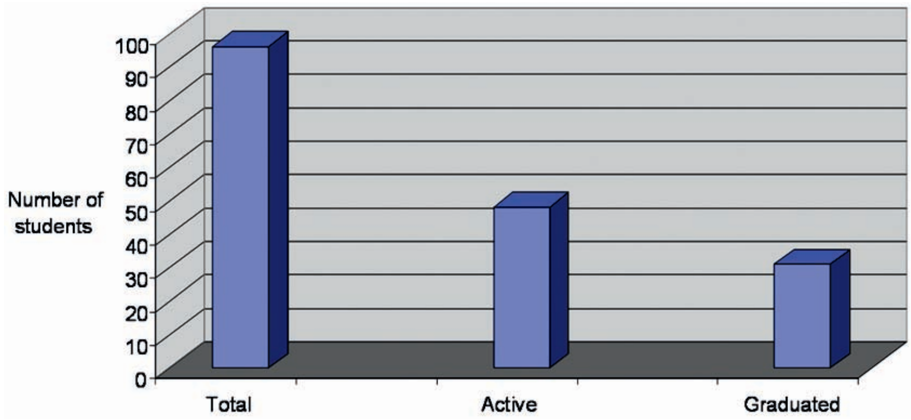


FIG. V–2. UNENE enrolment.

universities. These research funds are complemented by matching funds provided by the National Science and Engineering Research Council of Canada (NSERC).

Since the creation of UNENE, seven IRCs, listed below, have been established. The chairs were/are funded for five years in a first UNENE phase, and several of them are now being renewed for a second five-year term. In addition, several Collaborative Research and Development (CRD) projects have been awarded to other researchers at Canadian universities.

The established IRCs and ongoing CRD projects allow the purchase of research equipment, the support of students, and the hiring of new faculty. UNENE facilitates research on a large number of industry issues, and many researchers have been and are being trained in specialized fields of CANDU technology to help replenish the eroding CANDU expertise in the industry.

The currently established UNENE/NSERC IRCs cover the critical areas of CANDU technology described below:

- — Nuclear materials (R. Holt and M. Daymond, Queen’s University): this chair programme focuses its research on CANDU fuel channels (FC), basic mechanisms of pressure tube (PT) deformation and the effects of manufacturing variables, microstructure, and irradiation. The other focus of the Queen’s chair programme is the understanding of hydrogen effects on PT integrity and the behaviour of hydrides in zirconium to support research in delayed hydride cracking and fracture;
- — Nuclear safety (J. Luxat and D. Novog, McMaster University): this chair programme focuses on nuclear safety analysis methodology, primarily on ‘best estimate’ models of physical processes, plant conditions and failure events. The programme objective is to define the ranges of key plant parameters that ensure safety limits are met at a prescribed confidence level;
- — Nuclear fuel (B. Lewis, Royal Military College of Canada): the purpose of the Chair is to provide a better understanding of nuclear fuel chemistry, behaviour and performance in order to improve operating margins and safety in nuclear reactors;
- — Nano-engineering of alloys (R. Newman, University of Toronto): the primary focus of research in this chair programme is corrosion and protection of metals used in CANDU NPPs;
- — NPP Instrumentation and Control (J. Jiang, University of Western Ontario): the objectives of this chair are to:
  - • investigate new control concepts and systems in refurbishing the existing plants;
  - • develop new techniques to increase the reliability of neutron flux detectors;
  - • develop new techniques to relate probabilistic-based risk-analysis techniques to plant maintenance and outage planning.
- — Risk based life cycle management (M. Pandey, University of Waterloo): the primary objective of this chair is to advance the life cycle management of critical components of CANDU reactors, namely, fuel channels, steam generators and feeder pipes;

— Health physics and environmental safety (A. Waker and E. Waller, University of Ontario Institute of Technology): the primary objective of this chair is to perform research on characterization of radiation sources, techniques to minimize radiation fields, the development of specialized radiation detection devices, and the monitoring and modelling of the environmental impact of ionizing radiation.

V–6.6. Research based UNENE graduates

As mentioned earlier, the research performed by the Industrial Research Chairs and also within the Collaborative Research and Development projects is not performed by Professors alone. Graduate students participate in the research and thereby become highly qualified personnel in the nuclear field.

The level of research being performed suggests that approximately 90 master's and 30 doctoral students will be participating in the short term, along with 15 Post-Doctoral researchers. Currently, there are 16 master's, 10 doctoral, and 10 post-doctoral candidates registered in the research programmes.

V–7. OTHER UNIVERSITY RESEARCH CHAIRS

In addition to the above UNENE IRCs, there are also other University Chairs established outside UNENE. For example:

— NSERC, New Brunswick Power and Atomic Energy of Canada Ltd established the Chair in Nuclear Engineering in the Department of Chemical Engineering of University of New Brunswick. Since 1984 the Chair has taken a leading role in the training of personnel and the development of nuclear technology (www.unb.ca/che/Research/Research.html);

— Hydro-Québec has established the Industrial Chair in Nuclear Engineering affiliated to the Mechanical Engineering Department of École Polytechnique de Montréal. It supports a Nuclear Analysis Group (NAG) which is specialized in neutron transport, including the development of new numerical methods in transport theory and diffusion theory (www.polymtl.ca/recherche/rc/en/unites/details.php?Langue=A&NoUnite=29).

V–8. OTHER NATIONAL AND INTERNATIONAL LINKS

Canadian nuclear companies and Canadian universities enjoy many links to similar organizations and educational institutions worldwide: too many to list.

The Canadian Nuclear Association (CNA, http://www.cna.ca) is the trade association representing the interests of companies active in the Canadian nuclear industry. The CANDU Owners' Group (COG, http://www.candu.org) is a partnership of AECL and Canadian and offshore owners of CANDU reactors; it manages research projects for its members.

The Canadian Nuclear Society (CNS, http://www.cns-snc.ca) is the Canadian technical and learned society for individuals interested in the nuclear industry. It is dedicated to the exchange of information in the field of applied nuclear science and technology, and it organizes national and international nuclear conferences. In order to help broaden the knowledge of the working professional, the CNS also organizes continuing-education (non-university accredited) courses on CANDU reactor safety, CANDU fuel, CANDU plant configuration, CANDU chemistry, Eddy currents, regional overpower protection, etc. The CNS also has collaboration agreements with a large number of sister nuclear societies worldwide.

CANTEACH and NUCENG are other elements contributing to nuclear education in Canada. The CANTEACH site (http://canteach.candu.org) provides educational and training material, useful to nuclear professionals and students alike. It currently contains over 1500 CANDU-related technical documents. The Canadian regulator, the Canadian Nuclear Safety Commission, has kindly donated much of its training material for CANTEACH to use. NUCENG (http://www.nuceng.ca) is a site for students and others interested in nuclear engineering as it relates to the programme in the Department of Engineering Physics, McMaster University.

UNENE serves as an additional link to organizations in the national and international nuclear field. UNENE actively participates in WNU affairs. The role of UNENE in WNU is significant, as its officers and members serve on the WNU Academic Council Resource Committee and provide chair and membership of several working groups of WNU. In 2005–2006, UNENE hosted visits from representatives of the Asian Network of Education in Nuclear Technology (ANENT) and the Nuclear Technology Education Consortium (NTEC) of the UK. Mutual web links have been created and collaborative discussions continue. UNENE participated in a UK-Canada nuclear workshop and UNENE is leading the Canadian half of the working group established at that workshop. The WNU's very successful 2008 Summer Institute was held in Ottawa, Canada.

Annex VI

FRANCE

VI–1. BACKGROUND

France derives about 78% of its electricity from nuclear energy, generated by 58 highly standardized pressurized water reactors at 19 sites. The operation of these reactors has provided extensive feedback on safety, cost effectiveness, proficiency, and public outreach.

In producing nuclear energy, France has always relied on a closed fuel cycle approach, including reprocessing of the spent nuclear fuel. This approach is considered essential in optimizing the use of uranium resources and managing the ultimate waste products efficiently and selectively.

Recent years have confirmed the central role that, with additional renewable energy technologies, safe and sustainable nuclear energy should play in the French electricity supply. France pursues the development of fourth generation fast neutron reactors and investigates innovative methods for the separation and transmutation of high level, long lived nuclear waste. Scientific and engineering research for a safe and appropriate geological disposal of radioactive waste products is ongoing.

A new 1650 MW(e) European pressurized reactor (EPR) is under construction by EDF at Flamanville in Normandy. In 2009, the French government strengthened its commitment to pressurized water reactor technology by announcing its intention to let a second EPR unit be constructed at Penly, near Dieppe.

Drawing on France's experience in the nuclear energy domain, the French government decided to set up the France International Nuclear Agency (AFNI) in order to offer support to all countries interested in developing nuclear energy for civilian purposes within the context of intergovernmental cooperation. The main mission of AFNI is to help foreign governments prepare the institutional, human and technical conditions required for setting up a civilian nuclear programme that meets the requirements relating to safety, security, non-proliferation and environmental protection for present and future generations (Fig. VI–1).

VI–2. NEW CHALLENGES AND CURRENT CAPACITIES OF NUCLEAR EDUCATION

VI–2.1. National and international needs

To ensure a continuous and safe use of nuclear power in France, the country faces numerous challenges. These include: operation and maintenance of its existing nuclear fleet, waste management, dismantling and

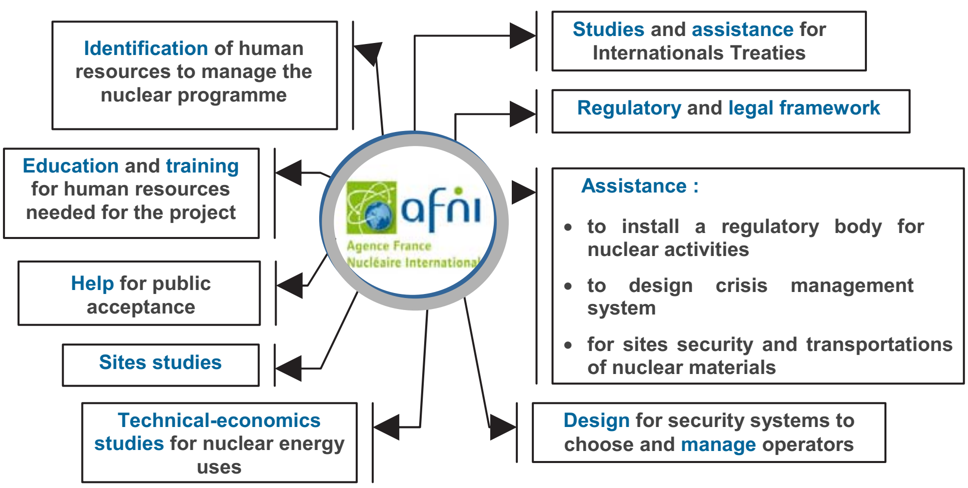


FIG. VI–1. The AFNI — A French initiative to support countries interested in developing nuclear energy for peaceful purposes.

decommissioning of obsolete reactors, and research and development for future nuclear systems. All of these efforts must be conducted in conformity with the best international practices.

Therefore, the human resource of the French nuclear industry must continually update its approaches and skills, taking into account both domestic and worldwide nuclear power developments. This calls for the hiring and the training of thousands of scientists and engineers each year in France and in its partner or customer countries.

Over the next ten years, domestic and international nuclear power activities in France will call for the recruitment of about 13 000 engineers with Master of Science or PhD degrees, and 10 000 science technicians and operators with Bachelor of Science degrees. The main employers will be EDF, AREVA, GDF-Suez, national agencies such as the *Agence nationale pour la gestion des déchets radioactifs* (ANDRA), sub-contractors, and R&D agencies such as the *Commissariat à l'Energie Atomique et aux Energies Alternatives* (CEA), and the technical safety organization, *Institut de Radioprotection et de Sûreté Nucléaire* (IRSN).

At the international level, France wants to address the present need for competence building in nuclear energy production by offering training opportunities in both French and English education programmes.

In particular, France has pledged to support countries that feel ready to start developing a domestic nuclear programme. The efforts are conducted mostly through the France International Nuclear Agency. For countries which adopt a bilateral cooperation scheme, partnerships created by French nuclear energy participants and by AFNI provide dedicated programmes, adjusted to the demand. These include assistance in building specific academic capacities, with industrial support, in partner countries.

VI–2.2. Present capacities of nuclear education in France

Before 2006, the number of graduated students at Engineer/Master levels did not exceed about 300 per year. Therefore the French government launched an initiative aiming at substantially increasing nuclear training in order to satisfy the needs anticipated by the nuclear industry. A close cooperation of representatives of the nuclear industry, the French academic system and governmental authorities led to setting up new curricula (see paragraph VI–3.3). At the end of 2009, various curricula contributed about 900 graduated students at Engineer/Master level in nuclear engineering or closely related training and a potential of about 1300 enrolments.

In addition to the efforts to increase the number of Engineer/Master graduates, similar actions have been devoted to prepare highly skilled technicians for the nuclear industry. The objective is training about 450 technicians per year. France presently encourages well motivated graduate students to pursue a PhD in nuclear energy science since it also provides career opportunities both in industry and research. Typically 100 students defend a thesis in this domain every year. It is worth noting that within an established tradition of French nuclear industry, comprising a small number of partly public corporations, most of the employees in these major companies are also trained 'on the job' through internal processes.

VI–3. EDUCATIONAL INSTITUTIONS INVOLVED IN NUCLEAR EDUCATION

VI–3.1. French educational system

In France, engineers are usually trained in special schools rather than at universities, unlike many countries. In that respect, the French high educational system is specific. Currently, around 25 000 students graduate at the Master Level per year from French engineering schools. The engineering graduates from universities need to be added to this figure, but they remain a small fraction.

The French educational system is highly centralized, organized, and ramified. It is divided into three different stages:

- Primary education (*Enseignement primaire*), which is predominantly public;
- Secondary education (*Enseignement secondaire*) leads to the *Baccalauréat*. The *Baccalauréat* is the diploma students sit for in order to enter university, a *Classe préparatoire*, or professional life. It is generally taken at 18. It is comparable to English A-Levels or American SATs or ACTs;

— Higher education (*Enseignement supérieur*), which is divided into two co-existing forms of institutions: Universities for all domains of education and specialized schools such as Engineering Schools (see Fig. VI–2).

It is not uncommon for graduate teaching programmes (master's degrees, the course part of PhD programmes etc.) to be operated in common by several institutions, allowing the institutions to present a larger variety of courses.

(a) Universities:
France's 83 public universities are spread throughout the country, from the Sorbonne in Paris (founded in 1179) to the new high-tech campus of Nice-Sophia-Antipolis, and cover the entire range of academic disciplines. Enrolment is open to any student holding a French *baccalauréat* or its foreign equivalent.
Following the 'declaration of Bologna', European countries have progressively adapted their university education schemes to the Bologna recommendations. Studies are subdivided into three major cycles, as follows:
— Licence lasting three years and leading to a Bachelor;
— Master requiring an additional two-year educational period;
— Doctorate lasting about 3–4 years and leading to a PhD.

(b) Engineering schools:

To enter an engineering school (*Ecole d'ingénieurs*), students have to accomplish two years of *Classes préparatoires* (though other pathways exist through university education programmes) and to pass a nationwide selective examination named the *Concours*. France has 224 engineering schools. Their programmes are so well attuned to the needs of industry that their graduates are in very high demand.
The study programmes usually last for three years. Most of the graduates directly go to the industry as engineers, but some of them continue in PhD programmes, as most of the engineering schools grant a master's degree.

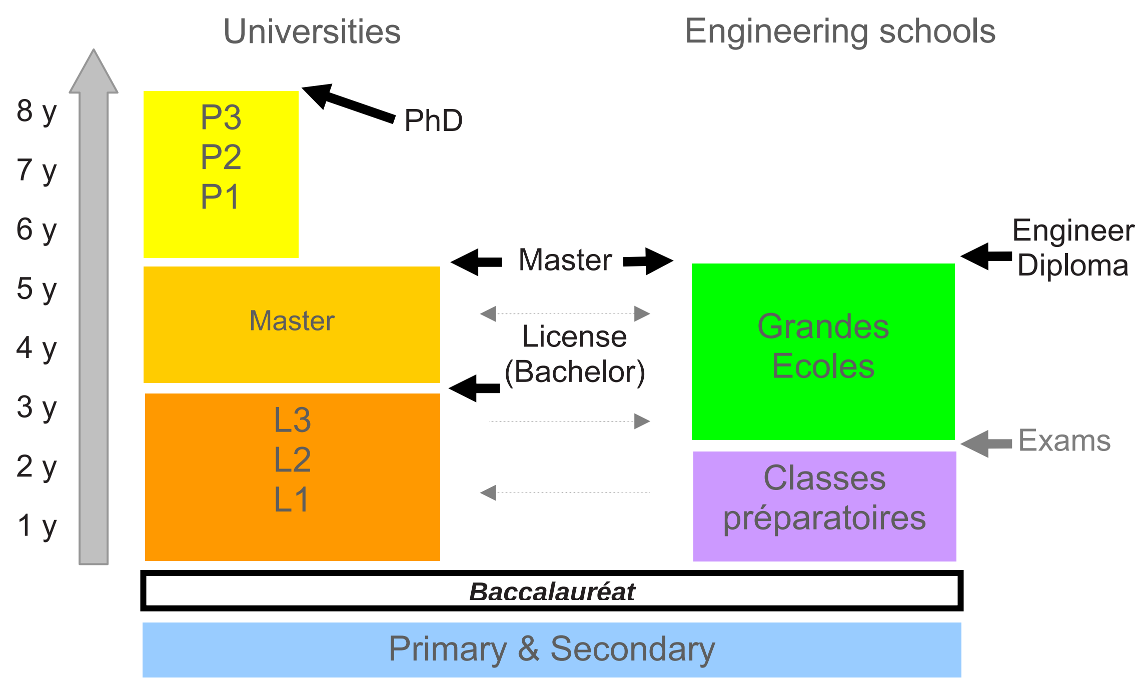


FIG. VI–2. Higher education system in France.

The most prestigious engineering schools fall into what is called *Grandes écoles. Grandes écoles* are unique institutions, prestigious and very selective. They are devoted to training high level managers in industry, business, public administration, etc.

VI–3.2. Institut International de l'Energie Nucléaire (I2EN)

Mandated by the French Government, the High Commissioner for Atomic Energy conducted a study of the needs in high level nuclear education as expressed by future employers to be compared with the education offered by the French universities and *Grandes Ecoles*. The High Commissioner report, released in February 2008, clearly indicated that the number of newly graduated engineers in the nuclear domain could not match the expected industrial demand. It was recommended that all universities and engineering schools with experience and competencies in nuclear related fields efficiently coordinate their efforts to significantly extend the education offered to a level which could satisfy future recruitment needs.

Consequently, in October 2008, the Minister for Research and High Education set-up the *Conseil des Formations en Energie Nucléaire* (CFEN, council for education and training in nuclear energy). The CFEN takes into account the present context of expansion of the French nuclear industry, the need for renewing its ageing staff and the opening of new activities and export markets. It is chaired by the High Commissioner for Atomic Energy. It comprises members representing universities and engineering schools having strong nuclear programmes, governmental authorities in education, research, industry and foreign affairs, the main industrials actors (AREVA, EDF, GDF-SUEZ, sub-contractors), and the main nuclear R&D public institutions (CEA, IRSN, ANDRA).

Following the announcement by the President of the French Republic at the opening the International Conference on Access to Civil Nuclear Energy, held in Paris on 8 March 2010, it was also decided to create the Institut International de l'Energie Nucléaire (I2EN). The composition of the governing board of I2EN is similar to that of CFEN with which it closely works. In particular, I2EN has set-up an operational structure in support of CFEN. The tasks entrusted to I2EN are:

- Assessing the adequacy between the education offered, the population of students in different curricula and the industrial and research needs;
- Assessing new curricula and providing expertise to CFEN to certify the quality of these curricula. In this respect, it acts as adviser to the Office of High Education for the opening of all submitted education offers in the nuclear domain aimed at delivering a national diploma;
- Encouraging and supporting the creation of international curricula such as the new International Master of Science in Nuclear Energy which started in 2009 (see paragraph VI–3.3.3);
- Providing students with a clear presentation of various educational trainings and degrees associated to possible professional careers in the nuclear field;
- Promoting systems of grants or scholarships funded by industry and government for the ablest students;
- Coordinating the international recruitment of students. I2EN is the point of contact for AFNI;
- Coordinating bids of pedagogical engineering in response to requests from foreign partners.

The Institut International de l'Energie Nucléaire (I2EN), which is located on the Saclay Campus, shares a building with INSTN and dispenses the well known *Génie Atomique* course, and with the new International master taught in English, MNE. It coordinates a network of science and technology curricula certified by CFEN. In the future I2EN will host a centre of excellence of sustainable nuclear energy.

VI–3.3. Initial education

VI–3.3.1 General overview — A broad offer

Presently, about 20 engineering schools and universities offer nuclear related curricula at a master level. These schools and universities are spread all over the country. This broad availability of competences led the government authorities to encourage them to build a national network.

The most famous curricula in nuclear training are undoubtedly to be found at the Institut National des Sciences et Techniques Nucléaires (INSTN, http://www-instn.cea.fr, see Paragraphs VI–3.3.2 and VI–3.4.1).

In the Paris area some prestigious engineering schools include specific nuclear training in their curricula, as, for example Ecole Polytechnique (http://www.polytechnique.fr/), ENSTA (Ecole Nationale Supérieure des Techniques avancées, http://www.ensta.fr/), ECP (Ecole Centrale de Paris, http://www.ecp.fr/), Ecole des Mines de Paris (http://www.mines-paristech.fr/, ENSCP (Ecole Nationale Supérieure de Chimie de Paris, http://www.enscp.fr/). Parisian engineering schools associated within the Paris Tech consortium (http://www.paristech.org/), ECP, Supélec (Ecole Supérieure d'électricité, http://www.supelec.fr/) have coordinated theirs efforts with the University of Paris at Orsay (Paris XI, http://www.u-psud.fr) and INSTN to build up a large Master in Nuclear Energy (see paragraph VI–3.3.3). The Université Pierre et Marie Curie in Paris (http://www.upmc.fr) has also opened new curricula in nuclear engineering.

In the west of France, the leading academic institutions in nuclear training are ENSICAEN (http://www.ensicaen.fr/), a national engineering school located in Caen, and Ecole des Mines de Nantes (http://www.mines-nantes.fr/), in cooperation with the local universities.

In the south-east, Grenoble has a long tradition of nuclear education. At Institut National Polytechnique (INP, http://www.grenoble-inp.fr/), PHELMA (http://phelma.grenoble-inp.fr) and ENSE3 (http://ense3.grenoble-inp.fr) provide engineering education in energetics and nuclear. In association with INP, Université Joseph Fourier (UJF, http://www.ujf-grenoble.fr) offers curricula at Master level in nuclear reactor physics. UJF also has a well established curriculum in waste management and decommissioning. PHELMA offers also an international Master of Science 'Materials for nuclear engineering' (http://phelma.grenoble-inp.fr/master-manuen). This curriculum with courses all taught in English, has been designed in close collaboration with EDF and CEA research institutes (see paragraph VI–3.3.3).

In the south of France, ENSCM (Ecole Nationale Supérieure de Chimie de Montpellier, http://www.enscm.fr/) together with the University of Montpellier II have set-up a Master curriculum in the field of chemistry for energetic and nuclear fuel cycle. The Ecole des Mines d'Alès has also a speciality in nuclear (cycle front end, safety, environment).

The Ecole des Mines de Saint Etienne, with INSTN, now offers a programme on nuclear plants engineering. ENSCI, an engineering school in Limoges who has a long reputation in ceramics and material science, has recently focused some of the courses on nuclear materials. Bordeaux university is also involved in instrumentation for nuclear (energy and health).

Other schools and universities (Aix-Marseille, Lyon, etc.) are presently building up some nuclear oriented curricula; their offers will soon be available.

VI–3.3.2 A diploma in Génie atomique'

As to specific initial nuclear training available at INSTN, the over 50 year old *Génie Atomique* curriculum has trained a large fraction of the leading French nuclear practitioners. This curriculum is open to students in engineering schools. It provides an extra diploma which certifies their qualification in nuclear engineering, operation of reactors, safety management, decommissioning, and waste management. Today the *Génie Atomique* curriculum welcomes 100 graduates yearly. Note however that courses are given in French.

One year's course curriculum is based on fundamental courses such as nuclear physics, neutronics, thermal hydraulics and nuclear materials. They are followed by applied courses in nuclear instrumentation, structural mechanics, fuel cycle, radiation protection, nuclear safety, decommissioning, and waste management. An important module is devoted to the study of the 'operation and safety of pressurized water reactors (PWR)' and to other nuclear reactors systems. The programme enables students to realize laboratory sessions on INSTN facilities such as ISIS training reactor, SIREP and SIPACT PWR Simulators and different CEA codes such as APOLLO, TRIPOLI, FLICA and CATHARE. The *Génie Atomique* professors are researchers from CEA and confirmed engineers from the industry or TSO, for the safety courses.

Following these 'theoretical courses' students prepare a master thesis project in research laboratories or industry in France or abroad (Europe, USA, Japan) during a minimum period of five months. A report is drafted and defended in front of a selected jury.

Foreign students are also admitted according to the same selection procedures following this course. Courses are organized in modules according to the recommendations of the European Nuclear Education Network Association (ENEN) with the objective of facilitating the mobility of students across Europe 27 and according to the mutual recognition agreements established in the framework of this network between its academic members. In spite of the fact that the courses are given in French, the *Génie Atomique* course is hosting around 30% of its students from foreign countries coming from China, Vietnam, Malaysia, Tunisia, Belgium, Spain, the Russian Federation and Cameroon.

VI–3.3.3 International Masters in Nuclear Energy

Some Masters of Science in Nuclear energy have their courses delivered entirely in English and thus are open to non French speaking students.

(1) The Master of Science in Nuclear Energy (MNE), Paris: http://www.master-nuclear-energy.fr.
In the Paris area, a consortium of engineering schools (Paris Institute of Technology and Ecole Centrale de Paris-Supélec), in conjunction with the University of Paris at Orsay (Paris Sud 11) and the National Institute for Nuclear Science and Technology (INSTN), has created an international two-year masters level programme in nuclear energy. The curriculum covers all aspects of nuclear energy activities and opens numerous opportunities for employment in the nuclear energy industry or in R&D agencies.
The first year of the programme (M1) is devoted to basic courses: nuclear physics and neutronics, materials science, process engineering and chemistry of reactive media, electrical engineering, fluid mechanics and heat transfer, economics of energy, and project management.
The second year (M2) includes five majors: Nuclear engineering, nuclear plant design, operations, fuel cycle (engineering or radiochemistry), and decommissioning and waste management (see Fig. VI–3).
The experimental sessions and training are carried out with EDF simulators. Instructional visits to nuclear sites and a master's thesis (20 weeks) complement the courses.
All course instruction is in English with the exception of a compulsory course in French language and culture.
The programme aims to train about 200 students per year, with a majority of foreign students. Admission is open to high potential international students with a bachelor's degree. Direct admission into the second year of the programme is possible for qualified students.
This state of the art programme receives the support of industrial enterprises (EDF, AREVA, GDF-SUEZ), and has secured a strong commitment from the European Foundation for Tomorrow's Energies, which EDF created and placed under the aegis of the Institute of France.

(2) International Master Degree in Materials for Nuclear Engineering (http://phelma.grenoble-inp.fr/master-manuen).
The *Institut National Polytechnique* of Grenoble (Grenoble-INP) offers a Master in Materials for Nuclear Engineering, in close cooperation with EDF and CEA, with a degree suitable for both industry and R&D. This M2 course is open to French and foreign students or professionals after physics or chemistry M1 level or

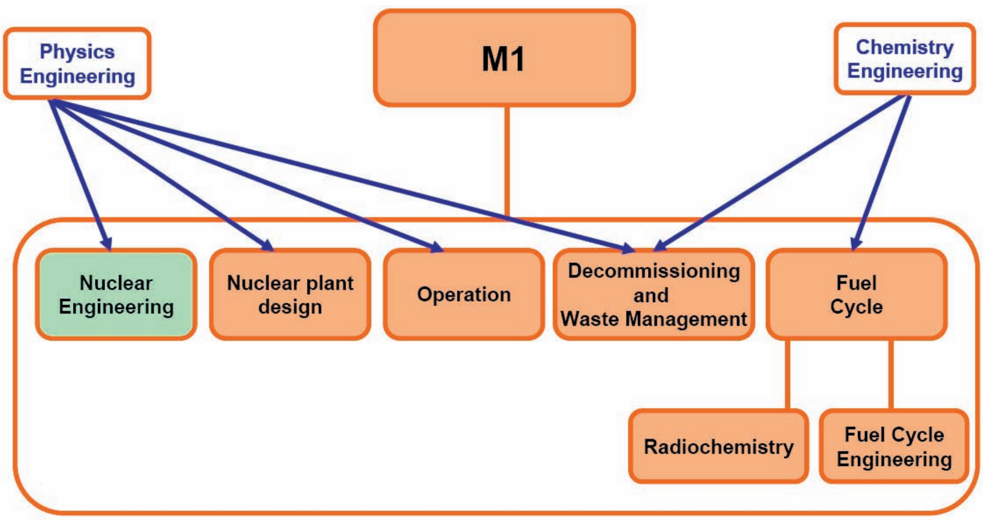


FIG. VI–3. Majors of the Master of Science in Nuclear Energy (MNE).

equivalent, and for engineers in the context of professional training. M1 level education in Materials Science is also available at Grenoble-INP.

This 300-hour course deals with the metallurgical and physic-chemical aspects of the under irradiation ageing of nuclear fuel and materials for reactors and components. A set of common lectures (200 h) provides the basics to understand the behaviour of materials in a nuclear environment. The optional ‘structure materials’ course is given by EDF engineers whereas the optional ‘nuclear fuel materials’ is given by CEA engineers. This gives the opportunity for students to interact on-site with researchers and engineers. The organization of the master is in modules so that some of the units can be taken separately as an intensive course in a short period. Some master courses are also proposed as advanced materials science lectures for doctoral studies.

VI–3.4. Continuing education

VI–3.4.1 National Institute for Nuclear Science and Technology (INSTN)

In 1956, the CEA created the National Institute for Nuclear Science and Technology (INSTN, http://www-instn.cea.fr/Page-Home.html) to provide technicians, engineers and researchers with highly specialized courses in nuclear science and technology, including graduate level curricula. INSTN’s mission is to disseminate CEA’s knowledge and know-how. It is in charge of:

- National and European academic courses, for students, engineers and technicians, nuclear physicians, radiopharmacists and medical physicists;
- Vocational training sessions for professionals and PhD students;
- Professional training for professionals from CEA and the nuclear industry;
- Training through research which the institute coordinates; it also offers assistance and guidance to PhD students and post-doctoral researchers working in CEA’s laboratories.

Today the INSTN offers a selection of nearly 210 continuing education sessions from its catalogue or on demand, including training for engineers and PhD students in English, such as physics and basic operation of light water reactors, decommissioning and waste management, fast neutron reactors, nuclear materials, etc. The doctoral training programme International School in Nuclear Engineering, designed for PhD students is also open to nuclear-engineering researchers and consists of nine one-week independent courses.

VI–3.4.2 French Institute for Radiological Protection and Nuclear Safety (IRSN)

The French Institute for Radiological Protection and Nuclear Safety (IRSN, http://www.irsn.fr/EN/Pages/home.aspx) is the nation’s public institute expert in nuclear and radiation risks, providing assessments and conducting research to meet the needs of public authorities and other players in the nuclear field. IRSN employs over 1700 people, including more than 1000 specialists, engineers, researchers, physicians, agricultural engineers, veterinarians and technicians, representing a unique body of experts in nuclear safety, radiation protection, nuclear security and control of sensitive nuclear materials.

The scope of IRSN’s research and public service missions covers, among others:

- Contributing to education and training;
  As an institute specialized in research and expertise, IRSN naturally contributes to initial education and to professional training in the fields of radiation protection nuclear safety and nuclear security, at the national and international levels. It organizes inter alias training courses directed at professionals working in the health sector and workers exposed to occupational hazards.
- Defining and implementing national and international research programmes.
  IRSN defines and conducts research programmes aimed at maintaining and developing the skills necessary for expert assessments in its specializations. It either carries out the programmes itself or, in a European or international context, may entrust them to other French or foreign research institutes. All IRSN major research programmes are carried out in the framework of international cooperation.

The French Institute for Radiological Protection and Nuclear Safety contributes to the initial training in radiological protection (http://formations.irsn.org/index_en.htm) as part of a partnership with the French National Education, the French National Institute for Nuclear Science and Technology (INSTN), engineering schools and administrations (National Institute of studies of the Civil Security). The trainings involved are qualifier trainings recognized nation-wide and usually of advanced standing.

The IRSN's workforce dedicated to training is constituted by a professorial team composed of almost one hundred teachers.

VI–3.4.3 Industry involvement in continuing nuclear education

Along with educational institutions, the industry has been committed to developing continuing training and education in the nuclear domain. For example EDF developed a strong internal organization to train its personnel, notably the operators for whom it is required to have both initial qualification training and periodic training.

VI–4. INITIATIVES FROM INDUSTRIAL COMPANIES

VI–4.1. The AREVA University

The AREVA University (areva-training@areva.com) is devoted to train engineers, executives and managers of the group or from partners companies or institutions. Its purpose is to maintain and develop skills and anticipate new requirements.

The programmes are based on varied plans, both technical or scientific and managerial, the latter being grouped together into six families:

- Personal development and management:
  - General management cycles: Leadership development;
  - Management modules: Optimize individual management careers;
  - Professions: Contribute to AREVA's excellence;
  - Continuous progress: Support change;
  - AREVA conferences: Understand new developments around the world.
- Technical and scientific training:
  - AREVA has developed a series of training modules encompassing all the scientific matters relevant for nuclear energy;
  - These modules are organized in training pattern to lead a new engineer to scientific excellence and possibly expertise;
  - Not directly technical, training modules are also offered on project management and safety.

Besides the AREVA University Campus in Germany (Offenbach and Erlangen) and in the USA (Lynchburg), a new AREVA University campus, opened in January 2009 in Aix-en-Provence. To date, more than 700 trainees of ten different nationalities have visited the AREVA University Campus of Aix-en-Provence.

A new introduction course on reactor technology, the underlying science knowledge and safety has been developed for all engineers having to deal with reactor engineering, construction or service and maintenance. Up to now more than 500 engineers benefitted from this course.

The AREVA University has also developed an initial training thought for all the engineers and executives recruited by the group worldwide. Two to three thousand people per year will be enjoying the benefits of an eleven-day professional proficiency course. In-depth classes on AREVA core skills and its fundamental values, where safety and security head the list, will be given.

AREVA is in collaboration with many universities worldwide for R&D programme and training and education activities. AREVA is involved in the creation of the newly created master for nuclear energy in Paris as well as in the European Nuclear Energy Leadership Academy. The AREVA University also has a network of correspondents and collaboration in Germany (TUM, KIT), North America (MIT, Stanford, Harvard…), South Africa (NWU), Latin America, China and India.

In 2008, AREVA and the Paris University la Sorbonne launched a master's degree in project management.Twenty young executives sent from South African organizations attended. Similar cooperation may be contemplated in other countries willing to develop their management capabilities in the energy field.

VI–4.2. EDF

VI–4.2.1 EDF Internal vocational education and training organization

Since the beginning of its nuclear programmes, EDF has developed a strong internal organization to train its personnel, notably the operators for whom it is required to have both initial qualification training and periodic training.

The detailed organization changed over time to adapt to the evolution of the needs both in terms of content and volume.

The organization was recently updated and now offers:

— An Academy for Operations, for all newcomers to the Nuclear Generation Division and also for part of the Engineering Division;
— An Academy for Engineering, for all the newcomers to the Engineering Division. The content of the education and training is adapted according to the initial academic education;
— Nuclear education and training courses for people in charge of operations (operators, safety engineers, etc.). This training includes initial education and training to get job qualifications as well as periodic training, mandatory for this type of job;
— Specific and specialized courses in a variety of domains, to train and accompany personnel during their professional career.

The organization offers about 1.5 million hours of training per year globally, with over 650 different courses in Process, Operation or Maintenance, supported by a staff of about 700 persons including teachers.

VI–4.2.2 European foundation for tomorrow's energies (http://www.energiesdedemain.com/?lg=gb)

For the past two or three years, EDF has significantly increased the number of recruitments in the nuclear domain, both for graduates and technicians, in order to face the challenges related to retirements as well as for new projects in France and abroad requiring additional workforce.

In this context, EDF reinforced interaction with engineering schools and universities, both in France and abroad, to help strengthen existing nuclear education programmes and to create an international master well adapted to industry's needs including operations (see paragraph VI–3.3.3).

To facilitate these actions, EDF created and placed under the aegis of the Institute of France, a foundation — Fondation Européenne pour les Energies de Demain; the European foundation for tomorrow's energies — to promote the development of energy related higher education both in France and abroad.

The Foundation contributes to the development and promotion of energy training by encouraging the establishment of new partnerships and the introduction of concrete plans of action at engineering schools and universities in France and worldwide. Its commitment is in the closest possible alignment with the expectations of students and needs of industrialists.

As a partner of schools and universities, the Foundation works to support the development of the various disciplines and excellence in energy related education. Training is thus perfectly adapted to the latest requirements of the nuclear, hydraulic, solar, wind, clean coal and energy efficiency domains.

The Foundation funds teaching and research chairs**,** and strikes agreements and specific partnerships with engineering schools and universities. It enriches the pallet of available training by supporting the creation and funding of master's courses specializing in energies, as well as the enhancement and creation of optional courses in energy for third year engineering students. It also supports new talents through the arrangement of funding, grants, study trips or work placements.

VI–4.3. GDF Suez — Nuclear trainees programme

The nuclear trainees programme is a specific one year programme that mixes courses and on the job training, coached by an experienced employee of the company. This programme allows junior engineers to become nuclear generalists and build their own network inside the group.

VI–5. AVAILABILITY OF RESEARCH AND EXPERIMENTAL FACILITIES

Thanks to its proximity to CEA laboratories, INSTN benefits from specific relations between education and experimental facilities. The INSTN on its own has various facilities and laboratories with sophisticated instrumentation: the experimental reactor ISIS (power 700 kW) and associated computing tools (PWR simulators for normal operation or accidental situations, calculation codes), a 2 MeV Van de Graaff accelerator, scanning and transmission electron microscopes fitted with an energy dispersive X ray analyser, teaching laboratories for: radiobiology, chemistry, radiochemistry, metallurgy, laser, nuclear measurement, data-processing equipment, etc.

On the job training in companies is always built in tight relation with industrial facilities (AREVA, EDF, GDF-Suez).

VI–6. INTERNATIONAL COOPERATION AND EDUCATIONAL NETWORKS

Most of the French educational institutions have agreements with foreign universities to favour thriving student exchanges.

In addition, many international cooperation and educational networks have been initiated, as described hereafter.

VI–6.1. Train the trainers programme

A programme led by AFNI (Agence France Nucléaire International) to train the teachers and instructors was implemented by the major French nuclear energy stakeholders. It is devoted to the training of university faculty and scholars. It is implemented in a close working relationship with them, on the basis of an in-depth analysis of the local education system. It consists of a two-phase course that includes visits and conferences at the chief French nuclear energy sites and facilities:

(1) Phase 1: A six week nuclear Tour de France:
The nuclear introductory session consists of a French tour of nuclear energy stakeholders. The drivers are the following:
- — Acquiring fundamentals to identify needs for further in-depth training and maximizing benefit of the nuclear tour;
- — Getting extended practical vision of nuclear energy research and industrial applications;
- — Networking with key points of contact amongst French stakeholders to prepare for future development of local nuclear training;
- — To meet and exchange with French education network;
- — To learn about and exchange communication and public acceptance.

(2) Phase 2: Twelve weeks intense advanced training;
It consists of a set of basic courses in nuclear energy science and technology, complemented by practical internships at leading French institutes. The internship will provide future educators in nuclear engineering with practical experience in a specific domain: reactor physics, reactor design, fuel, safety, waste management, etc. A personal work based on a subject jointly agreed to between the candidate and the host lab, and presented as a written report is expected.

VI–6.2. European Nuclear Engineering Network (ENEN)

The European Nuclear Engineering Network project (http://www.enen-assoc.org/en/home.html) was launched under the fifth framework programme of the European Commission in January 2002. It established the basis for conserving nuclear knowledge and expertise, created a European High Education Area for nuclear disciplines, and initiated the implementation of the Bologna declaration in nuclear disciplines. The ENEN Association, located in Saclay in France, was established afterwards on the basis of the European High Education Area by the partners of the European Nuclear Engineering Network project.

The basic objectives of the ENEN Association are to:

- Harmonize European Master of Science curricula in nuclear disciplines and promote PhD studies;
- Ensure the quality of nuclear education and training;
- Promote the exchange of students and teachers participating in this network;
- Increase the number of students by providing incentives;
- Establish a framework for mutual recognition;
- Foster and strengthen the relationship between universities, research organizations, regulatory bodies, the industry and any other organizations involved in the application of nuclear science and ionizing radiation by facilitating their participation in (or associating them with) nuclear academic education and by offering continuous training.

VI–6.3. European Nuclear Safety Training and Tutoring Institute (ENSTTI)

In cooperation with other European Technical Safety Organizations (TSO), IRSN has recently created the European Nuclear Safety Training and Tutoring Institute (ENSTTI, http://www.enstti.eu/) to provide vocational training and tutoring in the methods and practices required to perform assessments in nuclear safety, nuclear security and radiation protection. ENSTTI offers short applied training sessions and longer tutoring periods for both junior and experienced professionals in the nuclear sector, thus contributing to capacity buildup and maintenance for new, developing and established nuclear programmes.

ENSTTI held its first six-week induction course to nuclear safety in 2010 for 37 participants from 14 European and non-European countries. Conducted by experts from European TSOs, it was comprised of six modules including lectures, working groups and technical visits, and covered methods used and practical knowledge in the following areas: nuclear reactor safety, analysis of incidents and severe accidents, internal and external risks, safety of the fuel cycle including waste management and transport, nuclear security, operational radiation protection, emergency preparedness, evaluation of impacts on the public and the environment.

In the future, ENSTTI will continue to offer induction and specialized training courses as well as tutoring opportunities on specific subjects.

VI–6.4. Distance learning

Developing this part is one of I2EN objectives.

Annex VII

GERMANY

VII–1. ALLIANCE FOR COMPETENCE IN NUCLEAR TECHNOLOGY

In 2000, all R&D activities in the nuclear sector were evaluated by a high-ranking commission under the direction of the Federal Ministry of Economics and Technology (BMWi). The responsible Ministries of Education and Research (BMBF) and of the Environment, Nature Conservation, and Nuclear Safety (BMU) as well as the research institutions active in nuclear R&D took part in this evaluation.

In accordance with the recommendations made by this commission, the Alliance for Competence in Nuclear Technology was founded in April 2000 with the following members: Forschungszentrum Karlsruhe, Forschungszentrum Jülich, Forschungszentrum Rossendorf, and the Gesellschaft für Anlagen- und Reaktorsicherheit. The neighboring universities that are active in the nuclear field and cooperate with the research centers are invited as permanent guests. In addition, representatives of the ministries are also present as guests. The Alliance for Competence meets every six months.

The strategic goals of the Alliance for Competence are:

- Presentation of the trends of job development and training capacities in the nuclear technology sector;
- Enhanced cooperation with universities and support of international initiatives (e.g. ENEN, WNU);
- Coordination and bundling of the activities in publicly funded nuclear safety and repository research;
- Support of qualified young scientists — also by third-party funds;
- Participation in the further development of international safety standards (EU, IAEA, OECD-NEA).

In the scope of intensifying the cooperation with universities, four ‘sub-alliances’ of the Alliance of Competence in Nuclear Engineering came into existence, mainly on a regional level:

- The *Competence Centre East* (2004), consisting of the Research Centre Dresden-Rossendorf (FZD-R), the Verein für Kernverfahrungstechnik und Analytik (Association for Nuclear Process Technology and Analysis) Rossendorf (VKTA), the Technical University (TU) of Dresden, and the University of Applied Sciences (FH) Zittau/Görlitz;
- The *Association for Research and Lecturing in Nuclear Engineering in Southwest Germany* (2007), consisting of the Forschungszentrum Karlsruhe (FZK), the European Institute for Transuranium Elements (ITU), the Materials Testing Laboratory (MPA) Stuttgart, and the Universities of Karlsruhe, Stuttgart and Heidelberg as well as the Universities of Applied Sciences in Ulm and Furtwangen;
- The *Nuclear Engineering Forum West* (2009), consisting of the Jülich Research Centre (FZJ), the RWTH Aachen University, and the Aachen/Jülich University of Applied Sciences;
- The subject-oriented Final Disposal Research Group, consisting of the Federal Institute for Geosciences and Natural Resources (BGR), the Technical University of Berlin, and the University of Clausthal-Zellerfeld;
- The interregional *Alliance of Competence in Radiation Research* (2007), consisting of the Federal Office for Radiation Protection in Salzgitter (BfS), the Centre for Radiation Protection and Radioecology (ZSR) in Hanover, the German Research Centre for Environmental Health (GSF) in Munich, the Centre for Environmental Research (UFZ) Leipzig-Halle, the German Cancer Research Centre (DKFZ) in Heidelberg, the Centre for Heavy Ion Research (GSI) in Darmstadt, and the research centres in Jülich, Dresden/Rossendorf, and Karlsruhe;

Illustrating the spectrum of the activities pursued by our Alliances by sketching the institutions and funding associations involved results in the following diagram for 2010 (see Fig. VII–1).

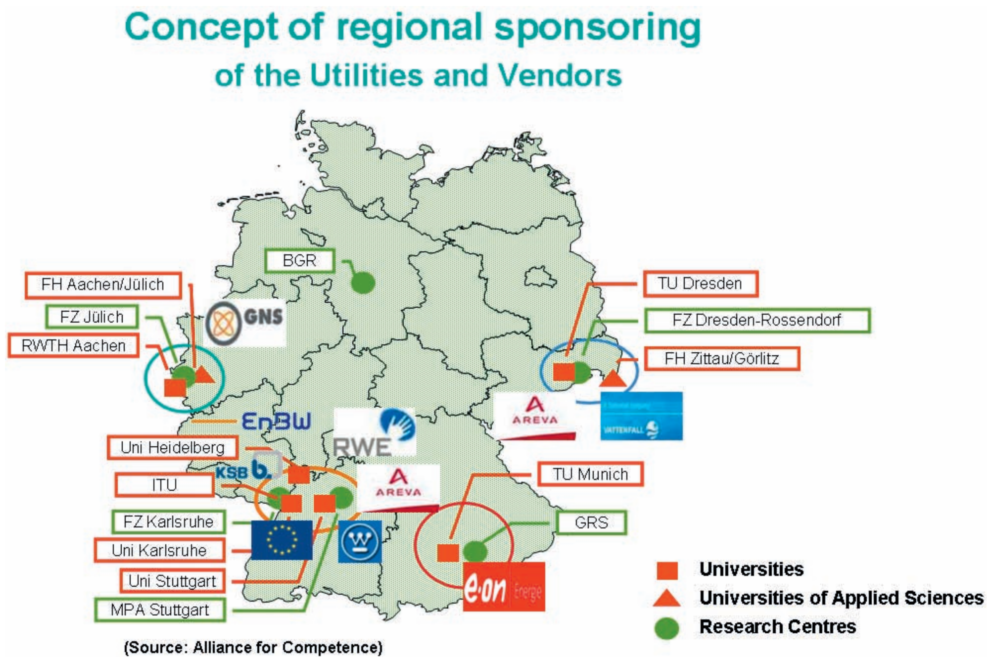


FIG. VII.–1. Alliance of Competence in Nuclear Engineering — Status 2010-03-30.

International activities were geared to two initiatives for the promotion of young nuclear scientists, in particular to the:

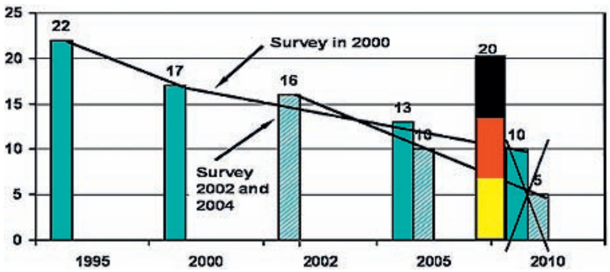
— ENEN (European Nuclear Engineering Network);
— WNU (World Nuclear University).

In both organizations, the Technical University of Munich is involved as the German representative of the Alliance of Competence. By the end of January 2010, the ENELA (European Nuclear Energy Leadership Academy) with its headquarters in Munich also joined.

VII–2. INTENSIFIED COOPERATION WITH UNIVERSITIES AND SUPPORTING INTERNATIONAL INITIATIVES

Intensified cooperation with universities was geared to both students and university teachers. Considering the number of professorships in nuclear engineering, the past six years have been a story of success: At all sites, expiring contracts were renewed and new professorships were filled and funded by the utilities, the industry and the Federal Laender, thus leading to presently 20 international professorships in nuclear engineering. And this story of success continues: In Dresden and Karlsruhe, applications for two further professorships are presently being invited, one for measurement technology and another one for the AREVA Nuclear Professional School.

Activities for students and PhD students: in close cooperation with the German Atomic Forum (DAtF) and the German Nuclear Society (KTG), interested students were invited for participation in several tutorials on Perspectives in Nuclear Energy. These provide young people the opportunity to obtain first-hand information from representatives of the nuclear energy sector on incentives and assured jobs in the nuclear field. To complete these activities, meetings with university teachers under the same leading topic took place in Bonn in January 2003, in Worms in March 2006, and in the Nuclear Power Plant Unterweser in October 2008. This initiative allowed the national research centres to further extend third-party funded research on innovative nuclear reactors, a field of great interest and scientifically challenging for students as well as for PhD students.



Note: New professorships (in reactor physics, reactor technology, reactor safety, nuclear and radio chemistry, radiation protection, decommissioning) at univesities Aachen, Clauthal-Z, Dresden, Heidelberg, Karlsruhe, Munich, Stuttgart (surveys by KYG (1994), FZK (2000, 2002 and 2008)).

FIG. VII–2. Professorships held in nuclear engineering in 2009 versus the prognoses of 2002 and 2004.

VII–3. PROMOTION OF QUALIFIED YOUNG SCIENTISTS (PhD STUDENTS)

Inspiring young people to study science and engineering requires — in addition to teaching the state of the art — offering an international perspective for innovative developments. Analogically, the same holds for PhD students. Under the auspices of the utilities and industry partnerships, the resources for R&D projects funded by third parties generously increased and could partially compensate the reduced institutional funding by the Federal Government (Berlin). By these indirect means, the centres succeeded in actively participating in the multinational cooperation ‘Generation IV International Forum (GIF)’ — although not under German colours, but under the EURATOM logo. Thus, the KIT (FZK) could for instance contribute its experiences made in the research on the safety of light water reactors to the international project ‘HPLWR’, and the FZJ its broad HTR know-how to the project ‘VHTR’.

As an example, the promotion of young scientists thus achieved at KIT and performed in close cooperation with the University of Stuttgart is demonstrated in an impressive way by means of the HPLWR project. Similar success can be pointed out by the other centres. In the frame of Generation IV, recent works concentrate on the safety philosophy of sodium cooled fast reactors.

Promotion of young scientists at KIT, in particular in cooperation with the University of Stuttgart for the HPLWR project

Speaking of PhD studies, an innovative initiative of the industry aiming at the promotion of young scientists in nuclear engineering should be mentioned: AREVA nuclear professional school was founded in close cooperation with KIT. The foremost goal of this initiative is the highly qualified specialized education of young professionals by experts of KIT and AREVA NP to become nuclear engineers and/or nuclear scientists.

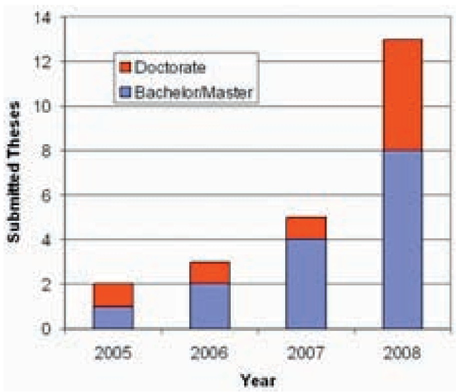


FIG. VII–3. Theses at KIT about supercritical water cooled reactors.

In the field of research, a good basis and a very good, internationally acknowledged quality of work exist with the help of industry. For example, when the Helmholtz NUKLEAR Programme was evaluated in 2009, R&D activities were assessed very positively by the experts.

The main topics are:

— Safety research for nuclear reactors:
  - Analysis of sequences of design basis and design extension conditions;
  - Application to operating power plants;
  - Investigation of severe accident phenomena;
  - Improvement of off-site nuclear emergency management;

— Safety research for nuclear waste disposal:
  - Characterization and immobilization of nuclear waste;
  - Reduction of radiotoxicity;
  - Long term safety of nuclear waste disposal;
  - Transfer of R&D results to construction and operation of repositories;
  - Radiation protection research;

— Maintenance of competence/training/teaching:
  - for operating nuclear power plants;
  - for decommissioning nuclear power plants;
  - for construction and operation of repositories.

Annex VIII

HUNGARY[5]

VIII–1. BACKGROUND

VIII–1.1. History

The ‘nuclear era’ in Hungary began after the first Geneva conference (1955), when the leading nuclear superpowers made the first steps to open up the way for the peaceful use of nuclear energy. The same year, the former USSR made an official offer to the Hungarian government that Hungary could purchase a nuclear research reactor and a cyclotron. This started an almost 30-year long procedure which finally ended with the purchase of four WWER-440 V213 units, which were connected to the grid from 1982 to 1986.

The main steps of this procedure were:

- Groups of physicists and engineers went to Moscow to study the physics of nuclear reactors;
- Construction of the first research reactor in the site of the Central Research Institute in Budapest. This reactor was Soviet designed and built, and went first critical in 1959. The initial thermal power was 2 MW. Since then it has been upgraded, and now is operating with 10 MW thermal power;
- Nuclear subjects were introduced in the curricula of mechanical engineers and physicists at several universities of the country;
- Based on the experience with the first research reactor, a Hungarian-designed and constructed ‘training reactor’ has been built on the campus of the Technical University of Budapest, which serves mainly educational purposes. This training reactor went first critical in 1971. Its initial thermal power was 10 kW, but it was upgradedto 100 kW in 1980;
- Since then, most of the nuclear experts are educated in Hungary at the Budapest University of Technology and Economics;
- The ‘training reactor’ and the acquired competence provided the country with sufficient number of nuclear experts, such that during the construction phase of the Paks NPP a strong national expert group could work with the Soviet experts, which lead to a very fruitful cooperation. Two of the four units started construction in 1974 and the other two in 1979. The four units started operation in the years 1982–1987;
- After the construction of the Paks NPP, a full scale simulator centre and a training centre have been established on the site, which took over the task of the training for the NPP personnel. The higher education of engineers, physicists, etc. is still maintained by the Budapest University of Technology and Economics (former Technical University of Budapest);
- Additionally, main reactor components (pressure vessel, steam generator, etc.) have been purchased and a *Maintenance Training Centre* has been constructed on the Paks site. The maintenance personnel are trained on original-sized, but non-active components. This training centre is widely used also by international training personnel.

VIII–1.2. Status

Now Hungary operates four WWER-440 V213 units at the Paks power plant, which provide almost 40% of the current electricity production. According to the original design, these units have to be closed after 30 years, from 2012 to 2017. However, the parliament’s economic committee has decided on a 20-year life extension project for the reactors. Also, the initial electric output power of these units was recently up rated from 440 MW(e) to 500 MW(e). Recently also new projects are being discussed about constructing new units. A decision of the parliament (on 30 March 2009) gave green light for Paks NPP to start with the preparatory work of a feasibility study of constructing two new units (1000–1600 MW(e) each).

[5] Prepared by C. Sükösd, Budapest University of Technology and Economics (BME), sukosd@reak.bme.hu.

VIII–2. NEEDS FOR NUCLEAR ENGINEERS

There are three major factors influencing the needs for nuclear experts:

(a) The replacement of the retired personnel in the nuclear-related institutions;
(b) Recruitment of new personnel for the life extension and for the related work;
(c) Recruitment of new personnel for the construction and operation of the new units.

In 2006, a survey was initiated by the Hungarian Atomic Energy Authority (OAH) to assess the future need of workforce in the energy sector (not restricted to nuclear energy).

There were over 500 participants invited to the kick-off conference, but only 150 persons appeared. Finally, only 23 companies have filled in the questionnaire. This number is quite low, therefore it cannot be considered as a reliable estimate; however, it might still indicate future trends.

The institutions that sent back the questionnaires currently employ 16 707 persons. Out of these there are 3881 persons who have some higher education degrees in scientific-technical subjects. Table VIII–1 shows the breakdown of these 3881 persons, and Fig. VIII–1 shows the average age of the personnel having scientific-technical higher education degrees in the institutions [VIII-1].

The age distribution (see Fig VIII–2) shows that within ten years about 25% of the personnel should be replaced (see Ref. [VIII-1]).

Figure VIII–3 shows the number of persons to be retired within ten years (see Ref. [VIII-1]). Please note that Paks NPP has the second highest number. There are also other nuclear-related institutions on the list (the Hungarian Atomic Energy Authority, and the Radioactive Waste Treatment Ltd).

TABLE VIII–1. DISTRIBUTION OF THE PERSONS HAVING HIGHER SCIENTIFIC-TECHNICAL DEGREES

Mechanical engineers	22.6%
Electrical engineers	12.6%
Chemical engineers	11.7%
Other (physicist, information technology, environmental engineer, mining engineer, civil engineer, engineer in petrol chemistry, etc.)	53.1%

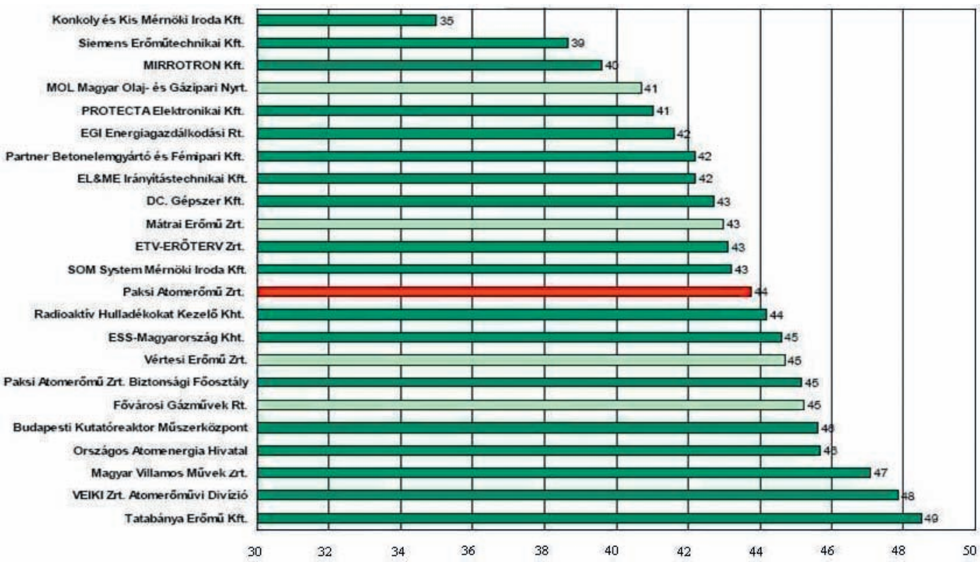


FIG. VIII–1. Average age of personnel having scientific-technical high education degrees.

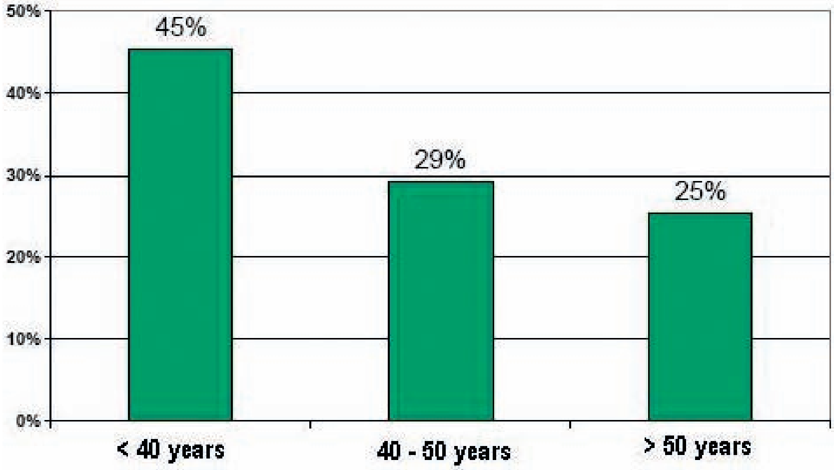


FIG. VIII–2. Age distribution of personnel having scientific-technical higher education degrees.

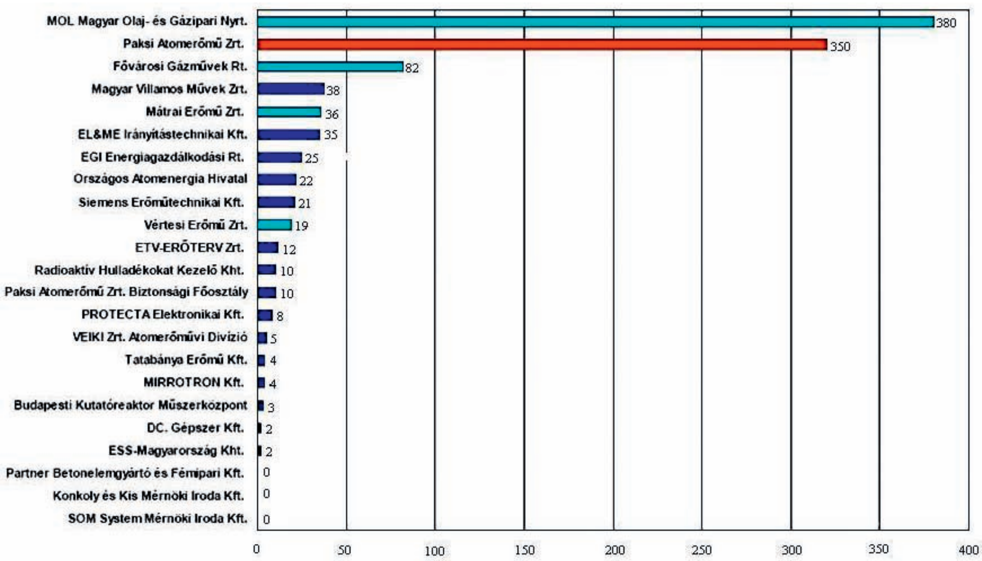


FIG. VIII–3. Number of people to retire within ten years.

TABLE VIII–2. PERCENTAGE OF RETIREMENT IN TEN YEARS OF THE HIGHLY EDUCATED PERSONNEL

Paks NPP	44%
Research Institute for Electric Industry (VEIKI), Division of Nuclear Power	42%
Hungarian Atomic Energy Authority	39%
Radioactive Waste Treatment Ltd	31%
Budapest Research Reactor\	23%

The numbers are even more striking if we show the percentage of the highly educated personnel in the different institutions. Table VIII–2 shows only those who need nuclear experts (see Ref. [VIII-1]).

According to the questionnaires, in the following ten years, the need for higher education degrees is approximately 1120 persons. The BSc is required for about 51% (~570 persons), for the rest, theMSc is required. Table VIII–3 shows the breakdown of the projected needs in highereducated personnel for the next decade (see Ref. [VIII-1]):

TABLE VIII–3. BREAKDOWN OF THE PROJECTED NEEDS IN HIGHER EDUCATED PERSONNEL

Speciality	BSc	MSc	Total
Energy engineers	69	75	144
Mechanical engineers	148	131	279
Electrical engineers	111	110	221
Chemical engineers	77	61	138
Other (physicist, information technology, environmental engineer, civil engineer etc.)	161	176	337
Total	566	553	1119

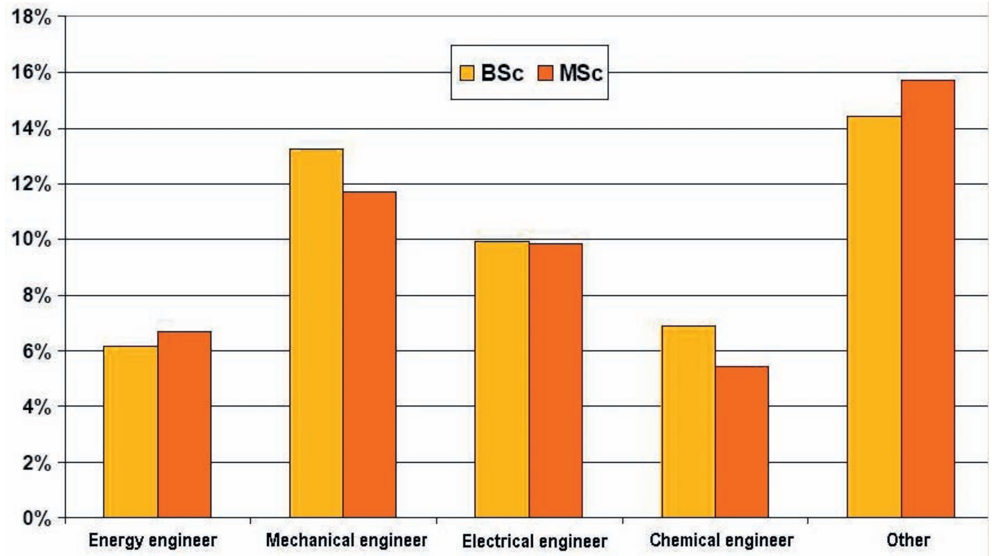


FIG. VIII–4. Percentages of the projected personnel needs related to the total needs.

Figure VIII–4 shows the percentage of the different levels (BSc, MSc) in the different disciplines related to the total needs.

When considering the above numbers we should note the following:

— They are based only on 23 questionnaires. The real need could be 2–3 times larger;
— They reflect the needs of the whole energy sector, not only the nuclear sector;
— The workforce need of the construction of two units for the NPP was not included (in 2006 there was no decision about this project).

For the latter there is an estimate that can be made based on the newly constructed Olkiluoto units.

According to the NPP Paks [2], during the construction period there will be a need in the direct workforce of about 11 000–13 500 man/a and in the indirect workforce about 16 500–20 300 man/a. The latter includes the workforce needs that are not directly involved in the construction, but they deliver some components and are only indirectly involved with the construction.

After the construction phase, for the daily operation/maintenance work, about 700–800 persons would be needed, from which about 30% should have a higher education. With the two new units there will be more work for the Hungarian Atomic Energy Authority and for the TSO organizations as well. It is difficult to guess the exact number of additional people for the time being, since it would depend on the choice of the final option.

Education in nuclear subjects is supported by a 100 kW training reactor operated by the Institute of Nuclear Techniques of the Budapest University of Technology and Economics. With the IAEA's assistance, a nuclear maintenance centre was built and a new generation of instructors were trained, as part of a project to improve the nuclear plant's professional training system and conditions. Future training needs are tied to the future nuclear developments, including decommissioning, life extension, and construction of new plants.

The largest human resources need in non-power applications in Hungary is the need for radiation protection experts in nuclear (and non-nuclear) medicine. In every hospital there are X ray facilities, many of them have radio-pharmacology laboratories, in the cancer radiation treatment centres there are accelerators and high activity gamma-sources, and recently more and more PET (positron emission tomography) diagnosis centres start operating throughout the country. All these facilities need personnel who have adequate knowledge, skill and competence in radioprotection and dosimetry. Therefore, in Hungary, the education and training in radioprotection and dosimetry have an additional, more or less complementary system beside the regular university education.

VIII–3. EDUCATIONAL SYSTEM AND EDUCATIONAL INSTITUTIONS INVOLVED IN NUCLEAR EDUCATION

VIII–3.1. The educational system

Going to school until the age of 18 is compulsory for Hungarian children.. This occurs with a system of primary and secondary schools. After the secondary school the pupils can enter into the higher educational institutions (universities, colleges) or they can continue in vocational schools. The system is shown in Fig. VIII–5 [3].

After secondary education, a certain number of university students are financed by the state while the remaining students, who do not qualify in this quota, may continue their education from their own resources. Until 2005 it took five years of study (equivalent to MSc level) both for engineers and scientists. After 2005 the 'Bologna process' was implemented in universities for academic formation. Since 2005 (engineers) and 2006 (for everyone, except medical doctors and lawyers), the universities started the three year long BSc (for engineers it is three and a half years) and a two year MSc study.

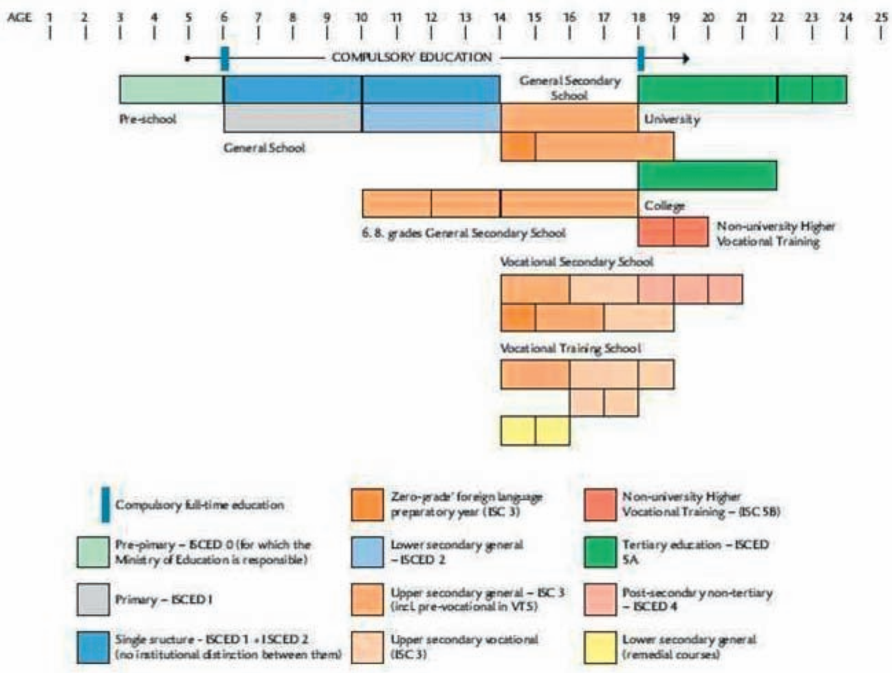


FIG. VIII–5. The Hungarian educational system.

VIII–3.2. Educational institutions involved in nuclear education

Although nuclear issues are mainly taught by higher educational institutions, it is important to mention that Hungary had already implemented, several decades ago, nuclear education in the general curriculum of secondary schools. The recommended curriculum for secondary schools includes basic topics of structure of nucleus, radioactivity, nuclear fission and fusion. Also, the 'Leo Szilárd' nationwide physics competition helps in orienting the brightest students of the secondary schools toward the nuclear sector.

The following universities offer nuclear education as (smaller or larger) part of their different educational programmes:

— Budapest University of Technology and Economics (BME) [4, 5];
— Roland Eötvös University Budapest [6];
— University of Debrecen [7];
— Semmelweiss Medical University Budapest [8];
— Pannon University of Veszprém [9].

Other than these universities, Paks NPP has its own education and training centre. This centre has two main training facilities: full-scale simulator for operator training and a Maintenance Training Centre for technicians and maintenance workers.

VIII–3.3. Budapest University of Technology and Economics

Budapest University of Technology and Economics (BME) is the main university contributing to nuclear education. Its Institute of Nuclear Techniques educates main nuclear subjects. This institute also operates a 100 kW research reactor. The nuclear education programmes of BME include BSc and MSc in physics, BSc for energy engineers. MSc for energy engineering has also been accredited and started in 2009. An MSc in nuclear engineering as well as an MSc in nuclear medicine is in the development stage. This university has also offered a specialization which was equivalent to nuclear engineering. A list of courses taught by the institute is shown below. A strong PhD programme is also offered. The students can perform research work either on the training reactor of the institute, or at the different experimental facilities of the Central Research Institute for Physics (KFKI) in Budapest. The latter operates a 10 MW research reactor, has long neutron beam lines, cold neutron source, and a wide range of spectrometers and neutron diffraction devices.

The following tables summarize the nuclear-related subjects taught in the various programmes. The full programmes contain also other subjects like mathematics, general physics, etc, but the non-nuclear related topics are not listed here. The subjects in italic are common to all students while the others are for nuclear specialization.

VIII–3.4. Roland Eötvös University Budapest (see Ref. [VIII–6])

This university offers a BSc and MSc in physics, chemistry and environmental studies and, since 2006, a PhD in environmental sciences. These are the programmes where nuclear-related subjects are taught. Before the Bologna agreement, there was no BSc level, only a five year diploma (equivalent to MSc) was issued. Within these educational programmes, several nuclear-related subjects are offered. The main emphasis of the educational programmes is on the formation of scientists (physicists, chemists, etc.) as well as of science teachers for secondary schools.

TABLE VIII–4. NUCLEAR RELATED SUBJECTS IN THE PHYSICS BSc PROGRAMME

Subject	Hours Le/Pr/Lab	ECTS
Radiation protection	2/0/0	2
Basics of environmental physics	2/0/0	2
Experimental nuclear physics	2/1/0	3
Introduction to the data handling	2/0/0	2
Environmental protection	2/0/0	2
Nuclear measuring techniques	2/0/0	2
Sustainable development and nuclear energy	2/0/0	2
Radiochemistry	3/0/0	3
Thermo hydraulics of NPPs	3/1/0	4
Isotopes applications	2/0/0	3
Nuclear safety	2/0/0	3
Monte Carlo methods	2/1/0	4
Medical imaging systems	2/0/0	2
Nuclear safety	2/0/0	3
Monte Carlo methods	2/1/0	4
Medical imaging systems	2/0/0	2
Noise diagnostics in industrial systems	2/0/0	2
Nuclear methods in geophysics	2/0/0	2
Reactor physics	3/1/0	4
Reactor technology	2/0/0	2
Radioactive waste	2/0/0	2

TABLE VIII–5. NUCLEAR RELATED SUBJECTS IN THE PHYSICS MSc

Subject	Hours Le/Pr/Lab	ECTS
Nuclear physics	3/0/0	4
Nuclear physics laboratory	0/0/6	6
Nuclear energy	3/2/0	5
NPP materials	2/0/0	2
NPP chemistry	2/1/0	3
Operation of NPP	3/1/0	3
Radio analytics for engineers	2/0/3	5
Nuclear energy systems	3/0/0	3
Nuclear non-proliferation	2/0/0	2
Sustainable development and nuclear energy	2/0/0	3
Fusion plasma physics I	2/0/0	2
Fusion plasma physics laboratory	0/0/4	4
Neutron transport theory	4/0/0	4
Computing methods in reactor physics	3/1/0	4
Reactor operation control and instrumentation	2/0/1	3
Radiation protection II	2/0/2	4
Computing methods in neutron- and gamma-transport	2/0/1	4
Simulation techniques	2/0/1	4
NPP simulation practices	0/0/2	3
Computing methods in thermo hydraulics	3/1/0	5
Radiological techniques in medicine	3/0/0	4
Transport of radioactive substances in environmental and biological systems	2/2/0	4
Safety of radioactive waste	3/1/0	4
Risk physics	2/0/0	2
Diagnostical methods in the industry	2/0/0	2
Diagnostics in fusion devices	2/0/0	2

TABLE VIII–6. NUCLEAR RELATED SUBJECTS IN THE ENERGY ENGINEERS BSc

Subject	Hours Le/Pr/Lab	ECTS
Nuclear- and neutron physics	3/1/0	4
Basics of nuclear energy	3/2/0	5
Reactor physics for engineers	3/1/0	4
Thermo hydraulics of NPPs	3/1/0	4
Reactor technology	2/0/0	2
Nuclear power plants	3/1/0	5
Nuclear measuring techniques	2/0/0	2
Environmental radiation protection	2/0/1	3
Operation of NPPs	3/1/0	4
Nuclear laboratory practices	0/0/6	6
Radioactive waste management	2/0/0	2
Radio analytics	2/0/0	2
Materials for NPPs	2/0/0	2
Nuclear electronics	0/0/2	2
Nuclear safety	2/0/0	2
Nuclear energy systems	2/1/0	3
Operational measurements and diagnostics	2/0/1	3

TABLE VIII–7. NUCLEAR RELATED SUBJECTS IN THE ENERGY ENGINEERS MSc

Subject	Hours Le/Pr/Lab	ECTS
Basics of reactor technology	*1/1/0*	*3*
Modern nuclear energy production	*1/1/0*	*3*
Analyses of NPP incidents	3/2/0	6
Safety and security of radioactive waste	1/0/1	2
Reactor instrumentation and control	2/1/0	3
Reactor technology II. (advanced)	2/1/0	3
Nuclear laboratory measurements	0/0/2	3
Design project work	0/0/4	6
Dispersion of radioactive materials	2/1/0	3
Environmental radiation protection	2/0/1	3
Modern industrial diagnostic devices	2/0/0	2

TABLE VIII–7. NUCLEAR RELATED SUBJECTS IN THE ENERGY ENGINEERS MSc (cont.)

Subject	Hours Le/Pr/Lab	ECTS
NPP chemistry	2/1/0	3
CFD methods and applications	2/1/0	3
Energy production by nuclear fusion	2/0/0	2
Nuclear electronics	1/0/1	2
Operation of NPPs	3/1/0	4

TABLE VIII–8. NUCLEAR-RELATED SUBJECTS OFFERED BY THE ROLAND EÖTVÖS UNIVERSITY

Training (diploma) title	Level	Since	Institution
Physics	BSc, (MSc)	2006	Faculty of Science, Institute of Physics
Chemistry	BSc, (MSc)	2006	Faculty of Science, Institute of Chemistry
Environmental Studies	BSc, (MSc)	2006	Centre for Environmental Science
Environmental Science	PhD	2006	Doctoral School in Environmental Science

Note: the MSc programme started in 2009, no students have been taught so far. Before the Bologna agreement there was no BSc level, only five year formation was existing giving a diploma, which is equivalent to MSc.

Nuclear information is taught in the above specializations within the following courses:

TABLE VIII–9. COURSES WITHIN THE SPECIALIZATIONS

Physics BSc	Nuclear physics	2 hours/week
	Nuclear chemistry	2 hours/week
	Laboratory practices	4 hours/2 weeks
Chemistry BSc	Nuclear physics	2 hours/week
	Nuclear chemistry	2 hours/week
Environmental studies BSc	Environmental physics	2 hours/week
	Laboratory practices	4 hours/2 weeks

In the last five years there were altogether about 500 students in these trainings (~100/year).

VIII–3.5. University of Debrecen (see Ref. [VIII–])

Nuclear subjects are taught at this university to physicists, physics teachers, physicists-informatics and environmental engineers. The university is working in close collaboration with the Atomic Research Institute (ATOMKI). Courses offered by Department of Physics at Faculty of Sciences are shown in the following tables. The university also has a PhD programme. The students can perform research work at the experimental facilities of the university (small neutron generators) or on the experimental facilities of the ATOMKI nearby (cyclotron, Van de Graaf, PET centre, etc.).

TABLE VIII–10. NUCLEAR RELATED COURSES OFFERED BY THE UNIVERSITY OF DEBRECEN

Course title	L/P/Lab	Target audience	No	C/E
		BSc level		
Quantum, atomic and nuclear physics	4/2/2	Physicists, teachers, physicist-informatics	25	C
Nuclear and particle physics	2/0/0	Physicists, teachers, physicist-informatics, environment	25	C
Health protection and radioecology	2/0/0	Environment engineers	30	C
Laboratory practices 1, 2	0/0/4	Physicists, teachers, physicist-informatics, environment	25	C
Nuclear techniques	2/0/0	Physicists, teachers, environmentalists	5	E
Atomic energy	2/0/0	Everybody	10	E
		MSc level		
Experimental nuclear physics	2/0/0	Physicists, teachers, environmentalists	10	C
Measurement methods in nuclear and particle physics	2/0/0	Physicists, teachers, environmentalists	5	E
Atomic energy	2/0/0	Everybody	10	E

Note: 'L/P/Lab' denotes the number of lectures/practices/laboratory hours per week. 'No' shows the average number of students attending the course in the last years, and C/E stands for Compulsory/Elective.

TABLE VIII–11. NUCLEAR RELATED COURSES OFFERED BY THE UNIVERSITY OF DEBRECEN FOR PhD LEVEL

Course title	L/P/Lab	Target audience
Methods for the analysis of nuclear reactions	2/0/0	Physicists, teachers
Particle detectors	2/0/0	Physicists, teachers
Charge and mass distributions of atomic nuclei	2/0/0	Physicists, teachers
Symmetries in two-body and many-body systems	2/0/0	Physicists, teachers
Nuclear models	2/0/0	Physicists, teachers
Nuclear astrophysics	2/0/0	Physicists, teachers
Nuclear fission	2/0/0	Physicists, teachers
Methods and practice of gamma-spectrometry	2/0/0	Physicists, teachers
Neutron and reactor physics	2/0/0	Physicists, teachers
Application of nuclear methods in science and technology	2/0/0	Physicists, teachers
Radioactivity and nuclear physics	2/0/0	Physicists, teachers
(Structure and reactions of) Light exotic nuclei	2/0/0	Physicists, teachers
Experiments with magnetic mass separator	2/0/0	Physicists, teachers
Angular distribution measurement of the elastically scattered alpha particles	0/0/4	Physicists, teachers
Measurements with magnetic spectrograph	0/0/4	Physicists, teachers

Note: 'L/P/Lab' denotes the number of lectures/practices/laboratory hours per week.

VIII–3.6. Semmelweiss (Medical) University, Budapest (see Ref. [VIII–8])

This university graduates medical doctors and dentists. A few nuclear-related topics are taught (for example radiology, radiation protection, radio-hygiene, radio pharmacology, etc.), partly embedded into other subjects (e.g. Biophysics).

— *Radiology* (taught by the Clinic of Radiology and Oncotherapy):
Audience: medical students at graduate level;
Intensity: 30 h lectures and 30 h practice;
Number of students: approximately 250.
— *Radiation protection* (taught by the Faculty of Dentistry, Section of Radiology):
Audience: dentist students at graduate level;
Intensity: 32 h lectures;
Number of students: approximately 80.
Specialities: Special lectures and practice for PhD students and for ‘medical resident’ post-graduate education.
Number involved in radiobiology, radiology and/or radio-pharmacology: approximately 10.
— *Radio-hygiene* (BS level — taught by the Faculty of Health Care):
Audience: students of public health and epidemiological inspection;
Intensity: 32 h lectures and 10 h practice;
Number of students: approximately 30.
— *Advanced radiation protection* (taught by the Radiation Protection Service):
A post-graduate course for workers involved in the use of ionising radiation;
Intensity: 26 h lectures (for clinical and laboratory assistants + 12 h practice), annually organized;
Number of participants: approximately 100 (50% of MS level and 50% of technician level).
— *Radio-pharmacology* (taught by the Post-graduate School for Health Care):
Participants: technicians and BS level;
Intensity: 56 h lectures;
Number of participants: approximately 25.

VIII–3.7. University of Pannonia Veszprém (see Ref. [VIII–9])

Since 2000, the Faculty of Engineering, Department of Radiochemistry delivers diplomas in Environmental Engineering at all the three levels (BSc, MSc, PhD).

Number of students**:** from 2003 to 2007, about 20 MSc and 4 PhD degrees were awarded.

VIII–4. RADIATION PROTECTION EDUCATION AND TRAINING SYSTEM

In the 1960s it became clear that the country would need a competent workforce in radiation protection. Not only because of the NPP project at that time, but also for several non-power applications. First the universities — especially the medical universities in Budapest and Debrecen, and the Technical University of Budapest — organized courses about isotope technology which were not embedded in the regular curriculum, but which were offered to workforces who needed to work with radioisotopes. Even some institutes of the Central Research Institute for Physics (KFKI) in Budapest organized such courses. Since the late 1970s and early 1980s, the legal framework for radiation protection was moved to the Ministry of Health. A person working in an environment potentially (or effectively) exposed to radiation should have one of the three possible qualifications: basic, extended and advanced. These qualifications should be renewed every five years. In connection with this, several courses are organized that allow the workforce to maintain and upgrade its competence in radiation protection and dosimetry. More than 150 certificates are given annually.

TABLE VIII–12. NUCLEAR RELATED SUBJECTS

Subject	L/P/Lab
BSc programme	
Basics of radiations	1+0+0
Radioecology	2+0+0
Radiations and radio-nuclides in the nature	2+1+0
Dosimetry and radiation protection	2+0+0
Nuclear metrology	2+0+0
Nuclear energetic and its environmental impacts	2+0+0
Nuclear emergency, radioactive waste management	2+0+0
Laboratory practices in radioecology and nuclear metrology	0+0+6
Lessons from the nuclear and radiation accidents	2+0+0
Uses of radioisotopes	2+0+0
MSc programme	
Radiation accident management	2+0+0
Radioactive waste disposal	2+0+0
Radiochemical calculations	2+0+0
Measuring ambient radiation	2+0+0
Radioactive tracer methods	2+0+0
Nuclear chemistry and application of radioisotopes	2+0+0
Decontamination	2+0+0
Radiation chemistry and technology	2+0+0
Radiation measurement, laboratory practice	0+0+6

Note: 'L/P/Lab' denotes the number of lectures/practices/laboratory hours per week.

In addition to these specially organized courses, there are also a number of students at the universities, who get a qualification (mostly extended) in radiation protection [VIII–10]. They have to take a separate examination in the presence of a delegated person from the national health authority. Table VIII–13 lists the number of university students receiving radiation protection qualification annually (average values based on the data from the last 2–3 years).

The subjects taught at the university level are reflecting the special orientation of the university. The most important subjects are listed in Table VIII–14 below.

TABLE VIII–13. THE NUMBER OF UNIVERSITY STUDENTS RECEIVING RADIATION PROTECTION QUALIFICATION ANNUALLY (see Ref. [VIII–10])

Institution	Certificate in gradual programmes	Certificate in separate courses	Diploma work[a]	PhD theses[a]
Budapest University of Technology and Economics	6–12	5–30	1–3	1–2
University of Debrecen Faculty of Natural Sciences	10–20	0	2–5	1–2
Eötvös University Budapest Faculty of Natural Sciences	10–15	1–2	2–4	0
Semmelweis Medical University Budapest	—	100–150	2–5	1–2
University of Szeged, Faculty of Natural Sciences	5–10	10–15	1–2	—
Pannon University of Veszprém	15–20	10–15	5–7	1–2
M. Zrínyi National Defense University	15–20	18–22	4–6	1–2

[a] Listed only if the work is related to radiation protection at least in 30%.

TABLE VIII–14. SUBJECTS RELATED TO RADIATION PROTECTION TAUGHT IN CERTAIN UNIVERSITIES

Course title[a]	Programme level	Total number of hours			Students annually
		Lec	Lab	Sem	
Budapest University of Technology and Economics					
Radiation and environmental protection	G–B	40	13	—	90
Radioactive waste	G–S	40	13	—	10
Migration of pollution in the environment	G–S	26	—	13	10
Radiation protection II	G–S	26	26	—	10
Nuclear environmental protection	G–S	26	13	—	35
Nuclear environmental protection	P	40	26	—	15
Techniques in radiology	P	52	—	—	30
Debrecen University					
Dosimetry	G–B	—	48	—	20
Environmental physics	G–B	12	4	—	90
Radiochemistry	G–B	28	—	—	40
Isotope technology	G–B, S	28	—	—	45
Radiation protection and dosimetry	G–B, S	28	—	—	20
Radioaktivitás a környezetben	G–B	28	—	—	8
Radiation health systems	G–S	28	—	—	12
Radioecology	G–S	28	—	—	10

TABLE VIII–14. SUBJECTS RELATED TO RADIATION PROTECTION TAUGHT IN CERTAIN UNIVERSITIES

Course title[a]	Programme level	Total number of hours			Students annually
		Lec	Lab	Sem	
Radiology in medicine	G–B	28	—	—	200
Nuclear medicine[b]	G–B	—	12	—	—
Eötvös University Faculty of Natural Sciences					
Introduction in the nuclear environ. prot.	G–B	26	—	—	15
Nuclear chemistry laboratory	G–B	—	26	—	40
Radiation protection	G–B, S	26	—	—	20
Pannon University, Veszprém[c]					
Basic knowledge for radiation	G–B	14	—	—	150
Radioecology	G–B	28	—	—	80
Nuclear measuring techniques	G–S	28	14	—	15
Managing and storing radioactive waste, recultivation	G–S	28	14	—	5
Lessons learned from nuclear- and radiation incidents and accidents	G–S	28	—	—	30
Modeling the dispersion of radionuclides in the environment. Simulation	G–S	—	—	14	8
Laboratory in radioecology	G–S	—	28	—	8
Radiation protection and dosimetry	G–S	28	—	—	35
Protection against non-ionising radiations[d]	G–S	14	—	—	—
Zrinyi Miklós National Defense University					
Radiology	G–S	40	13	—	15
Nuclear environmental protection	P	26	—	—	6
Preventing nuclear accidents	P	26	—	—	8
Radiation protection	P	26	—	—	3

Notes: Lec — lecture, Lab — laboratory practice, Sem — seminar, G–B — gradual basic programme, G–S — gradual specialization, P — post-gradual or PhD (see Ref. [10]).

[a] Some of these courses are also part of the pos-graduate (PhD) programme;

[b] New course, no data about the number of students available yet;

[c] Some of the subjects are taken by 5–8 PhD students as well;

[d] New course, no data about the number of students available yet.

VIII–5. FOREIGN STUDENT ENROLMENTS

While discussing foreign student enrolments one should consider that at each university the majority of courses are delivered in the Hungarian language. In each of the universities there are special programmes in English, or in other foreign languages, and there are some foreign students enroled in these programmes. However, it can be stated that the percentage of foreign students is usually quite low. Since nuclear engineers are only educated in the BME, and there are no regular enrolment of foreign students, it can be concluded that in Hungary education of foreign students in nuclear education does not occur.

It should be noted however, that there are some particular cases where foreign students learn also nuclear subjects in Hungary. Theses are mainly in the end phase of Master or PhD studies (diploma or thesis work). The BME also organizes and accepts the students of the doubly international Eugene Wigner Course for Reactor Physics Experiments, which is an annually organized three week course for European students, held in English. It is doubly international, since not only the students are recruited from different countries, but also the course is organized and performed in close cooperation of the Slovak Technical University Bratislava (Slovakia), Czech Technical University (Prague), Atomic Institute of the Austrian Universities (Vienna) and BME (Budapest). The students have the opportunity to do hands-on experiments on three different research/training reactors.

Also, BME accepts groups of students from Slovakia, the Czech Republic, and Sweden for a 1–2 week period. These programmes are organized on a case by case basis.

VIII–6. AVAILABILITY OF RESEARCH AND EXPERIMENTAL FACILITIES

Three main facilities could be mentioned which are utilized in nuclear education:

- The training reactor of the BME. It has max. 100 kW thermal power, and it has been designed directly for educational purposes. It is regularly used for undergraduate and graduate education (see Ref. [VIII–5]);
- The Budapest research reactor is located in Budapest, at the site of the Central Research Institute [VIII–11]. It has 10 MW thermal power, and is designed mainly for research purposes. However, students of the BME and of the Eötvös University Budapest visit regularly the Budapest Research Reactor and perform some experiments. They also can use this reactor and its various research facilities when doing their research work for their diploma work or PhD thesis;
- The cyclotron in the Institute of Nuclear Research in Debrecen [VIII–12]. The physics students of the University of Debrecen can come there and perform experiments for their research work related to diploma or PhD work. The cyclotron can accelerate protons, deuterons, ^{3}He and alpha-particles, and produces radioisotopes also for PET medical purposes.

VIII–7. COOPERATION/COLLABORATIONS WITH INDUSTRY AND GOVERNMENT

All universities cooperate with the nuclear industry. Naturally the volume of this cooperation varies from institution to institution. The closest — and probably the widest — cooperation with the Paks NPP is with the BME. That is why we show the different aspects of this cooperation in detail:

- Continuing educational programme for professionals. The BME regularly organizes a two year continuing educational programme for the professionals working in the nuclear sector. This is a pos-tgraduate programme in Reactor physics and Reactor technology. This is a means of upgrading the nuclear-related knowledge of people having mechanical, electrical and chemical engineering, or physics or chemistry diplomas;
- The BME is a TSO for the NPP Paks. This means that it has several contracts to perform applied research and scientific analyses for the NPP. The students are also involved in these researches, and this way they can establish contacts with their potential future employer in an early stage of their studies;
- The NPP also financially supports a foundation of the BME to promote the students' mobility, to provide special scholarships for the brightest students in the nuclear field, to cover travel expenses of students when they participate in conferences etc;
- The foundation above also announces valuable prizes for the students. For the 'best diploma work in nuclear', for 'the best PhD work in nuclear' etc.

The Hungarian Atomic Energy Authority (HAEA) is a governmental organization. This means that the cooperation with the government occurs through this body. The BME is also a TSO for the HAEA, and perform applied research and scientific analyses for this body. Also, employees of the HAEA take part in the continuing education programme in reactor physics and reactor technology.

The BME is a State-owned university; it is financed by the Ministry of Education. There is some problem, however, in the financing of the training reactor (TR). The TR is embedded in a university environment, and it is not financed separately with dedicated money. When distributing the money from the ministry within the university, the other departments of the university find it hard to accept that the nuclear reactor needs much more money for the operation than the other departments of the university. On the one hand, this causes tension between the training reactor and the other departments of the university, which creates an unfavourable environment for the training reactor within the university. On the other hand, this situation also forces the management of the TR to fight constantly to have a sufficient amount of money to ensure the safe operation of the reactor. A good solution would be to get the TR separately financed, with directly dedicated money. Then the other departments of the university would not feel that the TR ‘takes money away’ from them.

The other large experimental facilities (Budapest Research Reactor and Debrecen Cyclotron) do not have the same problem, since they are not embedded in universities. They are located in research institutes and their financing occurs with a completely different scheme.

VIII–8. NATIONAL AND INTERNATIONAL COOPERATION AND EDUCATIONAL NETWORKS

(a) National cooperation

The Training Reactor of the Budapest University of Technology and Economics is declared as an ‘inter-university’ facility; therefore it is open to the students of other Hungarian universities. Indeed, many students of the Eötvös University Budapest come and perform experiments on the TR. Students from other Hungarian universities have more difficulty to come, because of travel problems. There is a cooperation between the lecturers, since they mutually participate in the refereeing work of PhD theses, and there are also common research projects.

(b) International cooperation

Every university involved in the education of nuclear subjects has wide international relations concerning their research work. It would be a long list to quote every one of them. We would refer to their web-pages for a continuously updated list.

We quote only two international cooperations, which we think are the most relevant for nuclear education:

— Most Hungarian universities where nuclear subjects are taught regularly accept fellows from the IAEA for longer or shorter stays and for research work, and the academic personnel are regularly involved in different expert missions of the IAEA. Fellows arriving at the BME can use the training reactor.
— The Institute of Nuclear Techniques of the BME is a founding member of the ENEN Association [VIII-13]. It is a member of the Board of Governors, and takes part in many of the activities of the ENEN Association. One of the pilot international courses — the Eugene Wigner Course for Reactor Physics Experiments — was also initiated and organized by the BME, as mentioned earlier.

VIII–9. BEST PRACTICES

When listing the best practices which can be recommended to other countries one should keep in mind that Hungary is a small country, having only one NPP. This reflects in the limited need of workforce as well as in the relatively small number of nuclear programmes. Therefore our best practices can be recommended to countries with relatively small workforce demand.

VIII–9.1. Involvement of industry

The Paks NPP is involved in several ways in the education process. Students studying in the nuclear energy programme of the BME are performing a summer internship on its site. The NPP offers scholarships and awards for the best diploma and PhD thesis in nuclear subjects, and professionals of the NPP hold lectures on special subjects within the framework of the nuclear education programme of the BME.

Several universities have research contracts with the NPP.

The BME regularly organizes continuing education courses (second diploma) for the professionals of the NPP to upgrade their knowledge.

VIII–9.2. Involvement of government

The universities listed in this report are all State-owned universities; therefore the government is closely involved in ther educational process. However, there is no special treatment for nuclear education; it is financed on the same principles as any other discipline. There are, however, a few additional ways how the state is involved. The BME is one of the TSOs of the Hungarian Atomic Energy Authority, and gets regularly research contracts from it. Since HAEA is a government agency, this implies additional involvement of the government. Also, the students (undergraduate, graduate and PhD) of the BME go regularly to the Atomic Energy Research Institute (AEKI) to do experiments or to perform research work for their diploma work or theses. Since the AEKI is an institution of the Hungarian Academy of Sciences (and therefore it is partly financed by money from the national budget), this cooperation should also be considered as an additional, indirect involvement of the government.

An obvious best practice is the clear legal regulation and organization of the radiation protection education and training system, as we outlined it in the report. It is recommended to follow even for countries having only non-power nuclear applications.

VIII–9.3. Strong cooperation with international networks and institutions relevant for nuclear education

- European Nuclear Education Network Association (ENEN). The BME is a founding member of the ENEN, and also member of the governing board;
- International Atomic Energy Agency (IAEA). Close cooperation with the IAEA means accepting IAEA fellows for a stay in the BME, and participating in expert missions of the IAEA;
- Many bilateral links and cooperation exists between the universities in the region (e.g. Slovak Technical University in Bratislava, Atomic Institute of the Austrian Universities in Vienna, Czech Technical University in Prague, École de Mines de Nantes, France etc.).

VIII–9.4. Outreach activities

In Hungary, the basics of nuclear and radiation physics were introduced in the high school curricula in the 1970s. Since then the universities, with the help of the nuclear industry, put a large emphasis on outreach activities. University professors regularly attend the annual meetings of primary and secondary school physics teachers, and deliver lectures to them; they are also invited to ’school days’ to talk about nuclear subjects. Many thousands of pupils visit the different nuclear installations (Visitor Centre of the Paks NPP, training reactor and research reactor in Budapest, and the Radioactive Waste Depository in Bátaapáti). Nuclear summer camps are organized by the Hungarian Nuclear Society for talented high school pupils. A nationwide physics competition, named after Leo Szilárd, is organized annually with the main emphasis on nuclear physics (and modern physics). Every year a group of about 40 Hungarian high school teachers visit CERN for a week. This visit, which is led by a university professor, also reinforces the contact between academia and school teachers. Young professionals of the Hungarian Nuclear Society annually represent the nuclear community at a summer youth festival in Budapest (the Sziget), which is the largest festival of this kind in Europe. As an international recognition of their achievements the Young Generation of the Hungarian Nuclear Society has won the first Communication Award of the European Nuclear Society in 2005.

VIII–9.5. New media and electronic methods

Each of the relevant nuclear related institutions (Paks NPP, Radioactive Waste Management Ltd, HAEA, AEKI, BME, etc.) as well as several civil societies (Eötvös Physics Society, Hungarian Nuclear Society, Young Generation Network etc.) maintain a well constructed, comprehensive public webpage, where the public can find useful and unbiased information about nuclear issues. Thousands of hits are recorded every day on these pages. It is very important to note that in the case of a new nuclear event, these webpages reflect it immediately, almost at the same time as the newspapers. This assures that interested persons may get authentic information almost immediately. This way the sometimes misleading influence of the news media can be balanced.

REFERENCES TO ANNEX VIII

[VIII–1] ASZÓDI, A., Energetikai szakemberigények Magyarországon, (Needs of energy experts in Hungary), in Hungarian, http://www.reak.bme.hu/fileadmin/user_upload/felhasznalok/aszodi/letoltes_eloadasok/Aszodi_szake_igenyfelm_Szakujsagirok_20080415_v3.pdf

[VIII–2] Új atomerőművi blokkok létesítésének előkészítése, (Preparation for new NPP units), edited by MTA KFKI AEKI (2009), in Hungarian.

[VIII–3] Education in Hungary, http://www.okm.gov.hu/letolt/english/education_in_hungary_080805.pdf

[VIII–4] Budapest University of Technology and Economics (BME), http://portal.bme.hu/langs/en/default.aspx

[VIII–5] Institute of Nuclear Techniques of the BME, http://www.reak.bme.hu/index.php?id=1&L=1

[VIII–6] Roland Eötvös University Budapest, http://www.elte.hu/en

[VIII–7] University of Debrecen, http://ttk.unideb.hu/index.php?lang=english

[VIII–8] Semmelweiss University Budapest, http://english.sote.hu/

[VIII–9] Pannon University Veszprém, http://englishweb.uni-pannon.hu/

[VIII–10] KANYÁR, B., ZAGYVAI, P., HOMONNAY, Z., DEZSŐ, Z., FARKAS, G., FEHÉR, I., OZORAY, K., PELLET, S., URAY, I., VINCZE, Á., ZOMBORI, P., Radiation protection education at the college level, Fizikai Szemle, (2004) 224, (in Hungarian), http://www.kfki.hu/fszemle/archivum/fsz0407/zagyvai0407.html

[VIII–11] Budapest Research Reactor, http://www.kfki.hu/brr/indexen.htm

[VIII–12] Cyclotron Department Debrecen, http://www.atomki.hu/atomki/CyclAppl/

[VIII–13] European Nuclear Education Network Association, http://www.enen-assoc.org

Annex IX

INDIA

IX–1. BACKGROUND

To start nuclear research in India, the Tata Institute of Fundamental Research (TIFR), Mumbai, was inaugurated in December 1945. The Atomic Energy Act was passed in April 1948 and to exploit the nuclear energy for the nation, the Atomic Energy Commission was constituted in August 1948. The Atomic Energy Commission started the Atomic Energy Establishment, Trombay (AEET) in January 1954. All scientists and engineers engaged in the fields of reactor design and development, instrumentation, metallurgy and material science, etc. were transferred along with their respective programme from TIFR to AEET to become an integral part of the newly created AEET. The Department of Atomic Energy (DAE) was created in August 1954. After the death of H. Bhabha, AEET was renamed as Bhabha Atomic Research Centre (BARC) in January 1967.

No university in the country conducted any academic programme in nuclear engineering and science at the time the nuclear energy programme was started in India. In order to meet the manpower requirement for the atomic energy programme, AEET Training School (now called BARC Training School) was set up to train and recruit engineering and science graduates in to the DAE. Right from its inception in 1957, the Training School (TS) programme is of one year duration and continues to be the primary channel for recruiting engineers and scientists in DAE. However, though the TS continues to admit engineering graduates, the requirement for admission to the TS for science students is a post-graduate degree. Also, the TS programme is now called the Orientation Course for Engineering Graduates and Science Post Graduates (OCES) and has been expanded by opening the training schools at various locations for imparting specialized training in chosen areas of interest to DAE (see Section 2 for details).

The TS prepares the engineering and science student for the tasks of DAE but, till recently, it was not recognized with the award of any degree. The employees in DAE units used to register with universities for improving their qualification. A large number of engineers and scientists even got recognition as PhD graduates from different universities. In order to utilize fully its academic and technological strengths, in 2005, DAE established the Homi Bhabha National Institute (HBNI), a deemed to be university. The academic programmes of HBNI commenced from 2006. The focus of HBNI is on the post graduate and doctoral programmes. In particular the OCES programme of the BARC TS is now recognized for the award of Master of Technology (MTech) and Master of Philosophy (MPhil) degrees of HBNI.

Apart from the nuclear education programme of DAE outlined above, the Indian Institute of Technology, Kanpur also conducts MTech programme in nuclear engineering and technology. The status of university education in nuclear science and engineering in India otherwise remained the same till now as it was at the time the atomic energy programme was started. With the opening up of the Indian atomic energy programme to global cooperation and expectation of its large scale expansion, the Indian universities and academic institutions have only now started venturing in to the arena of nuclear education (see Section IX–3).

IX–2. NEEDS FOR NUCLEAR ENGINEERS

As stated above, the nuclear energy programme in India is presently managed only by the DAE for which it recruits engineers and scientists through the BARC Training School. Total number of engineers and scientists recruited annually is about 300. The future needs will be addressed in step with the programme evolution.

IX–3. EDUCATIONAL SYSTEM AND INSTITUTIONS INVOLVED IN NUCLEAR EDUCATION

The education system in India comprises ten years of schooling leading to matriculation followed by two more years for higher secondary certification. After higher secondary, students interested in a career in science, engineering and medicine may study for a bachelor’s degree at a university or an academic institution for a degree in science or for a professional degree like engineering and medicine. The bachelor’s degree in science (BSc) is

TABLE IX–1. NUCLEAR ENGINEERING AWARDING INSTITUTION. LANGUAGE OF INSTRUCTION: ENGLISH

Sr No.	Institution	Courses	Degree awarded	Web site contact
A	Homi Bhabha National Institute (HBNI)	Nuclear engineering, physics, chemistry, bioscience	MTech/MPhil/MSc(Engg.)PhD, post-graduate diploma	www.hbni.ac.in, www.hrdbarc.gov.in
B	Bhabha Atomic Research Centre	Industrial and Academic training courses	Nil	www.barc.gov.in
C	Indian Institute of Technology, Kanpur	Nuclear engineering and technology	MTech/MPhil/ PhD	www.iitk.ac.in
D	University of Delhi	Nuclear science and technology	MTech	www.du.ac.in
E	Jadavpur University	Nuclear engineering[a]	ME	www.jadavpur.edu.in

[a] This is a proposed programme and is expected to start later this year.

awarded after completing three years of course work. A master's in Science (MSc) is awarded after an additional two years further education, whereas the bachelor's degree in engineering or technology (BE or BTech) is awarded on completing four years of course work after higher secondary. The Master's of Technology (MTech) is awarded two years after BE/BTech/MSc. The MTech programme consists of one year of course work followed by one year of project work. A master's degree holder can register for a PhD though some universities permit registration for a PhD after BE/BTech. The bachelor's degree in medicine is named MBBS (bachelor of medicine and bachelor of surgery). There are several diploma courses as well after matriculation and higher secondary.

Education in nuclear engineering in India is presently only at post-graduate (i.e. post-bachelor degree) level. Some prominent educational institutions involved in nuclear education along with the courses offered by each of them are listed in Table IX–1.

A brief description of each of the above mentioned programmes is as follows:

(1) The post-graduate programmes of HBNI are conducted following ten units of DAE, called the Constituent Institutions (CIs) of HBNI:
- — BARC, Mumbai;
- — Indira Gandhi Centre for Atomic Research, Kalpakkam (IGCAR);
- — Raja Ramanna Centre for Advanced Technology, Indore (RRCAT);
- — Variable Energy Cyclotron Centre, Kolkata (VECC);
- — Tata Memorial Centre, Mumbai (TMC);
- — Institute of Plasma Research, Gandhinagar (IPR);
- — Institute of Physics, Bhubaneswar (IoP);
- — Harish Chandra Research Institute, Allahabad (HRI);
- — Institute of Mathematical Sciences, Chennai (IMSc;
- — Saha Institute of Nuclear Physics, Kolkata (SINP).

The PhD programme is conducted in all the CIs of HBNI in engineering, science and medicine. Following are its post graduate degree and diploma programmes:

(a) The MTech/MPhil programmes in nuclear engineering, science and its non-power applications are conducted at the BARC Training School at various locations as per the following details:
- — BARC TS in BARC, Mumbai conducts academic programme for R&D in nuclear reactors and basic sciences;
- — BARC TS at RRCAT provides training to scientists and engineers for R&D in lasers, accelerators, cryogenics, material science, superconductors, power electronics and microwaves;

— BARC TS at Nuclear Fuel Complex, Hyderabad imparts training to engineers in process development, design, engineering, construction, operation and maintenance of plants for production of heavy water and nuclear fuel;

— BARC TS at Nuclear Training Centres at Tarapur, Rawatbhata, Kaiga, Kalpakkam, and Kudankulam provides training for operation and maintenance of nuclear power plants;

— BARC TS at Kalpakkam offers the specialization in Fast Breeder Reactor technology.

After a rigorous selection process, the BARC TS admits engineering graduates in the following disciplines: mechanical, chemical, metallurgy, electrical, electronics, computers and instrumentation. It also admits science post-graduates in physics, chemistry and bioscience. Those selected undergo a one year course work at the BARC TS and, on successful completion of course work, are employed as scientific officers in DAE. After joining DAE, they are entitled to carry out one year project work to fulfil the requirement for the award of MTech/MPhil.

The average number recruited annually through the BARC TS is 300.

(b) Another programme for recruiting engineers and physicists in to DAE is the Graduate Fellowship Scheme (DGFS). Under this scheme, those engineering graduates or physics post-graduates who are selected for BARC TS and also get admission in an Indian Institute of Technology (IIT) are paid stipend and a tuition fee to study for an MTech at the IIT. The MTech project for DGFS fellows is selected by DAE and is carried out under the joint supervision of an IIT and a DAE guide. On successful completion of an MTech, the DGFS fellows are recruited in DAE. On joining and before starting regular work they take a four month orientation course at BARC TS in Mumbai. The average number recruited through this route is 25 annually;

(c) A scheme to recruit PhD or MTech degree holders with two years experience in DAE is the K.S. Krishnan Research Fellowship (KSKRA). After a rigorous selection process, those selected under this scheme carry out two years of research work in DAE. Those whose performance during those two years is satisfactory are offered employment at DAE. The average number recruited through this route is seven annually;

A summary of the average number of engineers and scientists recruited through channels (a)–(c) described above is given in Table IX–2.

(d) A training programme under the aegis of HBNI is conducted at the Institute of Plasma research to develop the expertise for the fusion programme;

(e) Diploma in Radiological Physics (DipRP) programme is conducted under the aegis of HBNI in BARC, Mumbai. It is a one year programme to train candidates having a Master’s degree in Physics for radiological applications;

(f) Diploma in Radiation Medicine (DRM) is a two year programme conducted at the Radiation Medicine Centre of BARC in Mumbai. The entry level qualification for the programme is a Bachelor of Medicine and Bachelor of Surgery (MBBS).

(g) Diploma in Medical Radioisotope Techniques (DMRIT) is a one year programme conducted at the Radiation Medicine Centre of BARC in Mumbai. The entry level qualification for the programme is a Bachelor of Science (BSc).

TABLE IX–2. AVERAGE NUMBER OF RECRUITS PER YEARS FOR EMPLOYMENT AS ENGINEERS, SCIENTISTS AND AS RESEARCH FELLOWS THROUGH THE SCHEMES (a)–(c)

Sr. No.	Scheme	Duration (years)	Eligibility	Average number/year
1	BARC TS	1	First class Bachelor’s degree in engineering/Master’s degree in science	300
2	DGFS	2	First class Bachelor’s degree in engineering/Master’s degree in physics	25
3	KSKRA	2	PhD or MTech with 2 years experience R&D	7

(2) BARC conducts following short term training programmes and courses.

TABLE IX–3. SHORT TERM RADIATION SAFETY RELATED TRAINING COURSES CONDUCTED BY RADIOLOGICAL PHYSICS AND ADVISORY DIVISION (RP&AD), BARC

Sr. No.	Name of the course	Duration	Eligibility
		Medical	
1	Radiation safety for radiation therapy technologist (RTT)	7 days	(i) 10+2 with science and (ii) 2-years radiation therapy technologists course or 5 years working experience as RTT
2	Radiation safety in servicing of radiotherapy equipments (SRT)	7 days	(i) Degree/Diploma in electrical/electronic/ biomedical/mechanical engineering (ii) 1-year working experience
3	Radiation safety and quality assurance in diagnostic radiology (QADR)	7 days	(i) Qualified X ray radiographer (ii) Qualified X ray service engineers
4	Orientation and certification course for radiological safety officer (RSO) (medical)	10 days	Qualified medical physicist MSc (med. Phys.) with more than 50% marks)
5	Certification examination for RSO in nuclear medicine	3 days	DRM/DMRIT or equivalent
		Industrial	
6	Radiation safety aspects for RSO in nucleonic gauges (NG)	7 days	Degree in science or Degree/Diploma in engineering
7	Radiation safety aspects for RSO in research applications (RA)	7 days	Degree in science (sponsored candidates only)
8	Industrial radiography testing level-1 (RT-1)	15 days	10+2 with science/Diploma in engineering and 6 months working experience
9[a]	Industrial radiography testing Level-2 (RT-2)	15 days	RT-1 + 36 months experience
10	Radiation safety aspects for RSO in radiation processing facilities	3 months	Degree in science
11[b]	Radiation safety aspects for operators in radiation processing facilities	3 months	Degree in science

[a] In collaboration with Isotope Applications Division, BARC.
[b] In collaboration with Board of radiation and isotope technology.

(3) Besides DAE, the Indian Institute of Technology, Kanpur (IIT, Kanpur) is the only other institution in the country which has been conducting a Nuclear Engineering and Technology programme for a long time. It not only offers MTech and PhD degrees in the area of nuclear engineering and technology, but also provides research and development expertise in the experimental and theoretical studies of fusion and plasma physics, radio isotope applications in manufacturing engineering, computer aided tomography, reactor safety studies, heat transfer in nuclear sub-systems, and development of radiation detectors. The main courses offered for the programme are:

— Reactor physics;
— Nuclear and reactor physics;
— Nuclear power engineering;
— Nuclear measurements laboratory;

— Neutron transport theory;
— Radioisotope application in engineering;
— Nuclear fusion;
— Nuclear reaction and interaction of radiation with matter;
— Introduction to computerized tomography;
— Non-destructive evaluation,
— Fast reactor technology;
— Mathematical methods in engineering.

(4) The Nuclear Science and Technology programme at Delhi University is a three year programme for those holding a Bachelor's degree in physics leading to the award of MTech in nuclear engineering. The programme is only in to its second year;

(5) The proposed Master of Nuclear Engineering programme at Jadavpur University is for those holding bachelor's degree in any of conventional engineering disciplines. It is expected to begin with the 2009 academic year.

IX–4. FOREIGN STUDENT ENROLMENT

No foreign students are presently enroled in HBNI. However, the DAE imparts a training programme to IAEA sponsored students in various non-power applications of nuclear energy.

IX–5. AVAILABILITY OF RESEARCH AND EXPERIMENTAL FACILITIES

Research reactor and accelerator facilities are available in various DAE units. The DAE facilities like reactors and accelerators are made available to the universities in the country through the University Grants Commission-DAE Consortium for Scientific Research and Inter University Accelerator Centre.

IX–6. COOPERATION/COLLABORATION WITH INDUSTRY AND GOVERNMENT

The nuclear energy programme in India is wholly managed in all its aspects by the Government of India through its Department of Atomic Energy.

IX–7. NATIONAL AND INTERNATIONAL COOPERATION AND EDUCATIONAL NETWORKS

The DAE provides through Board of Research in Nuclear Sciences (BRNS) extra mural funding and technical support for projects in universities in the frontline areas of research. At an international level, India is part of Asian Network for Education in Nuclear Technology (ANENT). It also participates in World Nuclear University conducted summer camps. The DAE also a participating member in various international mega projects like the International Thermonuclear Experimental Reactor (ITER), projects at CERN etc.

Nuclear education in India is in the stage of unprecedented expansion.

Annex X

ITALY

The country’s first scientific body to pursue civil nuclear power was established in 1946. In 1952, an agency to develop and promote nuclear power was established, and this was reorganized in 1960 under the name National Committee for Nuclear Energy (CNEN). Construction of the first nuclear power plant (British Magnox unit) started in 1958. The following year, construction of the first GE boiling water reactor (BWR) began. Construction on the first Westinghouse PWR started in 1961 and connected to the grid in 1965. The 860 MW(e) Caorso BWR plant started operation in 1981. Several research reactors are operating, including AGN Constanza (since 1960), University of Pavia's LENA Triga II (250 kW, since 1965), ENEA's Tapiro (5 kW, since 1971), ENEA’s Triga RC-1 (1 MW, since 1960) and a subcritical assembly.

The work on the nuclear programme was largely stopped by a referendum held in November 1987 18 months after the Chernobyl incident. In 1988 the government halted all construction related to anything nuclear, closed down the remaining reactors and decommission them from 1990. As well as the operating plants, two new nuclear BWR plants were almost complete and six locally designed PWR plants were planned. ENEA (formerly CNEN) also closed various fuel cycle facilities.

In 2004, a newly adopted energy law opened up the option of a joint course of action with foreign companies in relation to nuclear power plants and importing electricity from them. This happened due to a clear change in public opinion, especially among the younger generation favouring nuclear power for Italy. Now Italy is the only G-8 country without its own nuclear power plant. More than 10% of its electricity is imported from French NPP’s.

The ENEA is the most important agency for applied nuclear research which focuses its most R&D on decommissioning and waste, basic research continues in order to maintain the nuclear option in the light of climate change concerns.

The number of enroled nuclear engineering students has increased up steadily until the early 1990s and after, with some oscillations, decreased to an average value of about ten per year in each of the Italian university with nuclear engineering degree. The number of the nuclear engineering graduated students has increased up to about 300 in the early 1980s and stabilizes to about 100 in the last years.

Figure X–1 represents the history on nuclear engineering students (graduated) in Italian universities from 1960 to 2001. This trend shows the peak value of graduated students in early 1980s. Figure X–2 shows the nuclear engineering student (both enroled and graduated) trends from 1991 to 2003 for the University of Torino while Fig. X–3 gives the nuclear engineering student variation for university of Pavia.

The politically biased interpretation of the 1987 referendum and its consequences severely affected the nuclear education in the country. To combat with this declination from nuclear education, the universities were silently given the task to keep the culture, expertise, research and the education in the nuclear sector alive. Moreover, after several years, ENEA Government research organization was officially assigned the task to

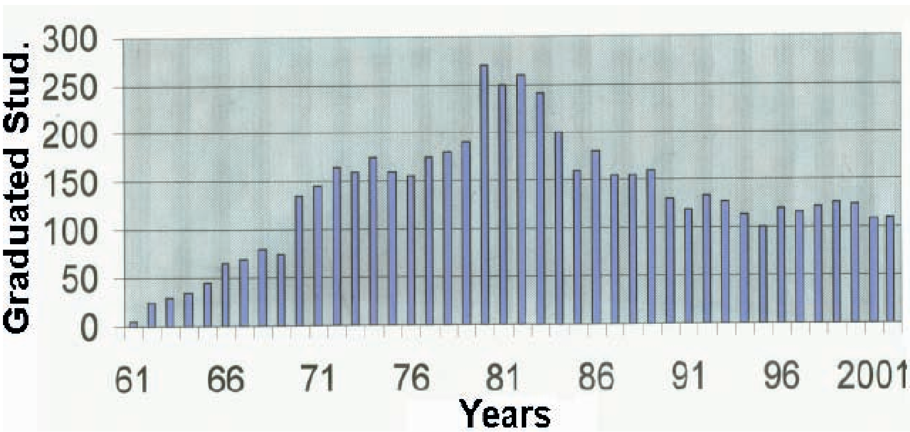


FIG. X–1. Annual variation trend of nuclear engineering graduated students in Italian universities.

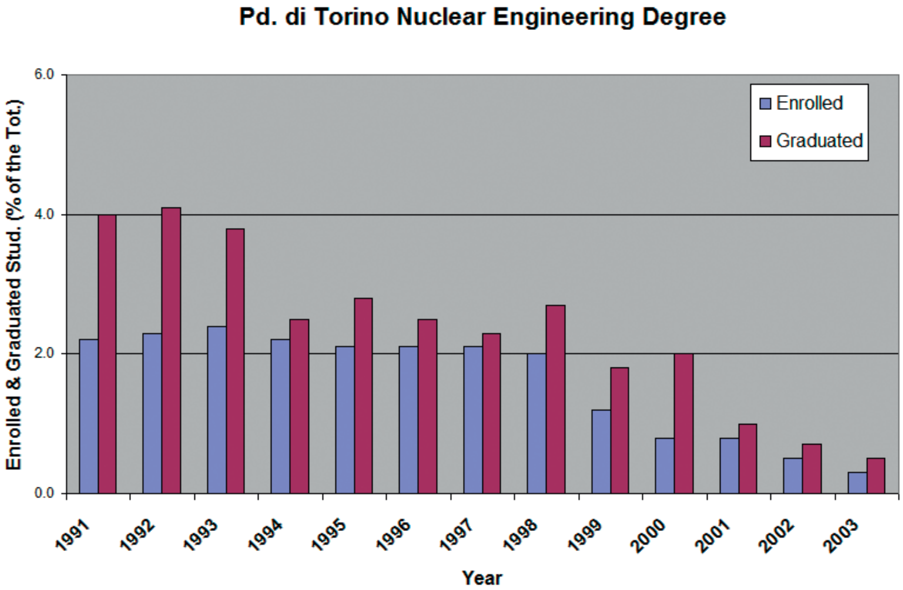


FIG. X–2. Annual variation of nuclear engineering enroled and graduated students (percentage of the total) in Torino University.

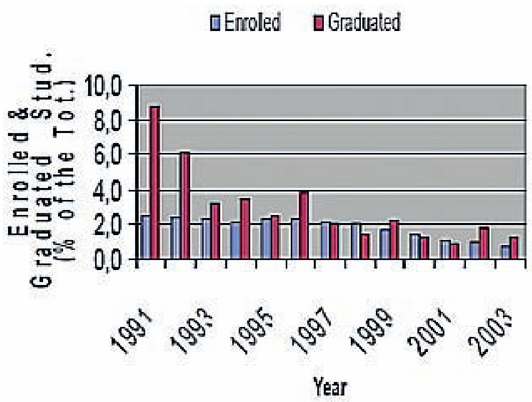


FIG. X–3. Variation of nuclear engineering enroled and graduated students (percentage of the total) in Pisa University.

'maintain a nuclear presidium' in Italy. The Italian universities tried to survive themselves in this very difficult period, i.e. mid 1990s to the present. They have been focusing on academic and research stand points.

With respect to academic points of view, the universities update their curricula so that well quality engineers, with enhanced knowledge in the basics and the new trends in nuclear engineering, can be produced. The board of each nuclear engineering course decided to introduce new topics concerning innovative reactors and nuclear fusion engineering. Also, improvement was initiated in the analysis of issues related to the radiation protection and engineering. It was also decided to maintain the former nuclear engineering course formation which gave the students good basic preparation and a systematic approach toward complex engineering problems. From a research point of view, they are trying to operate mainly on an international level and by means of their Consortium CIRTEN to compensate for the serious reduction of the national economic support and consequent risk of losing competences and young researchers interested in acquiring them.

The Bologna scheme of education has been implemented in all Italian universities. This scheme is based on the European credit system (ECTS) which needs three years (180 ECTS) for a first level degree (Bachelor's degree), two years (120 ECTS) for a second level degree (master's degree) and three years for a PhD degree. The following five universities offer a degree in nuclear education. Table X–1 shows the summary of nuclear engineering degree awarding institutions in Italy.

The *Polytechnics di Milano* offers an MSc in nuclear engineering with subjects on nuclear measurements and instrumentation (10 ECTS), nuclear plants and applied radiation protection (10 ECTS), the project of radiation

TABLE X–1. THE LIST OF INSTITUTIONS AWARDING NUCLEAR ENGINEERING DEGREES IN THE COUNTRY

Institution	Department	Degree
Polytechnics di Milano	Nuclear Engineering	MSc Nuclear engineering
Politecnico di Torino	Energetics (DENER)	MSc Energy and nuclear engineering BSc Energy engineering
University of Pisa	Mechanical Engineering and Nuclear Production	BSc Engineering of industrial and nuclear safety MSc Nuclear and industrial safety engineering
University of Palermo	Nuclear Energy	MSc Nuclear safety and tech. engineering
University of Roma	Energy	MSc Energy engineering

fields (10 ECTS), safety and control of nuclear power plants (10 ECTS), radiation application to medicine (10 ECTS), one additional course among the following, computational methods for signal analysis (10 ECTS), computational methods for safety and risk analysis (10 ECTS), technology of nuclear materials (10 ECTS), radiochemistry and radiation chemistry (10 ECTS) and a master's thesis (20 ECTS).

MSc in nuclear engineering — two years.

The *Politecnico di Torino* awards a master's degree in energy and nuclear engineering with nuclear subjects i.e. nuclear reactor physics/radiation protection (10 ECTS), nuclear power plants engineering and fuel cycle (5 ECTS), transport theory/fusion plasma physics (10 ECTS), nuclear power plants thermal hydraulics/nuclear power plants safety (10 ECTS), fusion engineering (5 ECTS), nuclear power plants technology (5 ECTS), radiation application to medicine (5 ECTS) along with a master's thesis (15 ECTS+5 ECTS for stage).

BSc energy engineering, MSc energy engineering and nuclear engineering.

The *University of Pisa* has an MSc nuclear and safety engineering with subjects as nuclear power plants protection and safety (12 ECTS), plant measurement and radioprotection (9 ECTS), design and construction of nuclear plants (12 ECTS), reactor physics and numerical methods for nuclear reactor (12 ECTS), nuclear power plants (6 ECTS), instrumentation and control in nuclear plants (12 ECTS), waste treatment and decommissioning of a nuclear plant (6 ECTS) and a master's thesis of 20 ECTS.

BSc in engineering of industrial and nuclear safety — three years.

MSc in nuclear and industrial safety engineering — two years.

The *University of Palermo* issues the degree of master's in nuclear safety and technology engineering and from next year it will start energy engineering. The *University of Roma* offers a master's in energy engineering.

Some other universities i.e. the University of Bologna, Pavia and Padova only offer some nuclear technology related courses rather than a pure nuclear degree. For example, the University of Bologna offers reactor physics, nuclear technology, thermo-fluid dynamics, plasma physics and radiation protection, etc.

Annex XI

JAPAN

Nuclear research in Japan was restarted in 1952 after World War II. The legislation of the Atomic Energy Act in 1955 provided the basis nuclear development of the country. The nuclear engineering course was inaugurated in the Department of Applied Physics of Tokai University in 1956 as the first nuclear engineering department in Japanese Universities. Major organizations like the Science and Technology Agency (STA), Japan Atomic Energy Research Institute (JAERI) and others started around 1955. The first reactor, JRR-1 went critical in 1957 at JAERI. Since then, various research reactors including general research reactors, educational or training reactors, and test reactors have been constructed.

Japan is the only country who has faced the devastating effects of nuclear weapons in World War II. Despite this terrible situation, Japan has embraced the peaceful use of nuclear technology to provide a substantial portion of its electricity. In 1966, its first commercial reactor started operation. Today, the country has 55 power reactors in operation, generating about 30% of the country's total electricity production. Japan plans to increase this to 41% in 2014.

Needs for nuclear scientists and engineers are closely related to the national nuclear programmes. The current status of nuclear power generation in Japan has been given above. Following are the main nuclear activities that need a nuclear technical work force in the country:

- Safe operation of current nuclear power plants;
- Development of new power and research reactors;
- Activities related to front end and back end sectors of fuel cycle;
- Nuclear related activities as fusion power development.

The public perception plays an important role in attracting talent towards this particular discipline of education. Unfortunately, since the Chernobyl incident, the nuclear community is facing negartive public perception regarding the risks of a nuclear accident. Specifically, in Japan, a series of local incidents have been reported in mass media such as; the sodium leak in Monju in December 1995, fire at the asphalt solidification plant in March 1996, invention of inspection data of spent fuel transportation casks in October 1997, criticality accident at JCO in Tokaimura in September 1999. The latest one, the JCO accident, is extremely serious because it seems to suggest at present a deteriorating situation of Japanese technologies. These accidents affected the public perception of nuclear education which reinforced the decreasing trends of nuclear engineering in the universities. According to a CECD report in 2002, in Japan, there has been an imbalance between graduated students and recruitment i.e. the number of students graduated from a nuclear related master’s course were almost 300 while the recruitment by nuclear engineering was about 70 every year.

In order to prevent nuclear education from a serious downturn, during the 1990s, the government changed its policy for national universities having nuclear engineering departments and restructured nuclear education. Major changes are to emphasize education on a graduate school level. The department for undergraduate education has been renamed at most of the universities. Nuclear engineering departments have disappeared from national universities except for Hokkaido University. Instead, the key words for the new department names are energy, quantum system and science. The key words, nuclear or nuclear energy are retained in the names of the graduate courses. Engineering fundamentals have been emphasized in undergraduate education. Moreover, nuclear engineering was projected as a study to utilize nuclear reactions for the welfare of mankind. Major nuclear reactions are fission and fusion, but dealing with other nuclear reactions is within the category of nuclear engineering. Since April 2004, all national universities have been reformed.

Table XI–1 shows the current names of the departments engaged in nuclear engineering education. Major national universities have changed the names of the former nuclear engineering departments except for the Tokyo Institute of Technology who kept the name of Nuclear Engineering Department and education curriculum of nuclear engineering.

TABLE XI–1. NUCLEAR EDUCATION IN GRADUATE SCHOOLS OF NATIONAL UNIVERSITIES

Institution	Department	Degree
Tokyo Institute of Technology	Nuclear Engineering	Graduate
Kyto University	Nuclear Engeering	Graduate/undergraduate
Osaaka University	Environmental Engineering	
Tohoku University	Quantum Energy Engineering	
University Tokyo	System Quantum Engineering	Graduate/undergraduate
Nagoya University	Material Science and Material Engineering	Graduate/undergraduate
Kyushu University	Energy Quantum Engineering	Graduate/undergraduate
Kobe University	Marine Engineering	
Fukui University	NuclearEnergy and Safety	
University of Tokyo	Nuclear Power	Graduate/undergraduate
University of Tokyo	Nuclear International	Graduate/undergraduate
Hokkaido University	Quantun Energy Engineering	Graduate/undergraduate

The *Tokyo Institute of Technology* started in 1957 with a graduate level nuclear engineering programme. During the 1990s, when the nuclear engineering education flow was facing 'reverse wind', efforts were made at the Tokyo Institute of Technology to sustain nuclear engineering research and education programmes with collaboration of outside institutes such as Japan Society for the promotion of Science (JSPS), Japan Atomic Energy Research Institute (JAERI), Japan Atomic Energy Agency (JAEA) and private companies etc. Since its start in 1957, it has produced about 1000 master's degree students and 200 Doctoral students from its nuclear engineering department. Figure XI–1 shows the recruitment statistics of its master's graduates for the past 19 years where the career courses are classified into four categories i.e.:

— Nuclear and heavy industries;
— Non-nuclear industries;
— Admission to PhD programme;
— Others.

The *University of Tokyo* operates two departments together i.e. Nuclear Engineering and Management and the other is the Nuclear Professional School. This university has fast neutron source reactor, femto second linear accelerator and femto second terra-watt laser system, a tandem Van de Graaf accelerator and a Tandetron for heavy irradiation research and a tandem Van de Graaf accelerator for accelerator mass spectrometry etc. The research reactor and the linear accelerator are used for exercise by the University of Tokyo students, both undergraduate and graduate level. The research reactor is also used for the reactor operation and kinetics exercise of the students of Tohoku University and Hokkaido University.

The department of Nuclear Engineering and Management produces master's and doctoral students along with its unique features to cover the social science aspects as well as the nuclear science and engineering. It consists of three main research areas, nuclear energy, nuclear-socio engineering and radiation applications. Its annual capacity is 23 master's students, 13 Doctoral students. Foreign students are accepted above from the capacity.

The nuclear professional school is a type of professional school who is jointly operated with JAEA. The nuclear professional school is a one-year graduate school. The graduates are given a master's degree of a nuclear professional. No thesis study is required, but extensive schooling is provided. The capacity of students is 15. Mostly it prepares its graduates for utilities, vendors, research institutes and the governments.

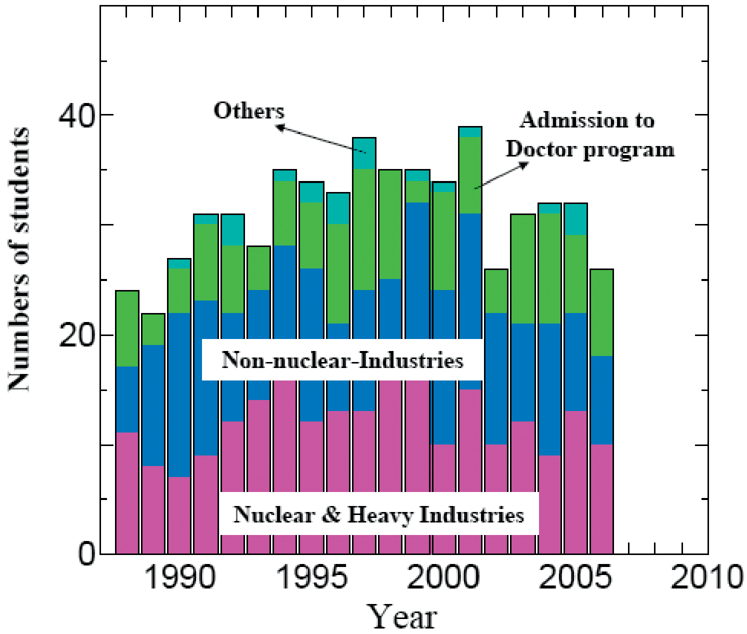


FIG. XI–1. Employment of master graduates from department of nuclear engineering.

Annex XII

KOREA, REPUBLIC OF[6]

XII–1. BACKGROUND

The Republic of Korea started its nuclear activities when it joined the International Atomic Energy Agency in 1957. In 1958 the Atomic Energy Law was enacted and the government established the Office of Atomic Energy in 1959. Its first research reactor was made critical in 1962, and commercial NPP operation began in 1978. From the middle of 1980s, The Republic of Korea launched its self-reliance programme for nuclear power, developing its own reactors, OPR-1000, which are in operation, and APR-1400 which is under construction.

Han-Yang University and Seoul National University opened nuclear engineering courses in 1958 and 1959 respectively. Since then, the number of universities offering nuclear engineering courses increased gradually, amounting to seven. The universities have supplied key manpower for the Korean nuclear power programmes. In parallel, the Korea Atomic Energy Research Institute (KAERI) opened its Nuclear Training Centre in 1967, to support manpower development for the nuclear power programmes. Along with the progress of power programmes, a number of training centres have been created specializing in nuclear power operation, nuclear power maintenance, nuclear safety, etc.

Nuclear human resource development in the Republic of Korea began with the establishment of a nuclear engineering department in two universities in the late 1950s. Then, the government awarded scholarships to more than 200 scientists for their study of nuclear energy abroad (1958–1962), as seeds for the future development of nuclear technology. In the 1960s, Korean nuclear education and training dealt with basic nuclear technology such as the utilization of radioisotopes and radiation protection. In the 1970s, education and training was oriented to basic nuclear power technology using the TRIGA Mark II research reactor at KAERI for personnel from the nuclear power project. This was expanded to include education and training in conventional fossil fuel power plants, and oversee on the job training in supplier’s organizations. The first half of 1980s was a period when further education and training efforts were made to support the accumulation of nuclear power technology including nuclear safety control, and related fields for nuclear industries. The education and training in the second half of 1980s and the 1990s was devoted to the provision of courses mainly for the localization and transfer of foreign suppliers’ technologies to Korean nuclear personnel through classroom based courses in the Republic of Korea as well as overseas on-the-job training and joint design in the suppliers’ organizations. The courses covered NSSS design and reactor safety, the design of nuclear fuel, rod and assembly, safety analysis, thermal hydraulic core design, and nuclear fuel service. From this period, the Republic of Korea began providing its own international courses to other countries. Entering into the first decade of the new millennium, the Republic of Korea’s nuclear education and training has become more active in sharing its experience with other countries; as discussed below.

XII–2. NEEDS FOR NUCLEAR ENGINEERS

The total manpower engaged in the nuclear field in the Republic of Korea amounted to 49 713 people as of 2007 [XII–1, XII–2], which can be categorized into two areas, namely, nuclear industry personnel (20 810) and radiation workers (28 903). Figure XII–1 shows the trends of the manpower during the past 11 years, where the number of nuclear industry personnel stays almost the same, while that of radiation workers increases steadily.

A recent study [XII–3] estimated nuclear manpower required by sectors (i.e. nuclear power, nuclear isotope utilization and academia) until 2030, as shown in Table XII–1. The estimate was made in three cases of assumption, namely business-as-usual (BAU), alternative (Alt) and high cases, corresponding to a set of contrasting but not extreme assumptions about parameters relevant to the implementation of nuclear power programmes. The Alt case is based on the Forth National Electricity Plan (2008). According to the estimate for the Alt case, the required manpower in nuclear power sector will increase sharply from 2010 (about 17 000 people) to 2020 (about

[6] Prepared by B-J. Min, Korea Atomic Energy Research Institute (KAERI); Nuclear Training Centre.

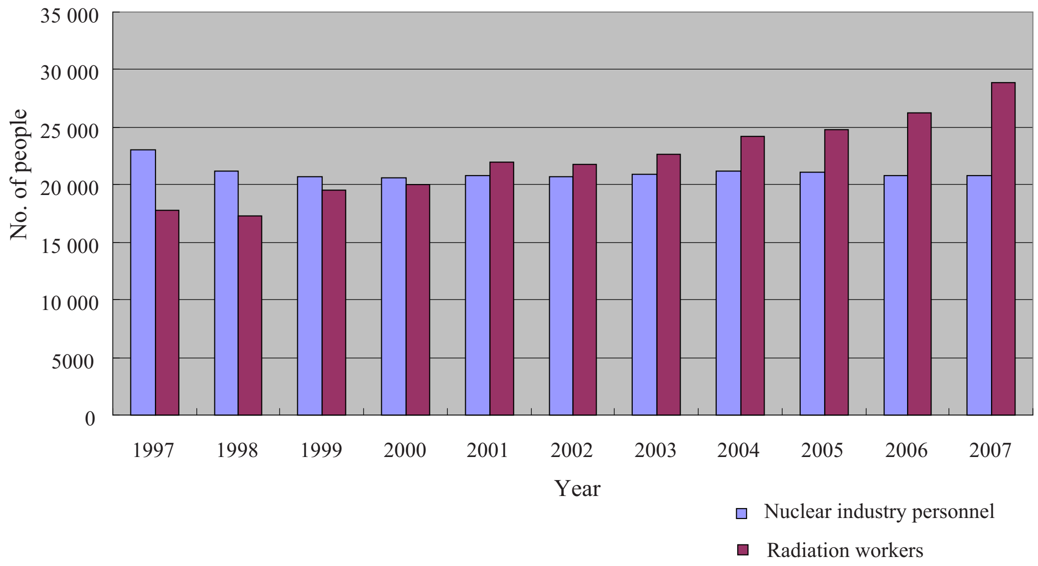


FIG. XII–1. Trends of manpower in the nuclear field in the Republic of Korea.

TABLE XII–1. ESTIMATED NUCLEAR MANPOWER DEMAND BY SECTORS IN THE REPUBLIC OF KOREA.

Sectors	2005			2010			2020			2030		
	BAU	Alt	High	BAU	Alt	High	BAU	Alt	High	BAU	Alt	High
Nuclear power		18 538		19 126	17 360	19 304	27 317	29 898 (61%)	32 299	34 229	36 220 (95%)	45 793
Nuclear radio-isotope utilizing		23 808		23 887	23 649	23 911	37 833	38 356 (61%)	38 842	55 470	56 007 (135%)	58 590
Academic		1454		1620	1613	1621	1963	1968 (35%)	1988	2291	2301 (58%)	2364
Total		43 800		44 633	42 622	44 835	67 114	70 222	73 129	91 990	94 528	106 747

30 000 people), leading to a doubling of the manpower demand by 2030 (about 36 000 people) compared to the current manpower level.

XII–3. EDUCATIONAL SYSTEM AND EDUCATIONAL INSTITUTIONS INVOLVED IN NUCLEAR EDUCATION

The Korean education system consists of primary school (6 years), middle school (3 years), high school (3 years) and university (4 years) or junior college (2 years). The National Technical Qualification System recognizes qualifications for engineers and craftsmen whose technical capabilities have reached a specified level, and accelerates the use of their capabilities. Figure XII–2 shows the structure of the qualification system linked with the national education system, where those who want to become engineers or craftsmen are required to take technical qualification tests, in their respective fields, after completion of their required education and/or training.

Seven universities are offering nuclear engineering courses as shown in Table XII–2.

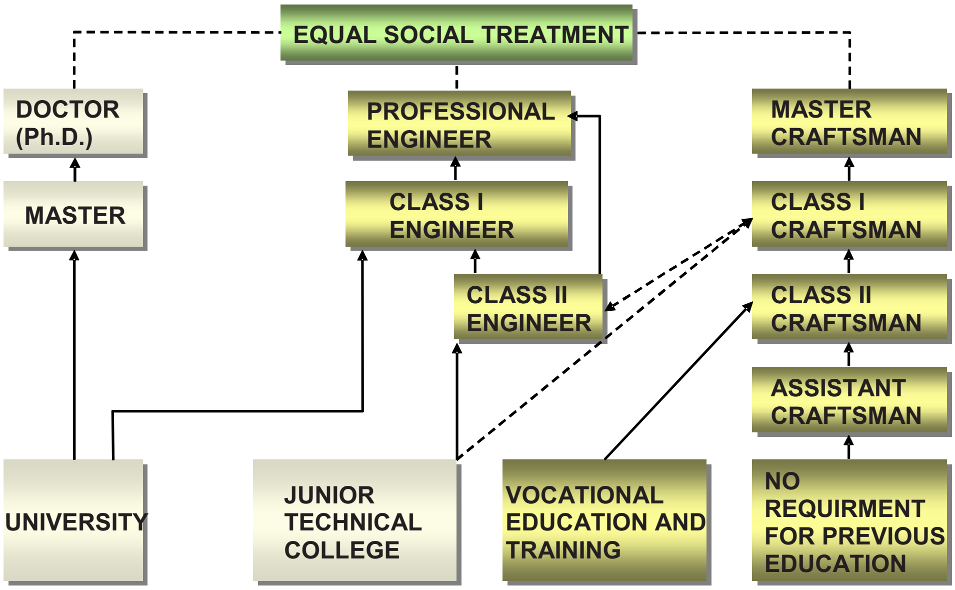


FIG. XII–2. The structure of National Technical Qualification System.

TABLE XII–2. STATUS OF UNIVERSITIES OFFERING NUCLEAR ENGINEERING COURSES (as of 2008)

Name	Web-address	Course level	No. of students
Cheju National University	www.jejunu.ac.kr	BSc, MSc, PhD	125 (104/12/9)
Chosun University	www.chosun.ac.kr	BSc, MSc, PhD	193 (167/25/1)
Hanyang University	www.hanyang.ac.kr	BSc, MSc, PhD	231 (183/21/27)
KAIST	www.kaist.ac.kr	BSc, MSc, PhD	146 (25/45/76)
Kyunghee University	www.khu.ac.kr	BSc, MSc, PhD	165 (151/10/4)
Seoul National University	www.snu.ac.kr	BSc, MSc, PhD	190 (137/36/17)
UST-KAERI	www.ust.ac.kr	MSc, PhD	6 (0/2/4)

TABLE XII–3. STATUS OF MAJOR NUCLEAR EDUCATION AND TRAINING ORGANIZATIONS IN THE REPUBLIC OF KOREA (as of 2008)

Name	Web-address	Course field	Number of trainees/year
NTC/KAERI	www.kntc.re.kr	Nuclear technology	5910 (staff) 1009 (domestic) 226 (international)
INSS/KINS	www.kins.re.kr	Nuclear regulation and safety	1475 (staff) 647 (domestic) 48 (international)
NPEI/KHNP	www.e-khnp.com	NPP operation	14 672 (staff)
NMTC/KPS	www.kps.co.kr	NPP maintenance	
KNEF	www.okaea.or.kr	Public acceptance	

Nuclear research institutions and industries have respective education and training functions. They include the Nuclear Training and Education Centre (NTC) of KAERI, International Nuclear Safety School (INSS) of Korea Institute for Nuclear Safety (KINS), Nuclear Power Education Institute (NPEI) of Korea Hydro and Nuclear Power (KHNP), Nuclear Maintenance Training Centre (NMTC) of Korea Plant Service (KPS), Korea Nuclear Energy Foundation (KNEF). Table .XII–3 provides key information of those organizations.

There are ongoing education and training programmes both at domestic and international levels. The NTC deals with subjects mainly on self reliance experience on nuclear power policy, planning and management; nuclear power technology including small and medium sized reactors, and advanced reactors; nuclear fuel cycle technology; research reactors; applications of radioisotopes and radiations to health, agriculture, industry, environment, etc., and radiation measurement and radioisotope handling. The INSS provides courses on radiation protection and emergency preparedness, for nuclear regulatory inspectors, on regulatory practices, etc. It also offers courses for the public and in particular, an International Nuclear Safety Master's Degree Programme in cooperation with KAIST. NPEI is operating in-house training programmes in the field of operation, maintenance, technical support, and construction of nuclear power plants, in three levels respectively, i.e. basic, advanced, and managerial course levels. KNEF is implementing education programmes for public understanding of nuclear issues.

A national project on nuclear human resource development offers programmes to university students. A programme is devoted to the cultivation of future nuclear R&D leaders through the dispatching of qualified university students and young researchers to foreign universities, research centres, and international events. A programme promotes making use of highly qualified nuclear human resources and education/training facilities for developing future manpower adequately. This includes courses operated by KAERI for university students majoring in science and engineering technology as well as in nuclear engineering to obtain practical experience on experiments on research reactor operation and associated research. A programme encourages participation in international education programmes (e.g. education and training using the research reactor at Kyoto University, Japan) and university student exchange programmes. A scholarship programme covers the teaching of university students to conduct individual research on nuclear subjects, and supporting new scientists in nuclear and combined advanced technology to establish human resources base for nurturing core experts and star researchers.

XII–4. FOREIGN STUDENT ENROLMENTS

As of 2007, 28 foreign students (MSc — 26, PhD — 2) received their degrees from the nuclear power related departments of these universities and 35 foreign students (BSc — 6, MSc — 17, PhD — 12) are now studying for degrees [XII–4, XII–5].

In addition, RCA Post-doctorate programme has been in operation since 2002 and it has awarded scholarships to 45 students from nine countries (e.g. Bangladesh, China, India, Indonesia, Vietnam, etc.) for their study in Korean research institutions.

XII–5. AVAILABILITY OF RESEARCH AND EXPERIMENTAL FACILITIES

A large number of research and experimental facilities are available from research institutions and universities. Important facilities include: research reactors, a thermo-hydraulic test facility, a simulator, an underground research facility, and an accelerator.

A research reactor called HANARO (High flux Advanced Neutron Application Reactor) with 30 MW is operated, together with associated facilities, by KAERI for the purpose of neutron beam analysis, irradiated material testing, radioisotope production, neutron activation analysis and other applications including education and training. Another research reactor, AGN-201K, with a maximum thermal power of 10 W, at Kyunghee University is used for education.

A large scale thermal-hydraulic integral effect test facility, ATLAS, is operational at KAERI for research conduction on evolutionary pressurized water reactors, OPR-1000 and APR-1400, through simulations for various accident and transient scenarios.

KAERI Compact Nuclear Simulator is intended to provide university students, researchers on reactor system design and safety assessment, and industry personnel with a tool for education and practice on a PWR system.

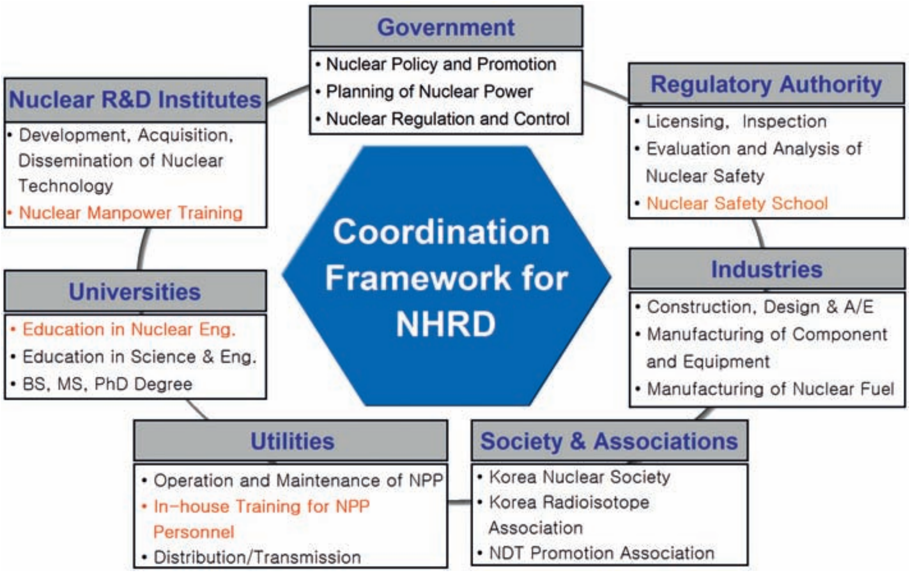


FIG. XII–3. Coordination framework for nuclear HRD in the Republic of Korea.

KAERI Underground Research Tunnel (KURT) serves as a field scale facility for research on the deep geological disposal of radioactive waste, in terms of geology, hydrology, geochemistry and migration of radio-nuclides.

The Pohang Light Source (PLS) is designed to provide synchrotron radiation with continuous wavelengths down to one. The PLS is a national user facility, owned and operated by the Pohang Accelerator Laboratory (PAL) and POSTECH on behalf of the Korean Government. It has been serving domestic and international users since September 1995.

XII–6. COOPERATION/COLLABORATIONS WITH INDUSTRY AND GOVERNMENT

The national framework of cooperation on nuclear human resource development in the Republic of Korea is formulated by sharing responsibilities along with the expertise of each involved party under the leadership of the government, as shown in Fig. XII–3.

For example, the Korea International Cooperation Agency (KOICA), as part of its programme, provides foreigners with short term courses on nuclear technology, which are supported by education and training organizations from research institutions and industries. In the case of NTC/KAERI, the centre is cooperating with universities to offer university students short term courses for conducting experiments using its research reactor, HANARO, and associated facilities. Another example is NSS/KINS-KAIST cooperation by which relevant lecturers from KAIST are provided for the operation of NSS's courses.

XII–7. NATIONAL AND INTERNATIONAL COOPERATION AND EDUCATIONAL NETWORKS

A concept of a national network, called K-NET for nuclear education and training, was conceived in 2003. Meetings by nuclear education and training centres from research institutions and industries, and universities have been organized.

Cooperation with the IAEA and RCA is of primary importance and deals with the provision of education and training courses in various fields of nuclear power and non-power applications to Member States in need. Also, the Republic of Korea is cooperating with countries including Vietnam, Indonesia, the UAE and Egypt in providing them with consultation and education/training primarily on the introduction of nuclear power as well as research reactor technology and non-power application technology.

The Republic of Korea participates in various international networks related to nuclear education and training such as the WNU (World Nuclear University), ANENT (Asian Network for Education in Nuclear Technology), ANSN (Asian Nuclear Safety Network) and FNCA (Forum for Nuclear Cooperation in Asia). KAERI hosted the 2007 WNU Summer Institute and continues to hold WNU courses jointly. KAERI is doing major roles for ANENT in the field of development and operation of web-portal and cyber platform, and implementation of e-training using the platform. KINS is actively participating in ANSN.

XII–8. BEST PRACTICES

As mentioned earlier, education programmes for public understanding of nuclear technology is implemented by KNEF, which includes: revision of the contents on nuclear issues appearing in textbooks for primary, middle and high school students; development of educational materials on nuclear issues; provision of diverse opportunities for the school students and teachers to be familiarized with nuclear activities (e.g. education, training and facility visit for teachers, nuclear camp for students) and operation of exhibition facilities. Also, KINS is carrying out programmes for school teachers and students, non-governmental organizations (NGO), and the public to experience nuclear safety through lectures, facility visits and exercise.

REFERENCES TO ANNEX XII

[XII–1] MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY, The Survey on the Status of the Nuclear Industries in 2007 (2009).

[XII–2] http://www.ri.or.kr/

[XII–3] MIN, B.J., KAERI's Nuclear Training Programme: Nuclear HRD strategy and Policy in Korea, Korea Atomic Industrial Forum, Proceedings of 24th KAIF/KNS Annual Conference, 8–10 April 2009, Seoul (2009).

[XII–4] Korea Nuclear Industry Forum, Nuclear Energy Yearbook 2008 (2008).

[XII–5] KOREA ATOMIC ENERGY RESEARCH INSTITUTE, Establishment of the International Nuclear Education/Training and its Cooperation Framework for Nuclear Transparency, KAERI/RR-2953/2008 (2009).

Annex XIII

LITHUANIA[7]

XIII–1. BACKGROUND

In the north-east of the country, the Ignalina nuclear power plant with two largest Soviet reactors of their type, known as RBMK-1500 has been in operation. Construction of this NPP started in 1978 and made critical in 1983 and 1987, with a 30-year life cycle. A third unit was planned but not completed and then demolished.

When Lithuania applied for EU membership, it was required by the EU to close both RBMK units. Political decision meeting this requirement was included into the EU entry agreement despite the numerous safety improvements implemented and the absence of serious safety concerns agreed on by the majority of both Lithuanian and foreign experts. Therefore unit 1 was closed in December 2004 and unit 2 was closed at the end of 2009. Currently one operating unit 2 at Ignalina NPP is generating net power up to 1300 MW(e), supplying up to 70% of the total country's electricity consumption.

The history of nuclear education in Lithuania is closely related with the development of the nuclear industry and infrastructure. It can be broken down into the three periods. The main player in this field is Kaunas University of Technology (KTU) — the biggest technical university in the country with 29 years of experience in nuclear engineering education.

XIII–1.1. Period 1978–1991

Since initially Ignalina NPP was staffed by specialists from the former USSR, education of nuclear engineers started at Kaunas University of Technology in 1978. Nuclear study programmes, curriculum, textbooks and manuals were the same as in the other higher schools of the former USSR. Using support from the Moscow Energy Institute and other Soviet institutes and NPPs, 56 nuclear energy engineers were educated during this period (see Fig. XIII–1). In 1986, just after the Chernobyl NPP incident, training of nuclear energy specialists at KTU was suspended.

XIII–1.2. Period 1991–2007

Just after Lithuania's independence was restored in 1991, education of nuclear energy specialists at KTU was renewed. Since then, the system of studies in nuclear engineering has been substantially modified and modernized, in order to implement the best practice of highly developed western countries. Seventy bachelors and 60 masters were educated during this period enabling to fulfil minimal and gradually decreasing needs for nuclear engineering specialists in the frame of approaching the closure of the Ignalina NPP (see Fig. XIII–1).

XIII–1.3. Period after 2007

On the basis of positive results of the feasibility study of construction of new NPP, a National Energy Strategy was endorsed in 2007. A new NPP is scheduled to be built in Lithuania by 2015. A decree endorsed by the Lithuanian Parliament in June 2007 recommended organizing the construction of a new NPP in cooperation with Latvia, Estonia and Poland. Currently, preparation for construction of the new NPP is going on: the national investor LEO LT and Visaginas NPP — core project management team has been established, the environment impact report has been prepared and analysed, possible technologies and sites have been examined, and other studies are being conducted or continued.

[7] Prepared by S. Ziedelis, Kaunas University of Technology.

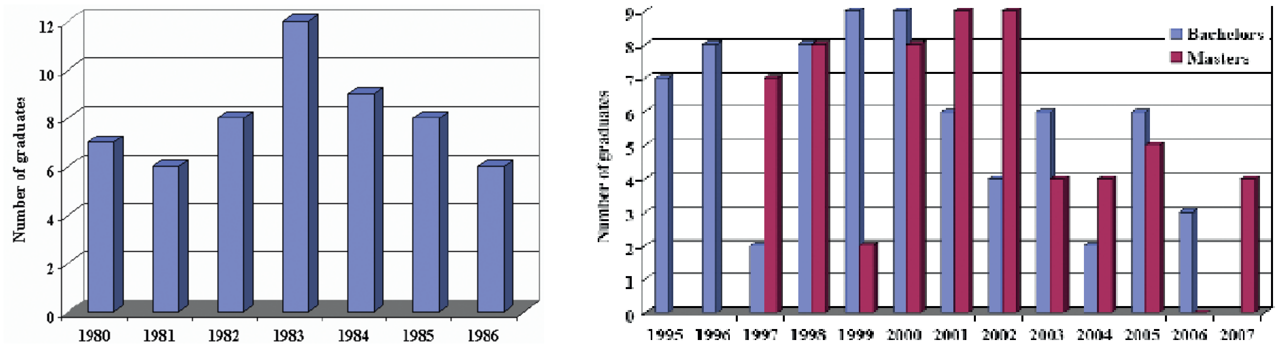


FIG. XIII–1. The history of nuclear engineering specialists' preparation at KTU.

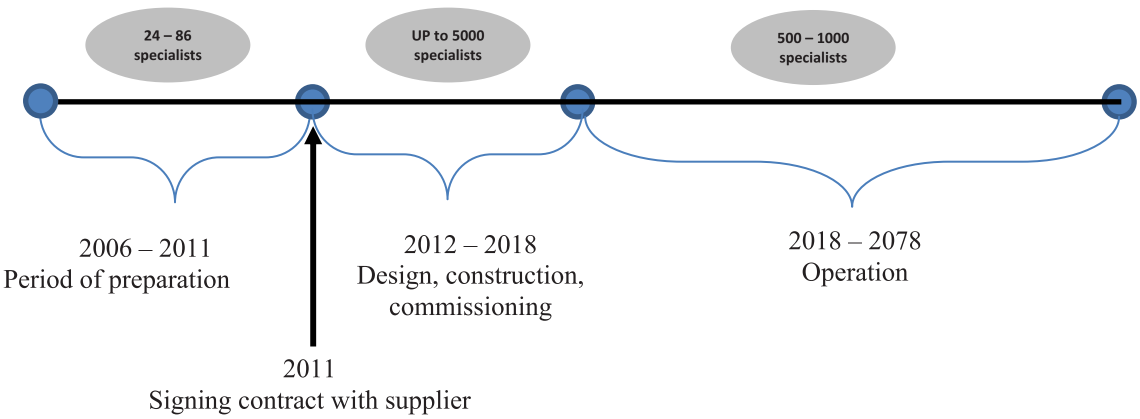


FIG. XIII–2. Dynamics of number of specialists needed for a new NPP.

XIII–2. NEEDS FOR NUCLEAR ENGINEERS

In the context of the approaching construction of a new NPP and developing an entire nuclear infrastructure, demand for nuclear engineering specialists in Lithuania started to grow in 2006 after a long period of gradual decreasing (see Fig. XIII–2). The number of required specialists and distribution of their specializations are changing during the different stages of the project realization (see Figs XIII–2 and XIII–3 and Table XIII–1). At the maximum, up to 5000 specialists will be required during design, construction and commissioning of a new NPP, but most of them will be subcontracted civil, mechanical or electrical engineering specialists and only 360 of them should have an education in nuclear engineering. Taking into account the decommissioning of the existing Ignalina NPP and future staffing needs of nuclear and radiation safety regulatory bodies; as well as periodically engaged maintenance, repair, research, education and other technical support organizations composing national nuclear energy infrastructure, the total needs of nuclear expertise could be evaluated as follows:

— For Ignalina NPP decommissioning service: 1600 persons;
— For a new NPP during construction and commissioning: up to 360 persons;
— For a new NPP during operation: 500–1000 persons;
— For nuclear energy infrastructure: 500–1000 persons.

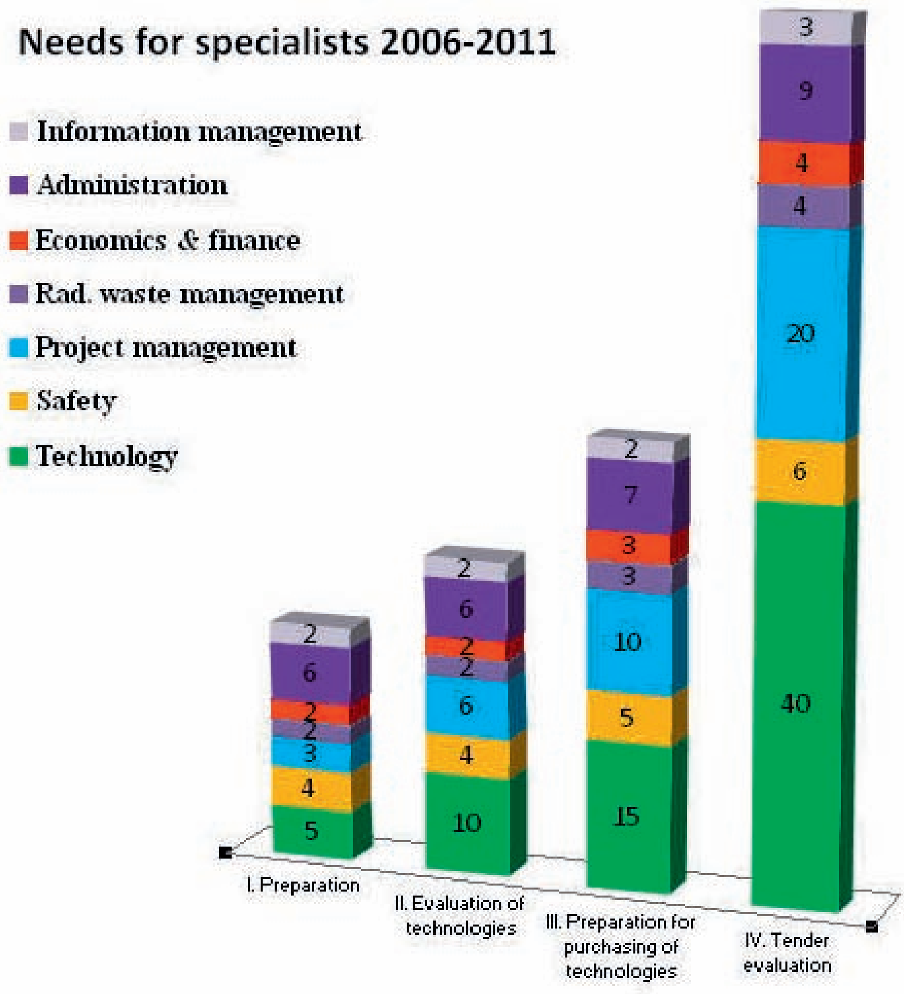


FIG. XIII–3. Needs for specialists during the first stage of construction of the new NPP.

TABLE XIII–1. NEEDS FOR NUCLEAR ENGINEERING SPECIALISTS FOR A NEW PLANNED POWER PLANT DURING CONSTRUCTION, COMMISSIONING AND OPERATION

Mission of personnel	Number of personnel
Safety and radiation inspections	60
New NPP construction and commissioning:	360
— Project management team;	10
— Engineering and procurement;	37
— Construction;	175
— Testing, start-up, commissioning;	95
— Contract monitoring, quality assurance.	40
Operation of new NPP with two units:	600
— Site management and direction;	10
— Unit operation and control;	140
— Safety — quality audits;	18
— Maintenance and technical support;	270
— Site support functions.	160

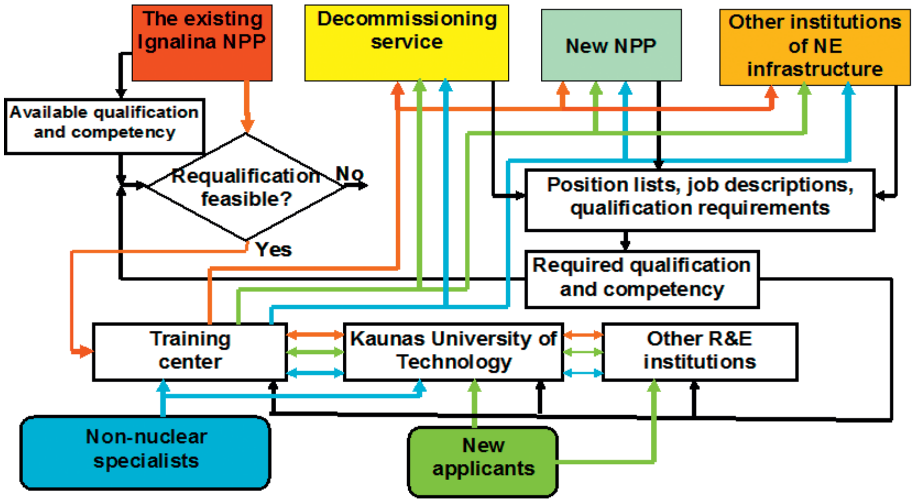


FIG. XIII–4. Possible staffing routes of a new NPP and nuclear education infrastructure.

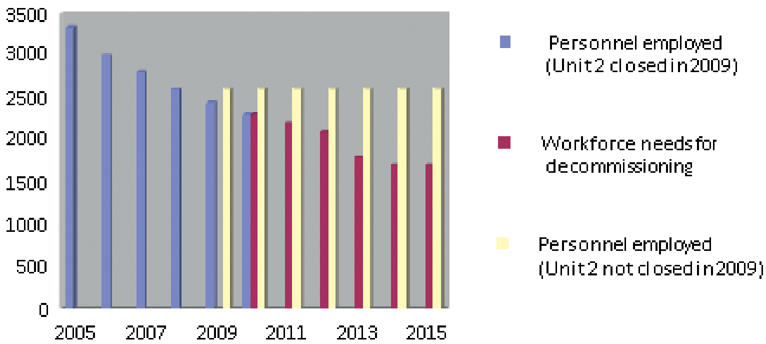


FIG. XIII–5. Planned changes in numbers of personnel of Ignalina NPP.

To satisfy this workforce demand, different staffing ways can be employed (see Fig. XIII–4). Currently, the biggest reserve of human resources — highly qualified, well trained and experienced nuclear engineering specialists is at the Ignalina NPP whose annual reduction of total staff was approximately 2700 persons at the beginning of 2009 (see Fig. XIII–5). However, the big part of Ignalina NPP's personnel currently is 48–52 years of age, and 2015–2018 will be the personnel approaching a retirement age. Employment of these specialists in a new NPP or other institutions of nuclear energy infrastructure is problematic due to various reasons, and the possible staff contribution from the existing Ignalina NPP seems to be not more than 20–30%.

The remaining part of the future nuclear workforce demand should be covered by newly educated nuclear specialists. It is a serious challenge for Lithuanian educational institutions because of their insufficient capacity.

XIII–3. EDUCATIONAL SYSTEM AND EDUCATIONAL INSTITUTIONS INVOLVED IN NUCLEAR EDUCATION

Higher education in Lithuania is divided into undergraduate (Bachelor), graduate (master), and postgraduate (doctoral) studies. The university awards bachelor's, master's, and doctor's degrees. Undergraduate studies in four years lead to a Bachelor of Science degree (BSc) and a master's degree (MSc) in two or one and a half further years (see Figs XIII–6, XIII–7 and XIII–8). The possession of a bachelor's degree or other qualification of higher education is a prerequisite of entry into a master's degree programme. The Doctor of Science degree (DSc), which equates with a PhD or with a somewhat higher degree elsewhere, takes a further four years to acquire and is only awarded to those whose research provide a significant and original contribution in the selected field.

FIG. XIII–6. Structure of study system in Lithuanian universities.

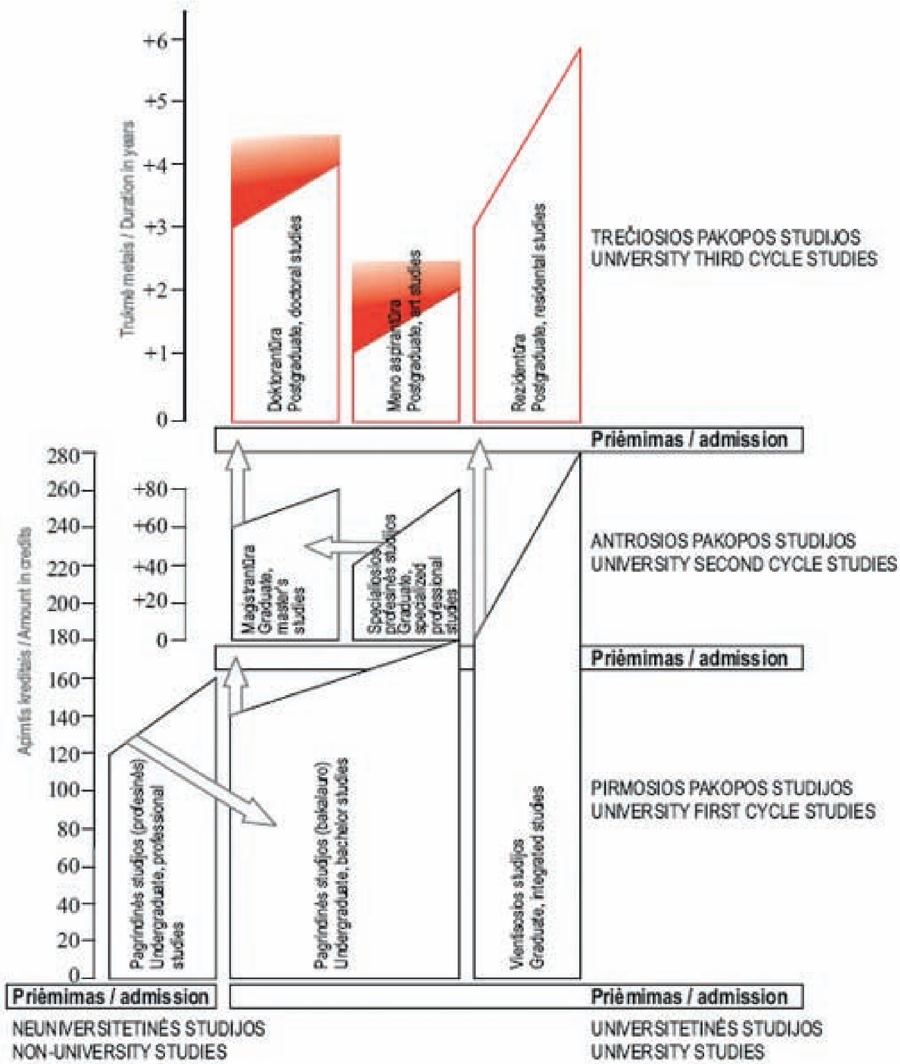


FIG. XIII–7. Structure of higher education system in Lithuania.

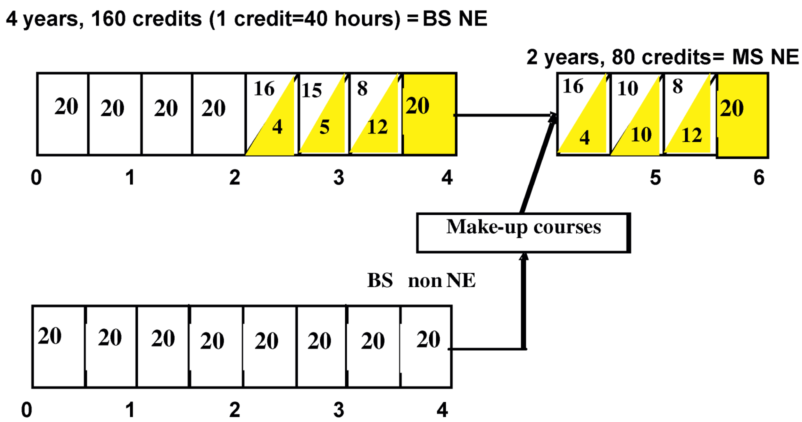


FIG. XIII–8. Structure of nuclear engineering studies' system at KTU.

All universities in Lithuania use a national credit system based on student workload with an average of 1600 working hours per academic year. One credit corresponds to 40 notional hours of student work (in classes, laboratories, independent work, etc.), or to one work week. One Lithuanian credit is equal to 1.5 ECTS credit.

Currently, nuclear education courses are offered by two universities in Lithuania:

(1) Kaunas University of Technology offers two new (established in 2008) study programmes:
— undergraduate (bachelor) study programme in nuclear engineering; (enrolment quota 25 persons);
— graduate (master) study programme in nuclear engineering (enrolment quota 15 persons);

(2) Vilnius University offers undergraduate (bachelor) study programme in nuclear energy physics (enrolment quota 30 persons).

XIII–4. FOREIGN STUDENT ENROLMENTS

There are no foreign students in the nuclear engineering study programmes in Lithuanian universities due to a language barrier: both Kaunas University of Technology and Vilnius University offer nuclear study programmes taught in Lithuanian only.

XIII–5. AVAILABILITY OF RESEARCH AND EXPERIMENTAL FACILITIES

There are no heavy specialized nuclear research and experimental facilities in Lithuania. Practical and laboratory training of students studying nuclear engineering is performed on the basis of cooperation using laboratory facilities at the Obninsk State Technical University for Nuclear Power Engineering (Russian Federation) or at the training centre of Ignalina NPP.

XIII–6. COOPERATION/COLLABORATIONS WITH INDUSTRY AND GOVERNMENT

In the area of nuclear education, the most important collaboration partner of Kaunas University of Technology is Ignalina NPP. Tripartite agreements are signed between Ignalina NPP, KTU, and each student in the third year of nuclear engineering education. The power plant is under contract to pay scholarship to students with sufficient marks and to accept them for work in the plant after graduation. Kaunas University of Technology obliges itself to educate highly qualified nuclear energy specialists for the Ignalina NPP needs. Students oblige themselves to study hard and to work at Ignalina NPP for at least five years after they graduate.

Strategy, programmes and plans for development of the study system in general and the nuclear engineering study system specifically are prepared in close cooperation between educational institutions and the Government.

For example, the new State National Programme for education of highly qualified nuclear engineering specialists, 2008–2015 was prepared in cooperation with the Ministry of Education and Science and the Ministry of Economy in 2008. This programme includes:

— Reorganization of the existing system of nuclear education;
— Creating or updating of training facilities and methodology;
— Modernization of pedagogical personnel’s competency improvement system;
— Creating or updating systems for the re-qualification of current nuclear and non-nuclear specialists;
— Systems for nuclear competency maintenance and improvement;
— Nuclear knowledge retention;
— Measures for advocation of the positive features of nuclear energy and improvement in public perception.

The first steps for implementation of the above mentioned programme — establishment of the two new nuclear engineering study programmes at Kaunas University of Technology and new bachelor level study programme in nuclear energy physics in Vilnius University.

XIII–7. NATIONAL AND INTERNATIONAL COOPERATION AND EDUCATIONAL NETWORKS

Since the very beginning, education of nuclear energy specialists in Lithuania was organized on the basis of wide international cooperation, using the substantial support of foreign countries, such as Sweden, Finland, Germany, the Russian Federation, France, USA, Japan, UK and others. For example, Swedish International Projects provided considerable financial support in publishing the first original Lithuanian textbooks: Introduction to Nuclear Engineering: Nuclear Fuel Cycle, Materials of Nuclear Energy Systems and others. Training and qualification improvement of teachers was provided by the Stockholm Royal Institute and Studsvik Research Centre in Sweden, Helsinki Technological University in Finland, Argonne National Laboratory in the USA, IPSN and Cadarache Nuclear Research Centre in France, GRS in Germany, JAPIC in Japan, KAERI in the Republic of Korea and many other institutions.

Another example of international cooperation is the joint participation of Ignalina NPP, Kaunas University of Technology and Obninsk State Technical University for Nuclear Power Engineering in the educational process. On the basis of the signed tripartite agreement, graduates of Kaunas University of Technology (bachelor of nuclear engineering) during two years continue their education at the Obninsk State Technical University for Nuclear Power Engineering.

Currently Kaunas University of Technology is preparing to establish closer cooperation with the European Nuclear Education Network (ENEN) and to become the effective member of this organization.

BIBLOGRAPHY TO ANNEX XIII

LITHUANIAN ENERGY INSTITUTE, Lithuanian National Energy Strategy, Kaunas (2003).

KAUNAS UNIVERSITY OF TECHNOLOGY, Course offerings, Kaunas (2002–2008).
http://internet.ktu.lt/en/index2.html
http://www.vu.lt/en/studies/

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF LITHUANIA, Education in Lithuania, Facts and Figures, Vilnus (2006).
http://www.smm.lt/en/stofedu/reports.htm

STATE NUCLEAR POWER SAFETY INSPECTORATE (VATESI), Nuclear Energy in Lithuania: Nuclear Safety, Annual Report — 2008, Vilnius (2008).

Annex XIV

MALAYSIA

Malaysia became a Member State of the IAEA in 1969. The development of nuclear science and technology began in earnest in 1972 with the establishment of the Tun Ismail Atomic Research Centre (PUSPATI), which is now known as the Malaysian Nuclear Agency (Nuclear Malaysia) under the Ministry of Science, Technology and Innovation (MOSTI). Nuclear Malaysia is the authorized Government agency responsible for promoting peaceful uses of nuclear science and technology in health, medicine, agriculture, industry, environment and safety in the country and also serves as the national focal point for the IAEA. Nuclear Malaysia operates a 1 MW TRIGA MKII research reactor and several radiation facilities.

Whereas Nuclear Malaysia acts as the promoting agency, the regulatory aspects of nuclear technology applications are within the purview of an independent regulatory body, the Atomic Energy Licensing Board (AELB).

Since the establishment of Nuclear Malaysia, there has been only one university that has established a full course in nuclear science at the undergraduate level. Of late, a few courses at the post-graduate level have been introduced. Table XIV–1 shows the list of main universities that conduct programmes related to nuclear science and technology.

The Nuclear Science Programme was first offered in 1978 at the National University of Malaysia (UKM). It is a broad-based programme covering areas in radiation and nuclear physics, radiation chemistry and radiochemistry, radiation biology, medical and health physics. This course has gained some popularity only in recent years, where students enrol with the aim of either pursuing post-graduate courses or to secure a career in biosciences, medical physics, nuclear technology, radiation processing, etc. Thus there has been a constant intake beyond 40 students each year since 1998. Another reason for this increase in popularity is the increased awareness among school-going students of the benefits and applications of nuclear technology as a result of exposure to publications, internet and the mass media. The student enrolment in Nuclear Science Education Programme at UKM is shown in Fig. XIV–1.

Another course that is gaining in popularity is the course in medical physics. Today, there are eleven nuclear medicine centres in Malaysia as opposed to only one in the 1970s. The expansion of activities in the application of radiation and nuclear technology in medicine requires an increasing number of medical and health physicists. Two public sector institutions of higher education, namely, the University of Science Malaysia (USM) and the University of Malaya (UM) offer courses at the post-graduate level in medical physics while one institution offers health physics course,s which is the University of Technology Malaysia (UTM) at the bachelor’s degree level. In addition, USM also offers a nuclear medicine course at the post-graduate level.

Nowadays, with recent renewed interest in a nuclear power programme, there are two universities,UTM and the University of National Energy (UniTEN) in the process of preparing curriculum on nuclear engineering as an elective subject in their engineering courses.

While universities offer formal education, Nuclear Malaysia leads in the provision of training in nuclear science and technology. Radiation protection courses were first offered by Nuclear Malaysia in 1982 while the first training course in non-destructive testing (NDT) was held in 1986. Training courses in these areas support the

TABLE XIV–1. PROGRAMMES RELATED TO NUCLEAR SCIENCE AND TECHNOLOGY CONDUCTED BY UNIVERSITIES IN MALAYSIA

Programmes conducted	University	Degree level
Nuclear science programme	National University of Malaysia — since 1978	Bachelor
Medical physics	University of Malaya and University of Science Malaysia	Masters
Nuclear medicine	University of Science Malaysia	Bachelor
Health physics	University of Technology Malaysia	Bachelor

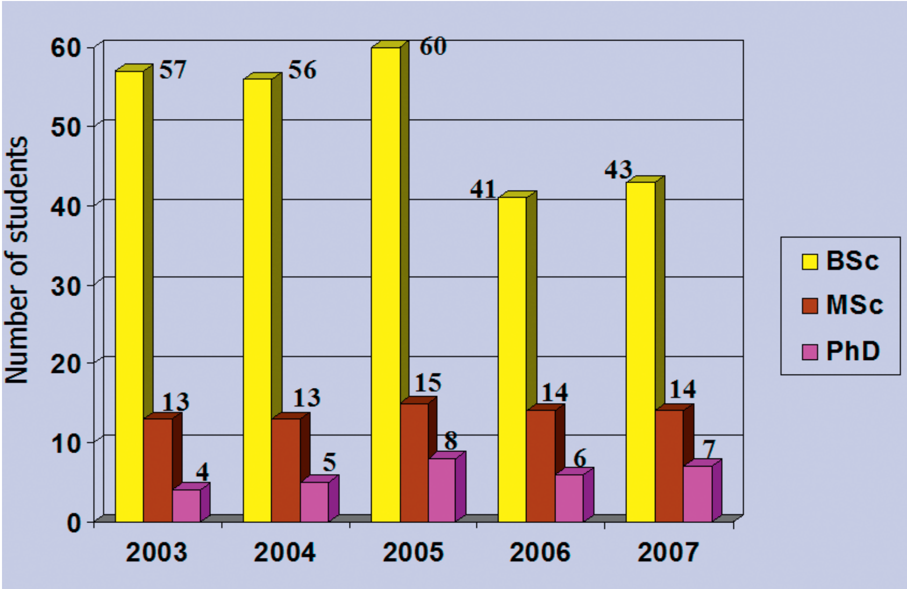


FIG. XIV–1. Enrolment in the Nuclear Science Programme in UKM, 2003–2007.

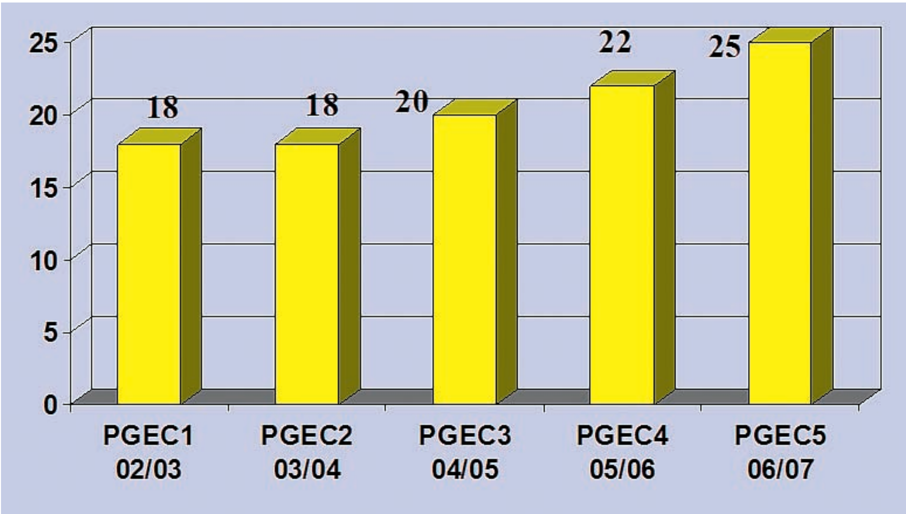


FIG. XIV–2. Numbers of participants attended PGEC.

licensing requirements stipulated by the AELB. In addition to the courses, for the purpose of regulatory compliance, Nuclear Malaysia also offers specialized courses in the application of nuclear science and technology in medicine, agriculture, industry and environment such as radiation safety and health, environmental safety and health, medical X rays for technologies and nuclear instrumentation.

Nuclear Malaysia also acts as a regional centre for the IAEA Post-Graduate Education Course (PGEC) on radiation protection and safety. The course was established in 2002 and is conducted at UKM for a duration of nine months. The numbers of participants that have attended the PGEC are shown in Fig. XIV–2.

In addition to the PGEC programme, the Masterin Radiation Protection and Safety was established in 2007. Nuclear Malaysia also has a multilateral programme with the IAEA which takes 12 months to be completed. The institution involved in conducting the programme is USM.

Annex XV

PAKISTAN[8]

XV–1. BACKGROUND

In order to promote peaceful applications of nuclear science and technology in Pakistan, the Government constituted the Pakistan Atomic Energy Commission (PAEC) in 1956. Soon after its establishment, the Commission embarked upon several projects related to the initiation of activities in nuclear science and technology. An agreement was signed with the American Machine Foundry (AMF) in 1959 for building a swimming pool type research reactor in Pakistan. A nuclear medical centre was founded in Karachi in 1961. Two years later, a nuclear research centre was set up in Lahore. During the same year, the first nuclear agriculture centre in Pakistan was set up at Tandojam. Construction of a nuclear research centre at Islamabad, now well-known as the Pakistan Institute of Nuclear Science and Technology (PINSTECH), was also started in 1963. The swimming pool type research reactor was built at PINSTECH and the reactor reached ‘first criticality’ in 1965.

In 1965, an agreement was also made with Canadian General Electric for the construction of a CANDU type nuclear power plant in Karachi. Construction of this first nuclear power plant in Pakistan, called Karachi Nuclear Power Plant (KANUPP), started in 1967 and the reactor achieved its first criticality in 1971. In 1967, a nuclear training centre, called the Reactor School, was established at PINSTECH. Two years later, an MSc degree programme in Nuclear Engineering was launched at the Reactor School by getting it affiliated with Quaid-i-Azam University, Islamabad.

XV–2. CURRENT STATUS OF ACTIVITIES IN NUCLEAR SCIENCE AND TECHNOLOGY

Currently, major areas of activities in the field of nuclear science and technology are: nuclear power generation, nuclear fuel production, nuclear medicine and oncology, applications of radioisotopes in agriculture and industry. Naturally, utilization of nuclear science and technology in these areas requires both, research and development work as well as education and training of required personnel. Research and development work is supported by several institutes dedicated to R&D in specific areas. The needed personnel is provided by several educational and training institutions, which focus on the specific areas of nuclear science and technology.

XV–2.1. Nuclear power generation

There is an acute deficiency of fossil fuels in Pakistan. However, due to geo-political issues related to the building of dams, no new dams have been constructed in Pakistan during the last three decades. Nonetheless, the demand for electricity has been growing continuously. Pakistan has highly valuable experience of operation of two nuclear power plants, 137 MW(e) CANDU type KANUPP, and 325 MW(e) PWR Chashma Nuclear Power Plant-I (CHASNUPP-I). KANUPP has been in operation since 1971 whereas CHASNUPP-I has been in operation since 2004. Another 325 MW(e) PWR, Chashma Nuclear Power Project-II (CHASNUPP-II) is, at present, under construction and it is expected to be completed by 2011. In view of the prevailing scenario of energy in Pakistan, the Government has planned to install eight new nuclear power plants, which would enhance the nuclear power component in Pakistan to 8800 MW(e) by the year 2030.

XV–2.2. Nuclear fuel production

Regular supply of nuclear fuel is an essential requirement of nuclear power generation. Fortunately, Pakistan has sufficient deposits of uranium. Natural uranium dioxide fuel for the CANDU type nuclear power plant, KANUPP, is produced locally. As the other operating nuclear power plant, CHASNUPP-I, and the under

[8] Prepared by M. Aslam, Rector of Pakistan Institute of Engineering and Applied Sciences.

construction nuclear power plant, CHASNUPP-II are both of PWR type, building of new facilities for production of PWR fuel has also been planned.

XV–2.3. Nuclear medicine and oncology

Pakistan has cancer hospitals in all of its major cities, where techniques of nuclear medicine are used for diagnostics and radiation therapy is used for the treatment of cancer. There are 13 fully functional nuclear medical and oncology centres/institutes in Pakistan (see Fig. XV–1). The two largest cities, Karachi and Lahore, have two nuclear medical centres each. Six new centres/institutes of nuclear medicine and oncology are in the process of development in order to facilitate treatment of patients in far flung areas of Pakistan.

XV–2.4. Applications of radioisotopes in agriculture and industry

For applications of radiation and radioisotopes in agriculture, there are three nuclear institutes of agriculture, namely, Nuclear Institute for Agriculture and Biology (NIAB) at Faisalabad, Nuclear Institute for Food and Agriculture (NIFA) at Peshawar and Nuclear Institute for Agriculture (NIA) at Tandojam. The three institutes focus on development of crop varieties resistant to local plant diseases by the utilization of radioisotopes and thus lead to enhancement in the overall yield of important crops. The National Institute for Biotechnology and Genetic Engineering (NIBGE) in Faisalabad conducts research and development in the important areas of biotechnology and genetic engineering. The National Centre for Non-Destructive Testing (NCNDT) in Islamabad promotes utilization of radiation and radioisotopes for industrial applications.

XV–2.5. Research and development in nuclear science and technology

There are several institutes for research and development in specific areas of nuclear science and technology, however, PINSTECH is the largest R&D centre for utilization of nuclear science and technology in the field of physical sciences. PINSTECH has a swimming pool type nuclear research reactor for research, training of personnel and production of radioisotopes.

XV–2.6. Education and training in nuclear science and technology

Education and training in various areas of nuclear science and technology is offered by Pakistan Institute of Engineering and Applied Sciences (PIEAS), Islamabad, KANUPP Institute of Nuclear Power Engineering

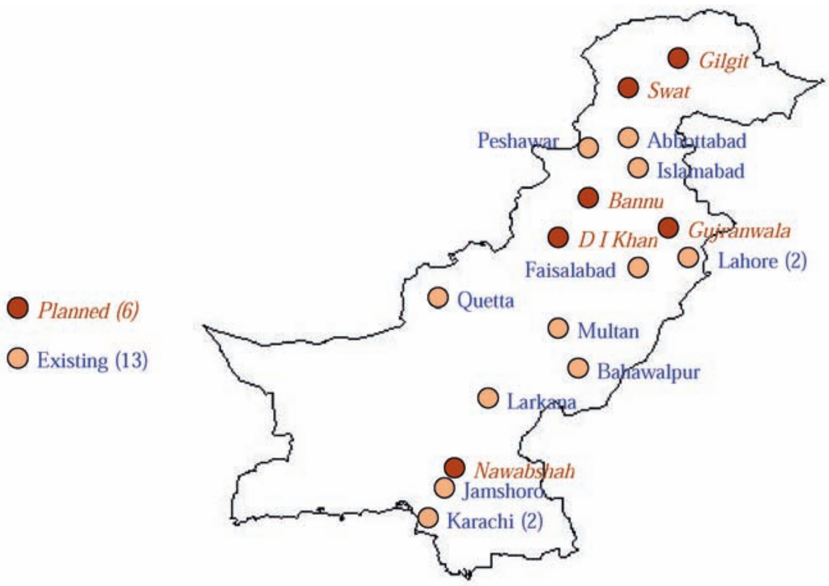


FIG. XV–1. The existing and planned nuclear medical centres in Pakistan.

TABLE XV–1. EDUCATION AND TRAINING PROGRAMMES IN NUCLEAR SCIENCE AND TECHNOLOGY

Programmes	Institutes			
	PIEAS	KINPOE	CHASCENT	NIBGE
PhD	— In several disciplines (20)			Biotechnology (5)
MS/c M Phil	— Nuclear Engineering (1147) — Nuclear Medicine (140) — Medical Physics (83) — Radiation and Medical Oncology (launched in 2008)	Nuclear Power Engineering (414)		Biotechnology (177)
One-year post-graduate training		Nuclear Power Technology (266)	Nuclear Power echnology (85)	
Short trainings	— Nuclear Orientation; — Health Physics; — Reactor Supervisors Course (total~1000)			

Note: The numbers in parentheses give accumulated number of graduates in each programme.

(KINPOE), Karachi, NIBGE, Faisalabad, CHASNUPP Centre for Nuclear Training (CHASCENT), Chashma, and NCNDT, Islamabad. Post-graduate degree programmes and training in nuclear science and technology offered by these institutes are provided in Table XV–1.

Eligibility requirement for admission to MSc and MPhil degree programmes at these educational institutions is a minimum of 16 years of education with a degree in the relevant discipline of engineering, science or medicine. Local candidates are selected on the basis of their performance in a written test and subsequent interview. Selected candidates are offered a fellowship which covers tuition fees, hostel room charges and a monthly stipend for living expenses. The successful graduates are offered positions of Junior Scientists or Junior Engineers or Medical Officers in PAEC and other governmental organizations.

Here it may be mentioned that PIEAS is a public sector university and both KINPOE and NIBGE are affiliated with it. At present, the annual output of graduates from PIEAS, KINPOE and NIBGE is around 200, 50 and 25, respectively.

XV–3. ANNUAL REQUIREMENT OF SCIENTISTS/ENGINEERS AND PHYSICIANS

In view of the Government’s plans for major enhancements in nuclear power generation and the establishment of more nuclear medical centres, the annual output of the graduates is required to double (Table XV–2). For this purpose, plans have been prepared for strengthening of infrastructure at PIEAS, KINPOE and CHASCENT.

XV–4. INTERNATIONAL STUDENTS AND GRADUATES

So far, 41 international students have graduated from PIEAS. Most of them have been from Asian countries except a few from the African continent. Thirty-three of them obtained an MSc degree in Nuclear Engineering. Six of them had an MSc in Nuclear Medicine. Two of them went on to complete their PhD studies as well. Some of these graduates were supported by IAEA.

Obviously, the number of international students, who were admitted to PIEAS, was much larger as some of them had to leave without completion due to their below par performance. Admission of international students in PIEAS is based on the grades from their undergraduate studies.

TABLE XV–2. PROJECTIONS OF REQUIREMENTS OF PROFESSIONALS FOR ENHANCED ACTIVITIES IN VARIOUS AREAS OF NUCLEAR SCIENCE AND TECHNOLOGY BY THE YEAR 2030

Sector	Required for	Number	Basis
Power generation and nuclear fuel production	Operation and maintenance	500	Per plant
	Design and safety	500	Total
	Nuclear fuel production	100	Per plant
	Substitution of retirees	75	Per annum
Nuclear medicine and oncology	Nuclear physicians	20	Per centre
	Radiation oncologists	10	Per centre
	Medical physicists	5	Per centre
	Substitution of retirees	5	Per annum
Agriculture and biology	Professionals	50	Per annum
	Substitution of retirees	10	Per annum
Research and development	Scientists	120	Per annum
	Engineers	50	Per annum
	Substitution of retirees	30	Per annum
Total requirement		650 Professionals per annum	

XV–5. RESEARCH AND EXPERIMENTAL FACILITIES

Location wise PIEAS and PINSTECH are adjacent to each other and therefore research and experimental facilities in PINSTECH are easily accessible for faculty and students of PIEAS. The most important facility in this respect is the 10 MW swimming pool type research reactor, named PARR-I. Another research reactor, 27 kW miniature neutron source reactor (MNSR) is also available. Students carry out standard experiments like:

— Approach to criticality;
— Calibration of control rod;
— Flux mapping;
— Neutron activation analysis.

Students also study thermal hydraulics of the two research reactors. PIEAS has well-established laboratories for detection and spectroscopy of fission fragments, alpha particles, beta rays, gamma rays and neutrons. Students perform experiments to study diffusion of neutrons in aqueous media and carry out albedo measurements. Shielding against gamma rays and neutrons is also studied extensively. Use of TLDs for personal dosimetry, calibration of radiation survey meters, measurement of environmental radioactivity and practice of decontamination procedures are carried out in the health physics laboratory.

Students learn principles of reactor operation by carrying out standard procedures of reactor operation on a nuclear reactor simulator. Standard phantoms for dose mapping and facilities for treatment planning are available at the medical physics laboratory. A gamma camera is also available for training and case studies by faculty and students of nuclear medicine.

In addition to specific experimental facilities, excellent general facilities of internet, digital library and video conferencing are available for faculty and students. The PIEAS Computer Centre operates round-the-clock, seven days per week. Majority of the students lives in the hostels at the campus. PIEAS has separate hostels for male and female students.

XV–6. COORDINATION/COLLABORATION WITH INDUSTRY AND GOVERNMENT

In Pakistan, nuclear power plants, nuclear medical centres, nuclear agriculture centres and nuclear research institutes are managed by governmental organizations. As most of the manpower for various areas of nuclear science and technology is produced by PIEAS, KINPOE and NIBGE, there is close coordination and collaboration between these educational institutions and the governmental organizations. Majority of the students at PIEAS and KINPOE are actually sponsored by governmental organizations and after graduation, they get employed by their sponsors. PIEAS and KINPOE maintain liaison with end-users of their graduates in order to enhance conformity between the education/training and their job requirements. Subject of thesis projects for the sponsored students is finalized in consultation with their expected employers. Experts from the governmental organizations participate in assessment of thesis project as external examiners. Some of the experts also serve on the board of studies of the relevant departments.

XV–7. NATIONAL AND INTERNATIONAL COLLABORATION

As already mentioned, KINPOE and NIBGE are affiliated with PIEAS. CHASCENT is also planning to initiate an MSc programme in nuclear engineering and so, for this purpose, the institution is expected to be affiliated with PIEAS. Thus, the four institutions conducting post-graduate education and training in various areas of nuclear science and technology have strong links among themselves.

The Higher Education Commission of Pakistan has established a network; the Pakistan Education and Research Network (PERN) to support collaboration among the major Pakistani universities. The network also provides digital library services to the universities. PIEAS is also a member of PERN.

PIEAS is a member institution of ANENT. PIEAS has active collaboration with universities in the USA, Canada, the UK, France, Italy, Japan, Brazil and Mexico.

XV–8. GOOD PRACTICES

It may be interesting to analyse the 40 years of education in nuclear science and technology at PIEAS and identify some important good practices, which made the MSc (nuclear engineering) programme at PIEAS so attractive for young engineering and science graduates that it has been running unabated for the last four decades. Some of the identified good practices are:

— The candidates for the post-graduate degree programmes are offered a fellowship comparable to a monthly salary of a young junior scientist or junior engineer with identical qualification;
— In order to enhance the conformity between the education and the job requirements, thesis projects of the sponsored students are finalized in consultation with their sponsors;
— On completion of the two-year MSc degree, the graduates are offered jobs with three advance annual increments and ante-date seniority of three years for their promotion to the next cadre. In this way, the MSc graduates surpass their contemporaries, who may have taken up their job right after completion of their BSc degree in science or engineering;
— Interdisciplinary nature of nuclear engineering involving nuclear physics, mechanical engineering, electrical engineering, chemical engineering, materials science, mathematical modelling and extensive computational work provides the students ample opportunities to pursue technical work in an area of their personal liking irrespective of their discipline in BSc degree;
— For those young scientists and engineers who are keen to pursue PhD studies, the MSc degree facilitates achievement of their professional goal;
— PIEAS offers some fundamental courses in nuclear science and technology as optional courses to students of MSc degree programmes in traditional disciplines. The most commonly pursued optional courses are listed below:

- Fundamentals of nuclear engineering;
- Fundamentals of radiation protection;
- Nuclear heat transport;
- Nuclear reactor analysis;
- Nuclear power plant systems.

BIBLIOGRAPHY TO ANNEX XV

CHASNUPP Centre for Nuclear Training, Chashma, www.paec.gov.pk/chascent

GOVERNMENT OF PAKISTAN, Planning Commission, Medium Term Development Framework, 2005–2010, Islamabad, (2005).

KANUPP Institute of Nuclear Power Engineering, Karachi, www.kinpoe.edu.pk

National Institute for Biotechnology and Genetic Engineering, Faisalabad, www.nibge.org

Pakistan Atomic Energy Commission, www.paec.gov.pk

Pakistan Institute of Engineering and Applied Sciences, Islamabad, www.pieas.edu.pk

QURESHI, I.H., Recollections from the Early Days of PAEC, The Nucleus **42** (1–2), Islamabad (2005) 7–11.

Annex XVI

ROMANIA[9]

XVI–1. BACKGROUND

In 1955, by the Decision of the Council of Ministers, the Committee for Nuclear Energy (CEN) was created as an authorization body and within the Institute of Atomic Physics (IFA) the Commission for Guidance and Control of Nuclear Units was created as a control body. At the same time, the first nuclear research reactor, VVR-S, within IFA started operation. In 1990, CEN became the National Commission for Nuclear Activities Control (CNCAN).

In 1967, the law on peaceful use of nuclear energy projected the construction of nuclear power plants in Romania, and in 1970, the CANDU type NPP was contracted. The owner of NPP Cernavoda is the State company Nuclearelectrica (SNN).

In 1996, the first unit of Cernavoda NPP started operation and in 2007, the second unit started operation. The third and fourth units are planned to start operation in 2013–2014. Studies for the possible location of a Gen-3+ NPP have started.

Nuclear research was initially carried out at IFA, but the ambitious programme for NPP implementation led to the creation of some other research organizations such as the National Institute for R&D in Physics and Nuclear Engineering 'Horia Hulubei' (IFIN-HH) and the Institute for Nuclear Power Reactors (IRNE). After 1990 IRNE split into:

— Institute for Nuclear Research in Pitesti (ICN) designated mainly as the research support for Cernavoda NPP;
— Center of Technology and Engineering for Nuclear Projects (CITON), responsible for design and engineering for nuclear projects, but having also research activities regarding waste disposal, decommissioning, etc.

Some other organizations need nuclear engineering expertise such as heavy water plant (ROMAG), nuclear fuel plant (FCN), and the National Institute of R&D for Cryogenics and Isotope Technologies in Rm. Valcea (ICSI).

In 2002 the National Nuclear Programme (PNN) was adopted, which states the main directions for nuclear power and non-power development in Romania and establishes the strategy and the ways to ensure the needed human resources.

In 2003, the National Agency for Radioactive Waste (ANDRAD) was created as the national competent authority for coordination at national level of the safe management of spent nuclear fuel and radioactive waste, including final disposal.

The Romanian Nuclear Agency (AN) is the government body in charge with all nuclear related activities at national and international levels.

XVI–2. NEEDS FOR NUCLEAR ENGINEERS

Needs for nuclear professionals have to be formally divided into nuclear engineers and nuclear physicists. Further, the generic name of nuclear engineer will be used for both categories.

As stated before, the main end-users of nuclear engineers are: utilities (mainly Cernavoda NPP, FCN, ROMAG and construction support organizations), R&D centres (ICN Pitesti, IFA, IFIN-HH, ICSI etc.), design institutes (basically CITON), state agencies (ANDRAD, AN) and regulatory body (CNCAN).

XVI–2.1. Nuclearelectrica and Cernavoda NPP

The evolution of the Cernavoda NPP staff in 1996–2009 is presented in Fig. XVI–1 [XVI–1].

---

[9] Prepared by P.Ghitescu, University Politechnica Bucharest.

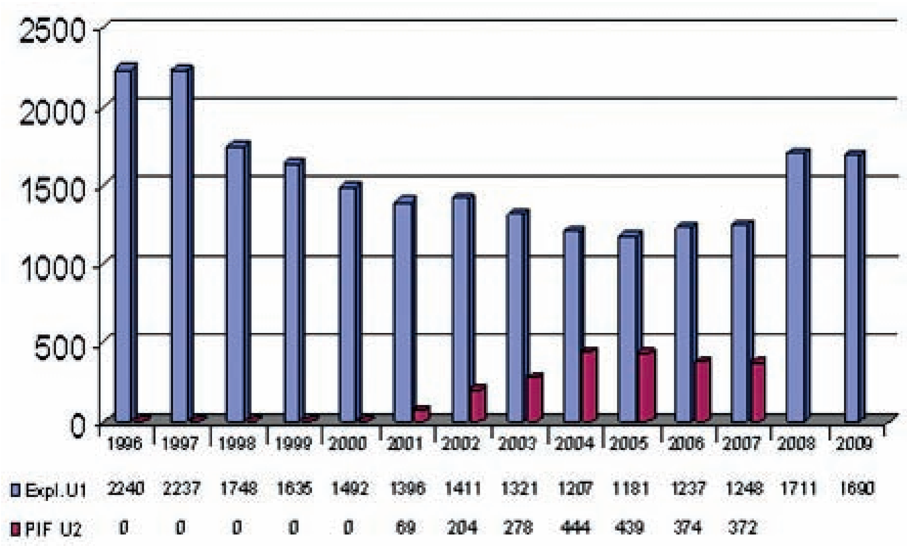


FIG. XVI–1. Evolution of staff of Cernavoda NPP Unit 1 and Unit 2.

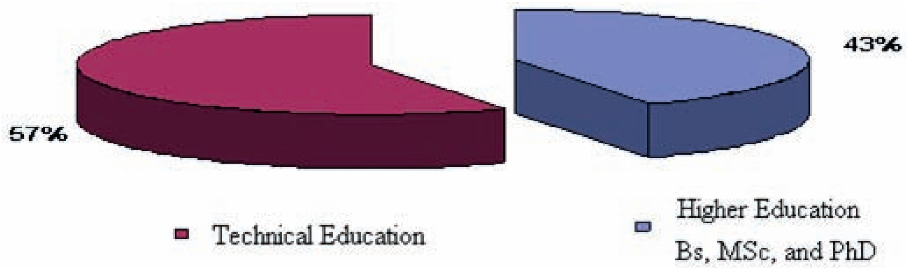


FIG. XVI–2. Structure of staff related to type of education.

The proportion of staff with higher education — about 43% of NPP personnel — is presented in Fig. XVI–2.

In the short term (1–2 years), the hiring rate will be low, about 30/year, mainly highly educated people to replace the normal exits from the organization.

On a 3–5 year range, assuming that units 3 and 4 start operation, around 260 nuclear engineers will be needed, in addition to about 30 persons to cover normal exits (see Ref. [XVI–1]).

XVI–2.2. Institute for Nuclear Research in Pitesti (ICN)

Evolution of R&D staff at ICN Pitesti is presented in Table XVI–1.

For the next decade, the ICN will be involved in technical assistance for the operation of units 1 and 2, construction of units 3 and 4, new Gen-3+ unit studies, life extension evaluations, Gen-IV research, technological transfer and support services etc. These activities will need new staff as follows: ca. 200 specialists in the next 2–3 years and a minimum of 500 in the next decade [XVI–2].

XVI–2.3. Centre of Technology and Engineering for Nuclear Projects

Evolution of the CITON staff, including the personnel temporarily despatched to other design/service suppliers, is presented in Fig. XVI–3 [XVI–3]. Among the CITON staff, 70% are highly educated personnel.

CITON management is taking into consideration short term perspectives of personnel gaps and will identify the critical knowledge positions in order to maintain the portfolio expertise. For example, there were 57 positions identified for CANDU type NPP in operation or under construction, 24 positions for heavy water plant, 11 positions for fuel fabrication, 18 positions for research reactor topics and 12 positions related to waste management. Each position is permanently monitored and future mobilities are correlated with the training perspectives of newly hired staff. Recently retired high expertise professionals are re-hired as private persons for NKM purposes.

TABLE XVI–1. STAFF DISTRIBUTION ON EXPERTISE LEVELS

Year	CS1/IT1		CS2/IT2		CS3/IT3		CS/IT		Total pers. R&D
	Total	PhD	Total	PhD	Total	PhD	Total	PhD	
2004	23	11	35	7	46	4	35	3	139
2005	21	10	34	7	45	6	34	5	134
2006	21	10	34	7	45	6	34	5	134
2007	19	11	34	7	96	14	31	1	180
2008	22	12	34	8	96	16	30	1	182

Notes: CS1 — researcher 1st degree;
CS2 — researcher 2nd degree;
CS3 — researcher 3rd degree;
CS — base researcher.

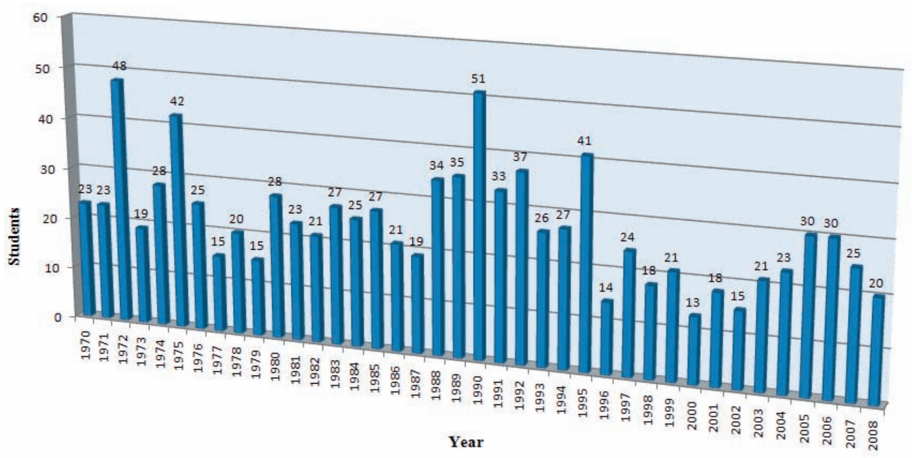


FIG. XVI–3. Number of graduating students of the Nuclear Power Department in UPB.

XVI–2.4. National Commission for Nuclear Activities Control (CNCAN)

The current personnel structure of CNCAN is presented in Table XVI–2 [XVI–4]. Due to the economic crisis in 2009 and 2010, there were some restrictions regarding the number of staff and the vacant positions that were blocked.

As CNCAN is the regulatory body, the required level of the staff qualification is higher than at other end-users and there is a continuous need in expertise upgrading through MSc and PhD studies. The most challenging domains are nuclear safety assessment and control room operator licensing for power and research reactors.

CNCAN considers that the opportunities for internal training are limited and the outsourcing of such activities is difficult.

XVI–2.5. National Institute of R&D for Cryogenics and Isotope Technologies in Rm. Valcea

Organizational structure and staff breakdown [XVI–5]:

— By age:
- 61 employees < 35 years;
- 73 employees 35–45 years;
- 78 employees 46–55 years;
- 9 employees > 56 years.

TABLE XVI–2. CNCAN STAFF STRUCTURE

№	Domain of activity	Necessary staff	On the job	Vacancy
1	Nuclear safety	71	19	10
2	Radioprotection of nuclear reactor and installations	29	13	5
3	Quality assurance licensing	15	11	1
4	Transport of radioactive materials	3	2	0
5	Physical protection	7	4	1
6	Nuclear guarantees	4	4	1
7	Ionizing radiation applications in economy	77	41	8
8	International cooperation	11	9	3
9	PR and mass media	4	10	0
10	Inside staff training	2	0	0
11	Support activities	27	24	5
12	Classified documents	3	2	0
	Total	253	137	34

— By qualification:
- Nuclear scientists/engineers — 33;
- Non-nuclear scientists/engineers — 62;
- Technical staff — 101;
- Administration and service — 25.

During 2004–2009 at the Tritium and Deuterium Separation Experimental Pilot Installation, 16 highly educated people were hired: 6 physicists and 10 engineers (who graduated with different specializations — nuclear, mechanical, electrical, materials, and environment). Among these, two had PhDs and 12 were PhD candidates. The average age of personnel hired in 2004—2005 was 28. Over the next five years, five new positions will be filled.

XVI–2.6. National Agency for Radioactive Waste

After its debut in 2003, the National Agency for Radioactive Waste (ANDRAD) [XVI–6] slowly attracted personnel from the existing nuclear companies, mainly from ICN (as the headquarters location is in the ICN yard). Thus in 2007 and in 2008 the total of existing personnel was 33 persons, including 30 with higher education. In 2009 there were 25 positions (among them 22 with higher education). For the short term, a slight increase in personnel is envisaged as follows: in 2010 — 42, in 2011 — 45 and in 2012 — 50 persons.

XVI–2.7. Conclusion

The necessary number of nuclear engineers in all nuclear energy sector related activities is considered to be around 1000 for the next decade (see Ref. [XVI–2]). For the 5-year range, this number could reach 600–750 job positions if the schedule for units 3 and 4 at Cernavoda NPP is kept.

XVI–3. EDUCATIONAL SYSTEM AND EDUCATIONAL INSTITUTIONS INVOLVED IN NUCLEAR EDUCATION

The main institutions delivering nuclear higher education are presented in Table XVI–3.

XVI–3.1. University Politehnica Bucharest

University Politehnica Bucharest (UPB) is the only higher educational institution in Romania that provides education in the nuclear power engineering field. The faculty of power engineering of UPB has a tradition of over 50 years in power engineering education, from which more than 30 years in higher education for nuclear power engineering. Every year the power engineering faculty yields more than 250 graduated students from which over 40 are nuclear power engineers. The last five years brought an accelerated updating of nuclear high education according to similar activities in EU countries: transferable credit system, the option of a major and a minor, curricular re-shaping according to Bologna, master studies, post-graduate studies, training for nuclear specialists and open courses. The cooperation with European countries in several TEMPUS programmes helped to develop a modern radiation protection laboratory and to establish master studies in nuclear safety and radiation protection. The department has three full professors, three associate professors and five assistant professors.

Due to the participation in ENEN project and related activities, the first European Master of Science in Nuclear Engineering (EMSNE) Diploma Supplement was obtained by a Romanian student in December 2005, which shows the acceptance of nuclear higher education delivered by UPB.

From 1970 to the present, 1023 students graduated from the Department of Nuclear Power (see Fig. XVI–4).

Since October 2005, the educational scheme in nuclear engineering was adapted following the recommendations issued by the Bologna Declaration with three levels of education:

- *Engineer Degree in Nuclear Engineering* with duration of four years is equivalent to the BSc undergraduate education and is power engineering oriented. The curriculum is aimed at nuclear industry needs and provides a basic nuclear engineering education;
- *Master of Science in Nuclear Engineering* has duration of one year and a half and is equivalent to MSc graduate studies. The curriculum is focused on NRC and R&D needs, on nuclear law and regulation, PSA and codes, advanced courses of reactor physics and nuclear materials. For this degree, thesis research work has an important weight;
- *Doctoral programme* (PhD) *of three years*.

For the Engineer Degree (BSc) the curriculum is organized as follows:

- *Year I–II* with courses on general sciences/engineering mathematics, physics, chemistry, computing science, science of materials, electronics, sustainable development, electricity and electrical machines, thermodynamics, fluid mechanics etc.;
- *Year III* — Power engineering with courses on heat transfer, strengthening of materials, control theory and automation, measurement and instrumentation, power equipment etc.;

TABLE XVI–3. LIST OF UNIVERSITIES OFFERING COURSES IN NUCLEAR EDUCATION

Organization name	Web-address	BSc	MSc	PhD
University Politehnica Bucharest	www.energ.pub.ro	x	x	x
University Bucharest	www.unibuc,ro	x	x	x
University Babes-Bolyai Cluj	www.ubbcluj.ro	x	—	—
University in Pitesti	www.upit.ro	x	x	—
University ‘Ovidius’ Constanta	www.univ-ovidius.ro	x	—	—

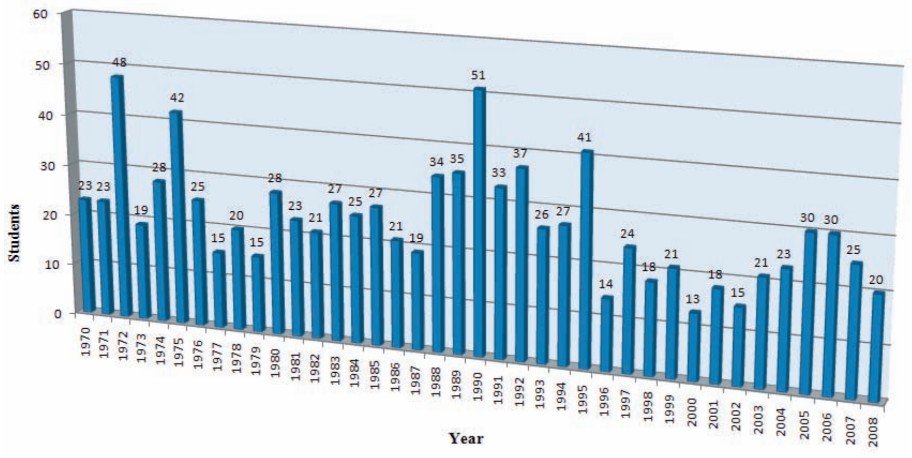


FIG. XVI–4. Number of graduating students of the Nuclear Power Department in UPB.

— *Year IV* — Nuclear engineering with courses on nuclear processes, radioprotection and dosimetry, reactor theory, nuclear materials, Reactor engineering, Nuclear power plants, Nuclear equipment and installations, NPP control and instrumentation, nuclear safety, radwaste management, numerical methods, reactor physics experiments.

Master of Science in Nuclear Engineering has three semesters (total of 90 ETCS — 50 ETCS for courses and 40 ETCS for research) and offers courses in advanced NPPs — Gen-3+ and Gen-4, nuclear reactor advanced physics and codes, nuclear materials for advanced reactors, numerical methods, modeling and simulation of dynamics of nuclear installations, nuclear safety, radioprotection/codes, nuclear installation impact on environment, PSA/codes, thermal-hydraulics/codes, nuclear law and regulation, safety analysis, and spent fuel storage and repository.

The educational capacity per each level (except PhD) in nuclear engineering is 40–60 students/year and depends mainly on the market demand and on the number of enroled students. At present the enrolment is ca. 34 students per year.

XVI–3.2. University of Bucharest

The University of Bucharest (UB) has a long tradition in delivering courses for physicist engineers, but this specialization was formally abolished during the transition period in higher education in the 1990's. Nowadays the Faculty of Physics is delivering some nuclear engineering courses.

The Faculty of Physics — established under the auspices of Faculty of Mathematics and Physics at the beginning, Faculty of Physics has a long and prestigious reputation in assuring the education of students in physics. The institution benefits from a strategic location inside the Institute of Atomic Physics (IFA) Platform.

The university provides:

— *Cycle I (Undergraduate studies).* The duration of studies is 3–4 years and there are two domains of license studies:
- Domain physics: (Academic Undergraduate Studies) with three year duration, containing the following specializations: physics, biophysics, medical physics and informatics physics;
- Domain applied engeneering sciences: the studies are four years duration, containing the specialization in technological physics.

Undergraduate studies are concluded by a graduation examination (license), consisting of three exams. Graduates from the three year programme obtain a Diploma in Physics, Biophysics, Medical physics, or Informatics physics. For the ones that graduate from the 4-year programme, they recieve a Diploma of physicist — engineer. The technological physics specialization offers, beginning in the third year, the direction of study in *physics and protection of the environment.*

The Faculty of Physics offers, in addition to the Curricula in the Romanian language, the possibility to study in English (physics) for the compulsory courses.

— *Cycle II (Master studies).* Graduate students can continue their education in the second cycle, following the MSc programmes, e.g. atomic and nuclear interactions.

The BSc in Physics obtained at any Romanian university is a prerequisite. The curriculum of the MSc programme, for every specialization, includes: three special course units per semester in the first two semesters and one course unit in the third semester. Students in the master's programmes are required to participate in one of the research projects offered by the department and to write a final dissertation.

— *Cycle III (Doctoral Studies)* PhD programmes are organized inside the Physics Doctoral School, of UB, in various fields of physics: biophysics and medical physics; condensed matter physics, atomic and nuclear physics; theoretical physics; optics, spectroscopy, plasma and lasers; physics of the Earth and meteorology; educational physics.

The Department of Atomic and Nuclear Physics has 21 staff members that provide the following courses: atomic physics, molecular physics, nuclear physics, elementary particle physics, interaction of radiation with the substance, reactors physics, radioprotection and dosimetry.

Educational capacity is at least 20 students/year, but at present it is difficult to enrol students due to low demand from the labor market and (as a subjective factor) the location of the university campus outside Bucharest.

XVI–3.3. University Babes-Bolyai in Cluj

The Babes-Bolyai University in Cluj-Napoca (UBB) is the oldest institution of higher education and the largest university in Transylvania. Today it claims a multicultural profile rooted on a multilingual basis. The official teaching languages are Romanian, Hungarian, German and English.

The UBB in Cluj-Napoca has a physics department and a didactic nuclear physics laboratory, equipped with some alpha, beta, gamma emitting sources and two neutron sources (one Am-Be and one Pu-Be); detection is made with old fashioned but working equipment.

The taught courses cover basic nuclear physics, radiation detection, radiation protection, nuclear reactors and nuclear materials. Additional optional courses such as nuclear interactions, nuclear magnetic resonance and elementary particles are available.

XVI–3.4. University of Pitesti

The University of Pitesti (UPIT) is a young, dynamic, modern and flexible institution of higher education which offers large educational possibilities to high school students, mostly at a regional basis.

Close links and location to the ICN in Mioveni-Pitesti and to the ICSI in Rm. Valcea raised the interest for nuclear education. Consequently, the Faculty of Sciences introduced courses with nuclear topics for physicist engineers (in the third and fourth years) such as: nuclear materials, reactor physics and nuclear materials, nuclear physics, nuclear technologies, nuclear safety, radwaste treatment and management, quality assurance in nuclear engineering, etc.

From 1999 until the present, 18 students graduated in the nuclear engineering field and currently, 100 students are studying nuclear engineering. The university has a didactic Laboratory of Atomic and Nuclear Physics as well as a modern Laboratory for Advanced (nuclear) Materials research.

XVI–3.5. University 'Ovidius' in Constanta

Starting in 2003, the University 'Ovidius' in Constanta (UOC) at the Faculty of Physics offered Chemistry, Electronics and Oil Technology and a 5-year programme in technological physics with two specializations: physics of materials and physics of nuclear reactors.

At the master's level, starting in 2002 a Master of Science was proposed in physics, technology and safety of nuclear reactors.

Transition to the Bologna system ended these programmes and, starting in 2005, the following were introduced [XVI–7]:

— Three-year programme in physics with a specialization in nuclear Physics offering courses in Radioprotection and dosimetry, Nuclear processes, Nuclear safety and environmental protection and Introduction in command of nuclear processes;
— Four-year programme in technology physics with a specialization in nuclear reactor physics offering in addition courses in nuclear materials, physics of power nuclear reactors, design and safety of nuclear reactors.

University ‘Ovidius’ also delivered courses for Cernavoda NPP personnel at the Training Centre in Cernavoda. The main difficulty that University ‘Ovidius’ has been facing is the lack of students as, for the time being, no student graduated from these courses.

XVI–3.6. National Institute for R&D in Physics and Nuclear Enginering — Vocational Training Centre for Nuclear Activities (CPSCDN)

CPSCDN represents one of the departments of IFIN-HH, which is in charge of education and training of all personnel working in the nuclear industry, except nuclear power personnel. It represents the basic training centre for the regulatory body — CNCAN, but also is providing courses required by different governmental institutions on radioprotection, decommissioning, etc.

The centre does not provide academic education, but training courses for regulatory body and industry. The training centre has an experience of more than 40 years in providing training courses in the following fields of activity:

— Radioprotection and radiological safety;
— Application of radioisotopes and nuclear radiation sources;
— Non-destructive defectoscopy;
— Radioprotection and nuclear safety for uses of the fixed X rays installations;
— Dosimetry and radioprotection;
— Transport of radioactive materials;
— Radioactive waste treatment;
— Mining radioprotection;
— Medical uses of open sources.

XVI–3.7. Conclusion

Industrial demands for nuclear expertise compared to what the educational system is able to provide shows that the educational capacity exists as well as the needed academic expertise. However, the actual problem is the number of enroled students, which is still low because of the unattractiveness of the location and especially the salary policy of the nuclear industry.

XVI–4. FOREIGN STUDENT ENROLMENT

All Romanian nuclear power programmes are centred on the CANDU-type nuclear power plant, which has no scientific, research or academic support in Europe. All taught courses are in the Romanian language and there are no short term perspectives or plans to change that. In this respect, foreign students need a preliminary year for learning the Romanian language. Therefore there are no foreign students at this time.

XVI–5. AVAILABLE RESEARCH AND EXPERIMENTAL FACILITIES

None of the universities mentioned above owns a nuclear research reactor or accelerator, but they have research laboratories. Access to big, expansive facilities is granted through a MoU or other kind of agreement with the R&D centres who own these facilities: ICN Pitesti for TRIGA reactor, IFA and IFIN-HH.

In the last decade, universities enhanced the research experimental infrastructure using the financing opportunities offered by the (fundamental) scientific research delivered on contractual basis.

(1) *University Politehnica Bucharest.* At the Faculty of Power Engineering there are the following laboratories:
— Radioprotection and dosimetry laboratory recently updated with α, β and γ-radiation measurement instrumentation;
— Modelling and simulation laboratory having simulation codes for all types of power plants — PWR, BWR, PHWR, and WWER;
— Numerical codes laboratory which provides students with the software necessary for course applications.
Applications for the classical part of the NPP are carried out in the thermal power plant of the university, as well as in the electrical equipment laboratory, instrumentation and measurement laboratory, pipe and flow laboratory, high voltage laboratory etc.
(2) *University of Bucharest — Faculty of Physics* has developed a series of laboratories based on the contractual research [XVI–8] such as:
— Thermo-luminescent detectors laboratory;
— High resolution X and γ spectroscopy laboratory;
— Laboratory of general dosimetry.
(3) *University Babes-Bolyai in Cluj-Napoca* has at the Laboratory of physics γ spectrometers, portable dosimeters, radon detecting and measuring chain (in water, air and soil), G-M counters, and neutron sources (Am-Be and Pu-Be).
(4) *University of Pitesti* has a Research Centre for Advanced Materials (CCMA). Here some very modern and high tech laboratories are integrated such as:
— The laboratory of surface physics, using slow electron diffraction techniques for study of materials surface;
— X ray diffractometry laboratory for materials characterization with X ray spectrometry in powders and thin layers;
— The laboratory for certification of electric and electronic equipment using X rays.
(5) *University 'Ovidius' in Constanta* has a basic didactic infrastructure for the courses presented above.

XVI–6. COOPERATION/COLLABORATION WITH INDUSTRY AND GOVERNMENT

In the period 2005–2008, Nuclearelectrica SA was a strong supporter of universities, both logistically and financially.

University Politehnica Bucharest has a close cooperation with SNN as follows:

— Yearly agreements to send two groups of nuclear engineering students, in July for a 2-week training in the Cernavoda NPP. The utility partially covers the costs of student lodging and chaperons the daily activity;
— Financial support for laboratory infrastructure upgrading and modernization. A protocol between the two organizations has been signed and is updated yearly;
— Sponsorship of national and international seminars on nuclear engineering;
— Starting in 2009, SNN will recruit students at the BSc and MSc level and will sponsor a number of scholarships (see Ref. [XVI–1]).

UPB also provided, on a contract basis, courses for Cernavoda NPP training centre as follows:

— Basic introductory courses for newly hired personnel;
— Courses on 'Basic processes and phenomena in NPP' for control room operators which included nine topical courses on reactor theory, thermal-hydraulics, nuclear materials, instrumentation, turbo-machines, primary circuit systems and installations etc;
— Technical English for NPP personnel.

The University of Bucharest also had contract based cooperation with SNN. As a result, the following web site http://e-nuclear.cpr.ro was created, which presents news and topics of common interest for SNN, UB and UPB.

The University ‘Ovidius’ in Constanta delivered a series of courses to SNN on the same topics as UPB (see Ref. [XVI–7]).

The University of Pitesti took advantage of the vicinity of ICN Pitesti and established a close cooperation regarding:

— Stimulation of students’ interest to nuclear field by organizing visits and presentations of the TRIGA nuclear reactor (see Ref. [XVI–2]);
— Presence of high expertise ICN researchers at university as Adjunct Professors;
— Co-participation with ICN in biding for research contracts.

As regarding the collaboration with the Government, its representative is the Nuclear Agency and the activities carried out by the universities under the National Nuclear Programme (PNN) are supervised by the Nuclear Agency. The Nuclear Agency is also the link with the IAEA and its activities.

XVI–7. NATIONAL AND INTERNATIONAL COOPERATION AND EDUCATIONAL NETWORKS

National and international cooperation guides academic and scientific research activities.

At the national level, cooperation between universities is formalized by the Council of Rectors of Romanian Universities, but one has to take into consideration the autonomy of academic institutions which virtually gives the Academic Senate the freedom to establish the educational strategy and the means to achieve it.

To strengthen the cooperation in the field of Nuclear Physics and Engineering, a project was carried out in 2005–2008 to establish ‘Romanian Network of Excellence in Nuclear Physics and Engineering — REFIN’ [XVI–9]. The project gathered UPB, UB, UBB, UPIT and ICN and aimed to create an educational network similar, at the national level, to the ENEN. The project partners developed a database with information about all nuclear courses in Romania and in EU countries; introduced new national and international pilot courses on radwaste management and on numerical and experimental methods in nuclear reactors; introduced e-learning and facilitated students’ access to nuclear courses; established criteria of mutual recognition based on SAT and self-evaluation reports (www.refin.pub.ro).

Cooperation at the national level also includes consortium agreements for scientific research contracts signed with the National Authority for the Management of Research Programmes.

At the international level the efforts are oriented towards:

— Exchange of students and teachers through Erasmus/Socrates programme;
— Organization of joint training courses;
— Participation in EU funded research programmes;
— Active involvement in ENEN Association.

University Politehnica Bucharest is a founding member of ENEN Association and is participating in Teaching and Academic Affairs Committee activities, including the yearly PhD Event, evaluation of EMSNE applications, work package leadership in ENEN projects, etc.

University Politehnica Bucharest is also involved in European cooperation, participating in EU-EURATOM contracts such as [XVI–10]:

— PC5 — European Nuclear Engineering Network (ENEN) in 2004–2005;
— PC6 — Nuclear Education Platform for Training and Universities Organizations (NEPTUNO) in 2006–2007;
— PC6 — Consolidation of Nuclear Education, Training and Knowledge Management, (ENEN II) in 2007–2009;
— PC7 — European Nuclear Education Training Schemes (ENEN III) in 2009–2011.

UPB is also partner in two project proposals under evaluation:

- PC7 — Training Schemes on Nuclear Safety Culture (TRASNUSAFE) which was evaluated with a score of 13/15;
- PC7 — ENEN Cooperation with the Russian Federation in Nuclear Education, Training and Knowledge Management (ENEN-RU).

XVI–8. BEST PRACTICES

In order to 'fill the pipeline' of the nuclear engineering field, every year in May, UPB — Faculty of Power Engineering is involved in a wide popularization of the nuclear department. The programme entitled UPB — Faculty of Power Engineering — open Gates aims to inform potential students about specializations which are offered and provided by the UPB Faculty of Power Engineering. Therefore the Nuclear Energy Division from the Faculty of Power Engineering is delivering department presentations on the nuclear engineering curricula for BSc and MSc and on existing didactic and research laboratories. They also present opportunities for scholarships/fellowships, for accommodation in the UPB campus and the attractiveness for nuclear job positions after graduation.

These activities are held in target cities like Cernavoda, Pitesti, Bucharest, Constanta and Megidia, which are located in the vicinity of the nuclear end users. Similar actions are carried out by the University of Pitesti and University 'Ovidius' in Constanta.

Web sites (e.g. http://e-nuclear.cpr.ro, www.energ.pub.ro) are also used in order to popularize nuclear career opportunities.

REFERENCES TO ANNEX XVI

[XVI–1] GANEA, L., Human Resources at Cernavoda NPP, Nuclear Info Day 2009, ISSN 2066–6128, Pitesti (11–12 June 2009).

[XVI–2] TURCU, I., PAUNOIU, C., CIOCANESCU, M., Needs for Professionals for National Energy Programme in Romania, Nuclear Info Day 2009, ISSN 2066–6128, Pitesti (11–12 June 2009).

[XVI–3] RIZEA, A., CITON Experience in Establishing Competences as a part of NKM in a free market of Nuclear Engineering Services, Nuclear Info Day 2009, ISSN 2066-6128, Pitesti (11–12 June 2009).

[XVI–4] BORBALA, V., BIRO, L., CNCAN Recent Achievements, Nuclear Info Day 2009, ISSN 2066–6128, Pitesti (11–12 June 2009).

[XVI–5] STEFAN, L., Human Resources Strategy in National Institute of Research and Development or Cryogenics and Isotope Technology–ICIT Rm. Valcea, Nuclear Info Day 2009, ISSN 2066–6128, Pitesti (11–12 June 2009).

[XVI–6] ANDREI, V., ANGHEL, E.M., NICULAIE, O., PETRESCU, A.I., Human Resources Expertise Upgrade for Final Disposal of Radioactive Waste, Nuclear Info Day 2009, ISSN 2066–6128, Pitesti (11–12 June 2009).

[XVI–7] CIUPINA, V., MOSCALU, F., GARTU, M., Curricula in Nuclear Reactor Physics and Technology at University 'Ovidius' in Constanta, Nuclear Info Day 2009, ISSN 2066-6128, Pitesti (11–12 June 2009).

[XVI–8] CHIROSCA, A., Radiological Protection Research Centre: Achievements and Perspectives, Nuclear Info Day 2009, ISSN 2066–6128, Pitesti (11–12 June 2009).

[XVI–9] GHITESCU, P., Romanian Network of Nuclear Education, Nuclear 2008, ISBN 978-973–0–05700–3, Pitesti, Romania (2008).

[XVI–10] GHITESCU, P., Nuclear Education and International Opportunities for Professional Up-grading, Nuclear Info Day 2009, ISSN 2066–6128, Pitesti, Romania (11–12 June 2009).

Annex XVII

RUSSIAN FEDERATION[10]

XXVII–1. BACKGROUND

Nuclear industry, research and academic programmes have been developing in the Russian Federation since the 1950s with the former USSR being the cradle of all nuclear programmes, which was later inherited by the Russian Federation. Moreover, the issue of nuclear personnel development has always been recognized as one of the imperatives for supporting research, engineering and production activities in the nuclear field. Thus, almost simultaneously with creating Soviet NFC sites, a number of University programmes aimed at preparing highly qualified and competent staff to meet the requirements of the field were established. The education and training system created then has been successfully operating in the country, having become mature and versatile. Hundreds of competent nuclear professionals are produced each year by leading national schools.

XXVII–2. NEEDS FOR NUCLEAR ENGINEERS

Basic Russian organizations that provide jobs for nuclear University graduates are R&D Institutes of the State Corporation on Atomic Energy (SCAE), engineering and other Departments at nuclear power industrial plants as well as those institutions who deal with ecology, medical issues and the like.

The number of recent Russian University graduates in major nuclear power plants is given in Fig. XVII–1.

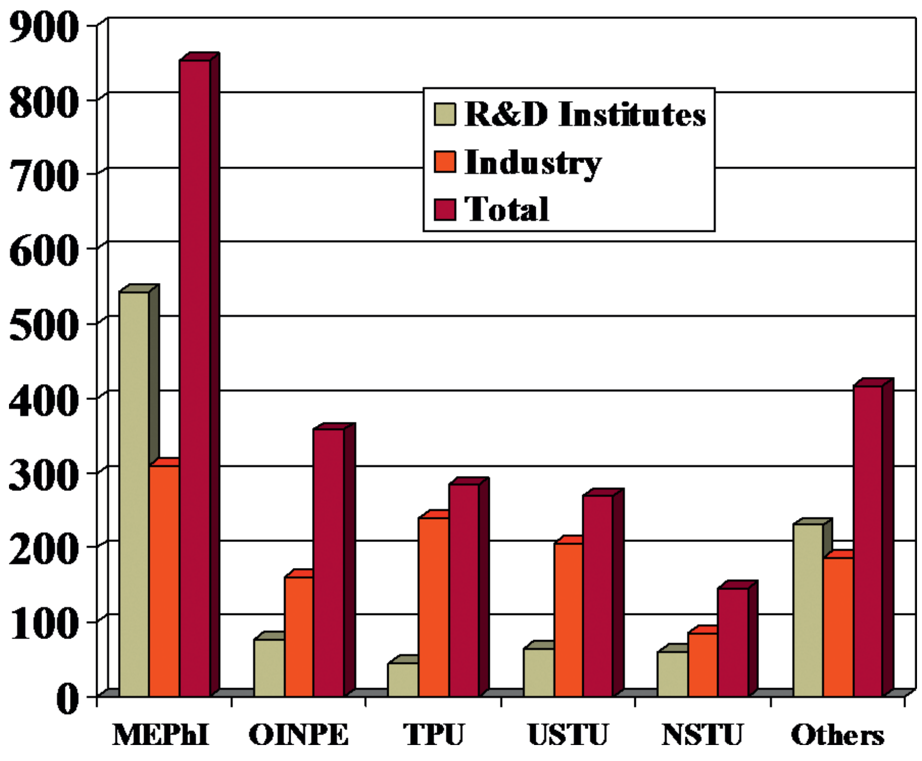


FIG. XVII–1. The number of recent RF University graduates in major nuclear power plants.

[10] Prepared by E.F. Kryuchkov, Vice Rector, Head of Nuclear Reactor Physics Department, MEPhI and I.A. Vorobieva, Head of International Relations Department, Obninsk State Technical University for Nuclear Power Engineering.

The demand in the Russian Federation for nuclear engineers has dramatically increased in recent years. In 2006, the Russian Federation President approved the Russian Federation Nuclear Power Industry Development Programme. The main goal of the programme is to achieve expanded production rate of nuclear industry through advancements in developing the following complexes: nuclear weaponry, nuclear power, nuclear science and technology, nuclear and radiation safety, international competitiveness in nuclear area, and improvement of the State management level.

Innovative development of the nuclear power industry is to be accompanied by its upgrading and restructured management. In order to accomplish this, Russian nuclear power industry is going through reforms; one of these being the creation of the State Corporation of Atomic Energy ROSATOM. Effectiveness of the reforms greatly depends on the quality and sufficient number of nuclear university programmes.

At present, the requirements for nuclear professionals with university qualifications exceed the number of nuclear programme graduates produced by all Russian universities annually. The main problem of the nuclear field and R&D institutes in particular, is ageing of personnel. Over the last 15 years, the number of young specialists in the 25–30 year age range applying for nuclear jobs decreased by double. Meanwhile basic nuclear personnel currently occupying nuclear related jobs is over the age of 60. Researchers and professors are 56–64 years old.

XXVII–3. EDUCATIONAL SYSTEM AND EDUCATIONAL INSTITUTIONS INVOLVED IN NUCLEAR EDUCATION

It should be noted that the Russian traditional education scheme has always been a continuous process starting with secondary school (which includes high school, i.e. 8–11 forms). High school could be substituted by professional schools (technicums). After high school or a professional school, a student could go on to further education in a university.

University graduates acquire diplomas ranking as high as Western MSc diplomas. Having defended diploma projects in technical specialties, the graduates are granted a qualification of engineer-physicist, engineer-designer, engineer-mathematician, etc., and can choose between two options: either continuing with their education to the PhD level, or getting a job at one of the nuclear industrial sites, research institutions, or other nuclear associated organizations. Once employed, they regularly go through updating and upgrading courses (according to the requirement of national regulatory bodies) and/or if necessary through retraining programmes.

Recently, a two-step university education (4-year Bachelor of Science Degree Programme — step 1, and a 2-year Master of Science Degree Programme — step 2, has been introduced in RF. A characteristic feature of the new system is that currently it includes the elements of the traditional and the new one, e.g. a specialist having either BSc or engineer’s diploma is eligible for being enroled into MSc programme. But BSc graduates cannot be enroled to the post graduate courses while engineers and MSc graduates can; with an MSc graduate having some privileges in competing when entering full-time post-graduate courses. Hence, the two educational schemes simultaneously existing are a unique experience whose lessons are to be learnt.

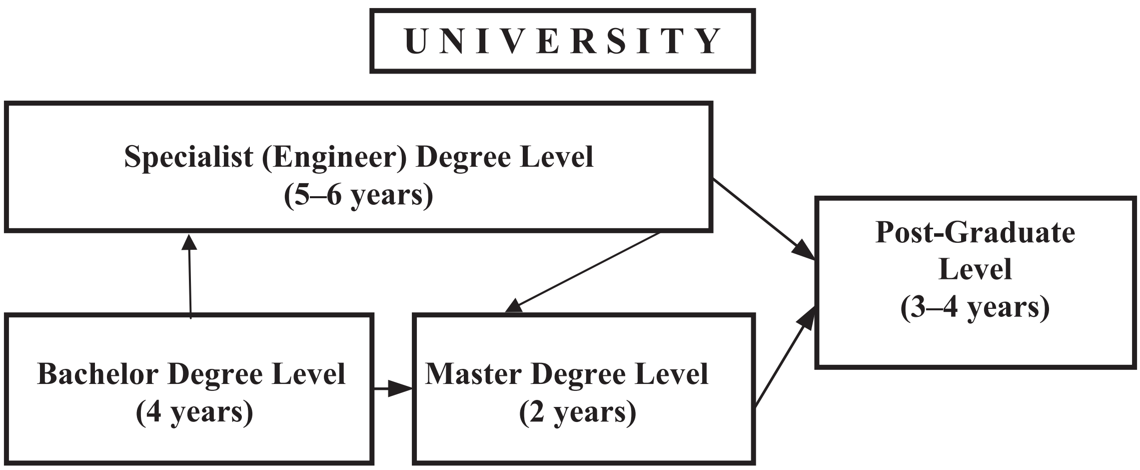


FIG. XVII–2. Nuclear school system in the Russian Federation.

The following are requirements for university programmes:

— All university programmes are to be licensed and accredited by Federal Government (Russian Agency on Education) every 5 years;
— All university programmes are subject to quality assurance (QA) control (curricula, plans, text books and other learning materials and instruments);
— For each group of specialties, Training and Methodological Associations (TMA) are established;
— For each group of specialties, Training and Methodology Commissions (TMC) are also established;
— University diplomas are certified by the National Government.

Education in the Russian Federation is a multi-level structured system that is properly managed which allows and provides a proper QA control at all levels. Training Methodological Commission functions for each specialty (major), it is designed to find solutions for problems of methodological or other character emerging in the group of specialties for which they are responsible.

All universities' specialties (majors) are grouped into about seventy 'Directions for preparing certified specialists', total number of the specialties exceeding 300. For each 'direction', TMA have been formed. Each of these bodies (the Russian Agency on Education, TMA and TMC) resolves specific problems on further development of the educational process and QA control. The bodies' activities mentioned obey the Russian Federation Act on Higher Education and regulatory documents of the RF Agency on Education. The responsibilities of each body are listed below.

The Russian Agency on Education activities and responsibilities are:

— Preparing Federal Laws;
— Preparing and issuing the Agency regulatory documents;
— Establishing new majors;
— Defining status of textbooks;
— Licensing university programmes;
— Accrediting schools as Governmental educational organizations.

The TMA is responsible for educating and training in one group of specialties. It is responsible for:

— Proposing and establishing new specialities;
— Defining a status of learning materials;
— Preparing National Standards and Exemplary Curricula;
— Controlling academic process;
— Collaborating with the Russian Agency on Education (expertise, inspection, proposals, etc).

TMC is responsible for training in a particular specialization:

— Establishing specialization programme;
— Preparing a State Educational Standard and curriculum for a specialization;
— Controlling the curriculum of a speciality in universities;
— Collaborating with the TMA (expertise, inspection, proposals etc).

The education and training in nuclear engineering, like in any other area of knowledge, include education and training activities which are defined by the Russian Federation Acts.

The following TMAs monitor quality of nuclear engineering education in the Russian Federation:

— Moscow Engineering Physics Institute (MEPhI) (19 universities and 6 military schools) — Nuclear physics and technologies.
  MEPhI-based TMA coordinates education, training and methodological activity in the following programmes:

- Nuclear reactors and power facilities;
- Safeguards and non-proliferation of nuclear materials;
- Electronics and automatics of physical facilities;
- Human and environmental radiation safety;
- Physics of charged particle beams and acceleration techniques;
- Physics of atomic nucleus and elementary particles;
- Physics of condensed state of materials;
- Physics of kinetic phenomena.

— Russian University on Chemical Technology (RUCT) after D.I. Mendeleyev (seven universities) — Chemical technologies.
RUCT-based TMA coordinates education, training and methodological activity in the following programmes:
- Current chemical technologies for power industry;
- Chemical technology of rare elements and RE-based materials.

— Moscow Power Engineering Institute (MPEI) (seven universities) — Atomic and hydrogen power.
MPEI-based TMA coordinates education, training and methodological activity in the following specialties:
- Nuclear power plants and nuclear facilities;
- Technical physics of fusion reactors and plasma facilities;
- Water and fuel technologies at fossil fuel and nuclear power plants.

Currently 32 nuclear engineer (specialist) programmes and more than 25 master degree programmes are offered by 30 Russian Universities as well as PhD, BSc, upgrading and retraining courses. The basic governmental Russian Universities in nuclear engineering are the following:

— Bauman Moscow State Technical University (BMSTU);
— Ivanovo State Power University (ISPU);
— Moscow Engineering Physics Institute (MEPhI) — the basic University of the State —Corporation on Atomic Energy (SCAE) and three MEPhI affiliates at the closed cities;
— Moscow Power Engineering Institute (Technical University) (MPEI);

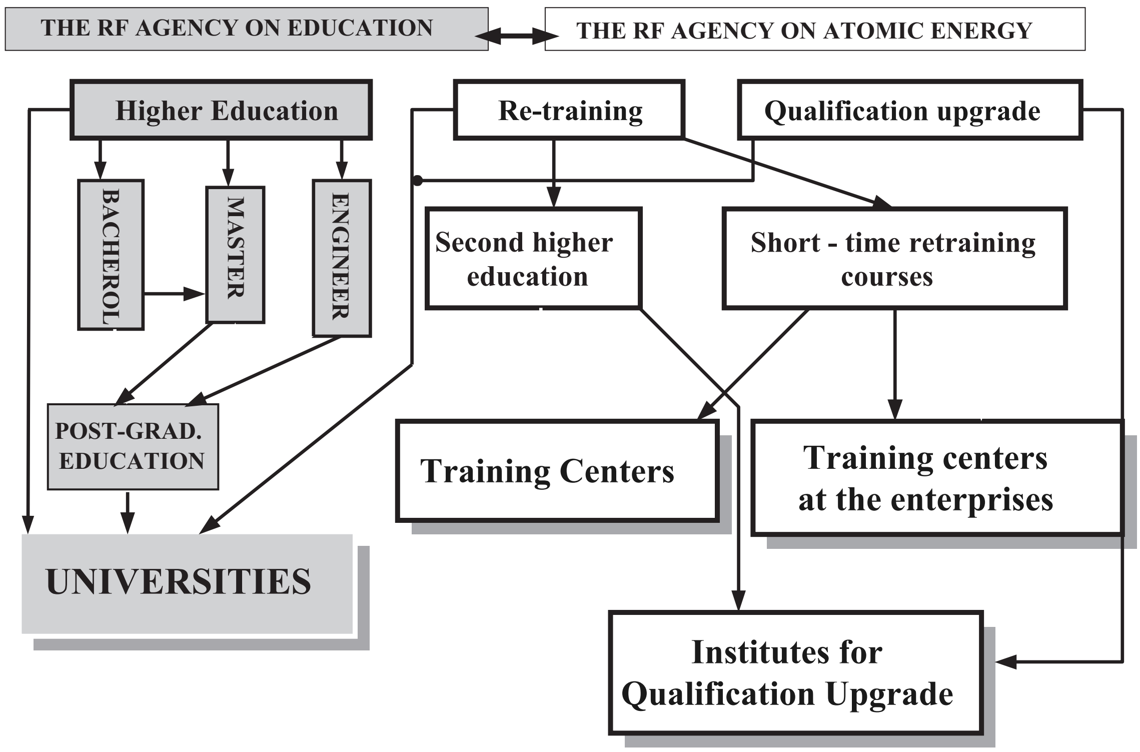


FIG. XVII–3. Continuous nuclear education in the Russian Federation designed to meet nuclear field requirements.

— Mendeleyev Russian University of Chemical Technology (RUCT);
— Obninsk State Technical University for Nuclear Power Engineering (IATE);
— St. Petersburg State Polytechnic University (SPbSPU);
— State Technical University (Nizhny Novgorod) (NSTU);
— Tomsk Polytechnic University (TPU);
— Urals State Technical University (USTU).

Apart from universities, more than 20 R&D Institutions of the SCAE offer post-graduate courses. Moreover, three updating institutes of the SCAE offer re-training and updating courses in the nuclear field.

The universities perform education and training in nuclear engineering in accordance with curricula and standards which reflect some requirements for the professional competence of specialists in this field. They are:

— Only full-time university education;
— Focus on fundamental knowledge in physics and mathematics combined with profound engineering skills;
— Large share of laboratory practical works;
— Students research work beginning in the seventh semester;
— Length of education and training should be 5–6 years, including 6 months for pre-diploma practice and 6 months for preparing a thesis (diploma project);
— Strong requirements for the student’s professional competence, which necessarily includes the safety culture and non-proliferation issues.

Experts and members of administration of the SCAE enterprises assess that annual demand for the certified specialists in nuclear area in RF would be about 3000–3500 persons including ~1100 specialists in nuclear reactors and nuclear power plants, ~600 specialists in nuclear fuel cycle, ~600 specialists in fundamental investigations and ~1200 specialists in other nuclear-associated specialties. Nuclear industry alone would require from 6000 to 9000 persons to go through updating and retraining courses annually.

Thus, developing highly competent personnel for the nuclear field is one of the most crucial current problems in Russian nuclear power development. The predicted rates and scales of nuclear power development in the Russian Federation require the outstripping growth of the specialists involvement into all the structures related with nuclear power industry.

A competent nuclear specialist is a professional with profound background in natural sciences, versatile nuclear engineering skills, ability of readily mastering new nuclear techniques, technologies, methodologies of conducting computer-aided numerical and natural experiments, evaluating experimental data reliability and trustworthiness. The specialist is ready to make a decision and to solve multi-parameter and multi-criteria

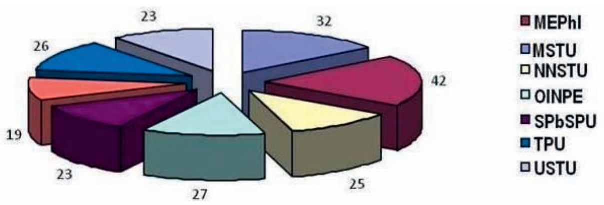


FIG. XVII–4. Number of alumni graduated from speciality ‘Nuclear reactors and power installations’ in 2006.

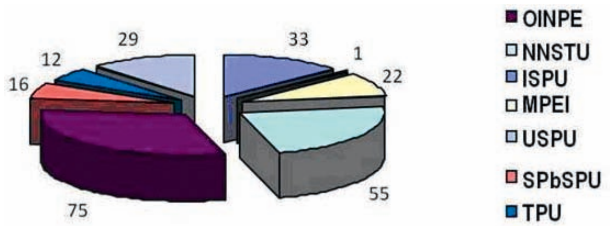


FIG. XVII–5. Number of alumni graduated from speciality nuclear power plants.

optimization tasks. Such competence means consideration of technologically, ergonomically and economically imposed constraints, professional IT-related competence, excellent communicative skills for team work, ability of contacting with the specialists from nuclear-associated technical areas, ability of working in the international projects, and fluency in English.

To achieve all these goals, a first step in consolidating expertise and infrastructures of Russian nuclear education organizations was made. In 2007, the Russian Nuclear Innovative Consortium (RNIC) was established. This consortium includes 21 universities, 3 institutes for qualification upgrading of nuclear specialists and 12 nuclear research centres, including Russian Research Centre — Kurchatov Institute, Russian Federal nuclear research centres in Sarov and Snezhinsk, State Research Centre — Institute of Theoretical and Experimental Physics (Moscow) and State Research Centre — Leipunsky Institute of Physics and Power Engineering. MEPhI is the leading University of this consortium. RNIC is designed to pursue the following:

— Developing collaborative activities in the area of nuclear education and nuclear sciences in the Russian Federation;
— Retaining, preserving, translating and predestining nuclear knowledge;
— Establishing effective system for certified specialists training through collaboration —between Russian higher schools, nuclear research centres and industrial enterprises;
— Disseminating high quality academic standards and best practices in nuclear education.

To pursue these ideas internationally, the International Nuclear Innovative Consortium (INIC) was created in 2008. Besides the Russian Federation, Belarus, Kazakhstan, Kyrgyzstan and Tajikistan became members of this consortium. INIC is designed to:

— form an international corporative network in the field of preparing specialists for civil atomic energy;
— implement innovative projects in professional areas on the integrated base of scientific, educational and innovative potential of the Consortium participants.

Also, an International Nuclear Education Centre was created at MEPhI to support the organization and coordination of international training activities in the area of peaceful use of atomic energy.

Recently, the Government of the Russian Federation made a decision to establish National Research Nuclear University ‘MEPhI’ (NRNU ‘MEPhI’). It is being created in accordance with the Russian Federation Presidential Decree and appropriate Decree of the Government of the Russian Federation.

The National Research University has been designed and structured as a network of regionally-distributed academic and R&D complexes centred on MEPhI. MEPhI, three MEPhI affiliates, Obninsk State Technical University for Nuclear Power Engineering, four universities in the ‘closed’ cities and 13 specialized professional education schools are to be incorporated into NRNU ‘MEPhI’. Around 35 000 students and post-graduates are to be taught in this new structure. The NRNU ‘MEPhI’ is to provide the highest quality of education and training, scientific and innovative support for the Russian nuclear industry as well as some other national high-tech, economic and social spheres due to perfectly structured continuous multi-level professional education and training, integration of research, academic and production activities.

The following challenges need to be met through the NRNU ‘MEPhI’:

— Improving national nuclear education so that both specific features of nuclear engineering education and specific features of current Russian nuclear industry development are taken into account;
— Creating common space in the area of nuclear research and technologies for educational purposes;
— Updating university research innovative activities through integration of science, education and production within the Russian nuclear power industry;
— Developing remote Russian regions through innovative research;
— Efficiently develop university infrastructure, materials and instrumentation supply;
— Developing personnel for nuclear enterprises due to multi-level education, specialists training, post-graduate courses and supplementary education;
— Collaborating effectively internationally;
— Rendering various academic and research services for international students.

The single educational space is to be created in accordance with the current principles and trends observed in nuclear engineering education worldwide, including:

— Credit-modular system of education;
— Use of the competence approach, elaboration of requirements to the content of the educational programmes on the basis of the requirements agreed with future employers;
— Inter-disciplinary approach for enhancement of knowledge background in natural sciences, in professional, informative and analytical training;
— Flexibility for introduction of operative changes into the educational programmes and plans when the employers introduce some changes into their requirements;
— Mobility of professorial staff and students (mobile teams, sharing bases for the internship and laboratories);
— Improving distant education.

NRNU ‘MEPhI’ structure will evidently become a highly competitive academia due to many subjective and objective circumstances, among those already described above are:

— The State Corporation on Atomic Energy ROSATOM created and the SCAE to be developed are basic players in Russian energy complex and mighty players in the world market of nuclear technologies;
— There is a guaranteed order of nuclear power industry for nuclear professionals;
— There is a need for educational services exported from the Russian Federation to other nations developing their own nuclear fields;
— A great number of national and international nuclear experts are to be involved in the University education process;
— Sharing education and research space, updating academic programmes is a powerful tool to promote further national Russian nuclear education.

XXVII–4. FOREIGN STUDENT ENROLMENTS

There has been little or no experience accumulated in RF universities in educating international students within nuclear programmes. Traditionally students from former Soviet republics used to study in the universities but they were ‘domestic’ students at those times. However, plans of enroling foreign students into nuclear MSc and PhD programmes are under discussion. There is a good example when Kaunas Technical University (in Lithuania) used to send their BSc graduates to be enroled into MSc programmes at IATE in Obninsk. Then, having defended their MSc thesis, they returned to occupy jobs at the Ignalina NPP (in Lithuania).

International activity of the National Research Nuclear University ‘MEPhI’ is aimed at gaining a leading position in the world sector of research and education alongside with the development of a wide range of educational services the university is ready to offer. To meet the objective, the university expands the existing number of educational programmes for foreign students; takes an active part in the development of joint educational programmes, arranges student-exchange programmes together with the leading nuclear research universities of the world; maintains close contacts with the IAEA, European Centre of Nuclear Research (CERN) as well as many other research centres and universities around the world.

XXVII–5. AVAILABILITY OF RESEARCH AND EXPERIMENTAL FACILITIES

In most universities there are experimental facilities available for the students’ laboratory works, research and hands-on practice. For example, in MEPhI and TPU there are operating research reactors available for training and experimental work. Unique experimental facilities for thermal-hydraulics studies of various coolants are available in NSTU, SPbSPU, MPEI and some other universities. Radiochemical laboratories with sophisticated instrumentation are available for carrying out research and training in RUCT, USTU and TPU. A number of laboratories, referred to as centres, have been established for research and training, including the Atomic Centre, Acceleration Centre, Laser Centre, Material Science Centre, Nuclear Non-Proliferation Centre and Nano-Technology Centre in MEPhI.

XXVII–6. COOPERATION/COLLABORATIONS WITH INDUSTRY AND GOVERNMENT

In recent years, a network of research and training centres with their infrastructures and expertise accumulated has been created in the Russian Federation. This approach enables continuous updating and upgrading of the academic process. It has become possible for universities to efficiently use research facilities of the leading Russian nuclear institutions and industrial enterprises for internship, students' research and diploma (thesis) projects.

A good example in this respect is the Federal Nuclear Research Centre (IPPE) in Obninsk whose first commercial NPP was shut down on its 50th anniversary and is undergoing decommissioning. About 900 kg of military type nuclear materials accumulated and stored on-site are an excellent testing site. These facilities are planed to be available both for RF and international students for their hands-on experience. Besides IPPE critical facilities BFS-1 and BFS-2 have developed capability to perform live experiments and deliver archived reactor operations data through direct student access (hands-on practice). This capability has matured to the point where significant educational content, including live laboratories, has been designed both for national and international students. The critical facilities have been set up both as a powerful research tool and an educational resource for students, instructors, and working professionals involved in the nuclear engineering field. The BFS-1 and BFS-2 currently have archived data and descriptions of different demonstrations and experiments that address a variety of subjects, including simulating future fast reactor types, optimizing neutronics of their fuel cycle, and validating the nuclear safety. Along with a continually growing set of lecture courses and sample experiments, the really unique aspect of these facilities is that it provides a direct link to real live experimental work for the students. In fact, everything on this site is related, in some fashion, to the future fast reactor types.

Dimitrovgrad Research Institute offers their experimental rigs and staff to educate and train future nuclear professionals. The RF NPP sites are places where university students perform their pre-diploma practice and accomplish their diploma projects with university professors and NPP specialists combining their efforts as advisors for the projects.

XXVII–7. NATIONAL AND INTERNATIONAL COOPERATION AND EDUCATIONAL NETWORKS

Starting in 1997, the world's first Master's Degree in Nuclear Safeguards and Security was established at MEPhI in the framework of a common project with the US DoE and leading US nuclear laboratories. Most of the graduates have gone on to work at government agencies, research organizations, or obtain their PhD. In order to meet the demand for safeguards and security specialists at nuclear facilities, MEPhI established a 5½ year engineering degree programme that provides more hands-on training desired by facilities. In February 2004, the first students began their studies in the new discipline Nuclear Material Safeguards and Non-proliferation. Fourteen students made up the first graduating class, receiving their engineering degrees in February 2007.

Over the last few years, a team of nuclear educators from the USA and the Russian Federation have been developing new MSc programmes to meet the new challenges emerging in the world. The Russian-American Programme in Nuclear International Security (RAP NIS) supported by the DoE (USA) and Rosenergoatom (Russian Federation) provides an opportunity for nuclear educators from Texas A&M University (USA), MEPhI and IATE (Russian Federation) to work together on urgent issues in developing human resources for the field. Professors from the three universities mentioned above have been developing new MSc programmes since 2004. New curricula developed at Texas A&M University, IATE and MEPhI include NP-oriented experimental and theoretical research, lecture courses which include 72 hours course on fast reactor physics, hands-on practice and foreign field experience (FFE) jointly designed and developed for international university students. A course of nuclear English (80 h) is an innovative element of the programme that enables efficient professional communication within the international nuclear community.

Another innovative result produced through these joint academic and research activities is that the methodology developed allows direct access of nuclear science and engineering students to international nuclear sites referred to in the programme as FFE. This gives them first hand experience of international capabilities.

Nuclear sites in France, Switzerland and the Russian Federation are also available for the FFE through the RAP NIS.

The FFE programme has turned out to be a powerful motivation and educational tool which has improved not only professional knowledge but also communication and interaction skills of the students involved.

The universities propose innovative projects within NKM and GNEP activities such as FFE for international students at RF nuclear sites, Nuclear English courses for the third countries students, and theoretical short term schools where outstanding specialists and nuclear experts are to deliver lecture courses. The primary goal and challenge of the programmes and events proposed is to serve as a tool for motivating new generation of nuclear students to come to work in the field and get them prepared to solve various technological problems as well as non-proliferation and international security issues.

MEPhI being an associate member of ENEN and ANENT contributes a great deal into international academic activities.

ADDITIONAL INFORMATION TO ANNEX XVII

Bauman Moscow State Technical University, www.bmstu.ru
Ivanovo State Power University, www.ispu.ru
Moscow Engineering Physics Institute (State University), www.mephi.ru
Moscow Power Engineering Institute (Technical University, www.mpei.ru
Mendeleev University of Chemical Technology of Russia, www.muctr.ru
Nizhny Novgorod State Technical University, www.nntu.ru
Obninsk State Technical University for Nuclear Power, Engineering www.iate.obninsk.ru
Saint-Petersburg State Polytechnic University, www.spbstu.ru
Tomsk Polytechnic University, www.tpu.ru
Ural State Technical University, www.ustu.ru

Annex XVIII

SLOVAKIA[11]

The construction of the first nuclear reactor in Slovakia started in 1958 by Skoda Plzen. It was completed in 1972. This reactor was in operation until 1977. Based on an agreement between the former CSSR and USSR, the construction of NPP V1 in Jaslovske Bohunice began in April 1974 with two units of WWER-440/230 type that were connected to the grid in December 1978 and in March 1980 (the second unit). The construction of NPP V2 began in June 1976 at the same locality with two other units WWER-440/213 type that were connected to the grid in August 1984 (the third unit) and in August 1985 (the last unit). The construction of another NPP in Mochovce (EMO) began in 1981. It was originally planned with four WWER-440/213 type units. After suspension of the construction from 1989 to 1996, units 1 and 2 were finished and connected to grid in July 1998 and December 1999, respectively.

On the basis of the Slovak Government resolution of privatization of the state electric utility, Slovenské elektrarne (SE), National Property Fund decisions and after fulfillment of all conditions, the GovCo, as company took over all current contracts and permissions from the 1 April 2006 including the responsibility for EBO V1 NPP operation, decommissioning of nuclear facilities, radioactive waste and spent fuel handling.

The privatization of 66% shares of Slovenské elektrárne was finally completed on the 27 April 2006 by signing the final contract with the company ENEL. The remaining 34% SE shares stayed in Assets of the Slovak Republic National Property Fund. The State organization Nuclear and Decommissioning Company JSC (JAVYS) is now operating the second unit of NPP V1 with two WWER-440/230 type units that were shutdown at the end of 2008. The first unit of NPP V1 was shut down at the end of 2006. The NPP A1 belongs also to JAVYS and is currently in the first stage of decommissioning. JAVYS operates a Treatment Centrum for low and intermediate radwaste, wet type of interim storage for spent fuel assemblies in Jaslovske Bohunice as well as Country Repository for Low and Intermediate Radwaste in Mochovce.

As with other WWER-440/213 units, engineering plans are being implemented to extend their operating lives for 40 years, which would enable the plant to operate until 2025. The country currently generates 2064 MW(e) nuclear power which contributes 57.2% of the total consumption.

In February 2007, SE announced that Italy was proceeding with the completion of Mochovce 3 and 4 (MO 3 and 4) units and ENEL had agreed to invest €1.8 billion to that. Completion of MO 3 and 4 were started in autumn 2008. The reactors are scheduled to be completed by 2013.

The following are the main goals of the Slovakian nuclear programme:

— To keep and improve safe operation of current nuclear power plants;
— To finish EMO 3 and 4 and connect to grid by 2012–2013;
— To keep high credit and independence of Slovak regulatory authority;
— To keep and improve nuclear knowledge and expertise (existence of SNEN — Slovak nuclear education network);
— To take part in international R&D projects;
— To keep high level of public acceptance of utilisation of nuclear power for electricity production.

The Faculty of Electrical Engineering and Information Technology (FEI) of Slovak University of Technology (STU) offer two branches of nuclear education i.e. nuclear power engineering and material science engineering. It offers undergraduate (BSc), graduate (MSc), post-graduate (PhD) and some training programme related to nuclear technology.

A post-graduate course on Safety Aspects of NPP is offered for operations staff of NPP, NRA officers, young researchers and nuclear safety specialists. It is only for university graduates with at least two years experience in the nuclear industry. This course consists of two semesters of study along with six subjects — all together 90 hours of lecture per semester. After the first semester examination, visits to selected foreign nuclear installations are

[11] Prepared by J. Hascik, Slovak University of Technology in Bratislava.

arranged. The course is completed with a final thesis (~60 hours) and its defence. Eight runs of these courses have been completed so far.

Five days per year training has also been arranged for NPP supervising physicists. Two days are fixed for theoretical work at STU and the remaining three are spent for reactor physics experiments at one of the research reactors in Vienna, Budapest or Prague.

A new obligatory course is under preparation for NPP safety engineers. Its duration will be four weeks along with 90 hours of lectures and 20 hours for experiments at one research reactor. Final examination will be taken by board.

It also organizes IAEA regional training courses for safety, management and utilization of research reactors. This course invites young experts from Czech Republic, Greece, Hungary, Poland, Portugal, Ukraine, Turkey, Slovenia, Slovakia, Romania, and the Russian Federation. STU in collaboration with three other universities (Budapest University of Technology, Czech Technical University in Prague, Technical University of Vienna) arranged an ENEN pilot project and courses with IAEA support.

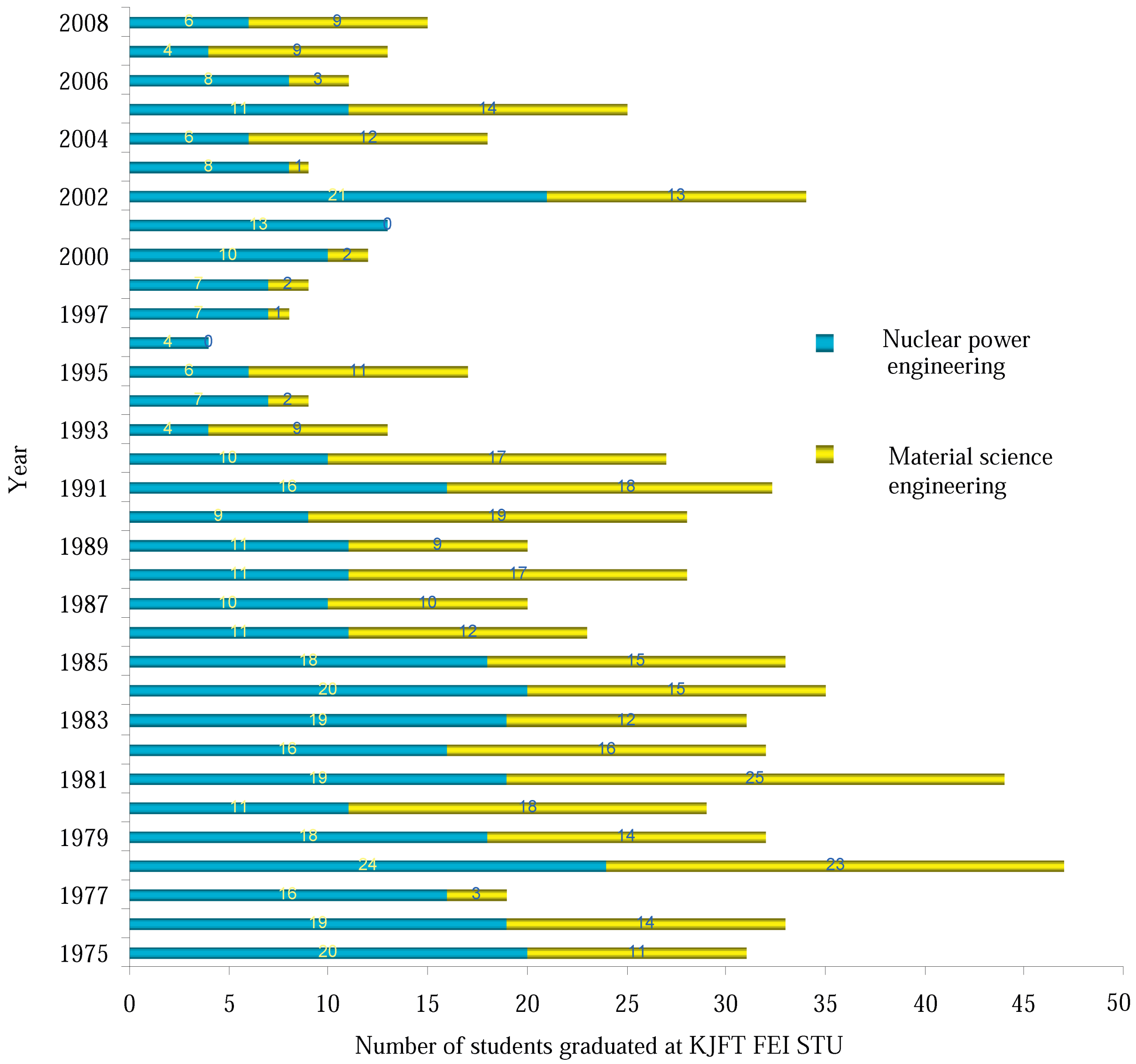


FIG. XVIII–1. The trends of nuclear programmes in STU.

TABLE XVIII–1. SLOVAKIAN INSTITUTIONS INVOLVED IN NUCLEAR HIGHER EDUCATION

Institution	Department/faculty	Degree	Training	Language
Slovak University of Technology	Electrical engineer and information technology	BSc MSc PhD	— Post graduate course ’Safety — Aspects of NPP operation’ — NPP supervisor physicists	Slovak/English
Nuclear power plant Research Institute (VUJE) in Trnava			Training Centre performs both theoretical preparation and training of personnel of NPPs on simulators[a].	Slovak

[a] More information of training programmes can be found at web site http://www.vuje.sk/en/

Annex XIX

SWEDEN [12]

XIX–1. NEEDS FOR NUCLEAR ENGINEERS

The Swedish nuclear industry is — like in many countries — in a state of rejuvenation. During the coming ten years, 6000 new staff will be employed, which in volume corresponds to the entire present industry. These numbers are based on retirements (easy to estimate), increased needs due to new-build, and to increased mobility of the new staff to be employed (more difficult to estimate). Until now, employment in nuclear power have often lasted very long. We anticipate, however, that the young people that will be recruited will be less prone to stay at the same place for long.

XIX–2. EDUCATIONAL SYSTEM AND EDUCATIONAL INSTITUTIONS INVOLVED IN NUCLEAR EDUCATION

XIX–2.1. Undergraduate course offerings

Until now, Sweden has never had a dedicated bachelor level nuclear engineering programme. This will, however, change. A new programme will start at Uppsala University in autumn 2010. An existing 3-year bachelor-level mechanics engineering education programme will get a third-year specialization in nuclear engineering. This specialization has been designed to allow students from any technical college or university in Sweden with mechanical or electric engineering in the curriculum. The studies will be in Swedish. Industry is involved both as sponsors and as contributors. The industry educational company (KSU) is closely involved, e.g. with simulator training.

XIX–2.2. Post-graduate (graduate) course offerings

The Royal Institute of Technology (KTH), Stockholm, has offered an international MSc in nuclear engineering since 2008. The programme has attracted 10–15 students per year. In addition, students at other programmes participate in some courses, resulting in about 25 students in an average course.

Chalmers Institute of Technology, Gothenburg, has started a new nuclear engineering MSc programme in autumn 2009. The programme has equal shares of reactor physics/technology and nuclear chemistry, reflecting the competence profile at Chalmers. This special curriculum is highly appreciated by the Ringhals nuclear power plant nearby, that houses three PWRs, and needs staff with combined reactor physics and nuclear chemistry competence.

Uppsala University has hitherto had a strategy to include one introductory course on nuclear power in many different educational programmes addressing the industry needs of people a bit further away from the core. However, a nuclear engineering specialization within a general energy systems engineering programme was initiated 2009.

XIX–3. FOREIGN STUDENT ENROLMENTS

Foreign students are admitted to all higher Swedish education, and nuclear engineering is no exception, however with one qualification. Restrictions apply for students from countries not having signed the nuclear non-proliferation treaty (NPT). Tuition is in general free in Sweden, irrespective of nationality, and Sweden is rather a popular country for university-level studies, given the fact that the language is not a major one. Teaching is, however, often but not always conducted in English.

---

[12] Prepared by J. Blomgren, Director of the Swedish Nuclear Technology Centre, Vattenfall Senior Expert Nuclear Education.

Both at KTH and Chalmers, both teaching in English, about 100 foreign students per year apply to the nuclear engineering programmes. A large fraction is rejected due to the NPT criterion. In addition, a large fraction of the students have previous exams of which the quality is difficult to assure. As a result, KTH accepted seven and Chalmers five foreign students to their nuclear engineering programmes in 2009.

The foreign enrolment is relatively large on diploma work or internships. For example, Uppsala University and Université de Caen, France, has a regular exchange programme in which three French students per year perform a 3-month internship in Uppsala. Similar programmes are common at all the three universities.

XIX–4. AVAILABILITY OF RESEARCH AND EXPERIMENTAL FACILITIES

Sweden closed its research reactors a few years ago. The only existing neutron facility is the cyclotron-based neutron source at the Svedberg Laboratory, Uppsala, which is operating at energies far above the reactor-relevant range. This facility is nevertheless important for diploma work etc. but not used in regular course studies. Uppsala uses the TRIGA reactor in Helsinki for its training exercises. Ferries frequently cross the Baltic sea, and part of the courses are taught onboard at the conference facilities of these boats.

KTH has used several different solutions, depending on the student attendance. Besides Helsinki, Mol in Belgium and the training reactor at Budapest University of Technology and Economics have been used. Discussions are in progress about purchasing a dedicated school reactor.

The industrial reactor simulators are also used for student training.

XIX–5. COOPERATION/COLLABORATIONS WITH INDUSTRY AND GOVERNMENT

The three Swedish nuclear power plants (Forsmark, Ringhals, Oskarshamn), Westinghouse and the Swedish Radiation Safety Authority jointly fund education and research at KTH, Chalmers and Uppsala. A joint organization, SKC, the Swedish Nuclear Technology Centre (www.swedishnuclear.se) has been formed to coordinate these activities. The fact that the inspectorate collaborates with industry on academic funding is — to our knowledge — world unique.

Besides the centre, all the universities have bilateral collaboration with industry as well as with the authority. Typically, the nuclear power plants support the closest university for recruitment purposes.

It should be pointed out that Sweden has no technical support organization (like CEA in France or VTT in Finland). Thus industry and academia need to have direct contact with no TSO as mediator.

XIX–6. NATIONAL AND INTERNATIONAL COOPERATION AND EDUCATIONAL NETWORKS

SKC is a national network. In addition all the universities are ENEN members.

ADDITIONAL INFORMATION TO ANNEX XIX

www.swedishnuclear.se

Annex XX

UKRAINE[13]

XX–1. BACKGROUND

Production of nuclear electric power occupies one of the most important places in the Ukrainian economy. This branch of industry employs more than 38 000 people. For recent years, although contributing only 22.8% of the total installed capacity, nuclear power plants during autumn and winter maximum loads generated about 53% of the country’s electricity. The share of nuclear electricity generation was stable over the past few years: in 1996, it was 43.8%, 45.3% in 2000, 53.2% in 2004, 52.3% in 2005, 46.4% in 2006 and 47.4% in 2007. Currently there are 15 operating power units at four Ukrainian NPP sites, including 13 units with WWER-1000, and 2 units with WWER-440. Ukraine is eighth place in the world and fifth place in Europe in terms of the installed power of the nuclear power stations.

With its decision on March 15 2006, the Ukrainian Government has adopted the Power Strategy of Ukraine until 2030 . The strategy foresees an additional 21 GW power on new nuclear power units. New spent fuel storages for WWER and RBMK reactor types were also planned to be built.

The main organization that is responsible for NPPs’ operation in Ukraine is the National Atomic Energy Company — ENERGOATOM. It is subordinated to the Ministry of Fuel and Energy of Ukraine. The Ministry formulates state policy in the field, represents and promotes interests of Ukraine regarding the nuclear power production at the IAEA and other international organizations. Foundation of ENERGOATOM was intended for introduction of the uniform technical and economic policy in the field. Increase in electricity production at nuclear power plants under conditions of the continued operational safety improvement was and still is the main task of ENERGOATOM. It also takes care of further development in the field. Specialists of the company work on such problems as the extension of Ukrainian power units’ operation, capacity overgrowth, selection of a new type of reactor, design of closed nuclear fuel cycle and searching for alternative nuclear fuel.

In conclusion, one has to say that such a developed branch of industry requires a huge number of engineers and researchers, which should be prepared and provided by higher educational institutions in the Ukraine.

XX–2. NEEDS FOR NUCLEAR ENGINEERS

Professional training is considered as one of the main problems of development in the nuclear branch. This development, planned by the Power Strategy of Ukraine until 2030, provides for construction of up to 15 new nuclear power units.

The Chernobyl incident in 1986 became the reason of the prejudiced reaction of the public to nuclear power engineering and the necessity of its development. Talented youth comes to this branch less often and competition to enter the technical universities has fallen considerably. It has become very difficult even to fulfill the state order for preparation of experts for this strategically important branch of industry. It has already led to a deficiency of highly skilled specialists and threatens greater problems in the future. Additionally, during the last decades, the experimental facilities have not been updated. This reduces the quality of preparation of students and the level of scientific research in nuclear physics, radiating physics, medical physics and physical material science at Universities. In the last few years, we have been dealing with significant outflow of experts from the branch, and as consequence, ageing staff which works on nuclear installations is already noticeable. This has become a problem not only for the operating enterprises of a nuclear power industry, but also for Institutes of the National Academy of Sciences of Ukraine. The latter not only provide scientific support of a technological chain of the nuclear power engineering, but also deal with problems of extension of the NPP’s operation and development of new more effective and reliable types of reactors.

---

[13] Prepared by S. Kulchytska, Ministry of Fuel and Energy of Ukraine, E. Pismenyy, National Technical University ‘KPI’, E. Popova, Odessa National Polytechnic University, I. Rudenko, Sevastopol National University of Nuclear Energy and Industry.

For many years, ENERGOATOM has been cooperating directly with the specialized technical universities of Ukraine, which prepare qualified engineers for the nuclear power plants: Sevastopol National University of Nuclear Energy and Industry, National Technical University of Ukraine, Kyiv Polytechnic Institute and Odessa National Polytechnic University. More than 200 graduates of these universities are employed at ENERGOATOM each year.

XX–3. EDUCATIONAL SYSTEM AND EDUCATIONAL INSTITUTIONS INVOLVED IN NUCLEAR EDUCATION

In the former USSR only one educational level existed — a specialist with typically five years of studies. In 1996, the Ministry of Education and Science of Ukraine reviewed the existing structure of higher education with the goal to meet the Bologna charter. At the first stage, three levels coexisted. Alongside a specialist, it included two additional education and professional levels — bachelors and masters degree:

— Education and professional level of a Bachelor with four years of study as standard;
— Education and professional level of a Specialist with an additional year of study as standard;
— Education and professional level of a Master with an additional two years of study as standard.

Safe operation of atomic power stations is provided with the qualified personnel having a high level of theoretical and practical preparation. In Ukraine, several higher educational institutions are engaged in professional training for the branch of nuclear power engineering. They are:

— Taras Shevchenko Kiev National University;
— National Technical University of Ukraine ‘Kiev Polytechnic Institute’;
— V.N. Karazin Kharkiv National University;
— Odessa National Polytechnic University;
— Sevastopol National University of Nuclear Energy and Industry (SNUNE&I);
— National Technical University ‘Kharkiv Polytechnic Institute’; etc.

All these Universities are of the fourth (the highest in Ukraine) accreditation level. Annually, these universities prepare more than 600 young experts for the nuclear branch. They are educated according to the following educational programmes:

— Nuclear physics;
— Nuclear power engineering;
— Applied physics;
— Experimental nuclear physics and physics of plasma;
— Physical material science;
— Medical physics;
— Biophysics of complex systems;
— Physics and chemistry of a surface;
— Audit in energy and energy saving;
— Information safety;
— Mounting and adjusting on nuclear power plant.

The previously mentioned universities are governed by two Ministries. The Ministry of Fuel and Energy governs the SNUNE&I and the Ministry of Education and Science governs the other Universities. The graduates of the above mentioned higher educational institutions (HEIs) are employed in the plants of Ukrainian nuclear and energy complex, particularly in NPPs, scientific, research and design institutes, enterprises of uranium mining industry, etc.

XX–3.1. Sevastopol National University of Nuclear Energy and Industry

During the years of independent Ukraine, only one new higher educational institution was created. It was Sevastopol National University of Nuclear Energy and Industry (SNUNE&I). It became the basic educational institution of the Ministry of Fuel and Energy of Ukraine. SNUNE&I was established in 2005.

Currently, SNUNE&I is the main higher education institution of Ukraine that trains qualified personnel for nuclear power complex operation for all nuclear power plants and engineers for the enterprises of nuclear fuel cycle of Ukraine. It is the centre of training and qualification improvement for the staff of nuclear power complex of Ukraine.

There are currently 30 chairs at the university. All of them make up three institutes and four departments:

— Institute of atomic energy;
— Institute of nuclear-chemical technologies;
— Institute of electrical engineering and energy-saving;
— Ecology-technological faculty;
— Faculty of metrology and management of quality systems;
— Faculty of information technologies;
— Faculty of general-scientific training.

In October 2004, the university was given a license by the State Nuclear Regulatory Committee to carry out training on improvement of the qualification of personnel on the physical protection of the nuclear installations and nuclear materials.

At the university, there are four trends of post-graduate studies, including heat and nuclear installations. For the last four years, 3 Doctors of Engineering Sciences and 21 Candidates of Technical Sciences defended their dissertations.

XX–3.2. Taras Shevchenko Kiev National University

In 1983, nuclear engineering specialization was started at the Chair of Nuclear Physics of Taras Shevchenko Kiev National University (KNU) in order to provide preparation of experts for nuclear branch of Ukraine. During design period of maintenance of power units with WWER reactors, there is a necessity of scientific and technical support for safe operation of these power units. For this purpose, the Chair of Nuclear Physics prepared experts for nuclear branch of the former USSR, and then for independent Ukraine. Hundreds of students with a BSc, specialists and MSc in nuclear engineering have graduated from the university till now.

The main feature of preparation of experts at the Chair of Nuclear Physics of KNU in the nuclear engineering specialty is aimed at arriving at solution to practical questions by application of fundamental knowledge. With this purpose, great attention is given to passing two practices (education and familiarization practice; pre-degree practice) by students at the Institute of Nuclear Research of NANU, at the institutions of technical support of safe maintenance of nuclear power plants and at other firms.

At present, the nuclear engineering of Ukraine starts the new stage of its development associated with the necessity to extend the life time of Ukrainian NPPs. Therefore in the last few years, the Chair of Nuclear Physics has started to prepare the experts in the field of calculation of the strained and deformed state of materials and constructions keeping in mind, tanks of reactors, and also the field of radiating safety.

XX–3.3. National Technical University of Ukraine ‘Kyiv Polytechnic Institute’

The National Technical University of Ukraine ‘Kyiv Polytechnic Institute’ (KPI) was founded in 1898 and named Kiev Polytechnic Institute. Among the students and professors of KPI were many famous scientists, such as D. Mendeleev, M. Zhukovsky, I. Sikorsky, A. Kudashov, V. Tolubinskiy, K. Timiryazev, and others. Currently, KPI consists of 28 different departments and institutes; more than 2000 professors and assistant professors; more than 1800 scientists and more than 27 000 students. KPI prepares qualified personnel in different industry branches: from bridge building to air and space industries.

The Department of Heat Engineering was founded in 1931. At present, it includes five chairs, which prepare specialists in the field of power engineering:

— Nuclear power plant and thermal engineering;
— Theoretical and industrial heat engineering;
— Automation of heat engineering process;
— Process automation and equipment design in power engineering;
— Equipment design for heat and nuclear power plants.

All graduates are employed at Ukrainian NPPs, organizations that support NPP's, nuclear research institutes, NAEC ENERGOATOM and Ukrainian NRC.

Today, the staff of the Chair of NPP and Heat Engineering includes: Member of Ukrainian National Academy of Science — 1, professors — 8, associate professors — 17, senior teachers — 3, assistants — 3, researchers — 41. 482 students study at the Chair. Since 1931, the Chair has prepared 1980 engineers in Mechanics, 700 engineers in Thermal Physics and 370 engineers in Thermal Energy.

The main trends of the Chair's research are:

— Development of materials on evaluation of the temperature of shells of the Chernobyl NPP (ChNPP) spent fuel assemblies in the holding pond under the conditions of normal operation and design accidents;
— Safety assessment of the thermal loadings of packages TK-6 at transportation and temporal storage of spent fuel assemblies PWR (WWER)-440;
— Nuclear safety assessment and estimation of temperature of shells of ChNPP spent fuel assemblies at reactor holding pond under the conditions of normal operation and design accidents;
— Experimental assessment of change of thermal model in the RELAP code for PWR (WWER)-1000 reactor for the probabilistic safety analysis (PSA) during the reactor operation on the lower power level and in a state of stop;
— PSA for unit 1 Rivne NPP and unit 1 Khmelnitsky NPP;
— Development of core model for South-Ukraine NPP (SUNPP);
— PNNL, Development of core model of the PWR (WWER)-1000 (Zaporozhye NPP unit 5), — PWR (WWER)-440 (Rivne NPP unit 1) for the NESTLE, RELAP-3D codes;
— Estimation of influence of retreats from the norm and roles of unit 3 SUNPP on containment and environment;
— The TACIS Programme, Project U2.01/02 Support of 'Energoatom' in development and realization of the qualification of equipment programmes;
— Criticality analysis for the dry storage system and transporting of the PWR (WWER) spent fuel;
— Development of the monitoring and early diagnostics system of explosion and fire dangerous situations on NPP;
— Development of the diagnostics system of cable NPP communications thermal modes.

XX–3.4. Odessa National Polytechnic University

Odessa National Polytechnic University (ONPU) was founded in 1971. Nowadays, training of personnel for nuclear energy and atomic industry is carried out by the following chairs:

— *Chair of nuclear power plants,* specialty Nuclear energy with following trends:
  - Operation of NPPs;
  - Assembling, setting up and repairing of NPPs' equipment;
  - Resource management and decommissioning of NPPs;

— *Chair of technology of water and fuel,* specialty Nuclear energy with the following trend:
  - Technology of coolant preparation and radioactive waste management;

— *Chair of theoretical and experimental nuclear physics*, specialty Nucleus Physics and Elementary Particles with the following trend:
  - Nuclear and radioactive safety;

— *Chair of automation of the technological processes,* specialty Automatized management of the technological processes.

The Chair of nuclear power plants is the basic Chair in training the personnel for nuclear energy in the ONPU and at the same time it is one of the main and important Chairs that trains qualified personnel for the NPPs of Ukraine.

Now the staff of the Chair of NPPs consists of 6 professors, 4 doctors of technical science, 8 assistant professors, and candidates of technical science. The structure of the chair and of the ONPU in general allows training of qualified personnel at both Bachelor and Masters degree level.

Two academic councils were organized and work on the basis of the Chair of NPPs for defense of Candidate and Doctoral theses in the field of nuclear and heat energy.

The main directions of scientific research at ONPU are:

— Thermodynamic analysis of the unit;
— Hydrodynamics of two-phase critical flows;
— Heat-hydraulic instability of two-phase boiling flows;
— Influence of the gas soluted in coolant on heat-mass exchange in NPPs equipment;
— Corrosion-erosive demolition of NPPs equipment;
— Reload and revision of nuclear fuel;
— Acoustic diagnostics of unsealed NPPs equipment;
— Probabilistic safety analysis of NPPs' system;
— Methods and systems of diagnostics of condition of NPPs equipment;
— Expert methods of reliability records of equipment.

The graduates of the Chair of Technology of Water and Fuel work at all Ukrainian TPPs and NPPs and at the great amount of CIS's NPPs. The main customers and consumers of the Chair graduates are chemical shops of TPPs and NPPs. In 1996, a new specialty entitled Coolant Technology and Processing of Radioactive Waste was started (within the trend Nuclear Energy). This specialty was started because there had appeared a need in Ukrainian nuclear energy in the neutraliztion of significant liquid radioactive waste. In the future, Ukraine will face the problem of isolation of NPPs whose lifetime reliability factor ends.

The Chair of Technology of Water and Fuel graduates Bachelors and Masters of daily and extramural educated systems. It also carries out personnel retraining and enhances the level of personnel skill to NPPs requirements. The Chair has five educational laboratories, control ion exchanger laboratory and the test centre 'Ecology' certified by the State Committee of Standardization.

The Chair has special disciplines on treatment and technology of water on the NPPs and also it has an excellent base of original manuals edited by teaching staff of the Chair.

The Chair of Theoretical and Experimental Nuclear Physics trains engineer-physicists with a fundamental knowledge in physics of atomic nucleus, theoretical and experimental nuclear physics, reactor theory physics, experimental reactor physics, dosimetry and radioactive safety and provides the scientific staff needs for safety NPPs operating, NPPs decommissioning, technologies of nuclear fuel and radioactive waste management implementation.

The staff of the Chair consists of 40% of Doctors of science, professors, 60% candidates of science, assistant professors. There are post-graduate courses on the base of the Chair.

The main directions of scientific research are:

— Elaboration of methods of neutron diagnostic of in-reactor processes and fuel mass;
— Nonlinear theory of the effect of small dose of ionizing radiation;
— Elaboration of new nuclear reactor of generation IV;
— Elaboration of new type detectors based on magnetic cylindrical domains;
— Radioactive safety and human and environmental protection from ionizing radiation.

XX–3.5. Retraining of the staff

Specific feature of operation in nuclear branch demands permanent *improvement of professional skill* and retraining of staff. In Ukraine, retraining of personnel takes place in institutions which have modern facilities, a significant experience of operation in the branch and qualified staff. Besides SNUNE&I, one such institution is the *Institute of Nuclear Research* of the National Academy of Sciences of Ukraine and its structural division — George Kuzmich Educational Centre. Retraining of personnel in the field of radiation safety is actively provided by Taras Shevchenko Kiev National University and Engineer and Technical Center of Professional Training for Nuclear Energy. With the assistance of the IAEA, professional seminars, training courses and conferences are arranged for officers of authorities and experts in nuclear engineering.

Special attention is given in Ukraine to the selection and preparation of staff for operating nuclear power plants. According to the current legislation of Ukraine, staff of a nuclear power plant should have a license from the State Nuclear Regulatory Committee of Ukraine for operation on nuclear power installations. This provides:

— Presence of the base education confirmed by a diploma;
— Experience of operation on positions of operation personnel of main departments of a nuclear power plant for not less than two years;
— Passing of retraining at education and training centre of a nuclear power plant which is equipped with full-scale simulators, and passing examinations at the end of retraining.

Education and training centers licensed by the State Nuclear Regulatory Committee for retraining of staff for operating the nuclear installation are arranged on all the nuclear power plants of Ukraine. These centers carry out training, control of knowledge of the future licensees and conduct final examinations. After passing the examinations, license for control of a reactor installation of a nuclear power plant are considered by the License Commission. After passing the procedure placed by the legislation, the license is provided to the candidate for two years.

To improve the professional level of the staff, the programme is developed according to which intermediate examinations are supposed to be taken by the licensed staff. At noncompliance, , the operation of the license can be suspended. The latter thus makes it practically impossible to permit a nonqualified staff to control the reactor installations of a nuclear power plant.

SNUNE&I has a treaty with NAEC ENERGOATOM on qualification improvement of the NPP personnel. The list of the qualification improvement courses is given below:

— Nuclear engineering;
— Steam turbine installations of NPP;
— Auxiliary equipment of NPP;
— Operation of safety;
— Operation and repair of reactor installations of NPP with PWRs;
— Repair work on NPP;
— Reliability and safety of NPP;
— Fire protection of NPP;
— Economics and operation of nuclear power;
— Physical protection of nuclear installations, nuclear materials, radioactive substances and other sources of ionizing emanation;
— Energetic management;
— Operation of the resource of nuclear power;
— Operation of the personnel (for the heads and educational training centre);
— Electric stations;
— Safety and reliability of operation of the electric part of NPP;
— The systems of relay protection and automatics of the electric part of NPP;
— Water-chemical regime and technology of coolants;
— Radiation safety on NPP;
— Ecological safety and environment protection;

— Modern technologies of deactivation;
— Radioactive wastes treatment;
— Automation of the technological processes and production;
— The systems of operation and automatics of NPP;
— Modern computer technologies (administering of the computer networks);
— Modern computer technologies and programme provision of the simulator training of the personnel;
— Modern computer technologies (operation of database and processes);
— Modern computer technologies (designing and operation of the computer systems);
— Quality management on NPP.

Moreover, qualification improvement of the heads reserve of the divisions of NPPs takes place at SNUNE&I.

XX–4. FOREIGN STUDENT ENROLMENTS

Ukraine was one of the most developed industrial and scientific republics of the former USSR. Youths from almost all former soviet republics studied in Ukrainian universities. Net of so-called preparatory Departments was developed in Ukraine for preparing the foreign students (from Arabian countries, Africa, India, China, Bulgaria, German Democratic Republic, etc.) to study at the universities. Till now there is a developed infrastructure for teaching foreign students in Ukraine.

At KPI, the special foreign students' department was created for the foreign students. During the first year of education at this department, students study Ukrainian language and additional classes in Mathematics, Physics and Chemistry. After this first year, the education process is the same for foreign students as for the local students. Chair of NPP and Heat Engineering has three or four foreign students each year in the Bachelor degree and one or two in the Masters degree programme.

There are a lot of students from Syrian Arab Republic, Islamic Republic of Iran and China at ONPU.

SNUNE&I trains 38 foreign students on full-time studies from such countries as the Islamic Republic of Iran, Sudan, China, Jordan, Tajikistan, Belarus and the Russian Federation.

KhNU also has the special foreign students' department. Hundreds of foreign students study at its 21 Departments. However, only one or two students study nuclear physics.

XX–5. AVAILABILITY OF RESEARCH AND EXPERIMENTAL FACILITIES

All the above mentioned universities have good research and educational facilities to provide a high level of nuclear education.

SNUNE&I has a unique training base:

— Educational-research operating nuclear reactor IR-100 for carrying out research and educational classes;
— Two subcritical assemblies of the nuclear reactor core;
— Radiochemical laboratory for works directly with radionuclides, spent nuclear fuel and radioactive substances;
— Radiochemical and spectrometric laboratory certified by the State Committee of Standardization of Ukraine;
— Research laboratory of personnel training problems and power complex equipment resource;
— Research laboratory of nuclear chemical technologies and radiation-technological control.

Production of the simulator base is of a great importance for education process at SNUNE&I. The electronic local simulators of reactor-, turbine-, electro-shops, chemical shop and heat automatics and measurements shop are developed, produced and implemented into educational process.

In SNUNE&I students have practical training with the operating equipment of the technological complex of nuclear research reactor IR-100. More than 300 hours of practical and laboratory classes are spent on the reactor every year.

Additionally, there is an analytical simulator of the electric safety operation with PWR-1000 (a prototype of the reactor B-320) in SNUNE&I.

ONPU has a laboratory with training equipment, training and scientific desks, in particular:

— Full scope disassembling turbine and desk with blades;
— Full scope flange model of upper block WWER-1000;
— Training console of the reload reactor machine WWER-1000;
— Desk for demonstration of hydrodynamics of steam generator;
— Desk for demonstration of hydrodynamics of two-phase flows, transportation pipelines vibration and water and air ejector operation;
— Desk of detailed heat scheme of turbine (unit 1 of SUNPP).

ONPU also has a full scope model for the research activity of feedback cooling system of the turbine NPPs condensers, research desk of chemical streaming and experimental desk decarbonization.

In addition to facilities available at NSC ‘KhPhTI’, KhNU has its own education and research equipment. In particular, the Chair of experimental nuclear physics is equipped with a unique set of facilities:

— Linear electron accelerator: LEA-6 with energy up to 6 MeV;
— Linear electron accelerator ‘Elektronika U-003’ with energy up to 8 MeV and power of a beam up to 5 KW;
— Electrostatic accelerator IG-410 with energy of protons up to 2 MeV;
— Ion-beam installation ‘Vesuvius-32’ with energy of particles up to 90 KeV;
— Low-background gamma-spectrometer scintillation installation with active and passive protection;
— Pulse high-current electron accelerator with energy of 1 MeV and a current 100 KA ‘Nadezhda’;
— Pulse nanosecond stand alone X ray device ‘ARINA’;
— Neutron generator ‘NG-150M’;
— Laboratory stand for testing the scintillation detectors and silicon matrixes.

XX–6. COOPERATION/COLLABORATIONS WITH INDUSTRY AND GOVERNMENT

In our opinion, the so-called ‘fiztekh’ system of preparing the experts for nuclear engineering (which is science-capacitive branch of industry) can be considered as the most appropriate system of a professional training. This system has appeared in Ukraine in the 1930s after the organization of the Ukrainian Institute of Physics and Technology. In those years, bases of new physical education of the former USSR were created in Kharkiv, Ukraine. Noble prize winner L.D.Landau had formulated main principles and methodical receptions of this system. They include the following issues:

— Early (from the second to the third year) engagement of students in scientific research;
— An optimal ratio of collective methods of training to individual operation;
— Problem-oriented character of training as well as education and research of students;
— Realization of high-end training by scientists which actively work in modern directions of physics;
— Complex character of education which consists in optimal association of high theoretical base with creation of experimental skills and desire to get an end result of a high level, worthy publications in prestigious journals, creation of an original technique, the instrument, etc.;
— Continuity of educational process at all stages of creation of the scientist from the student up to the doctor of sciences.

The main issue here is that scientists, on the one hand, have the remarkable possibility to prepare employees at their work places, and the student, on the other hand, to be engaged in research in the laboratories at the highest level. That is why after completion of the learning process it is easy for graduates to adapt for operation in the laboratory.

This system is based on integration with institutes of the Academy of Sciences. This is especially important at present time, when immense problems exist due to the lack of modern equipment, necessary materials, and qualified personnel for assurance of educational process. An example of such effective cooperation is long term (since 1948) teamwork on a professional training of V.N. Karazin Kharkiv National University and National Science Centre ‘Kharkiv Institute of Physics and Technology’ (NSC). It takes place in the field of theoretical and experimental nuclear physics, radiating material science, vacuum metallurgy, physics of accelerators, as well as plasma physics and physical technologies. The experts were prepared not only for NSC, but also for all the military and industrial complex of the former USSR. Organizational forms of professional training varied. Now the educational process is carried out through the joint educational and scientific complex. In NSC, branches of the Chairs of Experimental Nuclear Physics, Theoretical Nuclear Physics, Materials for Reactor Building, Plasma Physics and Physical Technologies have been created. The most prominent scientists of NSC head the operation of these branches. This allows students to listen to the lectures of academicians. Joint problem research laboratories function, joint researches are carried out, joint international projects are accomplished, and joint seminars take place. To some extent, the excellence of such teamwork can be demonstrated by successful scientific career of graduates of the Department of Physics and Technology of V.N. Karazin Kharkiv National University (KhNU). Namely, about 30% of graduates of this department have defended their theses for candidate’s and doctoral degree. About 30 graduates were elected to the Academies of Sciences of the former USSR, the Russian Federation, and Ukraine. About 100 graduates were awarded Lenin, State prizes of the former USSR, state prizes of Ukraine, the Russian Federation and Belarus in the field of Science and Engineering.

XX–7. NATIONAL AND INTERNATIONAL COOPERATION AND EDUCATIONAL NETWORKS

All the Universities mentioned above are involved in national and international cooperation projects both in academic and research respects.

SNUNE&I is an associated member of the World Association of Nuclear Operators (WANO) and plays an important role in providing safety and operational reliability of NPPs.

The graduates of ONPU work in different countries (USA, Germany, Hungary, Bulgaria, Slovakia, New Zealand, Israel, Syrian Arab Republic, India and Libyan Arab Jamahiriya). ONPU cooperates with partners from abroad and one of them is the Russian corporation ‘TVEL’, which provides nuclear fuel for Ukrainian NPPs. At present, ONPU closely cooperates with the Ukrainian NPPs and CIS’s NPPs in the sphere of scientific research and personnel training.

ONPU also has scientific relations with National Academy of Science of Ukraine, in particular: Institution of Nuclear Researches, NSC ‘Kharkiv Institute of Physics and Technology’, Institute of Nuclear Energy Problems, Slavutych laboratory of International Chernobyl Centre. ONPU has signed agreements on scientific and technical cooperation with all mentioned institutions.

ONPU also cooperates with the National Scientific Nuclear Centre, Institute ‘Jozef Stefan’ (Ljubljana, Slovenia), University of Bielefeld (Germany), Institute of Nuclear Researches and Nuclear Energy, Bulgarian Academy of Science (Sofia) in the framework of agreements on cooperation and students exchange.

KhNU has signed a number of MoUs with educational and academic institutions in Ukraine and abroad.

It has applied to join the ENEN Association in 2009. QA process is under way. The rector has been invited to take part in the General Assembly meeting in Ljubljana, Slovenia, 4–6 March 2010, to sign up the MoU.

The graduates of the Department of Physics and Technology at KhNU work at numerous European Universities and research centers, such as:

— ITER;
— Max-Planck-Institut für Plasmaphysik, Germany;
— GSI Helmholtzzentrum für Schwerionenforschung GmbH, Germany;
— S-DALINAC at Institut für Kernphysik, Darmstadt Technische Universität, Germany;
— Helmholtz-Zentrum Berlin für Materialien und Energie, Germany;
— SIEMENS;
— Departamento de Fisica Teorica, Facultad de Fisica, Universidad de Valencia, Spain;
— INFN, Sezione di Padova and Dipartimento di Fisica ‘Galileo Galilei’, Università degli Studi di Padova, Italy;

— Universite Libre de Bruxelles, Belgium;
— Institut für Niedertemperatur-Plasmaphysike, V. Greifswald, Germany.

They are successful in their scientific career in Europe. When speaking about the graduates of the Chair of experimental nuclear physics only, below in the Table XX–1 one can see the thesis topics, which were defended by the graduates of this Chair in Germany alone:

— GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt;
— Technische Universität Darmstadt, Institut für Kernphysik; and
— Johann Wolfgang Goethe-Universität, Frankfurt am Main.

TABLE XX–1. THESIS TOPICS

No.	Name	Title of the thesis	Date of graduation	Date of defence
1.	S. Khodyachykh	Experimental Study of the FEL with a Tapered Undulator and Numerical Simulations of Short Pulse Free Electron Lasers	1998	09.12.2002
2.	M. Gopych	Einfluss von Magnetfeldern auf die Guete der supraleitenden Beschleunigungsstrukturen des S-DALINAC und Untersuchungen zur Feldemission	1998	27.10.2003
3.	O. Patalakha	Design and Implementation of a Modular Client-Server Control System for the S-DALINAC	2000	06.11.2006
4.	N. Rezayeva	Search for the p1/2 — Resonance in 7He with the 7Li(d,2He) Reaction and Measurement of the Deuteron Electrodesintegration under 180 deg at the S-DALINAC	2002	06.11.2006
5.	M. Misky-Oglu	Supersear and nodaldomains statistics in Pseudoinzegrable barrier billiard	2002	11.08.2007
6.	A. Belikov	Neutrino-Nukleosynthese der seltenen Isotope ^{138}La und ^{180}Ta und Entwicklung eines Siliziumballs für exklusive Elektronenstreuexperimente am S-DALINAC	2003	17.11.2007
7.	O. Burda	Nature of Mixed-Symmetry 2^+ States in ^{94}Mo from High-Resolution Electron and Proton Scattering and Line Shape of the First Excited $1/2^+$ State in ^{9}Be	2002	19.11.2007
8.	O. Chorny	Measurement and Interpretation of the Bunched Beam Transfer Function in SIS-18 with Space Charge	2004	09.07.2008
9.	V. Gostishchev	Internal Target Effects in Ion Storage Rings with Beam Cooling	2004	18.06.2008
10	M. Chernykh	Electron Scattering on12C, the Structure of the Hoyle State and Neutron Ball for (e,e’n) Experiments at the S-DALINAC	2004	27.05.2008
11	O. Yevetska	Determination of the proton polarizability with an active target and dipole strength in the ^{235}U(γ,γ’) reaction up to 4.4MeV at the S-DALINAC	2003	24.06.2009
12	I. Pismenetska	Experiment zur Messung des Ladungsradius des Protons am S-DALINAC und Untersuchung der Feinstructur von Riesenresonanzen in ^{28}Si, ^{48}Ca und ^{166}Er mit Hilfe der Waveletanalyse	2004	22.07.2009
13	Yu. Aksyutina	Light Unbound Nuclear Systems beyond the Dripline	2006	14.08.2009

XX–8. ADDITIONAL INFORMATION

Chair of Thermal Engineering, NTUU 'KPI', www.tef.kpi.ua
List of State Universities of Ukraine, en.wikipedia.org/wiki/List_of_universities_in_Ukraine

Ministry of Education and Science of Ukraine, www.mon.gov.ua
Ministry of Fuel and Energy of Ukraine, www.mpe.kmu.gov.ua
NAEC ENERGOATOM, www.energoatom.kiev.ua
National Technical University of Ukraine 'Kiev Polytechnic Institute', www.kpi.ua

Odessa National Polytechnic University, www.opu.ua
Sevastopol National University of Nuclear Energy and Industry, http://www.sinp.com.ua
State Nuclear Regulatory Committee of Ukraine, http://www.snrc.gov.ua/nuclear/uk/index
Taras Shevchenko Kyiv National University, www.univ.kiev.ua

V.N.Karazin Kharkiv National University, www.univer.kharkov.ua

Annex XXI

UNITED KINGDOM[14]

XXI–1. BACKGROUND

The United Kingdom currently has ten operational nuclear power plants with another nine undergoing decommissioning.

The operation and decommissioning of the Magnox Reactors is the responsibility of the Nuclear Decommissioning Authority whilst the day-to-day operation is currently run by the two Parent Body Organizations Magnox North (Oldbury, Yr Wylfa, Hunsterton A, Chapecross and Trawsfynydd) and Magnox South (Bradwell, Berkeley, Dungeness A, Hinkley Point A and Sizewell A). Oldbury was scheduled to cease generation at the end of 2008 and Yr Wylfa by the end of 2010 but Oldbury continues to operate and a lifetime extensions is possible for Yr Wylfa. The AGRs and the PWR at Sizewell B are operated by British Energy. The ten operational reactors generate approximately 11 GW to the UK electricity mix, which is about 15% of the total UK requirement, down from a peak of 26% in 1997. Following an announcement early in 2008 by the government, with support from the main opposition party, it is expected that new nuclear plants will be built in the UK as soon as possible. Two new designs, the Westinghouse AP1000 and the Areva EPR, are currently undergoing a Generic Design Assessment by the UK regulator, the Nuclear Installations Inspectorate.

Decommissioning of the Magnox NPPs is the responsibility of the Nuclear Decommissioning Authority (NDA). They also own the liability of Capenhurst Fuel Enrichment Plant, Springfields Fuel Manufacturing Plant, the research reactor sites at Harwell and Winfrith, the fusion research centre at Culham, the Fast Reactor research centre at Dounreay and Sellafield.

Privatization of the Central Electricity Generating Board (CEGB) and the United Kingdom Atomic Energy Agency (UKAEA) and the subsequent closure of many national laboratories, together with the transfer of the liability for the decommissioning of the Magnox sites from BNFL to the NDA resulted in the re-organization of BNFL. The BNFL Research and Technology division was rebranded as Nexia Solutions which in 2008 became the National Nuclear Laboratory.

Reorganization has also taken place within government. The Office for Nuclear Development was established in early 2008 with a remit to facilitate new nuclear investment in the UK and advise the Secretary of State on the exercise of his regulatory and policy functions in relation to the nuclear industry. In October 2008 the Department

TABLE XXI–1. UK NUCLEAR POWER PLANTS

Magnox NPPs	PWR NPP	AGR NPPs	Decommissioning Magnox NPPs
Oldbury	Sizewell B	Dungeness B	Bradwell
Yr Wylfa		Hartlepool	Berkeley
		Heysham 1	Dungeness A
		Heysham 2	Hinkley Point A
		Hinkley Point B	Sizewell A
		Hunterston B	Hunterston A
		Torness	Chapelcross
			Trawsfynydd
			Calder Hall

[14] Prepared by J. Roberts and J. Billowes, Dalton Institute, University of Manchester.

of Energy and Climate Change was created bringing together energy policy (previously with BERR — the Department for Business, Enterprise and Regulatory Reform) with climate change mitigation policy (previously with Defra — the Department for Environment, Food and Rural Affairs).

The UK has also had a long involvement with nuclear fusion based at the Culham site in Oxfordshire. Currently operational are the Joint European Torus (JET) and the Mega Amp Spherical Tokamak (MAST). JET is run as collaboration between all European fusion organizations and the participation of scientists from around the globe. MAST is collaboration between EURATOM and the UKAEA Fusion Association. The UK is also involved in the ITER project which builds on much of the work accomplished with JET which is currently the world's largest tokamak.

XXI–2. NEEDS FOR NUCLEAR ENGINEERS

A detailed labour market analysis is currently being carried out by Cogent, the UK sector skills council for nuclear. The data will be available from their web site (www.cogent-ssc.com) later in 2009.

XXI–3. EDUCATIONAL SYSTEM AND EDUCATIONAL INSTITUTIONS INVOLVED IN NUCLEAR EDUCATION

The UK consists of four countries: Northern Ireland, England, Wales and Scotland. Each has a slightly different pre-university education system. In Northern Ireland, England and Wales university entrance is at the age of 18, after A-levels. In Scotland university entrance is traditionally at 17, but this adds a year to the university first degree courses.

The top tier of 20 research-intensive 'Russell Group' universities account for 65% of UK university research income, 56% of all doctorates and over 30% of all students studying in the UK. These universities are:

- Birmingham;
- Bristol;
- Cambridge;
- Cardiff;
- Edinburgh;
- Glasgow;
- Imperial College London;
- King's College London;
- Leeds;
- Liverpool;
- London School of Economics;
- Manchester;
- Newcastle;
- Nottingham;
- Queen's University Belfast;
- Oxford;
- Sheffield;
- Southampton;
- University College London;
- Warwick.

The second tier '1994 Group' are:

- Bath;
- Birkbeck University of London (UL);
- Durham;

— East Anglia;
— Essex;
— Exeter;
— Goldsmiths UL;
— Royal Holloway UL;
— Lancaster;
— Leicester;
— Loughborough;
— Queen Mary UL;
— Reading;
— St Andrews;
— School of Oriental and African Studies;
— Surrey;
— Sussex;
— York.

Figure XXI–1 shows a simplified education ladder for the UK. Most of the first and second tier group universities offer both 3-year bachelor (BSc, BEng) and 4-year integrated master's (MPhys, MEng, MSci) undergraduate degrees. Most universities have a higher progression threshold for the integrated master's and this is the preferred qualification for entry to a PhD (or 'DPhil') programme.

In most UK universities, the academic year is split into two 12-week teaching semesters. The student loading is 120 UK credits or approximately 60 ECTS per year (1200 hours of application). Current ECTS guidelines indicate that one credit stands for about 25–30 working hours. Current practice in the UK is to equate one ECTS credit with two UK credits. One UK credit is generally recognized to represent 10 notional learning hours, so that one ECTS credit in UK terms would equate to approximately 20 notional hours of learning.

The bachelor and integrated master's degrees are classified (1st Class, 2.i, 2.ii, 3rd, Pass, Fail). Entry onto a PhD programme requires a 2.i or above (integrated master's degree preferred) or a postgraduate master's degree (MSc). Entry onto a postgraduate master's degree (MSc) requires a 2.ii or above.

The UK postgraduate MSc degree tends to serve a different purpose to the European master's. It is a one-year full-time programme of 48 weeks duration (rather than two semesters) and typically has 120 UK credits of taught courses and a 60 UK credit project and dissertation. Using the conversion above 180 UK credits for the MSc equates to 90 ECTS credits, but this is probably an over-estimate as there is a recommended limit of 75 ECTS that can be earned in a single year. The MSc is typically used by students wishing to move across into a different field. Thus students from general engineering or physical science undergraduate degrees can acquire the necessary nuclear knowledge from an MSc programme to allow them a favoured route into the nuclear industry or to start PhD research in a nuclear-related area. The UK MSc also offers an alternative route to a PhD programme to students who did not achieve a 2.i in their first degree. The degree is often but not always classified (Distinction,

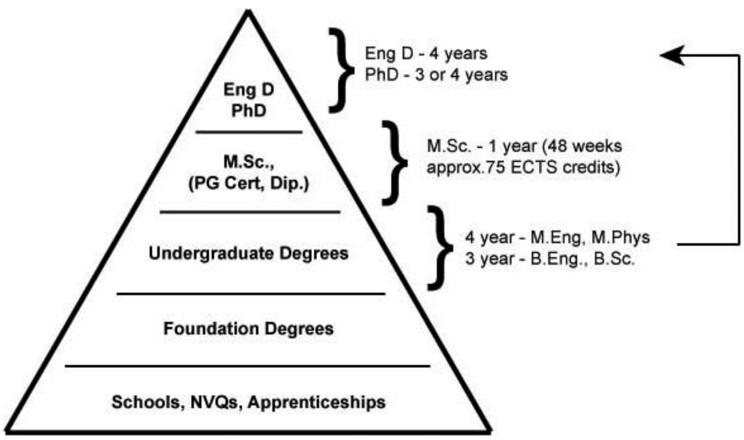


FIG. XXI–1. The education ladder in the United Kingdom.

Merit, Pass, Fail). MSc degrees may be taken part-time over three to five years. There is little enthusiasm in the UK to make the MSc Bologna-compatible.

At master's level, there are related awards of Postgraduate Certificate (60 UK credits of taught courses) and the Postgraduate Diploma (120 UK credits of taught courses).

At doctoral level, the standard PhD (or DPhil at Oxford and a few other universities) has traditionally been a 3-year programme. Research Councils who provide studentships for these degrees are now beginning to recognize the benefit of additional taught courses in the programmes and the degree is being extended to 3.5 or 4 years.

Two new types of PhD are now being funded by the research councils. Students at Engineering and Physical Sciences Research Council (EPSRC)-funded centres carry out a PhD-level research project together with taught coursework in a supportive and exciting environment.

The two types of centres are:

— Doctoral training centres;
— Engineering doctorate and industrial doctorate centres.

XXI–4. DOCTORAL TRAINING CENTRES

Students at these centres undertake:

— A 4-year PhD course or equivalent where the first year allows time for exploration before deciding on a project;
— A challenging and original research project at PhD level;
— A formal, assessable programme of taught coursework (up to 25% of the time and broadly equivalent to a master's in level and content) to develop technical interdisciplinary knowledge and broaden skills;
— Other activities to develop breadth of knowledge plus transferable skills training including public engagement.

XXI–5. ENGINEERING DOCTORATE AND INDUSTRIAL DOCTORATE CENTRES

Engineering Doctorate (EngD) is an alternative to the traditional PhD for students who want a career in industry. A four-year programme combines PhD-level research projects with taught courses, and students spend about 75% of their time working directly with a company.

The scheme has been expanded to include industrial doctorate centres across the whole of EPSRC's remit. Students on 4-year industrial doctorate programmes undertake technical and management training, assessed as part of the degree, to help their professional development. They carry out PhD-level research projects, jointly supervised by the university and a company, which aim to help the performance of the company. Like the EngD, around 75% of students' time is spent working within the company.

For more details on the following degree courses and degrees by research go to
http://www.nulcearliaison.com.

XXI–6. UNDERGRADUATE COURSE OFFERINGS

XXI–6.1. Foundation degrees

Foundation degrees in nuclear subjects are offered at The University of Central Lancashire (UCLan) in the following areas:

— Foundation degree in Nuclear Decommissioning;
— Foundation degree in Nuclear Project Management and Programme Control;
— Foundation degree in Nuclear Related Technology.

These courses can be converted into a full degree by taking the following top-up course BSc/BEng top-up degree in Nuclear Related Technology/Decommissioning.

These courses are delivered at Lakes College or Westfield Research Institute and at the sites of other decommissioning experts in West Cumbria, especially Gen. II Engineering and Technology Training. The Foundation degree in Nuclear Decommissioning course has also been franchised to Bridgwater College in Somerset to support the decommissioning of Hinkley Point. The courses are accredited by the National Skills Academy Nuclear (NSAN).

XXI–6.2. Undergraduate degrees

Nuclear aspects of science and engineering are taught as part of many undergraduate courses within the UK, such as many physics courses and the engineering course at the University of Cambridge but to list all these courses is beyond the scope this report. One indication of the recent trend towards more nuclear energy is the physics course at the University of Salford where 40 students are currently studying a major module on nuclear physics, which has a significant emphasis on nuclear energy. Currently the only dedicated nuclear undergraduate courses are offered by Lancaster University — M.Eng. In Nuclear Engineering — and Imperial College London that offers an M.Eng. in Mechanical Engineering with Nuclear, M.Eng. in Chemical Engineering with Nuclear and M.Eng. in Materials with Nuclear. Students take a generic first and second year and then take the following nuclear options — third year: Introduction to Nuclear Energy and Nuclear Chemical Engineering, fourth year: Nuclear Thermal Hydraulics, Reactor Physics and Nuclear Materials. From 2009 students at the University of Manchester will be able to transfer to an undergraduate degree in Mechanical Engineering (Nuclear) and from 2010 students will be able to register for a three or four year degree in Mechanical Engineering with Nuclear Engineering.

The Managing Radioactive Waste Safely (MRWS) programme will need a number of qualified geology and earth science students. There are currently 26 UK universities teaching these subjects:

Aberystwyth	Aberdeen	Birmingham	Bristol
Cambridge	Camborne School of Mines	Cardiff	Durham
Edinburgh	Imperial College London	Keele	Lancaster
Leeds	Leicester	Liverpool	Manchester
Newcastle	Open	Oxford	Portsmouth
Plymouth	Royal Holloway	Sheffield	Southampton
St Andrew’s	University College London		

The British Geological Survey report that they are still able to recruit satisfactory numbers of good geosciences graduates but they are becoming increasingly concerned about the shortage of highly numerate recruits who will be needed in areas such as modelling work related to the MRWS programme.

XXI–7. POST-GRADUATE (GRADUATE) COURSE OFFERINGS

The following postgraduate taught courses are currently offered by UK Universities. Direct links to these courses are available from www.nuclearliaison.com.

— University of Birmingham:
MSc in Physics and Technology of Nuclear Reactors;
MSc in Medical and Radiation Physics;
Postgraduate Certificate and Diploma in Radioactive Waste Management and Decommissioning.

— University of Central Lancashire (UCLan):
MSc, Postgraduate Diploma and Certificate in Energy and Environmental Engineering (Nuclear Decommissioning).

— University of Dundee:
  Master of Laws (LLM) and associated Diploma in International and Comparative Nuclear Law and Policy.
— Lancaster University:
  MSc in Decommissioning and Clean-Up;
  MSc in Safety Engineering;
  Both courses are run part time over two years.
— University of Liverpool:
  MSc in Radiometrics: Instrumentation and Modelling;
  Postgraduate Certificate in Radioactive Waste Monitoring and Decommissioning.
— University of Sheffield:
  MSc in Nuclear Environmental Science and Technology.
— University of Surrey:
  MSc in Radiation and Environmental Protection;
  MSc in Radiation Detection and Measurement.
— Nuclear Technology Education Consortium (NTEC) is a consortium of UK universities and other institutions providing postgraduate education in Nuclear Science & Technology. The consortium comprises the Universities of Birmingham, Lancaster, Leeds, Liverpool, Manchester and Sheffield, City University, London, HMS Sultan, Imperial College London, UHI Millennium Institute&Westlakes Research Institute.
  MSc, Diploma, Certificate and CPD programme.
— Nuclear Department within the Defence Academy (HMS Sultan):
  MSc in Nuclear Technology and Safety Management;
  Postgraduate Certificate in Radiation Protection.

Twenty-three institutions offer a taught MSc in some aspect of engineering geology (including soil/rock mechanics and mining):

Bangor	Durham	Imperial College London	Reading
Birmingham	Glasgow	Manchester	Sheffield
Camborne	Greenwich	Newcastle	South Bank
Cambridge	Heriot-Watt	Nottingham	Southampton
Cardiff	Kingston	Nottingham	Trent
Dundee	Leeds	Portsmouth	

XXI–7.1. Post-graduate research

Against a backdrop of reduced public funding for UK nuclear research and lab closures within UKAEA and the CEGB from the early 1980s to late 1990s, BNFL decided to consolidate its University research funding into four core centres of excellence, beginning in 1999 with three further centres opened in the following years:

— 1999 Centre of Radiochemistry Research (CRR) at the University of Manchester;
— 2000 Institute for Particle Science and Engineering (IPSE) at the University of Leeds;
— 2001 Immobilisation Science Laboratory (ISL) at the University of Sheffield;
— 2002 Materials Performance Centre (MPC) at UMIST (now the University of Manchester).

This industrial funding invigorated the public sector and several nuclear research consortia were established.

XXI–7.2. Research consortia

- KNOO — Keeping the Nuclear Option Open.
  Led by Imperial College London with Bristol, Open University, Sheffield, Manchester, Leeds, and Cardiff. £6.4 million over four years, 26 PhD students and 20 Post Doctoral Research Associates (PDRAs);
- DIAMOND — Decommissioning, Immobilisation and Management of Nuclear wastes for Disposal. Led by Leeds with Sheffield, Imperial, Manchester, Loughborough, ULC, and £4 million from July 2008 for four years, 28 PhDs and seven PDRAs;
- Nuclear Engineering Doctorate Programme (£7 million) from October 2007 for seven years. EPSRC-funded programme led by the University of Manchester in partnership with Imperial College London, with the Universities of Bristol, Leeds, Sheffield and Strathclyde. 18 projects have so far been funded;
- SPRing — Sustainability Assessment of Nuclear Power: An Integrated Approach. Led by University of Manchester with City University and Southampton. (£2.3 million).

XXI–7.3. Doctoral training centres

- Nuclear FiRST DTC (£7 million). Led by the University of Manchester with the University of Sheffield;
- E-Futures DTC (£7 million). The University of Sheffield.

XXI–8. AVAILABILITY OF RESEARCH AND EXPERIMENTAL FACILITIES

Imperial College London are currently deciding if life extension of the Consort research reactor is appropriate and hope to use the reactor for training and to restart experimental work based mostly around activation. In April 2009 a consortium comprising Serco, Battelle and the University of Manchester took over the management of the National Nuclear Laboratory (NNL). The main facility of the NNL is the former BNFL Technology Centre now known as the Central Laboratory, Sellafield. The Central Laboratory has extensive active facilities that support new reactor build, operation of reactors, operations of fuel processing plants and decommissioning and clean-up.

XXI–9. COOPERATION/COLLABORATIONS WITH INDUSTRY AND GOVERNMENT

The Nuclear Institute (NI) was created on 1 January 2009 by the merger of the British Nuclear Energy Society and the Institution of Nuclear Engineers. The Institute is able to offer a range of memberships at both a professorial level, for those seeking registration with the Engineering Council for example, to the layperson with an interest in nuclear matters. Supported by both industry and academia, one of the key roles of the NI is the advancement of education relating to nuclear energy and its application. This work is promoted by the NI Education and Training (E&T) Committee. NAILS is the UK Nuclear Academic Industry Liaison Sub-Committee of the NI and acts as a forum for exchange of information between the nuclear industry and nuclear universities.

Radioactive Waste Immobilisation Network (RWIN) brings together universities, industry, regulators and government agencies for regular meetings on the management of radwaste.

All the major educational consortia have industry representation on Management Committees.

XXI–10. NATIONAL AND INTERNATIONAL COOPERATION AND EDUCATIONAL NETWORKS

The Universities of Manchester and Birmingham as well as HMS Sultan are members of the European Nuclear Education Network (ENEN). Other universities are also involved with other EU Framework funded programmes such as ACTINET and CARBOWASTE.

XXI–11. ADDITIONAL INFORMATION

Cogent Sector Skills Council, http://www.cogent-ssc.com
Nuclear Liaison, http://www.nuclearliaison.com

Nuclear Institute, http://www.nuclearinst.com
Radioactive Waste Immobilisation Network, http://www.rwin.org.uk

Annex XXII

UNITED STATES OF AMERICA[15]

XXII–1. BACKGROUND

Nuclear science and engineering is vital to a number of fields including national security, power production, new reactor designs, radioactive waste management and many other science and related fields. The USA, a pioneer in nuclear energy, currently generates 19% of the nation's electricity through the use of nuclear power. Moreover, new initiatives in applied radiation sciences in conjunction with industrial and medical research, as well as initiatives in biotechnology, require students with a nuclear background.

Nuclear engineering programmes with an initial emphasis in fission-powered electricity generation were established in the late 1950s and 1960s. These were interdisciplinary efforts in many of the top research universities, and provided the human resources for this technical discipline. During the same time, a number of university nuclear reactors were constructed. These facilities were instrumental in the education of students in nuclear engineering, and launched a wide variety of university research programmes in the nuclear field. Since the 1960's, US universities have been leaders in this technology, and served a vital function in educating significant numbers of students.

XXII–2. INTERNATIONAL STUDENTS

The USA has had a long history of providing opportunities for nuclear education and training for students around the world. It would be challenging to identify the total number of students who have participated. This effort began in the 1950s at Oak Ridge National Laboratory with the Oak Ridge School of Reactor Technology. Many international students attended courses there. Subsequently, US universities with programmes in nuclear engineering have historically been very open to enroling students from other countries. This tradition continues to this day. After graduation, a large number of international students chose to remain in the USA. Many noteworthy leaders in the nuclear field in the USA started their careers in this way. Their contributions to nuclear technology in this country have been immense.

Conversely, a great many that came to the USA for studies, either undergraduate or graduate, chose to return home after finishing their academic programmes. Often they have become key leaders in the nuclear industry in their own country. In addition, the 'professional networks' that have emerged from these early career ties might be seen to this day as a defining characteristic of the international nuclear enterprise.

XXII–3. NUMBER OF PROGRAMMES AND HISTORICAL TRENDS

After an initial strong growth in nuclear engineering programmes in the USA, since the middle of the 1980s, the number of independent programmes and research reactors have seen serious decline. However, over the past five years, there has been a reversal with some universities either establishing, or re-establishing, nuclear engineering programmes. The same has not been the case for university research reactors. From a peak of 76 reactors 25 years ago, there are now 26 university research reactors in the USA.

The trend of nuclear engineering programmes from 1955 to 2008 is given in Figure XXII–1. The enrolment at the BSc, MSc and PhD levels in nuclear engineering programmes followed a similar path and the closures of nuclear engineering programmes and the decrease in student participation were closely linked.

---

[15] Prepared collaboratively by G. Brown, J. Gutteridge, A. Klein, K. Peddicord and A. Waltar. Questions should be addressed to K. Peddicord at k-peddicord@tamu.edu.

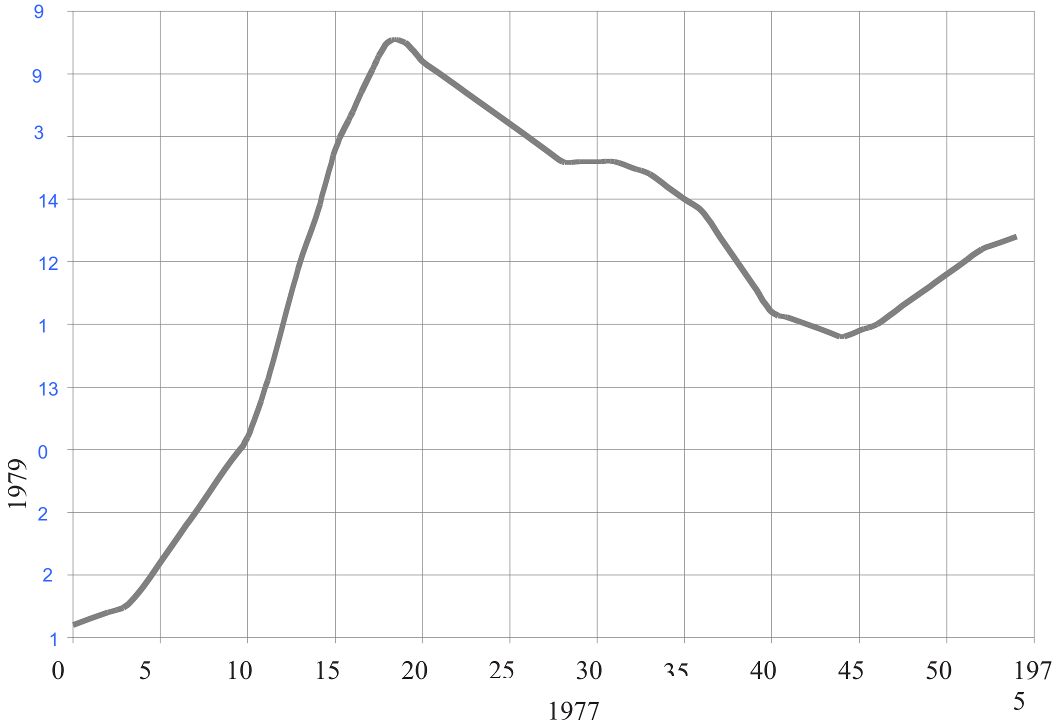


FIG. XXII–1. Historical trends of nuclear engineering programmes in the USA.

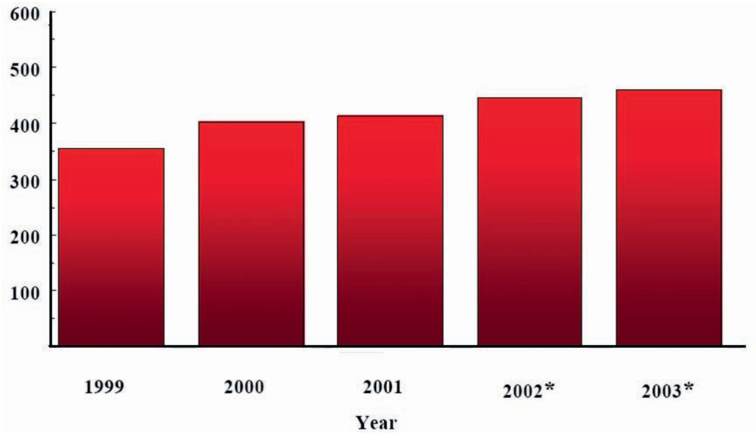


FIG. XXII–2. Gap between BSc and MSc annual employment needs and students graduated (for the fission nuclear power industry).

Shortages in the nuclear workforce were anticipated as early as 1999. This was due to many factors, i.e. including impending staff retirements at operating reactors, development of a future generation of new plants, new initiatives in the radiation sciences with applications in industry, medicine and biotechnology. The growing gap between supply and demand would be detrimental to the national interests, and its magnitude can be seen in Fig. XXII–2.

Also beginning in the late 1990s, as seen in Figure XXII–3, public opinion began to change and showed increasing acceptance of the need for nuclear power. This combination of increased public acceptance, retirements from the nuclear workforce, and plans for new plants put increasing pressure on the need for new graduates in nuclear engineering.

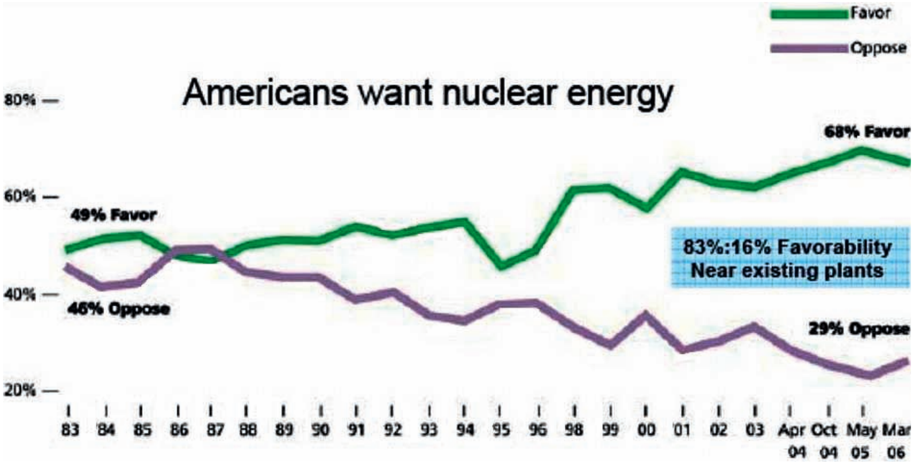


FIG. XXII–3. Steady improvement in public opinion.

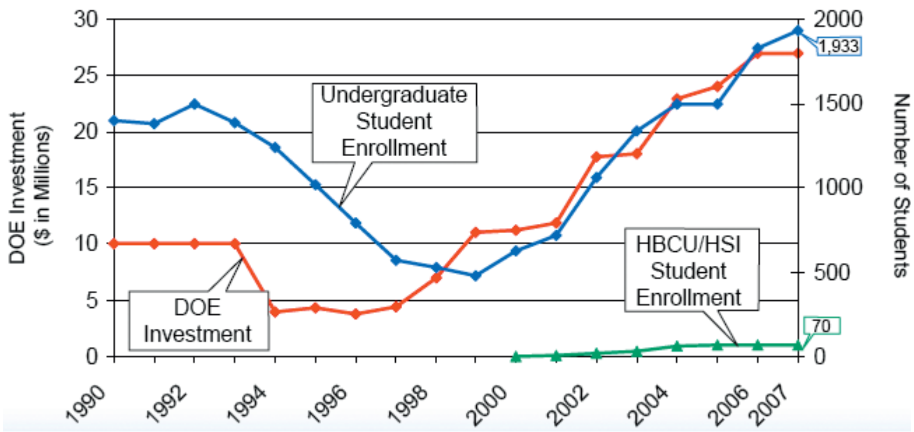


FIG. XXII–4. Improvement in undergraduate student enrolment.

XXII–4. RECENT DEVELOPMENTS

In November 1999, the DOE office of Nuclear Energy, Science and Technology requested that the Nuclear Energy Research Advisory Committee (NERAC) form an ad hoc panel to consider and address the educational issues related to the future of nuclear science and engineering. The panel recommended developing a strategic plan and associated actions for a future research programme in nuclear science and engineering.

In the early 2000s, several new DOE programmes were started including the Generation-IV programme, the Advanced Fuel Cycle Initiative (AFCI), and the Global Nuclear Energy Partnership (GNEP). More importantly, significant changes were implemented by the Nuclear Regulatory Commission (NRC) in the licensing process that utilized a combined Construction and Licensing Application (COLA) approach for the approval of new power plants. Combined with the high costs of natural gas and increasing public concerns about CO_2 emissions, by 2008 utilities announced an interest in submitting license applications for 34 new reactors to the NRC. These developments have had very positive impacts on student interest. With the prospects of good careers, undergraduate enrolments recovered to pre-1990 levels while graduate enrolments show steady growth with the availability of research funding. These improvements are shown in Figure XXII–4.

With the resurgence in interest in nuclear and by maintaining a base programme for university research reactor assistance, the trend in closures of university reactors was halted, as seen in Figure XXII–5. The funding support for educational programmes and experimental facilities is undergoing significant changes. After a two-year gap in support from the DOE Office of Nuclear Energy, Congress has provided funding for university programmes through not only DOE-NE, but also through the Nuclear Regulatory Commission and the National Nuclear Security

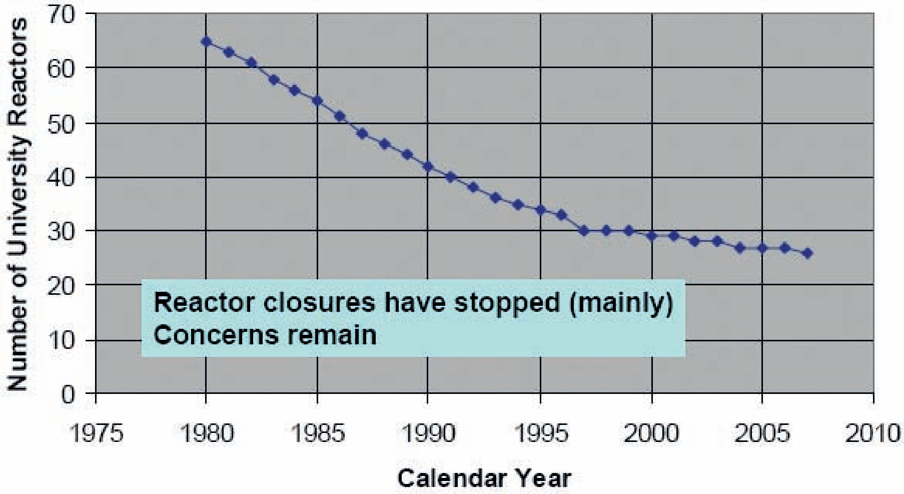


FIG. XXII–5. Number of universities research reactors in the USA.

Administration Office of Defence Nuclear Non-proliferation. In May 2009, DOE-NE awarded 71 university research projects totalling US $44 million. In addition, in 2008, the Nuclear Regulatory Commission issued 88 grants for various educational activities, and announced a further 102 grants in June 2009. These covered a broad spectrum of research projects, curriculum and academic programme development, scholarships and fellowships, and human resource development programmes.

This has led to a strong recovery in enrolments and academic programmes. Table XXII–1 shows the current status of US universities offering nuclear engineering degrees including the BSc, MSc, PhD, BE and ME. Other universities are offering courses in nuclear related subjects. Figure XXII–6 shows the enrolment in each programme at the undergraduate and graduate levels for the 2008–2009 academic years. However, even with this recovery, it is not yet clear that sufficient numbers of nuclear engineers will be graduated to meet the needs across the entire breadth of the nuclear enterprise.

Additional information can be found by visiting the web site for each institution.

XXII–5. BEST PRACTICES IN NUCLEAR EDUCATION IN THE USA

A large number of universities, colleges, agencies, laboratories and professional organizations are involved in the education of nuclear engineering students in the USA. Each of the academic programmes has its particular strengths and unique offerings, and many best practices might be referenced. The listing below is not meant to be complete. Instead it shows several examples of best practices in the preparation of nuclear engineers and related disciplines in the USA. By visiting the web sites of the programmes listed in the country report, a number of other significant capabilities can be found.

XXII–5.1. Nuclear Engineering Department Heads Organization

The Nuclear Engineering Department Heads Organization (NEDHO) is composed of the leaders of all the academic programmes in the country. NEDHO meets twice a year at the meetings of the American Nuclear Society. These get together provide a forum for discussions, and an opportunity to receive updates from federal agencies such as the Department of Energy and the Nuclear Regulatory Commission and hear from industrial groups like the Nuclear Energy Institute and the Institute for Nuclear Power Operations. These meetings are very helpful in keeping the academic community up to date on developments related to the university programme.

NEDHO also serves the function of representing the views of the nuclear engineering academic community to other organizations and constituencies. These can include the Department of Energy, the Nuclear Regulatory Commission, the Nuclear Energy Institute, and decision makers at the federal and state level including the US Congress. The role of NEDHO as a cohesive entity that brings together the key academic leaders is extremely important.

TABLE XXII–1. NUCLEAR ENGINEERING DEGREE AWARDING INSTITUTIONS IN THE UNITED STATES

Institution	Department	Degree
Air Force Institute of Tech.	Engineering Physics	MSc, PhD
Kansas State University	Mechanical and Nuclear Engineering	BSc, MSc, PhD
Georgia Institute of Technology	Nuclear and Radiological Engineering	BSc, MSc, PhD
Idaho State University	Institute of Nuclear Science and Engineering	BSc, MSc, PhD
Massachusetts Institute of Technology	Nuclear Science and Engineering	BSc, MSc, PhD
North Carolina State University	Nuclear Engineering	BSc, MSc, PhD
Ohio State University	Nuclear Engineering	MSc, PhD
Oregon State University	Nuclear Engineering and Radiation Health Physics	BSc, MSc, PhD
Pennsylvania State University	Mechanical and Nuclear Engineering	BSc, MSc, PhD
Pennsylvania State University	Distance Learning Programme in Nuclear Engineering	MEngr
Purdue University	School of Nuclear Engineering	BSc, MSc, PhD
Rensselaer Polytechnic Institute	Mechanical, Aerospace and Nuclear Engineering	BSc, MSc, PhD
Texas A&M University	Nuclear Engineering	BSc, MSc, PhD
University of California, Berkeley	Nuclear Engineering	BSc, MSc, PhD
University of Cincinnati	Mech., Industrial and Nuclear Engineering	BSc, MSc, PhD
University of Florida	Nuclear and Radiological Engineering	BSc, MSc, PhD
University of Idaho		MSc, PhD
University of Illinois at Urbana-Champaign	Nuclear, Plasma and Radiological Engineering	BSc, MSc, PhD
University of Maryland, College Park	Materials and Nuclear Engineering	MSc, PhD
University of Massachusetts Lowell	Chemical Engineering	BSc
Univ. of Michigan Ann Arbor	Nuclear Engineering and Radiological Sciences	BSc, MSc, PhD
University of Missouri–Columbia	Nuclear Science and Engineering Institute	MSc, PhD
University of Missouri–Rolla	Nuclear Engineering	BSc, MSc, PhD
University of New Mexico	Chemical and Nuclear Engineering	BSc, MSc, PhD
University of Tennessee at Knoxville	Nuclear Engineering	BSc, MSc, PhD
University of South Carolina	Nuclear Engineering	ME, MSc, PhD
University of Texas at Austin	Nuclear and Radiation Engineering	MSc, PhD
University of Wisconsin-Madison	Engineering Physics	BSc, MSc, PhD
US Naval Academy	Nuclear Engineering	BSc
US Military Academy	Nuclear Engineering	BSc

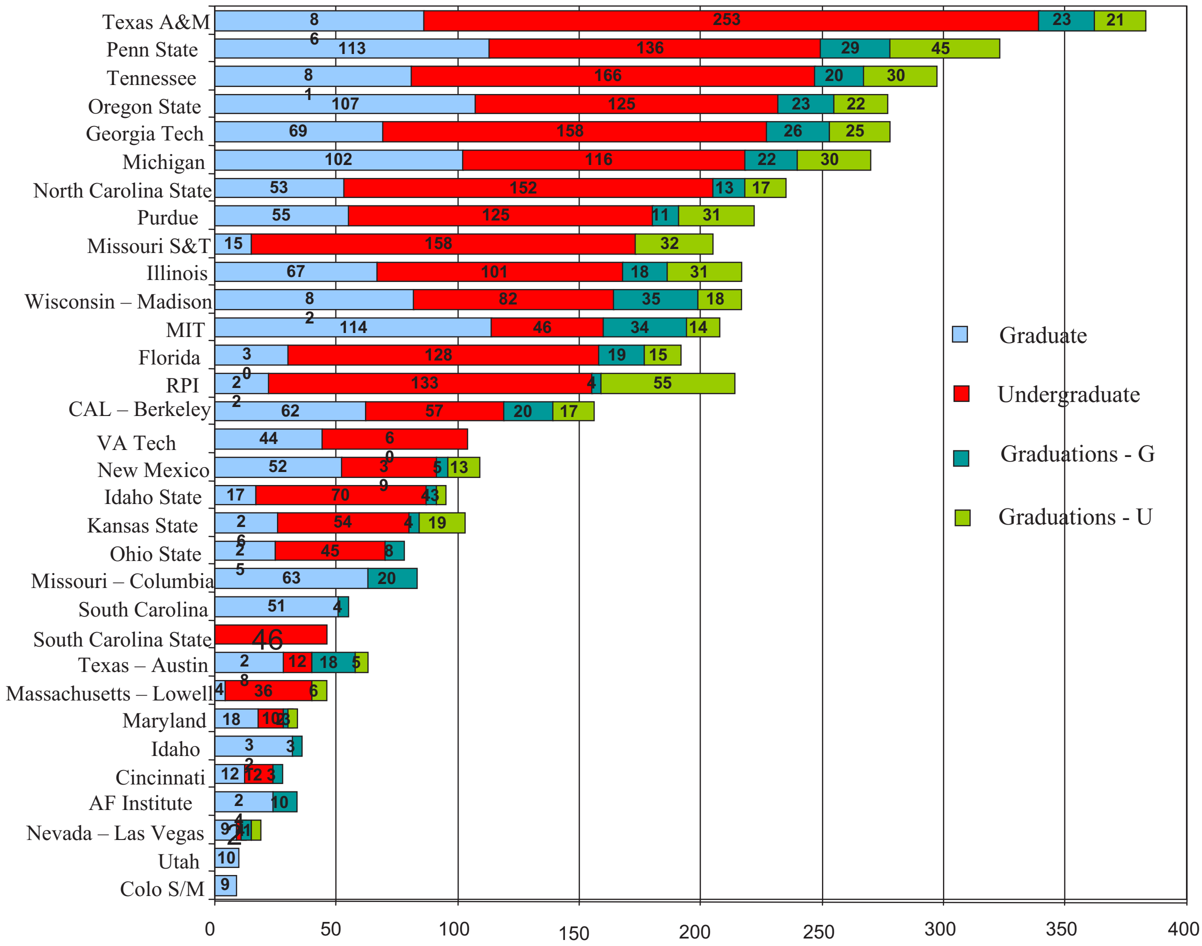


FIG. XXII–6. Nuclear engineering enrolment and graduations 2008–2009.

XXII–5.2. Universities — National laboratory collaboration

The Department of Energy (DOE) national laboratories and universities have historically collaborated in education and research. The interaction between university nuclear engineering programmes is extensive and takes on a wide variety of formats. Academic ties exist with virtually every DOE lab. In some cases, universities alone or in partnership with an industrial firm have partnered to operate a national laboratory. Below are two examples of university-national laboratory interactions.

— *University of Tennessee*
In 2000, the University of Tennessee at Knoxville joined with Battelle Memorial Institute to form UT-Battelle for the management of the Oak Ridge National Laboratory (ORNL). In this capacity, UT-Battelle oversees the operation of ORNL. It provides opportunities for students and faculty from the University to participate in laboratory activities. UT-Battelle is also very active in promoting science education through a wide range of regional outreach initiatives, and by equipping laboratories at high schools and community colleges [XXII–1].

— *National University Consortium*
The National University Consortium (NUC) is different in that a geographically dispersed set of five universities with academic programmes in nuclear engineering have joined the Battelle Energy Alliance to operate the Idaho National Laboratory (INL). INL has been given the responsibility by the Department of Energy's Office of Nuclear Energy to provide leadership in the advancement of nuclear energy. The NUC, established in 2005, is composed of the Massachusetts Institute of Technology, University of New Mexico, North Carolina State University, Ohio State University and Oregon State University. The NUC institutions

have interacted with INL for the mutual benefit of the NUC institutions and INL. In terms of governance, the NUC holds one seat on the INL Board of Advisors and serves on a number of technical advisory committees at INL. This provides a number of opportunities for the NUC institutions to learn about and critique the laboratories programmes. Each NUC university has defined an area of expertise. INL supports these areas to sponsor annual workshops on various topics where subject matter experts, along with students, are brought together to access the state of the art in various science and technology fields and associated needs. In addition, support for faculty, staff and student visits ranging from a single day to an extended period is important to enhancing NUC-INL interactions. This has resulted in a number of joint NUC faculty-INL staff appointments, and collaborative research projects involving students. As any new endeavour, the types of NUC-INL interactions continue to evolve so as to maximize the benefits to all participants.

In addition, the Department of Energy (DOE) in collaboration with the State of Idaho and its three universities — University of Idaho, Idaho State University and Boise State University — together with INL have formed the Centre for Advanced Energy Studies (CAES). The Centre is housed in a new 55 000 square foot research facility in Idaho Falls. This centre has facilitated the collaboration among the three universities and INL including dramatically increasing the number of students enroled in undergraduate and graduate education in nuclear engineering and science. Joint appointments and internships supporting a variety of research activities are underway utilizing the shared equipment and resources of CAES [XXII–2, XXII–3].

— *Berkeley Nuclear Research Centre*

The Berkeley Nuclear Research Centre (BNRC) is a joint venture between the University of California at Berkeley with Lawrence Livermore National Laboratory and Los Alamos National Laboratory. The Centre will promote exchange and collaboration among faculty, laboratory researchers, students and international partners, particularly from Asia-Pacific countries. BNRC-supported Laboratory scientists spend from several weeks to several months on the UCB campus as Affiliated Researchers, participating in proposed research, contributing to graduate teaching in various UCB departments (Nuclear Engineering, Physics, Chemistry, Public Policy, and others), and participating in seminars and workshops. The Centre also supports several graduate students per year and several postdoctoral researchers per year who spend extended periods of time at the national laboratories [XXII–4].

XXII–5.3. Distance delivery and web based programmes

With the advent of distance delivery and web based Internet options, a number of the nuclear engineering and health physics academic programmes in the USA have expanded their offerings to meet increasing needs. A number of these are underway, and three examples are cited below.

— University of Texas at Austin

The Nuclear and Radiation Engineering Area within the Department of Mechanical Engineering at the University of Texas at Austin is offering courses through distance learning alternatives. Videotaped lectures can now be viewed directly off of the Internet class site. Expansion of the programme capabilities to provide complete degree offerings of MS and PhD degrees is currently available. The Nuclear and Radiation Engineering distance learning coursework is designed for those students who already have an undergraduate degree and are currently working in the nuclear industry. Presently the Nuclear and Radiation Engineering Programme has distance-learning students who are employees or have been employees of the Texas Department of Health, PANTEX, Los Alamos National Lab, Pacific Northwest National Lab, Framatome, Allegiance Healthcare, and several consulting companies. These courses are also available for on-campus students who have course conflicts or are working part-time [XXII–5].

— Oregon State University

The Department of Nuclear Engineering at Oregon State University offers the Masters degree in Radiation Health Physics through its electronic, or E-campus, programme. The programme can be completed in a minimum of 2 years and no more than 7 years. Typically, students complete the programme in 3–4 years. Students are admitted in the fall term only. Master of Health Physics students are required to take a comprehensive oral exam and to complete a thesis and thesis defence. Travel to campus is required for two one-week, on-campus summer laboratory classes. Each student must be present on campus for their thesis defence or comprehensive oral exam at the end of their programme [XXII–6].

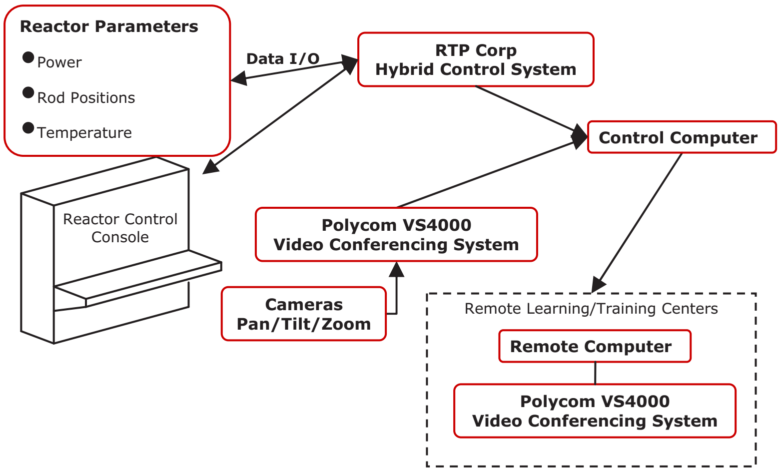


FIG. XXII–7. A schematic of the system used to connect the PULSTAR to the Internet.

— *Georgia Institute of Technology*
The Nuclear and Radiological Engineering Programme in the Woodruff School at Georgia Tech has approved 18 remote facilities around the country where students can access the medical physics programme. These remote facilities can be used by distance-learning medical physics students to meet the clinical rotation requirements in the curricula [XXII–7].

XXII–5.4. Virtual reactor laboratories

In an effort to provide access to research laboratory capabilities, several universities have created virtual reactor laboratories. Two such initiatives are listed below.

— *North Carolina State University (NCSU) PULSTAR Virtual Reactor*
Educational activities are one of the primary mission objectives for the PULSTAR reactor. Its utilization in the education of nuclear engineering students at NCSU at both the undergraduate and graduate levels extends back to the days of its establishment in 1972. Nuclear engineering classes in reactor physics and heat transfer incorporate the reactor into their curricula. In addition, in recent years the PULSTAR reactor has also become a regional centre for education in the USA. Through the utilization of the Internet and video conferencing technology, nuclear engineering students at off-campus sites are able to connect to the PULSTAR reactor and observe experimental exercises in a fashion that is highly similar to on-campus students. Since 2004, this capability has been implemented in reactor laboratory courses offered to nuclear engineering students on the campuses of the University of Tennessee and Georgia Institute of Technology. Figure XXII–7 below shows a schematic of the system used to connect the PULSTAR to the Internet. Experiments such as approach to criticality, control rod worth measurements, and estimation of the power coefficient of reactivity have been successfully conducted. Consequently, this utilization of a university reactor ushers in a new approach for its use in education, which is completely defined by the technical capabilities of the twenty-first century, namely, the Internet. Notably, this approach can also be implemented on an international scale, where students in other countries can connect to the PULSTAR and perform their experiments.
The schematic of the distance education system shows how it is implemented at the PULSTAR reactor. Digital reactor data such as power, rod positions and coolant temperature are transmitted through the Internet to the remote site [XXII–8, XXII–9].

— *University of Massachusetts at Lowell*
UMass-Lowell has developed a system for making real time and archived research reactor data available to educational users via a standard web browser. This capability is available online to facilitate various remote learning activities and training exercises via the http://nuclear101.com web site. The system offers nearly all the same real time and archival data acquisition capability as available to the UMass-Lowell Research

Reactor (UMLRR) control room operators, and gives the remote user nearly the same look and feel as if the person were actually present in the control room.

This remote accessibility uses a standard personal computer to act as a web server along with the use of a special purpose software package that receives data from the control room computers and distributes it in a web based format. This software tool is used to create a series of screens that allow a remote user to observe most of the same real time and historical information that is accessible to the reactor operators in the UMLRR control room. Some limited real time remote control of the secondary system controls is under development. This new capability should enhance the remote user's interaction with the system and expand the range of innovative experiments and demos that are possible within the fullMLR UR facility.

UMass-Lowell's capability to perform live experiments and deliver archived reactor operations data via a web-based interface to remote users allows simultaneous delivery of significant educational content to as many as 30 remote sites. The http://nuclear101.com web site serves as a general educational resource for students, instructors, and working professionals interested in the nuclear engineering field. The web site currently has archived data and descriptions for a dozen different demonstrations and experiments that address a variety of subjects, including energy balance considerations, differential worth measurements, xenon poisoning, temperature coefficient effects, approach to critical experiments using 1/M plots, and a variety of routine operational transients (power manoeuvres, flow transients, etc.). The unique aspect of this web site is that it provides a direct link to real time and archived data from the UMLRR, along with a continually growing set of lecture notes, example experiments and demos that can serve as a general resource for the nuclear engineering educational community [XXII–10].

XXII–5.5. Outreach to students and teachers

In the USA, university nuclear engineering departments carry out very active outreach programmes to high schools. These initiatives include visits to describe nuclear engineering and nuclear energy to high school students. Other approaches include participation in high school ‘college days’ and ‘career fairs’. Frequent visits occur by high school groups to university campuses for tours of facilities such as university reactors. There is a similar focus on teachers. Specialized teacher workshops are held by professionals from academia and industry. Organizations such as the American Nuclear Society (ANS) and Health Physics Society (HPS) put on these events either at local schools or as part of regional and national conferences. The Department of Energy and the Nuclear Regulatory Commission have resources available for teachers. Many utilities are active in educational and outreach efforts in their local communities.

A number of examples are shown below:

— *US Nuclear Society*

ANS provides programmes for teachers. One such resource is entitled Detecting Radiation in Our Radioactive World. In the description, teachers can learn how to use Geiger counters to detect radiation from background and manmade sources. Teachers who complete the workshop receive a free Geiger counter, Teacher Handbook with ideas for classroom use, and instructions and information about radioactive sources that can be safely used in the classroom. Designed for middle school and high school, these materials are applicable to all areas of science instruction.

Workshop locations and dates will be posted on the ANS web site as they are scheduled and additional information added as it becomes available.

This popular workshop programme includes classroom experiments and demonstrations crucial to making classroom learning come to life.

Educational materials developed by ANS volunteers and staff are provided free to classroom teachers. The items include booklets, supplemental handouts, posters, and other instructional tools. Materials are developed for students ranging from elementary through young adult level [XXII–11].

— *Health Physics Society*

HPS provides materials and support for teachers. In this case, the information is about a variety of issues relating to radiation. These include links to the Radiation Fact Sheets and Radiation Terms and Definitions. A Radiation Awareness slide presentation is available for use in teaching the basic concepts of radiation science. In addition, an ‘Ask the Expert’ resource is available so questions can be asked about the Society, radiation protection, or the field of health physics using the interactive features of the site. There are many questions that have already been answered, and these can be viewed on the ‘Ask the Experts’ questions and answers page [XXII–12].

Another web site dedicated to public education contains scientific and objective information about radiation in a friendly, easy-to-read format [XXII–13].

— *US Department of Energy*

On its web site, the Office of Nuclear Energy at DOE has a page devoted to students. This is constructed along the lines of interactive web-based games that are very popular among young people. The page is entitled ‘The Power Pack’, and includes activities at three progressing more challenging levels. These are for Young Visitors, ‘Just Right’ Details, and Deep Discussion. There is also a Teachers’ Lounge for additional course and curricular materials [XXII–14].

— *US Nuclear Regulatory Commission*

On its web site, the NRC has a page devoted to students and teachers. The focus is on the role of the Commission, the goals and the regulatory process. The information is put into a more easily understandable format [XXII–15].

— *Exelon Corporation*

The ‘Stay in School Initiative’ is an Exelon collaboration with the United Way focused on spurring graduation rates and stemming truancy in three Chicago communities with some of the highest dropout rates in the city. Students who participated in the ‘Stay in School Initiative’ last year had a 93% 2008 Citizenship Highlights graduation rate, well above the 55% average in Chicago Public Schools. These results are part of an annual report card [XXII–16].

— *North Carolina State University*

A student life cycle approach is taken at NC State's Nuclear Engineering Outreach Programme. It is about students, educators, parents, counsellors and peer groups-in both formal and informal settings. The programmes include science class visits (on and off campus), a 3-week high school summer programme hands-on interaction, teacher workshops in collaboration with local utilities, teacher associations and school boards, science fair participation, science club/boy scout/girl scout interaction, involvement with state level Department of Public Instruction, new student orientation (incoming freshman students), recruitment-admissions involvement, teaching introductory general classes and infusing a nuclear project into freshman design projects, continued retention programmes (e.g. scholarships, research programmes, professional development) through graduation, graduate recruitment, industrial field trips, ANS Student Chapter advising, and alumni development. These activities are done in association with the College of Engineering, industry, and nuclear engineering student ambassadors-faculty-fellow staff members. Demonstrating a nuclear ‘family’ makes a difference to undergraduate and graduate students' educational careers [XXII–17].

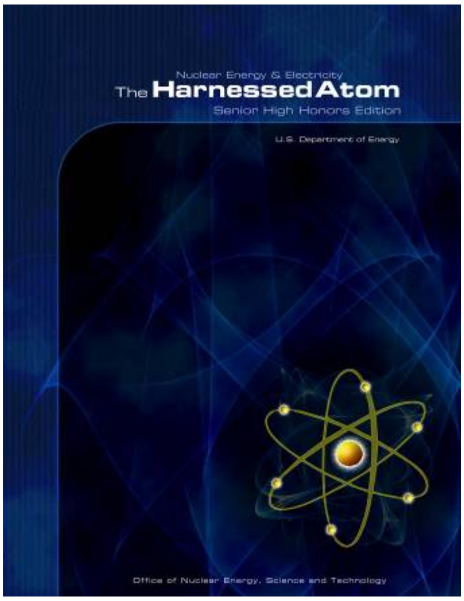
XXII–5.6. The Harnessed Atom

An important part of informing students of the role of nuclear energy and the associated science and technology are developing materials that teachers can use as part of their educational function. One such good example is The Harnessed Atom.

Developed through support from the US Department of Energy, this is part of a nuclear energy curriculum designed for grades six through eight. The complete kit includes a written text, filmstrip, review exercises, activities for the students, and a teacher’s guide. The 19 lessons in the curriculum are divided into four units including:

— Energy and electricity;
— Understanding atoms and radiation;
— The Franklin nuclear power plant;
— Addressing the issues.

The teachers guide contains suggestions for using the materials, including ideas for a learning centre. The material was developed to help teachers teach concepts as well as basic skills. Also included are discussion questions, answers to review exercises and activities, a list of materials, and a list of additional resources [XXII–18].



A re-designed High School curriculum:

- For advanced students grades 11–12;
- Updated content and format;
- Worked with public school classroom teachers to review and validate through Pilot Test of the curriculum;
- '07–'08 Field Test of a revised edition in five regions across the USA;
- Afterwards, distribute curriculum nationally in partnership with labs, academic institutions, public and private sector.

FIG. XXII–8. A re-designed high school curriculum.

XXII–5.7. Centre for Energy Development, Wharton County Junior College

In Bay City, Texas, the South Texas Project (STP) acquired a facility away from the plant site to house the engineering staff for units 3 and 4. This was a large store that was no longer in use. The result was the Centre for Energy Development. In addition to the staff from STP, it was also possible to locate in the same facility the academic programme leading to the Associates degree in Nuclear Power Technology offered by Wharton County Junior College. The result is an exceptional environment in preparing students. The students have an opportunity to interact with plant staff on an ongoing basis. Likewise, the engineers can directly participate in the teaching functions of the college programmes. This is an excellent best practice that might be replicated elsewhere to produce optimum benefits in preparing new members of the nuclear workforce [XXII–19].

XXII–5.8. Integrated university/community college programmes

Often the educational programmes at various levels in preparing students to enter the nuclear workforce are organized and carried out in isolation from one another. For example, in the USA, programmes at the 2-year level in community colleges are under development without connection to the 4-year university programmes. Best result arises from integrating the efforts to include 2-year community colleges, 4-year universities, industry and utilities, appropriate government agencies, high schools and secondary schools and teachers, and outreach to engage the students. Without this type of integration and partnership, the various efforts to develop the nuclear workforce can be disconnected and less effective [XXII–20].

XXII–5.9. International collaboration

Opportunities for international experiences and ties are seen to be an extremely important part in the educational experience of students and have become part of the activities of many nuclear engineering programmes in the USA. Some examples of this type of collaboration are listed below.

— *University of California at Berkeley*
The Department of Nuclear Engineering at the University of California at Berkeley has annually hosted the Asia-Pacific Forum dealing with current nuclear issues. In 2008, the topic was integration of safety, security

and sustainability of nuclear technology. In 2009, the forum covered nuclear technology, safeguards and nuclear forensics. Overseas participants have included experts and leaders from industry (AREVA), universities (University of Tokyo, Tokyo Institute of Technology, Tsinghua University and Shanghai University), and international organizations (JAEC, JAEA, KAIST, KAERI, CRIEPI, and IAEA). The forums have provided students an excellent opportunity to interact with individuals from the international nuclear community.

— *Massachusetts Institute of Technology (MIT)*
The MIT International Science and Technology Initiative (MISTI) facilitate summer internships around the globe. With support from the Centre for Advanced Nuclear Energy Studies, approximately ten students have been placed at research centres in countries including Japan (TEPCO and Toshiba), France (CEA and AREVA), Germany (Karlsruhe Energy Centre), and the IAEA. In addition, since 2005 agreements to hold joint symposia on nuclear technology that have included students from the Tokyo Institute of Technology, Ecole Polytechnique and the University of Sao Paolo along with students from MIT.

— *Texas A&M University*
Since 1996, the Department of Nuclear Engineering at Texas A&M University has collaborated with the Moscow Engineering Physics Institute (MEPhI) and the Obninsk Institute for Nuclear Power Engineering (INPE) in the Russian Academic Programme in Nuclear and International Security (RAP-NIS). The programme has developed new curricula and programmes in nuclear materials safe management, radiation protection of man and the environment, decommissioning and decontamination of facilities in the nuclear fuel cycle, and nuclear non-proliferation. In addition to joint research projects and annual meetings involving faculty members from all three universities, a key part of RAP-NIS is the Foreign Field Experience (FFE). In this activity, students from A&M, MEPhI and INPE join together for a weeklong series of lectures, visits and tours of a broad range of nuclear facilities. FFE events have taken place in the USA, France, Belgium and Switzerland. This gives students an opportunity to observe modern standards and practices, and build enduring professional networks.

XXII–5.10. Professional development and education

Continuing education and professional development are vitally important for specialists in any field to keep current with emerging technologies. Nuclear engineering programmes offer several opportunities in this area. Some examples are listed below.

— *Massachusetts Institute of Technology*
The Department of Nuclear Science and Engineering at MIT offers annual short courses for professionals in the power industry with a focus on nuclear plant safety and reliability methods in nuclear plant operations. A typical class involves 30 people. Participants come from academia, industry, governmental agencies and overseas organizations [XXII–21].

— *University of Wisconsin*
The University of Wisconsin in collaboration with other institutions annually conducts a short course on modelling and computation of multi-phase flows. Topics include new reactor systems and methods, computational multi-fluid dynamics, and computer fluid dynamics commercial codes [XXII–22].

REFERENCIES TO ANNEX XXII

[XXII–1] http://ut-battelle.org/
[XXII–2] www.inl.gov
[XXII–3] https://inlportal.inl.gov/portal/server.pt?open=512&objID=281&mode=2
[XXII–4] http://www.nuc.berkeley.edu/
[XXII–5] www.me.utexas.edu/~nuclear/information/dl.shtml
[XXII–6] http://ne.oregonstate.edu/prospective/Ecampus.html
[XXII–7] www.nre.gatech.edu/about/mp_remote.shtml
[XXII–8] www.ne.ncsu.edu/NRP/pulstar.html
[XXII–9] www.ne.ncsu.edu/NRP/virtual_reactor.html

[XXII–10] http://nuclear101.com
[XXII–11] www.ans.org/pi/edu/teachers/workshops/
[XXII–12] hps.org/sciencesupport/
[XXII–13] www.radiationanswers.org
[XXII–14] www.ne.doe.gov/students/intro.html
[XXII–15] www.nrc.gov/reading-rm/basic-ref/students.html
[XXII–16] http://www.exeloncorp.com/corpresponsibility/community
[XXII–17] http://www.ne.ncsu.edu/outreach/index.html
[XXII–18] www.antiqbook.com/books/bookinfo.phtml?nr=1174602003&Language=en
[XXII–19] www.wcjc.edu/campuses/BayCity/default.asp
[XXII–20] www.nuclearpowerinstitute.org
[XXII–21] http://mit.edu/canes/education/education.html
[XXII–22] http://www.ascomp.ch/ShortCourse/

Annex XXIII

VIETNAM[16]

XXIII–1. BACKGROUND

— 1923–1924: Beginning of use of radioactive sources for cancer treatment in Vietnam (namely in the L’Institut de Radium de L’Indochine, which was founded in Hanoi on 19 October 1923 (see Fig. XXIII–1) [XXIII–1];
— 1960–1969: Nuclear physics began to be studied in the following education institutions in the country:
  - University of Natural Sciences (in Hanoi);
  - Institute of Physics (in Hanoi);
  - Hanoi University of Technology (in Hanoi);
  - Saigon University and Nuclear Reactor in Da Lat (South Vietnam).

XXIII–2. NEEDS FOR NUCLEAR ENGINEERS, INCLUDING GRAPHICS TO SHOW STATISTICS[17]

Since the early 1960s, nuclear techniques were applied in Vietnam for searching coal mines and minerals. Since then there were more and more demands in nuclear engineer for industrial applications. According to idea of the first Minister of the Ministry of Higher Education of Vietnam, the Late Prof. Ta Quang Buu, on introducing Nuclear Engineering Education into the country, preparation for establishing the Department of Nuclear Engineering Physics (DONEP) was started at the end of 1967. This process led to the establishment of the DONEP at Hanoi University of Technology (HUT) in 1970.

The objectives of nuclear engineering education programme of HUT are as follows:

— To develop peaceful applications of atomic energy in Vietnam;
— To prepare initial engineering manpower for introduction of nuclear energy into Vietnam.

The number of students enroled in the nuclear engineering education programme at HUT was 10–15 people every year during 1970–1990. The period 1990–1999 was the most difficult post-Chernobyl time for nuclear education in the country. During this time, the HUT’s DONEP could not enrol any new students to follow its

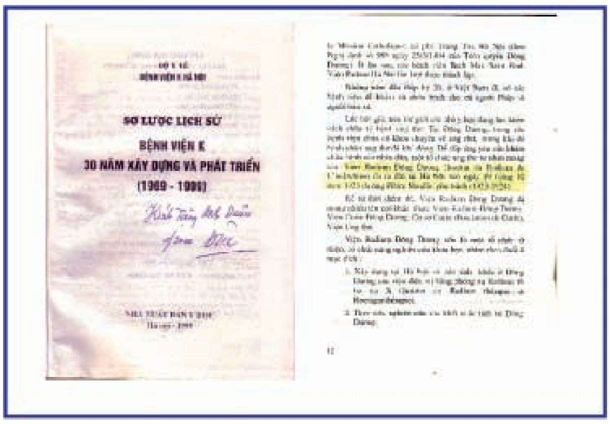


FIG. XXIII–1. Date of foundation of Institute of Radium in Vietnam; October 19, 1923.

[16] Prepared by P. Van Duan, Institute of Nuclear Engineering and Environmental Physics, Hanoi University of Technology, Vietnam, E-mail: pvduan@mail.hut.edu.vn.

[17] Industrial demands for nuclear expertise compared to what the educational system is able to produce, trends over the past few years.

education programme. In order to overcome the severe difficulties in this period, DONEP had to adapt its programme considerably. The education programme of DONEP was adapted by keeping its above mentioned traditional objectives without any changes but successfully realizing a fruitful combination of the field of nuclear engineering and the field of environmental physics, thus keeping nuclear engineering education alive at HUT. Right after DONEP took such adaption and simultaneously renamed the Department of Nuclear Engineering and Environmental Physics (DONEEP) in February 2000, many students came to follow the education programme in Nuclear Engineering and Environmental Physics (NEEP) at HUT. Since 2000–2001, new students continuously come to follow the HUT's NEEP-programme and every year a group of 6 to 13 students receive a Diploma of Engineering degree in NEEP [XXIII–2–XXIII–4].

There were very important landmarks for nuclear engineering education in Vietnam in 2006 and 2007. The strategy for peaceful uses of atomic energy in the country up to 2020 was approved by the Prime Minister on 3 January 2006. It is in this strategy that the introduction of a nuclear power plant into the country was officially pronounced for the first time. The Master Plan for implementation of the strategy was approved by the Prime Minister of next term on 23 July 2007. According to the Master Plan, the Ministry of Education and Training (MOET) has the main responsibility in setting up education projects in nuclear engineering HRD [5–7]. These events bring strong impulses for nuclear engineering education in general and particularly for nuclear power engineering education in the country.

To meet the demands for nuclear engineers and for introducing nuclear energy and other peaceful applications of atomic energy into the country, the DONEEP made great efforts towards upgrading itself. Its two-year persevering preparation full of difficulties has resulted in the establishment of the Institute of Nuclear Engineering and Environmental Physics (INEEP) at HUT according to the decision of the Minister of MOET of Vietnam on 4 April 2008.

In the academic year 2008–2009, the INEEP established its new education programme which has come into force in 2009–2010. The new education programme at NEEP at HUT consists of three parts as follows:

— The first part of the NEEP-Programme consists of 130 credits considered for the first four years of study;
— The second part of the NEEP-Programme consists of 30 credits for the fifth year of study;
— The third part of the NEEP-Programme consists of 36 credits for applications field or 43 credits for research field, which are considered for one year of study.

Having finished the first part, a student can receive a Bachelor degree. The Diploma of engineering degree will be issued to students who successfully finish 160 credits including 130 credits of the first part and 30 credits of the second part. The NEEP-engineers, having successfully completed the third part of the programme, will receive a Diploma of Master degree. The students who are involved in NEEP-Programme for a master degree but are not NEEP-engineers should complete a number of supplementary credits.

In order to meet the demands of the country in development of nuclear engineering human resources, the MOET had set up a Council for Establishing a Mandatory Skeleton Programme of Education in Nuclear Engineering (CEMSPE in NE) at the end of December 2008 for Vietnam's higher education institutions. The CEMSPE in NE consisted of 11 members from universities and related scientific organizations. The Skeleton Programme proposed by the Council in May 2009 is considered for an engineer degree and has 98 mandatory credits. Universities should insert into the Skeleton Programme at least 52 additional credits selected by themselves to set up their full programme of education for engineer degree in nuclear engineering. Universities should also base on this Skeleton Programme to set up their programme for bachelor degree in nuclear engineering.

The aforementioned measures are the useful steps in adjusting nuclear engineering education towards providing the nuclear engineering human resources for the first nuclear power plants in the country in the 2020s years.

XXIII–3. EDUCATIONAL SYSTEM AND EDUCATIONAL INSTITUTIONS INVOLVED IN NUCLEAR EDUCATION [18]

In Vietnam, according to MOET's statistic for the academic year 2007–2008, there are 209 colleges with a total of 0.42 million students and 160 universities with 1.18 million students and 38.2 thousand teaching staff. Among this total number of teaching staff of 160 universities, only 5.5% of them have academic title of professor, 14.8% of them have doctoral degrees and more than 40% of them have a master's degree [XXIII–8]. This fact reflects also the present situation of the teaching staff in field of nuclear education in the country. The fact clearly indicates that enhancement of the quality of teaching staff, in order to heighten capacity in nuclear education especially in nuclear engineering, should be considered the most urgent task of the Vietnamese nuclear community at present.

Among the above mentioned higher education institutions, there are only four universities currently offering nuclear education [XXIII–9–XXIII–12] (see Refs [XXIII–2–XXIII–4]). These institutions are listed in Table XXIII–1 together with the duration of their nuclear education programme and degree of diplomas issued to students having finished the programme. In addition to the list in Table XXIII–1, the Institute of Physics participates also in nuclear education for master degree.

Since 1970, the HUT is the only institution which offers an education programme in nuclear engineering. The number of students following its NEEP-programme of education since the academic year 2000–2001 is given in Table XXIII–2. The Table XXIII–2 shows that number of students of the HUT's NEEP-Programme dramatically increases since the academic year 2006–2007.

The progress in nuclear engineering education in Vietnam is due to the following factors:

- Influence of the strong impulses for nuclear engineering education, which were mentioned above in connection with the approval of the strategy of peaceful uses of atomic energy in the country and the Master Plan for implementation of this strategy;
- Impacts of the appropriate improvement of NEEP-Programme of education at HUT and results of research activities in the field of NEEP, which students can observe;
- Affects of technical support from the IAEA TC-Project and the World Bank Sub-Project, which were implemented 2003–2006, and other international cooperation activities for supporting education in NEEP at HUT;
- Positive influence of the web site of HUT's NEEP-Programme of education and effects of a combination of appropriate additional measures towards propagating the NEEP programme and its activities among new students;
- Unceasing efforts in the right direction in preparation and/or creation of conditions towards development of the NEEP-Programme;
- Appointment of a right person having professional capacity and personal qualities, who is full of initiatives and sense of responsibility, to the post of head of nuclear engineering education programme for a long enough period of time.

TABLE XXIII–1. INSTITUTIONS OFFERING NUCLEAR EDUCATION PROGRAMMES IN VIETNAM

Name of nuclear education institution	Duration of education programme and degree of first diploma	Degrees of diplomas
University of Natural Sciences in Hanoi	4 years: Bachelor degree	Bachelor, Master, PhD.
University of Natural Sciences in HCM City	4 years: Bachelor degree	Bachelor, Master, PhD.
University in Dalat	4 years: Bachelor degree	Bachelor
Hanoi University of Technology	5 years: Engineer degree	Engineer, Master, PhD.

[18] Undergraduate course offerings, Post-graduate (Graduate) course offerings. (Description of the educational system of your country, listing of universities offering courses in nuclear education, including their web addresses and extent of education (BSc, MSc, PhD), some statistics on the courses (number of students) and trends over the past few years, etc.).

TABLE XXIII–2. NUMBER OF STUDENTS FOLLOWING THE NEEP-PROGRAMME AT HUT

Academic year	Number of students received diploma of engineer degree	Total number of students of NEEP-programme for engineer degree
2000–2001	8	8
2001–2002	7	7
2002–2003	7	7
2003–2004	8	8
2004–2005	7	7
2005–2006	8	8
2006–2007	9	22
2007–2008	13	19
2008–2009	6	15
2009–2010	9 (expected)	About 60 (expected)
		Distribution of students on year of study:
		5th year: 9
		4th year: 20
		3rd year: 15
		2nd year: X[a]

[a] X — the number of second year students will be available in the beginning of the academic year.

XXIII–4. AVAILABILITY OF RESEARCH AND EXPERIMENTAL FACILITIES (SUCH AS A RESEARCH REACTOR, ACCELERATORS, ETC.)

The following experimental facilities are available in Vietnam and can be utilized for nuclear education:

— Nuclear reactor (of power of 500 kW, in Da Lat);
— Electron accelerator Microtron MT-17 (in Hanoi);
— Pulse neutron generator (in Hanoi);
— Cyclotrons (in Hanoi);
— Linear accelerators which are used for medical purposes (in Hanoi, Saigon, Can Tho etc.) but can be also utilized sometime for education.

XXIII–5. NATIONAL AND INTERNATIONAL COOPERATION AND EDUCATIONAL NETWORKS

Nuclear education institutions have close cooperation amongst themselves as well as with the nuclear community in the country; for example:

— Master course students of Department of Nuclear Physics (DNP) of the Hanoi University of Natural Sciences (HUNS) often conducted their experiments at the DONEEP and the INEEP of the Hanoi University of Technology;
— Many scientists of the Centre of Nuclear Physics (CNP) of the Institute of Physics (IOP) are invited lecturers of the HUT's DONEEP and INEEP, as well as of the HUNS's DNP;

— Many additional joint short courses or seminars were organized at the IOP's CNP and at the VAEC's units for students and young staff of nuclear community in the country;
— The Councils for Evaluation of Defending of Master Degree Theses or Doctoral Degree Dissertations usually consisted of the professors from these three institutions as well as scientists from the Institute of Nuclear Science and Techniques;
— Professors of nuclear education institutions often are members of the councils responsible for approving the research subjects of the VAEC's scientists as well as members of the Advisory Council of the Vietnam Agency for Radiation and Nuclear Safety (VARANS).

National cooperation and feedback helped the nuclear education institutions to correctly adjust and improve their education programme to meet the demand of the country.

Alongside national cooperation, Vietnam's nuclear education institutions are involved in active international cooperation and educational networks, especially the Asian Network for Education in Nuclear Technology (ANENT). Prof. Ph. Van Duan from HUT was responsible for one of the five main tasks of the ANENT cyber platform of which serves as a good means for teachers and students references.

Cooperation of Vietnam's nuclear education institutions with Korean, Japanese, French and Russian partners as well as with Toshiba Corporation results in first sweet fruits. It is necessary to emphasise that effective assistance by the IAEA and other international organizations have played an important role in strengthening the capacity of nuclear education and, particularly of nuclear engineering education, in Vietnam.

XXIII–6. BEST PRACTICES, INCLUDING PRACTICES/OUTREACH PROGRAMMES TO 'FILL THE PIPELINE' (CONNECTION TO HIGH SCHOOL STUDENTS AND TEACHERS)

For the last 15–20 years, nuclear education in Vietnam passed a long way and its nuclear engineering education branch achieved first results in development since the year 2000. From this practice one may draw the following important lessons:

— Unceasing efforts in the right direction in preparation and/or creation of conditions towards development of the Nuclear Engineering Education Programme;
— Using all means possible for disseminating information on the Nuclear Engineering Education Programme to involve students' interest in the programme. The means may be the following: web site, meetings, seminars, discussions, direct exchange of opinions or correspondences via electronic mail, writing articles for newspapers, newspapers and/or television interviews, appointment of tutors for groups of newcomer students, to invite students to visit labs and, even organizing some short entertainment in appropriate events;
— And having the right person with professional capacity and personal qualities, who is full of initiatives and sense of responsibility, as head of nuclear engineering education programme for a long enough period of time to draw a correct programme of activities with high vision and then to carry out the programme with flexible adjustments to go to its final goals.

REFERENCES TO ANNEX XXIII

[XXIII–1] MINISTRY OF PUBLIC HEALTH, History of building and development of the Hospital K, Publishing House Medicine, Hanoi (1999).
[XXIII–2] http://ineep.hut.edu.vn, http://www.hut.edu.vn
[XXIII–3] VAN DUAN, Ph., PHUNG VIET ANH, Transfer of Nuclear Engineering Knowledge at Hanoi University of Technology: Lessons Learned and Challenges, IAEA-CN-153/4/O/04, IAEA NKM Conference, Vienna (18–21 June 2007). http://www.iaea.or.at/inisnkm/nkm/documents/nkmCon2007/fulltext/FP/IAEA-CN-153-4-O-04fp.pdf
[XXIII–4] VAN DUAN, Ph., Nuclear higher education in Vietnam: Status and perspective (1960–2008 overview), IAEA Technical Meeting, Pavia, Italy (17–20 June 2008). http://www.iaea.org/inisnkm/nkm/events/tech_meeting_2008_italy/presentations/10_duan.pdf
[XXIII–5] http://www.vista.gov.vn/portal/page?_pageid=33,374036&_dad=portal&_schema=PORTAL&pers_id=312111&item_id=527555&p_details=1

[XXIII–6] http://www.most.gov.vn/tintuc_sukien/mlfolder.2007-01-29.1123125565/mlnews.2007-07-30.2365782970/view
[XXIII–7] http://varans.gov.vn/ShowItems.asp?actType=23&ItemID=1331&TypeGrp=1&menuid=105110&menulink=100000&menuup=105000
[XXIII–8] http://www.moet.gov.vn/?page=11.10&type=&view=930 and
[XXIII–9] http://www.dlu.edu.vn/detail_major_faculty.aspx?majorid=28&orgId=59 http://www.dlu.edu.vn
[XXIII–10] http://www.hcmuns.edu.vn and
http://www.phys.hcmuns.edu.vn/index.php?option=com_content&task=view&id=19&Itemid=29
[XXIII–11] http://www.hus.edu.vn/?portal=main&obj=donvitype&id=2&cache=pjJnS88TGxy6s+29tnSlqz6JRxbMAMkT0LSc28gJKdsfTts6ZyBdrFpWISf0JRDy and http://www.hus.edu.vn
[XXIII–12] http://www.iop.vast.ac.vn/nuc

Annex XXIV

ASIAN NETWORK FOR EDUCATION IN NUCLEAR TECHNOLOGY[19]

XXIV–1. DEVELOPMENT OF THE ANENT

Asian Network for Education in Nuclear Technology (ANENT) is a highly effective web-based educational system to complement conventional knowledge transfer methods by networking teachers, students, and their institutions that are engaged or interested in the peaceful uses of nuclear technology and other applications.

ANENT is primarily aimed at Asia and the Pacific region, where huge economic growth is now under way and expected to continue, accompanied by rapidly increasing demand for energy. The demand cannot, and should not, be met only by fossil fuels. Fossil fuels are limited and increasingly expensive, and are thought to be the largest cause of global warming. Nuclear energy is expected to play an important role to close the widening gap between energy supply and demand.

While some countries in Asia have been operating nuclear power plants (NPP) for decades, there are some potential newcomer countries to nuclear power programmes. Other countries are to maintain and expand the use of radiation and radioisotopes. Demand in human resources is increasing in the field of energy and nuclear technology in the region. At the same time, however, many countries are facing urgent issues of nuclear knowledge management such as ‘brain drain’, shortage of educational opportunities, resources and facilities. Thus, the Asian region needs to develop a wide spectrum of nuclear education and training programmes for capacity and infrastructure building.

The basic concept of ANENT was discussed and agreed upon at a consultancy meeting held in Daejeon, the Republic of Korea(2003), in cooperation with Korea Atomic Energy Research Institute (KAERI). On the basis of the basic agreement, ANENT was established at the first coordination committee meeting held in Kuala Lumpur, Malaysia (2004), with the cooperation of the Malaysian Institute for Nuclear Technology Research (Malaysian Nuclear Agency). The participants agreed upon the initial Terms of Reference and an action plan for launching ANENT. Implementation of five group activities was also agreed upon.

ANENT is a new regional partnership for knowledge management and capacity building in the peaceful applications of nuclear technology. It aims at aiding networking of nuclear research institutes, universities, and other educational facilities as well as developing a web-based education and training system to complement existing mechanisms. This regional partnership is intended to disseminate knowledge and information on nuclear technology in a reliable and economic manner to a broader audience.

XXIV–2. OBJECTIVE AND STRATEGIES

ANENT has the following objectives:

- To provide effective mechanisms for developing human resources;
- To strengthen scientific infrastructure;
- To develop a self-sustaining network of institutions in the Asia-Pacific region;
- To contribute to enhancing nuclear education, training, knowledge; management, and associated research and development activities in the region.

The strategies to achieve these goals are:

- Integrating available knowledge resources and materials for enhancing nuclear education and training;
- Facilitating mutual personnel exchanges and joint research activities to share scientific knowledge and soft infrastructure for the sustainable use of nuclear technology;

[19] Prepared by K. Hanamitsu, Department of Nuclear Energy, IAEA.

— Standardizing nuclear educational resources such as reference curricula, materials, academic credits, degrees, and qualifications in countries within the region;
— Promoting feedback and improvement of the processes through assessment and review of the results of joint activities and networking;
— Coordinating linkages with other regional and global networks for smooth communication and potential synergy in the future.

XXIV–3. ANENT MEMBERS

The ANENT Coordination Committee holds an annual meeting of all the members and collaborating members. The participants report and review activities, discuss issues to be addressed, and develop action plans. At each annual meeting, a chairperson is appointed who also plays the role of spokesperson for ANENT during the following year.

Any regional organization that is involved in nuclear education and training for peaceful uses of nuclear energy can apply for membership. This includes academic institutions, research centres, governmental entities, and other related organizations. An individual institution can attain the ANENT membership at the request of an authorized representative of a member country made at the Coordination Committee meeting. Organizations outside the region may apply as collaborating members. Any international institution or network wishing to become a collaborating member can do so by having an authorized representative of that institution express the request directly to the IAEA. Currently ANENT has 33 member institutions from 16 countries and 9 collaborating members. The lists of ANENT member organizations, the collaborating organizations and current and previous Chairpersons are given as in Tables XXIV–1, XXIV–2, and XXIV–3 respectively**.**

TABLE XXIV–1. THE LIST OF ANENT MEMBER ORGANIZATIONS

Country	Organization [a]
Australia	Australian Nuclear Science and Technology Organization (ANSTO)
Bangladesh	Bangladesh Atomic Energy Commission (BAEC)
China	China Institute of Atomic Energy (CIAE) Tshinghua University
India	Bhabha Atomic Research Centre (BARC), Department of Atomic Energy (DAE)
Indonesia	Centre for Education and Training, National Nuclear Energy Agency (BATAN)
Republic of Korea	Nuclear Training and Education Centre, Korea Atomic Energy Research Institute (KAERI) Cheju National University Chosun University Korean Advanced Institute of Science and Technology Kyung Hee University Seoul National University Hanyang University Nuclear Safety School, Korea Institute of Nuclear Safety (KINS) Nuclear Power Education Institute, Korea Hydro and Nuclear Power Company (KHNPC) National Radiation Emergency Medical Centre, Korea Institute of Radiological and Medical Sciences (KIRMS) Department of Nuclear Medicine, Seoul National University
Lebanon	Lebanese Atomic Energy Commission (LAEC)
Malaysia	Malaysia Nuclear Agency (Former Malaysian Institute for Nuclear Technology Research) University Kebangsaan Malaysia (UKM) University Putraa Malaysia (UPM)
Mongolia	Nuclear Research Centre, National University of Mongolia

TABLE XXIV–1. THE LIST OF ANENT MEMBER ORGANIZATIONS (cont.)

Country	Organization [a]
Pakistan	Pakistan Institute of Engineering and Applied Sciences (PIEAS), Pakistan Atomic Energy Commission (PAEC) KANUPP Institute of Nuclear Power Engineering (KINPOE) Centre for Non-Destructive Testing
The Philippines	Philippine Nuclear Research Institute (PNRI)
Sri Lanka	Atomic Energy Authority University of Colombo
Syrian Arab Republic	Atomic Energy Commission of Syria (AECS)
Thailand	Thailand Institute of Nuclear Technology (TINT) Office of Atoms for Peace (OAP)
United Arab Emirates	Khalifa University of Science, Technology and Research (KUSTAR)
Vietnam	Hanoi University of Technology (HUT)

[a] The organization at the top of the list is responsible for Coordination Committee meeting in each country.

TABLE XXIV–2. LIST OF EIGHT COLLABORATING MEMBERS (IN ALPHABETICAL ORDER)

Asian School of Nuclear Medicine (ASNM)
European Nuclear Education Network Association (ENEN)
Moscow Engineering Physics Institute (MEPhI)
The most comprehensive educational and reference library on CANDU technology (CANTEACH)
Tokyo Institute of Technology
University Network of Excellence in Nuclear Engineering (UNENE)
The World Nuclear University (WNU)

TABLE XXIV–3. LIST OF THE CURRENT AND PREVIOUS ANENT CHAIRPERSONS

2004–2005	Amim, F. M., Malaysia Institute of Nuclear Technology Research (current Malaysian Nuclear Agency), Malaysia
2005–2007	Han, K-W., Nuclear Training and Education Centre, Korea Atomic Energy Research Institute, Republic of Korea
2007–2008	Puri, R. R., Bhabha Atomic Research Centre, India
2008–2009	Fan, S., China Institute of Atomic Energy, China

XXIV–4. CURRICULA DEVELOPMENT

The first skeleton of reference curricula for mastership in nuclear engineering was developed at the IAEA meeting held in Moscow in December 2005. It was developed after comparing nuclear engineering education curricula between ANENT member countries with the cooperation of the Moscow Engineering Physics Institute (MEPhI). The curricula consisted of the following five courses totalling 40 subjects:

— Introductory/basic course consisting of 9 subjects, such as nuclear physics, material science, and health physics;
— The Common course is comprised of 4 subjects, including energy physics and advance maths;
— The Nuclear Power Generation course is comprised of 12 subjects, including reactor design;
— The Non-Power Applications course has 7 subjects, for example, nuclear imaging;
— The Nuclear Fusion course has 7 subjects, such as advanced laser application engineering and plasma processing analysis.

The reference curricula help members define the basic standards and requirements for education in nuclear power engineering, non-power applications, and fusion technology. Some members are taking part in related activities under some of the IAEA regular programmes to follow up on these activities.

XXIV–5. ANENT ACTIVITIES

Four of the Member States are currently playing leading roles in the following activities:

— The Republic of Korea in development of cyber education platform (Activity 1);
— Lebanon in facilitation of human resource mobility (Activity 2);
— Philippines in promotion of knowledge management practices in education (Activity 3); and
— Vietnam in development of reference curricula (Activity 4).

All members are working on liaison and communication (Activity 5).

XXIV–5.1. Activity 1 — Development of cyber education platform

The ANENT web-portal plays an important role in disseminating information about the ANENT to the public and facilitating communication between its members. It includes a cyber platform which consists of a learning management system for deciding on a course, registering and implementing the chosen course, and post-learning activities. In the near future, a greater number of researchers and students will be able to get reliable knowledge and information on nuclear technology through this web-based platform. Agreement has been reached to implement the following tasks within the framework of this activity:

— Identification of existing information and material;
— Operation and maintenance of the ANENT web system;
— Establishment of a web-based network, including its operation, amendments and additions.

XXIV–5.2. Activity 2 — Facilitation of human resource mobility

This network facilitates the mobility of human resources including students, teachers and researchers between older and younger generations, between developed and developing countries within and beyond the Asia-Pacific region. Planned and ongoing activities include providing fellowship for young researchers and arranging scientific visits for senior managers as well as organizing meetings and training courses. Larger synergy effects can be expected by combining direct human exchange with web-based isolated education and training. The activity would be promoted through:

— Establishment of a working mechanism to support human resources development;
— Facilitation of bilateral cooperation as a starting point for multilateral networking.

XXIV–5.3. Activity 3 — Promotion of knowledge management practices in education

Knowledge management (KM) helps the members to address future workforce management and increase the quality and quantity of nuclear education. It includes academic curricula development, networking universities, as well as providing web-based education and training. KM ‘Assist Visit’ to educational organizations provides specific services to the member countries in this direction. Good practices and lessons learned from those experiences and activities should be shared among the members to facilitate further development of policies and strategies in nuclear education.

The following actions are expected to be carried out for this purpose:

— Facilitation of holding knowledge management related events;
— Promoting awareness of ‘KM Assist Visit’ scope and objectives;
— Making excellent nuclear education available through web-based ANENT and other electronic media;

XXIV–5.4. Activity 4 — Development of reference curricula

ANENT members have different patterns of nuclear energy development and education. These differences can be obstacles to mutual understanding in performing joint activities. These gaps can be reduced by establishing reference curricula common to the whole Asia-Pacific region by harmonizing and unify educational quality and level across the region. This activity would be implemented through the following steps:

— Exchange and analysis of existing curricula;
— Establishing recommended requirements for reference curricula.

XXIV–5.5. Activity 5 — Liaison and communication

All activities of ANENT are based on networking people and consolidating available resources in nuclear education and training into a network system. The following actions are expected to be taken by the members:

— Identification and development of mechanisms to link ANENT with other networks such as RCA, ANSN, and FNCA as well as the ANENT collaborating members;
— Serving as a facilitator for communication between ANENT member organizations and other regional and global networks.

With these activities, ANENT expects to achieve its goals; including regional nuclear capacity building, infrastructure development, and better use of existing information resources.

XXIV–6. ANENT WEB-PORTAL

In April 2005, the English version of the ANENT web-portal, developed and maintained by KAERI, became available at www.anent-iaea.org. It provides basic and operational information on the ANENT, which will help update regional education, training materials and curricula, and promote external and internal communication.

The web-portal has seven items:

(1) About ANENT;
(2) Board;
(3) Links;
(4) Activities;
(5) NET data base;
(6) Related events;
(7) Cyber learning.

The first three items are currently open to the public. Those accessing this web site can see all three of them without any restriction. Number (4) — Activities is accessible only for the ANENT members representing each member country. It provides information about ongoing activities including the five group activities. For the latter three items, a log-in user name and password is necessary. The user name and password can be obtained by registering on the main menu.

For anyone wishing to know the ANENT, access to About ANENT on the front page would be most recommended. There is a lot of information about ANENT objectives, members, structure, and activities. The ‘Board’ serves as a notice board providing a list of activities in the past, present and foreseeable future including archival information and photos taken during the events. A large number of useful web sites on nuclear knowledge and management are introduced at ‘Links’.

For members who log in with their user name and password, ‘NET (nuclear education and training) database’ and ‘Related events’ are good meeting places. The ‘NET database’ currently contains more than 900 inputs of data about ongoing lectures and training courses in the region. A search function helps the users to analyse those data from various viewpoints. As database grows and the number of search items increases, the database is expected to become increasingly more valuable in promoting other ANENT activities. ‘Related events’ inform the members of details of various types of activities such as training courses, workshops and meetings.

XXIV–7. ANENT CYBER PLATFORM

The ‘cyber platform’ was added on the web-portal in August 2006 to support the users to access various types of training courses. The cyber platform adopted an original learning management system to control a whole range of online operations from course establishment and registration to scoring and issuance of certificate. The major functions and operating modes are summarized as follows:

- — Learning purpose: academic course, training course, seminar/workshop/meeting;
- — Recognition: no recognition (self learning), pass-fail, credit based;
- — Access type: open, approval, closed;
- — Delivery type: online, off-line, blended;
- — Contents type: video on demand (VOD), multimedia, voice, etc.;
- — Contents source: produced in the LMS, uploaded, linked;
- — Course hierarchy: field, course, subject, lesson;
- — Operating mode: learner, lecturer, course manager, and general manager.

To enter the cyber platform, the user should enter their personal information via the online registration form and obtain their user ID and password. The cyber platform appears when the users log-in and select the cyber learning menu. In the drop-down menu, there are four modes: learner, lecturer, course manager, and general manager. Each mode has several functions depending on their roles and operating process:

- — *Learner* chooses a course from the course availability menu, and registers for learning, and receives the scoring and certificate as post-learning;
- — *Lecturer* prepares subjects and lessons for a specific course, and delivers them;
- — *Course manager* establishes courses by identifying some elements such as name, period, level, lecturer and so on, and then operates the course and ends it with post-learning menu;
- — *General manager* approves courses at the time of their establishment, launching, completion and post-learning.

XXIV–8. E-TRAINING COURSES USING THE ANENT CYBER PLATFORM

ANENT members have agreed to focus on addressing the following five areas of common interest to all members. Joint efforts are being made to collect available education and training materials from the members, the IAEA and other related organizations and upload them onto the cyber platform for future use:

- — Energy planning;
- — Nuclear engineering;

— Non-power applications;
— Nuclear medicine;
— Knowledge management.

The first E-training course was conducted by the Planning and Economic Section (PESS) of the IAEA in cooperation with KAERI in November 2007, entitled E-Training Course on SIMPACT Model for Evaluating External Cost of Health and Environmental Impacts from Nuclear Power and other energy Energy Options. The course started with a video conference session, connecting 35 participants simultaneously from seven countries: India, Indonesia, the Republic of Korea, Malaysia, Pakistan, the Philippines and Thailand. During the week long course, the participants used specially developed distance learning material which was uploaded onto the ANENT cyber platform prior to beginning the course. An online tutor provided technical support to the participants through communication channels on the cyber platform. Participants conducted evaluation of external costs from different power projects using their national data, and submitted their case studies at the end of the course.

Another E-training course entitled MESSAGE Model for Elaborating Sustainable Energy Strategies was conducted in February 2009 in the same way as the first one. The course took place through the ANENT cyber platform at KAERI at the initiative of PESS of the IAEA. It started with a video conference session that connected 34 participants simultaneously from nine countries — China, India, Indonesia, the Republic of Korea, Malaysia, Pakistan, the Philippines, Sri Lanka and Thailand to share the objectives and expected outcomes of the course. During the self-learning process, the participants used the special learning package through the cyber platform which was uploaded prior to the course. Communication between an online tutor and the participants was made through supporting functions such as the forum and notice. The course lasted 12 days and ended with the submission of case studies conducted by the participants.

The two E-training courses proved that this kind of distance learning could supplement the conventional face-to-face events for capacity building in the field of sustainable energy development. In particular, the first E-training made an important step towards that direction and provided valuable experience to further develop the programme.

XXIV–9. PRACTICAL ARRANGEMENTS BETWEEN THE IAEA AND KAERI AND ENEN REGARDING TO THE ANENT

The IAEA Department of Nuclear Energy has concluded the Practical Arrangements with KAERI and European Nuclear Education Network Association (ENEN) respectively to enhance cooperation and support relating to the ANENT in 2009. The Practical Arrangements are official records of agreed modalities of cooperation signed by the Deputy Director General (head of the Department) of the IAEA and the representative of each organization.

With KAERI, the relationship is strengthened toward promotion of the use of the ANENT cyber platform, the joint maintenance and operation, and overall facilitation of web based education and training. Based on the agreements, the backup server of the ANENT web system is being installed at the IAEA to expand the networking into other regions. With ENEN, agreement was made to facilitate partnership through attending mutual meetings, exchanging of information and jointly developing education and training materials. Both agreements have given momentum to the ANENT for future technical and substantial progress of the cyber platform.

Annex XXV

CONSORZIO INTERUNIVERSITARIO PER LA RICERCA TECNOLOGICA NUCLEARE

XXV–1. INTRODUCTION

Consorzio Interuniversitario per la Ricerca Tecnologica Nucleare (CIRTEN) was created in 1994 by Polytechnic of Milano, Polytechnic of Torino, University of Padova, University of Palermo, University of Pisa and University of Roma (La Sapienza). Its main objectives were to promote the scientific and technological research as well as to coordinate the universities participation to the knowledge development and collaboration with national and international research institutions and industries. CIRTEN main issues of interests are:

- Energy production and energy system related R&D;
- Nuclear energy power and fuel cycle plants;
- Nuclear and industrial plant designs, operation and safety problems;
- Environmental safety, impact and protection;
- Decommissioning of nuclear installations;
- Radioprotection, shielding and effects of ionizing radiations on materials;
- Internationalization of Italian teaching in nuclear engineering through participation in the main international programme in this subject.

XXV–2. INTERNATIONAL COORDINATION

CIRTEN represents the Italian network institution for education in nuclear engineering. It also participates in the following nuclear education related international programmes:

- European Community (EC) ENEN project of the 5° EC FWP (2003);
- European NEPTUNO project of the 6° EC FWP (2005);
- European Community ENEN II project of the 6° EC FWP (2006);
- World Nuclear University (WNU).

The past and present R&D programmes carried out by CIRTEN:

- EC 4° FWP ‘ATHERMIP’ — LWR Cont. leak tightness;
- EC 4° FWP ‘INCOR’ — LWR Cont. Safety in accident cond.;
- EC 5° FWP ‘FIKI-2000 HTNL — HTGR neutronics’;
- EC 5° FWP ‘FIKI-2001 HTNL — HTGR neutronics’;
- EC 5° FWP ‘RMPS’ — LWR termalhydra, Codes reliability;
- MIUR-ENEA-INFN ‘TRASCO-ADS’ programmes;
- Industry financed tests and analysis on fuel element types and components of new plant concepts;
- EC 6° FWP ‘ELSY’-2006–2008 — Innovative lead fast reactor design development;
- Participation to the international consortium promoted by Westinghouse for the first international innovative reactor ‘IRIS’ design (2005).

XXV–3. CIRTEN MEMBERS

CIRTEN composed of following associated universities carrying research and education in the field of nuclear technology.

XXV–3.1. Polytechnic of Milano

The department of nuclear engineering currently offers the Master of Science in Nuclear Engineering. The curriculum is divided in two branches, both dealing with the study and the use of radiation i.e. the nuclear system curriculum, focusing on engineering and research problems connected with nuclear plants for energy production. The radiation curriculum deals with the use of radiation for purposes other than energy production.

XXV–3.2. Polytechnic of Torino

The Department of Energetic (DENER) was established in 1980 by merging the former Institutes of Technical Physics and Nuclear Plants and Fluid Machines and Engines. DENER includes three branches: applied thermodynamics and energy saving, nuclear engineering and fluid machines and engines. This department offers both a Bachelor and a Master degree in energy engineering.

XXV–3.3. University of Pisa

The department was established in 1980 by merging the former Institutes of Nuclear Plants and Applied Mechanics and Mechanical Constructions. As it is clearly implied by its name, the department includes three branches: Mechanical engineering, nuclear engineering and production engineering; that joined more recently. The recent activated programmes are BSc in Engineering of Industrial and Nuclear Safety (three years) and MSc in Nuclear and Industrial Safety Engineering (two years).

XXV–3.4. University of Palermo

Its department of nuclear energy awards the master degree in nuclear safety and technology engineering. Next year it is expecting to start a master’s programme in energy engineering. (http://din.din.unipa.it/).

XXV–3.5. University of Roma (La Sapienza)

This university offers a master degree in energy engineering.

Annex XXVI

EUROPEAN NUCLEAR EDUCATION NETWORK ASSOCIATION[20]

XXVI–1. BACKGROUND

Regarding nuclear engineering education in Europe, indicators like declining university enrolment, changing industry personnel profiles, dilution of university course content, and high retirement expectations show that future of nuclear technology expertise seems at risk (OECD/NEA 2000).

The European Nuclear Education Network (ENEN), started as a project under the fifth framework programme (FP5) of the European Commission in January 2002. It established the basis for conserving nuclear knowledge and expertise, created a European High Education Area for nuclear disciplines, and initiated the implementation of the Bologna declaration in nuclear disciplines. Pursuing the sustainability of the concept, the ENEN partners organized themselves into a non-profitable legal association called ENEN, in 2003 under the French law of 1901. The first general assembly was held on 11 November 2003 in Luxemburg, with representatives from the European Commission, the Nuclear Energy Agency of the Organization of Economic Cooperation and Development and the International Atomic Energy Agency.

XXVI–2. OBJECTIVE

The main objective of ENEN is the preservation and the further development of expertise in the nuclear fields by higher education and training.

To meet with this objective, the ENEN Association has to:

- Promote and further develop the collaboration in nuclear education and training of students, researchers and professionals;
- Ensure the quality of nuclear education and training;
- Increase the attractiveness for engagement in the nuclear fields for students, researchers and professionals;
- Promote life long learning and career development at post-graduate or equivalent level.

The basic objective of the ENEN Association shall be to:

- Harmonize European Master of Science curricula in nuclear disciplines and promote PhD studies;
- Establish a framework for mutual recognition;
- Promote exchange of students and teachers participating in the frame of the Network;
- Increase the number of students by providing incentives;
- Foster and strengthen the relationship between universities, research organizations, regulatory bodies, the industry and any other organizations involved in the application of nuclear science and ionizing radiation by facilitating their participation in (or associating them with nuclear academic education and by offering continuous training).

The aim of the ENEN Association shall be achieved by:

- Discussion on educational objectives, methods and course contents among the members and with external partners, particularly national and European industries;
- Organization of internal audits on the quality of nuclear education curricula;
- Awarding the European Master of Science certificates in nuclear disciplines to the curricula satisfying the criteria set up by the ENEN Association;

---

[20] Prepared by J. Safieh, P. de Regge and R. Kusumi, ENEN Association.

— Cooperation between the ENEN members, and with universities, research organizations, regulatory bodies, the industry and any other organizations involved in the application of nuclear science and ionizing radiation for enhancement of mobility of teachers and students, organization of training and advanced courses, use of large research and teaching facilities or infrastructures;
— Cooperation with international and national governmental institutions, agencies and universities;
— Synergy with European Union initiatives in nuclear science and technology;
— Facilitation the exchange of information between ENEN Members — on course objectives, content, modes of presentation and other matters.

The general goals of the ENEN Association are defined as follows:

(1) Towards academia:
- — To develop a more harmonized approach for education in the nuclear sciences and engineering in Europe;
- — To integrate European education and training in nuclear safety and radiation protection;
- — To achieve a better cooperation and sharing of resources and capabilities at the national and international level.

(2) Towards end users (industries, regulatory bodies, applications):
- — To create a secure basis of knowledge and skills of value to the EU;
- — To maintain an adequate supply of qualified human resources for design, construction, operation and maintenance of nuclear infrastructures and plants;
- — To maintain the necessary competence and expertise for the continued safe use of nuclear energy and applications of radiation in industry and medicine.

XXVI–3. MEMBERSHIP AND COOPERATION BEYOND EUROPE

The ENEN Association has two kinds of members. All members should have a legal status in an EU member state or a candidate country.

The Effective Members, primarily academics, provide high level scientific education in the nuclear field in combination with research work, and use selective admission criteria.

The Associated Members, such as universities involved in nuclear research, nuclear research centres, industries and regulatory bodies, have a long term tradition of relations with effective members in the field of research, training or education and are committed to supporting the ENEN Association.

As of March 2009, the ENEN Association has members in 17 European countries and 3 non-EU countries, as given in Table XXVI–1, consisting of 31 Effective Members and 20 Associated Members. With only a few members from the industry and with an overwhelming membership of universities, the ENEN Association so far has been mainly oriented to academic activities. Despite this, the training programmes and courses organized by its members are well attended by young professionals from the nuclear industry from European countries and worldwide.

Since early 2008, the ENEN Association has concluded a Memorandum of Understanding (MoU) with partners beyond Europe for further cooperation (South Africa, the Russian Federation, Japan, etc.).

XXVI–4. STRUCTURE

ENEN’s structure is presented in Fig. XXVI–1.

The General Assembly meets annually early March to discuss the general policy of the ENEN Association according to its objectives, to approve the proposed activities and action plan, the annual budget, to decide on membership applications, and to appoint the members of the Board of Governors and the Secretary General.

The Board of Governors is composed of nine ENEN Members as designated and elected by the General Assembly. The Board meets at least two times a year, and is in charge of the administration and management of ENEN Association.

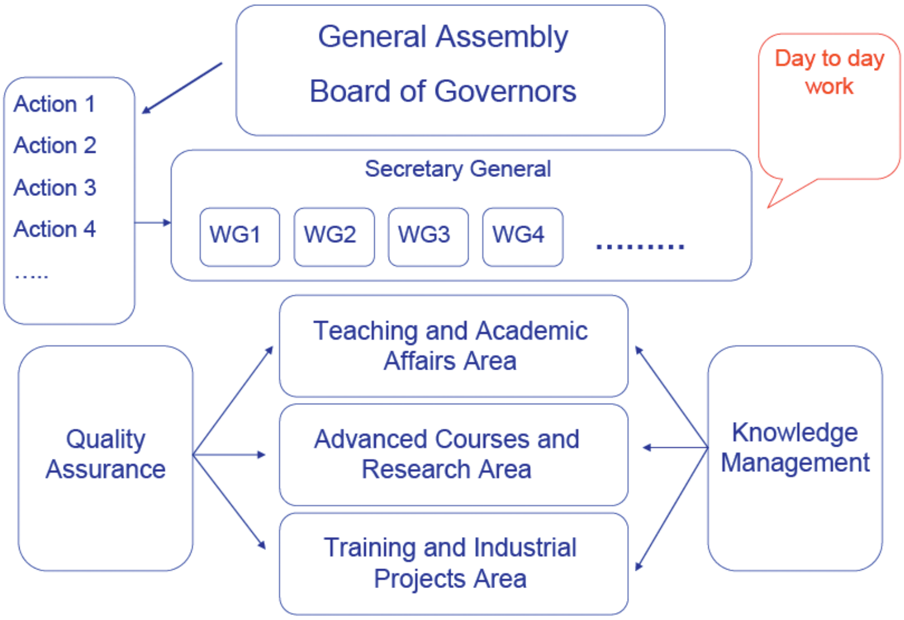


FIG. XXVI–1. ENEN structure.

TABLE XXVI–1. ENEN MEMBERSHIP AS OF MARCH 2009

1	Atominstitut der Oesterreichischen Universitaeten, Austria, Vienna
2	Katholieke Universiteit Leuven, Belgium, Leuven
3	Université Catholique de Louvain, Belgium, Louvain-la-Neuve
4	Czech Technical University in Prague, Czech Republic, Prague
5	Helsinki University of Technology, Finland, Helsinki
6	CEA — INSTN — Centre d'Etudes de Saclay, France, Gif-sur-Yvette
7	Technische Universitaet Muenchen, Germany, Garching
8	Budapest University of Technology and Economics, Hungary, Budapest
9	CIRTEN, Italy, Torino
10	Delft Univerity of Technology, Netherlands, Delft
11	University ‘Politechnica’ Bucharest, Romania, Bucharest
12	Slovak University of Technology in Bratislava, Slovakia, Bratislava
13	Universidad Politecnica de Madrid, Spain, Madrid
14	University of Ljubljana, Slovenija, Ljubljana
15	KTH — Holding AB, Sweden, Stockholm
16	Swiss Federal Institute of Technology (ETH), Switzerland, Zurich
17	Swiss Federal Institute of Technology (EPFL), Switzerland, Lausanne
18	Lappeenranta University of Technology (LUT), Finland, Lappeenranta
19	University of Manchester, United Kingdom, Manchester
20	Ghent University, Belgium, Gent

TABLE XXVI–1. ENEN MEMBERSHIP AS OF MARCH 2009 (CONT.)

21	University of Birmingham, United Kingdom, Birmingham
22	Institut National Polytechnique de Grenoble, France, Grenoble
23	UPC Escola Tecnica Superior d'Enginyeria Industrial, Spain, Barcelona
24	Universitaet Stuttgart, Germany, Stuttgart
25	Uppsala Universitet, Sweden, Uppsala
26	'Jozef Stefan' Institute, Slovenija, Ljubljana
27	SCK – CEN, Belgium, Mol
28	Nuclear Research Institute Rez plc, Czech Republic, Rez
29	Defence Academy CMT, United Kingdom, Hants
30	Institute for Safety and Reliability, Germany, Garching
31	AGH-University of Science and Technology, Poland, Krakow
32	J.W. Goethe Universität, Germany, Frankfurt am Main
33	ETS Institut Quimíc de Sarrià, Spain, Barcelona
34	Ruhr Universität Bochum, Germany, Bochum
35	Université de Liège, Belgium, Liege
36	Universidad Nacional de Educacion a Distancia, Spain, Madrid
37	Universidad de Sevilla, Spain, Sevilla
38	University of Santiago de Compostela, Spain, Santiago de Compostela
39	Universität Hannover, Germany, Hannover
40	Université Libre de Bruxelles, Belgium, Brussels
41	Chalmers University Göteborg, Sweden, Göteborg
42	University of Valencia, Spain, Valencia
43	Westinghouse Corporation, Belgium, Brussels
44	North West University, South Africa, Potchefstroom
45	Moscow Engineering Physics Institute, Russian Federation, Moscow
46	Ecole des Mines de Nantes, France, Nantes
47	Clausthal University of Technology, Germany, Clausthal
48	Vrije Universiteit Brussel, Belgium, Brussels
49	Centre National de la Recherche Scientifique, France, Paris
50	Tokyo Institute of Technology, Japan, Tokyo
51	Japan Atomic Energy Agency, Japan, Tokai

A list of actions for coming year is decided by the General Assembly according to the needs. The same number of Working Groups is established. Each Working Group (WG) belongs to the following five working areas. The scope of each area is as follows:

(1) Teaching and academic affairs area (TAAA) — to disseminate the relevant knowledge of nuclear education.

— To evaluate applications for the European Master of Science in Nuclear Engineering certification;
— To promote student and faculty exchange by encouraging and supporting the organization of international exchange courses by ENEN Members;
— To support the organization of high quality nuclear related education by ENEN Members;
— To evaluate ENEN exchange courses and award the International ENEN Course label, in collaboration with the ENEN Quality Assurance Working Group.

(2) Advanced courses and research area (ACRA) — to enhance the organization of advanced courses and research activities in the nuclear field.
— To provide advanced and/or specialized courses to post-graduate students, PhD students and research members in the frame of ENEN Association, or in collaboration with other associations around the world;
— To promote the establishment of research in nuclear related topics throughout Europe;
— To keep connections between universities and research laboratories in the organization and/or participation in advanced research programmes by ENEN members;
— To evaluate ENEN advanced courses, in collaboration with the ENEN Quality Assurance Working Group.

(3) Training and industrial projects area (TIPA) — to facilitate and support collaboration between Associated and Effective Members of ENEN Association.
— To identify the industrial needs for continuous professional development;
— To organize training sessions and courses on subjects of common interest for the associated members;
— To create and maintain a catalogue of training and industrial continued professional development courses organized by ENEN Association's members;
— To facilitate the mobility of students and professors from different institutions and raise funds for this purpose;
— To facilitate integration of European and National industrial research projects.

(4) Quality assurance area (QAA) — to promote the established quality policy of the ENEN Association and to maintain its quality objectives. Quality is regarded as a multidimensional concept which embraces all functions and activities of ENEN.
— To serve as a working group for the ENEN management on various quality issues related to policy making, setting objectives, identification and development of systems, processes, efficiency and continual improvement;
— To further ENEN documentation on its activities including quality manuals, quality plans, specifications, guidelines, instructions, web site and records;
— To evaluate applications of new effective memberships of ENEN and to provide support of quality reviews of ENEN Members;
— To support the organization of high quality nuclear related education by ENEN Members in collaboration with the ENEN Teaching and Academic Affairs Working Group;
— To evaluate ENEN exchange courses and award the International ENEN Course label, in collaboration with the ENEN Teaching and Academic Affairs Working Group;
— To support other quality assessment tasks and products as assigned by the ENEN board.

(5) Knowledge management area (KMA) — to identify and monitor deficiencies in scientific knowledge relevant to nuclear technology and safety.
— To prepare, maintain and implement an action plan by academia in order to preserve valuable scientific knowledge;
— To ensure efficient use of ICT for the dissemination of knowledge, for supporting teaching and learning, and for accessing and maintaining databases;
— To provide access to simulators and specialized software;
— To publish books, and produce CDs and DVDs of interest to ENEN members.

The ENEN Secretariat is located at CEA-Saclay, France, and led by the Secretary General appointed by the General Assembly. He is responsible for the day to day management of ENEN Association and the coordination of the Workin Groups' activities. He reports to the Board of Governors and to the General Assembly on all ENEN activities.

XXVI–5. MAIN ACHIEVEMENTS SINCE 2003

The activities of the ENEN Association since 2003 are briefly described Section XXVI–5.1.

XXVI–5.1. European Master of Science in Nuclear Engineering

Supported by the Fifth and Sixth Framework Programme of the European Community, the ENEN Association has established and continues to monitor the equivalence of nuclear engineering education curricula at the ENEN member universities through its Teaching and Academic Affairs Working Group. As a result, the ENEN Association developed the European Master of Science in Nuclear Engineering. A reference curriculum, consisting of a core package of courses and optional substitute courses in nuclear disciplines, has been designed and mutually recognized by the ENEN members. To advertise and promote this realization, ENEN has established the qualification of European Master of Science in Nuclear Engineering (EMSNE). For this purpose, ENEN developed bylaws and procedures for handling and selecting the candidates and for awarding the EMSNE certificate. An information leaflet to attract applications for this EMSNE certificate has been designed.

(1) *Objectives of the EMSNE*

The objectives of the EMSNE framework are:

- To educate students towards analytic, resourceful and inventive nuclear engineers by combining the joint state of the art know-how of the participating universities;
- To train these students by making full use of the unique nuclear research and industrial facilities throughout Europe;
- To develop a common safety culture throughout Europe;
- To develop an international network of nuclear engineers and scientists by participation of students of different nationalities, by contact and collaboration with local students, and by education in several countries with different educational views, different nuclear reactor concept and technologies, and different nuclear policies.

(2) *Assuring quality*

The EMSNE Certification is awarded to students who have obtained a master degree in nuclear engineering, or equivalent, that meets the objectives and quality standards set by the ENEN Association. This certification is a guarantee that the master education received was of the highest quality in Europe.

(3) *General requirements for the EMSNE certificate*

Students who have obtained a master degree in nuclear engineering, or equivalent, from an ENEN member institution can apply for the European Master of Science in Nuclear Engineering Certification, on the condition that their master programme fulfilled the following requirements:

- The total course load leading to the master degree in nuclear engineering, or equivalent, must be at least 300 ECTS (European Credit Transfer System) at university level, of which at least 60 ECTS credits must be in nuclear sciences and technologies, preferably engineering;
- The master programme must have been an equilibrated nuclear engineering programme consisting of at least a profound coverage of the following subjects: reactor engineering, reactor physics, nuclear thermal hydraulics, safety and reliability of nuclear facilities, nuclear materials, radiology and radiation protection, nuclear fuel cycle and applied radiochemistry;
- The applicant must have successfully defended a nuclear engineering master thesis project;
- At least 20 ECTS of nuclear engineering courses or a master thesis project must have been taken at an academic ENEN member situated in another country than the home institution.

A European Master of Science in nuclear disciplines will be delivered under ENEN certification in the near future extending ENEN’s certification to other disciplines such as radioprotection and waste management and disposal. By-laws have to be established.

XXVI–5.2. International exchange courses

The equivalence of nuclear engineering curricula also relies on the mutual recognition of courses among the ENEN member universities. ENEN therefore also has the task of promoting student and faculty exchanges by encouraging and supporting the organization of international exchange courses and high quality nuclear engineering courses by the ENEN members. In this framework, ENEN produced an information package on 10 established ENEN exchange courses, 23 proposed exchange courses and 5 Master of Science thesis projects at ENEN member institutions. Information on those courses is posted on the ENEN web site: http://www.enen-assoc.org.

A typical example is the Eugene Wigner course, a three-week course on nuclear reactor physics including theory lectures and practical exercises at three different reactors, which has been organized five times since 2003 by a group of universities and research centres in central Europe, addressing nuclear engineers and young professionals.

Selection of offered courses:

- Eugene Wigner course on reactor physics;
- Nuclear thermal hydraulics;
- Nuclear reactor theory;
- International seminar on the nuclear fuel cycle;
- Radiation protection and nuclear measurements;
- Nuclear reactors systems;
- Nuclear power plant safety;
- Fusion reactor engineering;
- Neutron physics;
- Fluid mechanics in nuclear reactors;
- Reactor dynamics and kinetics;
- Back end of the nuclear fuel cycle;
- Reactor design study project;
- Reactor materials and lifetime behaviour;
- Reactor instrumentation;
- Numerical methods for nuclear reactors.

XXVI–5.3. Courses and seminars

XXVI–5.3.1. Advanced courses

(1) *Disseminating nuclear know-how in Europe*
The most familiar nuclear engineering application is the production of electricity by means of nuclear power. Over 30% of electricity production in the EU is provided by nuclear power. Moreover, Europe has developed a wide range of nuclear technologies and activities: power plants, fuel production, radio-elements' production, engineering, accelerator design and fabrication, waste management and disposal, safety management and nuclear medicine.

(2) *Purpose*
To offer Master students, PhD students and professionals the possibility to take advantage of the nuclear engineering expertise present in Europe, the ENEN Association fosters international exchange courses, where the different ENEN Members offer courses in their field of expertise while making use of the unique experimental and training nuclear infrastructure throughout Europe.
The advanced courses and Research Committee Working Group ensure the link between the ENEN academic members and research centres in the European Community. It establishes exchanges with other networks and, through developing close relations with research centres, universities and industry; it identifies and disseminates topics for internships, theses and PhDs. It also encourages and supports student mobility in this respect, and designs and organizes advanced courses for students, PhD candidates and young professionals.

(3) ENEN advanced courses

Topics identified as the result of a questionnaire on needs:

— Scaling and uncertainty in system thermal hydraulics;
— Coupled 3-D neutron kinetics and thermal hydraulics and application to nuclear reactor theory;
— System thermal hydraulic code assessment and code user training and qualification;
— Natural circulation in existing reactors and innovative reactor concepts;
— Radiological protection;
— Safety aspects of WWER operation;
— Eugene Wigner extension, experimental training in reactor physics on LWR critical assembly;
— MSc design study (project);
— Reactor physics for accelerator driven systems;
— Nuclear fusion technology;
— International course on advanced thermal hydraulic;
— Advanced course on pressure vessel aging.

The principle advanced courses have been organized by ENEN in the framework of the Integrated Project EUROTRANS (see Paragraph XXVI–5.5).

XXVI–5.3.2. Seminars and training sessions

In particular, education and training courses have been developed and offered to provide the core curricula and optional fields of study for nuclear degrees in a European exchange structure. Pilot editions of courses and try-outs of training programmes have been successfully organized with the support of nuclear industries and international organizations, and there has been commendable interest, attendance and performance by the students.

The Training and Industrial Projects Working Group is dedicated to identifying and responding to the industrial needs for continued professional development. It organizes continuous training sessions and courses on different subjects of common interest for ENEN Associated members, regulatory bodies and nuclear industries. Together with the Knowledge Management Working Group, it maintains and disseminates a database on third-cycle advanced courses and continued professional development sessions. It facilitates and supports professional training, the mobility of professionals and lecturers, assists in accessing large nuclear infrastructures and integrates European industrial and national projects.

The training courses in the format of seminars organized by the ENEN Association, part of them in the framework of the NEPTUNO project, are open to students as well as to professionals. Seminars have been held on nuclear safety (in Saclay, France; Bratislava, Slovakia and Munich, Germany, 2–3 weeks duration), radioactive waste (Saclay and Bucharest, one week), the dismantling experience of nuclear installations (Saclay, one week), the nuclear fuel cycle (France, two weeks) and new developments of nuclear energy in Europe (Helsinki, Finland, one week).

Further seminars are planned in 2009 by different institutions members of ENEN. The number of participants ranges from 12 to more than 50 and include young professionals from nuclear industries, research centres and regulatory bodies inside and outside the European Union. The students have the opportunity to pass an examination on the contents of the seminar and to earn a corresponding number of European Credit Transfer System credits for their academic curriculum.

Academic/training courses that have been organized:

— Nuclear safety for WWER subcontractors, Bratislava, May 2005, ten participants;
— European utility requirements course 2005, Helsinki, 6–10 June 2005, 35 participants registered (5 students);
— International seminar on dismantling experience of nuclear facilities, France, 26–30 June 2006, 19 participants (2 students);
— International seminar on nuclear waste management, France, 9–13 October 2006, 13 participants;
— Fourth generation: nuclear reactors systems for the future, France, 8–12 October 2007;

— International seminar on the nuclear fuel cycle, France, organized four times November–December 2004, 2005, 2006 and June–July 2008 (70 participants);
— Training course on nuclear safety, Munich, 12–23 March 2007, 42 participants;
— International seminar on dismantling experience of nuclear facilities, France, 13–17 October 2006 [XXV–1].

XXVI–5.4. NEPTUNO (FP6) deliverables, database and communication system

Other ENEN products related to the implementation of the EMSNE, to exchange courses as well as to training sessions for young professionals are available on the web site of the Sixth Framework project — Nuclear European Platform of Training and University Organizations (NEPTUNO) — at http://www.sckcen.be/neptuno. Deliverables of this Coordination Action include guidelines, best practices and do-it-yourself kits for the organization of international ENEN exchange courses, with examples of flyers and application forms (http://www.sckcen.be/neptuno/deliverables).

The NEPTUNO communication system has been developed and established by the ENEN Nuclear Knowledge Management Working Groupand has the following features:

(1) *General*
- — Is in full operation since August 2004;
- — Provides a platform for a common knowledge base for nuclear fission;
- — Merges classical database driven information systems with role based research and education functionalities to a common knowledge system;
- — http://www.neptuno-cs.de/.

(2) *Main features*
- — Based on a framework that uses a building blocks approach with basic system components to build web-based knowledge and communication systems for research and training;
- — Basic system components customised to NEPTUNO needs;
- — Each component can be programmed to have access to other components (e.g. an on-line course supported by a simulation package);
- — Provides basic support for communication in the nuclear community like addresses, databases, technologies, E-learning platforms, etc.

(3) *Courses in nuclear disciplines*
- — Courses are arranged in four types: education, training, education and training, others. Fourteen categories covering different nuclear disciplines;
- — Total number of courses — 497 collected from various sources and data sheets, approved courses confirmed and implemented by the organizing institution — 230 courses, not (yet) approved nor confirmed — 267 courses.

(4) *Role based access to a common knowledge base*
- — Different users have special role — dependent views on the common database (e.g. teacher, student, scientist, etc.);
- — Views on the database are optimised to respond to the needs of the role;
- — Knowledge can be easily managed;
- — Information is kept in one place with different access methods depending on the goal. Information is consistent, preserved and reused.

XXVI–5.5. Participation to the Integrated Project EUROTRANS (FP6)

In this context, ENEN is organizing ten advanced training courses for PhD students in the framework of the European research programme for the transmutation of high level nuclear waste in an accelerator driven system (EUROTRANS). EUROTRANS is a major project in the Sixth EU Framework Programme that develops a concept of transmutation of long lived higher actinides in nuclear waste into short lived products by accelerator irradiation.

Design and feasibility assessment of an industrial prototype Accelerator Driven System (ADS) dedicated to transmutation, together with the definition of a design backup solution, to perform nuclear incineration of long lived radioisotopes after their partitioning from high level waste streams.

So far, the following eight courses were organized:

- — 5–8 October 2005 — KTH, Stockholm, ADS: objectives, context, concepts, challenges (scientific and technical), and nine PhD students;
- — 7–10 June 2006 — Universidad Santiago de Compostable, nuclear data for transmutation: status, needs and methods, 15 PhD students;
- — March 2007 — University Catholique Louvain, ADS thermal-hydraulics: system codes, models and experimental validation, nine PhD students;
- — 10–11 May 2007 — Nuclear Research Centre SCKCEN, Mol, Particle Accelerator Technology;
- — 26–29 November 2007 — Fuels and structural reactors materials, CIRTEN-UniPi in Pisa, Italy;
- — 2–5 April 2008 — Core design and reactor safety analysis, UPM — UNED, Spain;
- — 15–18 December 2008 — Impact of new nuclear data on the design of transmutation experiments, CNRS, Strasbourg, France;
- — 3–6 February 2009 — Impact of new results on the design of the spallation target and the subcritical blanket, CIRTEN, Politecnico di Torino.

XXVI–5.6. ENEN II project — Extension to other nuclear disciplines

The ENEN-II Coordination Action consolidates and expands the achievements of the ENEN and the NEPTUNO projects attained by the European Nuclear Education Network Association in respectively the fifth and sixth framework programme of the European Commission. The objective of the ENEN-II project was to develop the ENEN Association in a sustainable way in the areas of nuclear engineering, radioprotection and radwaste management, including underground disposal. The current developments in the seventh framework show that this has partially been achieved. Indeed, the interaction between the different communities, engineering, radiation protection and waste management, has been considerably strengthened. The ENEN Association experience has been exploited to the benefit of the other communities in the development of their networks and the definition of their education curricula and the training programmes. Although the training projects ENEN-III, PETRUS-II and ENETRAP-II now starting under the seventh framework programme are distinct activities, they have been prepared in mutual consultation by the three communities and ENEN Association is a partner in the three consortia, assuming a pivotal role in the coordination and streamlining of education and training activities in the European Union.

The ENEN-II project activities have been mainly structured around the five Working Areas (WA) of the ENEN Association in close collaboration with selected consortium partners. The first Work Package dedicated to the development of Networks has initiated, supported and monitored the development of nuclear education and training networks at the national level to provide a solid basis for networking at the European dimension. The networks already developed in Belgium (BNEN), Italy (CIRTEN), Germany (Kompetenzverbund Kerntechnik) and France (the INSTN antennas), have been joined by recently established national networks in the United Kingdom (NTEC), Romania (REFIN), Czech Republic (CENEN), Finland (FINNEN), the Netherlands (KINT), Switzerland (joint MSc degree by EPFL, ETH and PSI) and emerging regional networks such as the South West Germany Nuclear Research and Education Cluster. On the European level, the ENEN Association is a partner in the Sustainable Nuclear Energy Technology Platform, co-chairing its Working Group on education, training and knowledge management and participating to the European Nuclear Energy Forum. Beyond the European Union, the ENEN Association has strengthened its cooperation with the Asian Network for education in nuclear technology. It has formalized cooperation with universities in Russian Federation and South Africa and is negotiating with research and education organizations in Japan, Ukraine and Saudi Arabia. Cooperation with the IAEA has been continuing and to some extent also with the World Nuclear University.

In Work Package 2, curricula leading to an MSc degree have been developed. It relies on the ENEN Association principles of a modular approach, common qualification criteria, a common mutual recognition system across the European Union, and the facilitation of teachers and student mobility schemes. Course materials and syllabi have been produced in a cooperative way for radiological protection, analytical radiochemistry and radioecology, and an educational programme for geological disposal and underground storage of radioactive waste has been established. Lists with institutions providing the course modules in those curricula have been compiled, the requirements and procedures for mutual recognition have been established, and the structure and tools for student mobility schemes within the ENEN Association have been reviewed. An application for an Erasmus Mundus scheme in radioecology has been submitted and a pilot curriculum in radioecology has been started.

In Work Package 3, several approaches for combining different databases on courses, training opportunities, internships, thesis work and job vacancies in the nuclear field have been developed and demonstrated. The final version, combining the best approaches is being negotiated with the ENEN web site provider. A sustainable financial structure for supporting student mobility for internships and thesis work has been developed though not yet implemented. A major achievement in this Work Package is the organization of PhD events on a yearly basis where young researchers can present their work to peers and colleagues in the framework of a major conference session. The contest character of the event and associated evaluation by the jury is a major motivation for PhD students and resulted in an excellent quality of the presentations. Twelve and respectively 14 PhD students presented their work at the International Youth Conference on Energetics in Budapest, 2007, and at the International Nuclear Youth Congress in Interlaken, 2008. Within Work package 3 a think tank activity, within the ENEN Association, resulted in the publication of a vision document and a strategy for future nuclear education and training in the short and medium term.

Work Package 4 produced a report of education and training courses offered outside the universities in comparison to the needs by the end users in order to identify gaps and opportunities and to provide guidance for the ENEN Association and training organizations in development of their education and training programmes, and to optimize the use of resources. Joint training courses have also been delivered under this Work Package, such as

— Management of Radioactive Waste organized by the Polytechnic University of Bucharest and the French Agence Nationale pour la gestion des Déchets Radioactifs;
— a course on the Decommissioning of Nuclear Facilities organized by the CEA-INSTN and the Belgian Nuclear Research Centre;
— a joint face-to-face distance learning course on modules of the curriculum of MSc for geological disposal and underground storage of nuclear waste, organized by several universities under the leadership of the Institut National Polytechnique de Lorraine.

A joint course on Neutronics for LWRs, organized by CEA-INSTN, the Czech Technical University in Prague and the Delft University of Technology was successfully organized in March 2009.

Under Work Package 5, the ENEN Association web site has been completely modernized and furbished with news and project dedicated pages, registration and communication tools and pages related to the management and governing instruments of the Association. The web site is very much appreciated by the users and has had an average of 3500 hits per day over the last year. In view of the database under construction, a network of national contact points has been established over the European Union in order to monitor the database content and to initiate updates, corrections and removal of obsolete events. Further deliverables of this Work Package are a very comprehensive textbook on neutronics, a multimedia course on nuclear reactor physics and several E-learning and distance-learning modules.

The project organization has been defined in a kick-off meeting and progress has been monitored in two project follow-up meetings held respectively in Madrid, October 2007 and Bucharest, October 2008. The quality of the ENEN products and the project deliverables, the reports, courses, training packages, certificates, and the reliability of the information is continuously monitored by the ENEN Quality Assurance Working Group.

XXVI–5.7. ENEN-III, PETRUS II and ENETRAP II Projects — Nuclear Fission Training Schemes — ENEN-III

The ENEN Association submitted a project proposal for European Fission Training Schemes under the seventh Framework Programme of the European Commission. The proposal covers the structuring, organization, coordination and implementation of training schemes in cooperation with local, national and international training organizations, to provide training courses and sessions at the required level to professionals in nuclear organizations or their contractors and subcontractors. The training schemes provide a portfolio of courses, training sessions, seminars and workshops, offered to the professionals for continuous learning, for updating their knowledge and developing their skills to maintain their performance at the current state of the practice and to anticipate the implementation of new scientific and technological developments. The training schemes allow the individual professional to acquire a profile of skills and expertise, which will be documented in his training passport. The essence of such passport is that it is recognized within the EU (and possibly abroad) by the whole nuclear sector, which provides mobility to the individual looking for employment and an EU wide recruitment field for employers in the nuclear sector. The recognition is subject to qualification and validation of the training courses according to a set of commonly agreed criteria, which can be ratified by law or established on a consensus basis within a network.

The assessment of the needs identified a list of generic types of training where specific training schemes have to be developed including training sessions, seminars, workshops, etc. to constitute the portfolio offered to post-graduates and professionals for training and further personal development. Training schemes in the following four generic types will be developed in the project:

XXVI–5.7.1. Type A — Basic training in selected nuclear topics for non-nuclear engineers and professionals in the nuclear industry

The shortage of engineers with basic nuclear knowledge with respect to the demands of the industry leads to the concept of providing education and training of nuclear topics to non-nuclear engineers during graduation or as postgraduate courses. The target group consists of engineers supporting the operation of a nuclear power plant, for example:

— Programme engineer;
— Performance/reliability engineer;
— System/component/maintenance engineer;
— Design engineer;
— Safety assessment engineer.

The experience obtained during the FP6 NEPTUNO[21] project will be exploited to define the qualification profile with the required knowledge and skills. The NEPTUNO project aimed at a few key positions in the plant, outlining the job descriptions, the corresponding set of core qualifications and competences and a recommended training programme. The current ENEN-III project intends to provide essential knowledge and skills to a broader target group of professionals working in the nuclear industry.

XXVI–5.7.2. Type B — Basic training in selected nuclear topics for personnel of contractors and subcontractors of nuclear facilities

Nuclear facilities contractors are defined as any personnel working for a nuclear facility who are not directly employed by this nuclear facility. In 2001, IAEA published a technical report [2] on assuring the competence of NPP contractor (and subcontractor) personnel. The report displays general conclusions and recommendations, followed by a diversity of contractor personnel assessment schemes and utility case studies. The compilation of the individual approaches in different countries and by different utilities is certainly very valuable, but the variety observed shows that a common and mutually recognized training scheme for NPP contractor and subcontractor personnel would be beneficial and provide considerable added value on a European scale.

Contractor personnel provide essential services to nuclear power plants, particularly during plant outages or for projects involving major upgrades to plants. In providing these services, contractor personnel encounter similar problems to those that challenge nuclear power plant personnel. Accordingly, contractor personnel must be similarly competent and effectively interface with NPP personnel when performing their assigned duties. It is in this context that a well-designed training scheme would assure the competence of contractor personnel. Accreditation and recognition of the training scheme on a European level would alleviate the assessment of the contractors’ competence and skills by the utilities.

[21] FISA Luxembourg, 2006.

XXVI–5.7.3. Type C — Technical training for the design and construction challenges of Generation III nuclear power plants

The Generation III reactors currently in the construction and planning stages have been designed on the basis of several fundamentally different concepts with respect to Generation II reactors and their evolutionary improvements and back fittings. Following the categorization of those concepts by T. Dominguez[22], five different fields can be identified and the challenges they represent should be addressed in the education and training programme for the engineers involved in the detailed design and construction of those GEN III plants.

The first field is the technology, including passive safety systems, extensive use of mixed oxide fuels, high burnup resistant fuels, new materials, etc. The second field is the international dimension of the GEN III design, forcing and requiring the harmonization of licensing criteria and procedures, of quality standards, certification programmes and validation tests. The third field relates to the changing infrastructure and organization of the construction projects, involving the utilities, the vendors, the safety organizations and their interactions. Cost optimization strategies by reducing the construction period and exploitation of past operational experience to reduce or eliminate unnecessary margins and tolerances are the fourth category. The recovery of infrastructures and component manufacturing techniques is an additional element in this category. Finally, the extensive availability and use of innovative engineering software tools, 3-D models, standardization, optimization and automation is a fifth field to be addressed in the training of the new nuclear engineer. Training schemes for GEN III construction should therefore address the innovative technologies, the safety requirements, the project stakeholders, interactions and logistics, the operational experience, and the design codes, standards and tools.

XXVI–5.7.4. Type D — Technical training on the concepts and design of GEN IV nuclear reactors

Research centres and engineering companies are studying and developing advanced reactor concepts of the fourth generation to optimize the energy production and reduce the quantities and the long term risks of nuclear waste. In the same way as the utilities operating nuclear power plants and their contractors, the research centres are facing the shortage of engineers with a satisfactory background in nuclear disciplines and expressed their interest in a training scheme on the concepts and design of GEN IV nuclear reactors.

The GEN IV nuclear reactors are characterized by higher operating temperatures, requiring gas or liquid metal coolants in the primary circuit, although supercritical water cooling and molten salts are possible options as well. High temperature materials, corrosion effects, liquid metal dynamics, heat exchangers are typical topics which would fit to this training scheme. GEN IV nuclear reactors are also characterized by fast neutron fluxes for both breeding fresh fuel in blanket materials and enhanced burning of long lived waste products. In combination with the higher temperatures and the new primary coolants, those features will need the development and testing of entirely new nuclear fuels and fuel cycles, together with new fuel fabrication and fuel recycling concepts. A training scheme for the design of GEN IV nuclear reactors, including this large variety of components, will be more research oriented and will have a broader and less specialized scope than the former ones. Nevertheless it is expected to respond to the current needs of the research communities in order to design and build the prototypes of the nuclear reactors of the future.

(1) *PETRUS-II*

The PETRUS-II project is developing and implementing training schemes in the framework of geological disposal and underground storage of radioactive waste. The ENEN Association is a partner in the PETRUS-II project and will contribute to the following tasks:

— Quality assurance of the courses and training sessions and the project deliverables;
— Facilitate mobility and assist the organization of workshops and pilot sessions;
— Assist to the implementation of a framework for mutual recognition of the courses and training sessions through the ENEN Network and realization of a training passport at the European level;
— Harmonization of the attribution of the ECTS credits to the modules of the curriculum and the training programme;

[22] FISA Luxembourg, 2006.

— Host and operate the web pages of the Petrus-II project on the ENEN web site ;
— Knowledge management by providing assistance to the advertising and documenting of the courses and training sessions through the ENEN database.

Moreover, the ENEN Association will assist in the coordination of the project by representing four of its university members providing major contributions to the project.

(2) *ENETRAP-II*

The ENETRAP-II project is developing training schemes in the field of radiation protection at the expert and officer levels. The ENEN Association is a partner in the ENETRAP-II project as Work Package leader in charge of the establishment of mutual recognition of the training schemes and the implementation of a Training Passport. The ENEN will further contribute to the protocol for the evaluation of training materials, events and providers by using the ENEN quality assurance system. ENEN will also participate to the Advisory Board with respect to questions related to higher education and post-graduate training. Additionally, ENEN will ensure the contacts with the three EU Platforms SNE-TP, ENEF and HLG.

XXVI–6. ENEN SUPPORTED ACTIVITIES

The ENEN Association provides support to lecturers and students for the organization of and participation to selected courses, seminars, conferences and training sessions in nuclear fields. Some recent examples are:

— International Conference on Nuclear Energy for New Europe, 5–8 September 2005, Bled, Slovenia;
— ENC 2005, 12–15 December 2005, Versailles, France;
— World Nuclear University Summer Institute, July–August 2006, Stockholm, Sweden;
— International Youth Conference on Energetic, 31 May–2 June 2007, Budapest, Hungary;
— Materials for Generation IV Nuclear Reactors, from 24 September–6 October 2007, Cargese, France.

XXVI–7. INTERNATIONAL COOPERATION

XXVI–7.1. European Union

The ENEN Association is intricately involved in several activities on nuclear education and training in the European Union. In addition to the information provided above, the ENEN Association intends to contribute to the European Institute of Technology and has applied for participating in to the Seventh Framework Programme.

On the 21 September 2007, the Sustainable Nuclear Energy Technology Platform (SNE-TP) was launched with the aims of coordinating research, development, demonstration and deployment (RDD&D) in the field of nuclear fission energy. It gathers stakeholders from industry (technology suppliers, utilities and other users), research organizations including Technical Safety Organizations (TSO), universities and national representatives.

In the framework of the SNE-TP, the ENEN co-chairs with the EDF the Working Group on education, training and knowledge management with the objective to make proposals to the SNE-TP Governing Board on a future framework of nuclear education, training and knowledge management at European level and implement it in a sustainable manner to ensure the further development of nuclear energy technology in Europe.

ENEN Association is represented in the Board and the Executive Committee of SNE-TP.

XXVI–7.2. International Atomic Energy Agency

The ENEN Association has been involved in several technical meetings, consultants’ meetings, workshops and conferences related to education, training and knowledge management organized by the International Atomic Energy Agency.

Through the IAEA, the ENEN Association exchanges information and participates on a regular basis to meetings of the Asian Network for Education in Nuclear Technology. Asian network representatives are invited to the meetings of the ENEN Association.

XXVI–7.3. World Nuclear University

The ENEN Association has been supporting the World Nuclear University from its foundation in 2003 and has participated to the meetings of its Working Groups 1 and 2 since 2004. The ENEN Association is requested to lead the WNU Working Group on academic education and curricula development.

XXVI–8. FURTHER CHALLENGES

The ENEN Association has developed a knowledge and human network of European high level education and training in nuclear-related subjects, in particular within the nuclear disciplines of engineering, radiation protection, radioactive waste management and decommissioning, together with relevant academic and industrial entities and international organizations. In the framework of the ENEN Association major education and some training institutions in Europe are working together, and the ENEN is acting through education and training for the renewal of competencies across the nuclear energy life cycle (design and built, operate, decommission and dispose).

Through the Network, the adjustment of curricula and training packages has been enhanced and contributed to the young professionals, academic entities and the end-users needs, thereby improving employment and career opportunities, and the qualifications of the young professionals. Its further challenges are:

— Expand into nuclear disciplines outside nuclear engineering such as radiation protection, radio chemistry, waste management;
— Expand activities from the academic and research environment into the industrial and regulatory organizations and attract their membership;
— Define, harmonize and promote international mutual recognition of professional training for key functions in nuclear industries, regulatory bodies and nuclear applications;
— Participate to EC framework projects, in particular in the European Higher Education and European Research Areas;
— Continue to support and strengthen cooperation with other international and regional networks.

Through its educational activities, ENEN Association is actively contributing to the consolidation of the European Higher Education Area in the nuclear field.

The ENEN Association, its structural bodies and working committees and their members endeavour to implement this challenging programme, which will significantly contribute to the development of higher nuclear education and expertise within the European Union as well as on a global level.

REFERENCES TO ANNEX XXV

[XXVI–1] www.enen-assoc.org

[XXVI–2] INTERNATIONAL ATOMIC ENERGY AGENCY, Assuring the Competence of Nuclear Power Plant Contractor Personnel, IAEA-TECDOC-1232, IAEA, Vienna (2001).

BIBLIOGRAPHY TO ANNEX XXV

BLOMGREN, J., MOONS, F., DE REGGE, P., SAFIEH, J., Atomic 21, European Nuclear Education Network Association, (February 2007), 26–27.

CCE-FISSION Working Group on Nuclear Education, Training and Competence, Reflection paper, (2000).

DE REGGE, P., The role of the European Nuclear Education Network Association in the academic and industrial environment, ETRAP, Third International conference on Education and Training in Radiological Protection, Belgium, Brussels (23–25 November 2005).

MOONS, F., BNEN, The Belgian Nuclear Higher Education Network, Your way to the European Master of Nuclear Engineering, ETRAP, Third International conference on Education and Training in Radiological Protection, Belgium, Brussels (23–25 November 2005).

OECD/NEA, Nuclear Education and Training: Cause for Concern? ISBN 92–64–18521–6, (2000).

SAFIEH, J., DE REGGE, P., KUSUMI, R., Nuclear Disciplines in Response to Industry and Regulatory Needs through the European Nuclear Education Network Association, Nuclear Energy Review 2007, (2007) 46–47.

SAFIEH, J., ANS Meeting in conjunction with The European Nuclear Society, proceedings of the Conference on Nuclear Training and Education CONTE 2007, (February 2007).

SAFIEH, J., DE REGGE, P., NEPTUNO, the Nuclear European Platform of Training and University Organizations, EU Research and Training in Reactor Systems, FISA conference proceedings EUR 21231, Luxembourg (13–16 March 2006), 399–412.

For further information, please contact:

European Nuclear Education Network Association, Centre CEA de Saclay — INSTN — Bldg 395 Pe 34,
F-91191 Gif-sur-Yvette Cedex, France, Tel +33 1 69 08 97 57;
Fax +33 1 69 08 99 50;
Email: sec.enen@cea.fr;
Web site: http://www.enen-assoc.org

ANNEX XXVII

NUCLEAR ENERGY AGENCY

XXVII–1. BACKGROUND

The OECD Nuclear Energy Agency (NEA) was established on 1 February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20 April 1972, when Japan became its first non-European full Member. Now, NEA membership consists of 28 OECD Member countries, i.e. Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Republic of Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States of America. The NEA is the only intergovernmental nuclear energy organization which brings together developed countries of North America, Europe and the Asia-Pacific region in a small, non-political forum with a relatively narrow, technical focus.

— NEA membership represents much of the world's best nuclear expertise;
— By pooling this expertise, the NEA provides each Member access to the substantial experience of others and an opportunity to substantially leverage its resources in this field;
— Homogeneity of NEA membership makes possible a like-minded approach to problems, a climate of mutual trust and collaboration, the full exchange of experience, and a frank assessment of issues;
— The NEA is relatively unfettered by political and bureaucratic constraints, and is able to focus effectively on the specific needs of its Members;
— NEA scientific and technical work is in the forefront of knowledge and is known for its depth;
— The NEA publishes consensus positions on key issues, providing Member countries with credible references;
— The NEA is cost effective. It operates with a small staff, relying on Member country experts, and provides significant added value;
— The NEA's system of standing technical committees enables the Agency to be flexible and responsive;
— NEA joint projects and information exchange programmes enable interested Members and non-members to join forces in carrying out research or scientific inter comparison exercises on a cost sharing basis;
— The NEA, as part of a larger multi-disciplinary organization, is uniquely placed to address nuclear energy in the context of broader cross-cutting issues such as sustainable development.

Through international cooperation, NEA assists its member states to maintain and further develop the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes. The NEA also provides authoritative assessments and forges common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development. It is a non-partisan, unbiased source of information, data and analyses, drawing on one of the best international networks of technical experts.

In nuclear technology related tasks, NEA works in close collaboration with the IAEA and other international organization in this field. The Commission of the European Communities also takes part in the work of the NEA.

XXVII–2. NEA AND EDUCATION

The International School of Nuclear Law (ISNL) was established in 2001 by the University of Montpellier 1 and the NEA. The ISNL is supported by the International Nuclear Law Association (INLA) and the IAEA. The ISNL aims to provide a high quality course of education on the various aspects of this discipline. It is open to both law students pursuing their studies at doctoral or masters level who wish to follow an introductory course on nuclear law and familiarize themselves with career opportunities open to them in this field. It is also open to young legal professionals who are already active in the nuclear sector and who wish to develop their knowledge. Independent of its teaching role, the School serves as a forum for students to meet recognized specialists in nuclear law in a studious yet convivial atmosphere[23].

NEA also cooperates in organization of WNU Summer Institute.

XXVII–3. NEA AREAS OF WORK

(1) *Nuclear safety and regulation*: Its mission to assist Member countries in maintaining and further developing the scientific and technical knowledge required to assess the safety of nuclear reactors and other nuclear installations. It also develops the efficient and effective regulation that is based on current scientific and technical knowledge and gives priority to factors most important to safety.

(2) *Nuclear energy development:* To provide authoritative, reliable information on nuclear technologies, economics, strategies and resources to governments for use in policy analyses and decision making, including on the future role of nuclear energy within the context of energy policies that contribute to sustainable development.

(3) *Radioactive waste management:* To assist Member countries in developing safe management strategies and technologies for spent nuclear fuel, long lived radioactive waste and waste from the decommissioning of nuclear facilities.

(4) *Radiation protection and public:* To assist Member countries in the regulation and application of the system of radiation protection by identifying and addressing conceptual, scientific, policy, operational and societal issues in a timely and prospective fashion, as well as clarifying their implications.

(5) *Nuclear law and liability:* To assist Member countries in the regulation and application of the system of radiation protection by identifying and addressing conceptual, scientific, policy, operational and societal issues in a timely and prospective fashion, as well as clarifying their implications.

(6) *Nuclear science:* To help Member countries to identify, collate, develop and disseminate scientific and technical knowledge used to ensure safe, reliable and economic operation of current nuclear systems and to develop next-generation technologies.

(7) *The data bank:* To be the international centre of reference for its Member countries with respect to basic nuclear tools, such as validated computer codes and nuclear data, and to provide a direct service to its users by developing, improving and validating these tools and making them available as requested.

(8) *Information and communication:* The NEA produces a large selection of printed material, part of which is on sale, and part of which is distributed free of charge. The full Catalogue of publications is available free on request from the OECD/NEA Publications Section, 12 boulevard des Îles, 92130 Issy-les-Moulineaux, France. The Catalogue is also available electronically at www.nea.fr/html/pub. Orders may be sent by mail, or placed online at www.oecd.org/publications.

(9) *The NEA web site :* In addition to basic information on the Nuclear Energy Agency and its work programme, the NEA web site offers free downloads of hundreds of technical and policy-oriented reports. A monthly electronic bulletin is also sent free of charge to subscribers, providing updates of new results, events and publications. Sign up at www.nea.fr.

XXVII–4. NEA COMMITTEE STRUCTURE

The NEA secretariat serves seven specialized standing technical committees under the leadership of the Steering Committee for Nuclear Energy, the governing body of the NEA, which reports directly to the OECD Council.

— Committee on the Safety of Nuclear Installations;
— Committee on Nuclear Regulatory Activities;
— Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle;
— Radioactive Waste Management Committee;
— Committee on Radiation Protection and Public Health;

[23] http://www.nea.fr/html/law/isnl/index.html

— Nuclear Law Committee;
— Nuclear Science Committee.

XXVII–5. NUCLEAR EDUCATION AND TRAINING ‘CAUSE FOR CONCERNS’

The NEA study report entitled Nuclear Education and Training: Cause for Concern? (2000). According to this study, in most of the countries there are less high quality nuclear technology programmes at universities than before. The ability of universities to attract top quality students to those programmes, meet future staffing requirements of the nuclear industry, and conduct leading edge research in nuclear topics is becoming seriously compromised. Following concerns were found by this study.

— The decreasing number and the dilution of nuclear programmes;
— The decreasing number of students taking nuclear subjects;
— The lack of young faculty members to replace ageing and retiring faculty members;
— Ageing research facilities which are being closed and not replaced;
— The significant fraction of nuclear graduates not entering the nuclear industry.

By these concerns, this study confirmed that nuclear education have declined to the point where the expertise and the competence in the core nuclear technology is becoming increasingly difficult to sustain. Conclusion of this worked study was that a failure to take appropriate steps immediately would seriously jeopardise the provision of adequate expertise in the near future. To arrest the situation, following recommendations to government, academia and industry were proposed to act on immediate basis.

XXVII–5.1. Strategic role of governments

— Engage in strategic energy planning, including consideration of education, manpower and infrastructure;
— Contribute to, if not take responsibility for, integrated planning to ensure that human resources are available to meet necessary obligations and address outstanding issues;
— Support, on a competitive basis, young students and provide adequate resources for vibrant nuclear research and development programmes including modernisation of facilities;
— Provide support by developing ‘educational networks or bridges’ between universities, industry and research institutes.

XXVII–5.2. The challenges of revitalising nuclear education by university

— Provide basic and attractive educational programmes;
— Interact early and often with potential students, both male and female, and provide adequate information.

XXVII–5.3. Vigorous research and maintaining high quality training

— Provide rigorous training programmes to meet specific needs;
— Develop exciting research projects to meet industry’s needs and attract quality students and employees (research institutes).

XXVII–5.4. Benefits of collaboration and sharing best practices

— Industry, research institutes and universities need to work together to coordinate efforts better to encourage the younger generation;
— Develop and promote a programme of collaboration in nuclear education and training, and provide a mechanism for sharing best practices in promoting nuclear courses between member countries.

Annex XXVIII

NUCLEAR TECHNOLOGY EDUCATION CONSORTIUM

XXVIII–1. INTRODUCTION

To reinforce the government efforts toward the restoration of nuclear education health, a new concept in post-graduate level training for the nuclear sector has been developed by a strong consortium of UK universities and HE institutions under the title Nuclear Technology Education Consortium (NTEC). The basis of this consortium were designed to meet the UK projected nuclear skills requirements in decommissioning and cleanup, reactor technology, fusion and nuclear medicine. The structure and content of the programme, which leads to qualifications up to master's level in nuclear science and technology, was established following extensive consultations with the UK nuclear sector, including industry, regulators, MoD, NDA, Government Departments and the Cogent Sector Skills Council. The programme is coordinated by the Dalton Nuclear Institute at The University of Manchester. This programme has been approved by the Institution of Mechanical Engineers. Following are the key features of this consortium:

- It was only designed to fulfil the needs nuclear sector;
- It offers subjects in broad spectrum, from reactor theory through decommissioning to waste disposal and storage, the subject matter being presented by leading specialists in their field;
- Each topic is presented in short course format which is ideal for employees within the industry;
- It offers part-time basis over a period of three years as well as full-time in one year post-graduate courses in nuclear science and technology;
- This programme also covers the Post-graduate Diploma or Post-graduate Certificate opportunity for students;
- Individual subjects are presented in ‘short course’ modular format, providing excellent access to the programme for engineers and managers in full-time employment who wish to advance their skill and knowledge base;
- The core of each module is one week of direct teaching at the relevant institution, minimizing the time away from the workplace for an employee whilst maximizing its effectiveness;
- A distance learning option is being developed;
- The pass mark is 50% for all modules and is the same for students taking an MSc, PG Diploma, or PG Certificate.

Modules are generally delivered on the campus of the providing institution. Students seeking a post-graduate qualification register with the University of their choice and visit other members of the consortium to attend their selected modules. All modules are delivered by direct teaching but some are being converted into a distance learning format as an alternative method of delivery to provide greater choice for students.

XXVIII–2. NTEC MEMBERS

(1) *The University of Birmingham* has more than 50 years of experience of teaching post-graduate courses related to the nuclear industry and applied and medical radiation physics. They have for some years liaised closely with industry and the regulators regarding course syllabus and delivery.

(2) *City University, London,* has a major research programme in risk and reliability in the aerospace, nuclear and medical fields.

(3) *Imperial College London,* Nuclear Technology and Nuclear Reactor Technology courses have been taught and continuously developed at Imperial over the past two decades.

(4) *Lancaster University* brings expertise in innovative nuclear course design including part-time industry-based schemes involving modules in the Design of Safety critical Systems and Decommissioning and Robotics Engineering.

(5) *University of Leeds* provides a unique opportunity to produce multi-disciplinary teams capable of solving some of the complex problems that can arise in an industry as diverse as nuclear decommissioning or nuclear power generation.
(6) *The University of Liverpool* runs over 20 masters training programme in the faculties of Science, Engineering and Medicine.
(7) *The University of Manchester* has nuclear research activities in ten departments covering aspects of materials, radiochemistry, nuclear physics, fusion, nuclear medicine and environmental science. Manchester has also established the Dalton Nuclear Institute to coordinate and grow its nuclear research capacity.
(8) *The University of Sheffield*, its post-graduate taught courses examine the fundamental issues of processes and materials for nuclear waste immobilization such as glasses, glass-composite materials, ceramics and metals.
(9) *Nuclear Department at HMS Sultan — DCMT,* its Nuclear Department (ND) uses its full range of academic expertise, from a staff of almost 100, to provide the consortium with core modules on the nuclear fuel cycle and criticality safety management, and an elective module on reactor thermal hydraulics.
(10) *UHI Millennium Institute*, the Decommissioning and Environmental Remediation Centre (DERC) is a unique initiative, building on nearly 50 years of experience in Nuclear Safety and Engineering Training. A European Masters in Nuclear Decommissioning is being developed.
(11) *Westlakes Research Institute* (WRI) undertakes research focused on environmental, health and nuclear activities.

XXVIII–3. PROGRAMME STRUCTURE

There are two types of MSc. programmes i.e. a full-time and a part-time programme. Both these programmes require a total of eight modules (four cores and four elective) along with research project and dissertation to complete. The part time MSc programme needs three years to complete. Four core modules and it successful completion in first year can also attain Post-graduate Certificate. Second year demands four elective modules and its successful completion make the candidate eligible for Post-graduate Diploma. Final and third year of part time MSc programme only focuses on research project and dissertation.

The full time MSc programme have a year to complete; i.e. core and four elective modules are completed in nine months and research project and dissertation take three month completing.

XXVIII–3.1. Short course attendance

The completion of any individual module can be taken as a short course for continuing professional development purposes. Students attending a short course will be given an appropriate certificate but will not achieve a formal qualification from the institution presenting the module. Students successfully completing an individual module may transfer to the full programme subject to acceptance by their chosen university.

XXVIII–3.2. Module selection

The core and elective modules are given in the following. Each module will accrue 15 credits, requiring approximately 150 hours application by the student.

XXVIII–3.3. Core modules

(1) Decommissioning:
— N04 Decommissioning / Waste / Environmental Management;
— N10 Processing, Storage and Disposal of Nuclear Wastes;
— N29 Decommissioning Technology and Robotics;
— N31 Management of the Decommissioning Process.

(2) Nuclear Technology:
    — N01 Reactor Physics, Criticality and Design;
    — N02 Nuclear Fuel Cycle;
    — N03 Radiation and Radiological Protection;
    — N13 Criticality Safety Management.

XXVIII–3.4. Elective modules

(1) Decommissioning:
    — N08 Particle and Colloid Engineering in the Nuclear Industry;
    — N09 Policy, Regulation and Licensing;
    — N14 Risk Management;
    — N21 Geotechnical Aspects of Radioactive Waste Disposal;
    — N22 Public and Political Aspects of Nuclear Decommissioning;
    — N23 Environmental Impact Assessment;
    — N24 Environmental Decision Making Applied to Decommissioning;
    — N30 Design of Safety-Critical Systems.
(2) Environment and Safety:
    — N07 Safety Case Development;
    — N09 Policy, Regulation and Licensing;
    — N10 Processing, Disposal and Storage of Nuclear Wastes;
    — N14 Risk Management;
    — N21 Geotechnical Aspects of Radioactive Waste Disposal;
    — N22 Public and Political Aspects of Nuclear Decommissioning;
    — N23 Environmental Impact Assessment;
    — N24 Environmental Decision Making Applied to Decommissioning.
(3) Nuclear Technology:
    — N05 Water Reactor Performance and Safety;
    — N06 Reactor Materials and Lifetime Behaviour;
    — N09 Policy, Regulation and Licensing;
    — N12 Reactor Thermal Hydraulics;
    — N14 Risk Management;
    — N30 Design of Safety — Critical Systems;
    — N32 Experimental Reactor Physics.
(4) Distance Learning.
    From September 2008, eight of the core modules will be offered in distance learning format. Delivery of elective modules in this format will commence at a later date. Each module will contain the same syllabus as its counterpart delivered by direct teaching, will have the same learning outcomes and will be delivered once per annum at a fixed time in order to facilitate the concept of a ‘virtual classroom’. The core modules are:
    — Decommissioning stream:
        • N04 Decommissioning/Waste/Environmental Management;
        • N10 Processing, Storage and Disposal of Nuclear Wastes;
        • N31 Management of the Decommissioning Process;
        • N29 Decommissioning Technology and Robotics.
    — Nuclear Technology stream:
        • N03 Radiation and Radiological Protection;
        • N01 Reactor Physics, Criticality and Design;
        • N02 Nuclear Fuel Cycle;
        • N13 Criticality Safety Management.

The distance learning platform is WebCT, a web-based Virtual Learning Environment, accessible anywhere, anytime and includes course handbooks, course content, timetables, course news, discussion groups, video clips and e-mail.

Annex XXIX

THE WORLD NUCLEAR UNIVERSITY SUMMER INSTITUTE — A FORUM FOR NUCLEAR KNOWLEDGE TRANSFER AND LEADERSHIP[24]

XXIX–1. INTRODUCTION

Education and training involve passing knowledge to the next generation and sharing knowledge for capacity building. Education in this context denotes higher education received in universities etc., whereas training denotes transfer of shorter, skill oriented specialized knowledge, which is usually done by the nuclear industry or organizations. Thus, education and training are considered important tools for preserving and sustaining knowledge. Recently, networking of educational institutions has been considered a key strategy for capacity building and efficient use of available educational resources. The strength of the IAEA lies in its ability to propose and facilitate frameworks in which Member States can work together and collaborate.

The idea of the WNU was presented at the IAEA for the first time during various IAEA meetings in 2001 and 2002. The Department of Nuclear Energy was involved in most of this work through its sub-programme on Nuclear Knowledge Management [XXIX–1]. The World Nuclear University is a global partnership committed to enhancing international education and leadership in the peaceful applications of nuclear science and technology. The central elements of the WNU partnership are:

- The global organizations of the nuclear industry: World Nuclear Association (WNA) and World Association of Nuclear Operators (WANO);
- The inter-governmental nuclear agencies: IAEA and Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development (OECD);
- Leading institutions of nuclear learning in some thirty countries.

The WNU was inaugurated in 2003 in a London ceremony commemorating the 50th anniversary of President Eisenhower's historic *Atoms for Peace* initiative; the visionary proposal that gave birth to the IAEA. This United Nations specialized agency is one of the four world organizations known as the WNU's 'Founding Supporters'. Within the United Nations system, the WNU is recognized as a 'Partnership for Sustainable Development' by the United Nations Commission on Sustainable Development (CSD) [XXIX–2]. The mission of this new university is to strengthen the international community of people and institutions in their efforts to further develop:

- The safe and increasing use of nuclear power as a proven technology able to produce clean energy on a global scale;
- The many valuable applications of nuclear science and technology that contribute to sustainable agriculture, medicine, nutrition, industrial development, management of fresh water resources and environmental protection.

Through a worldwide network of established institutions of nuclear learning, the WNU seeks to promote academic rigour and high professional ethics in all phases of nuclear related activity. The WNU has been created as a forward looking initiative, offering new forms of cooperation for the world nuclear community and having the synergy of people and ideas as its main objective.

The IAEA has been supportive in assisting the WNU, particularly during the early formative stages, to define its mission and focus thus avoiding duplication and preventing potential rivalries and competition for the same resource (see Ref. [XXIX–1]). The overall objective in supporting the World Nuclear University is to leverage the value of the IAEA's programmatic, training and educational activities by using WNU platform as an additional vehicle and tool for implementation, especially in cases where this offers better and more widely distributed results and impacts.

---

[24] Prepared by Y. Yanev, M. Saidy, A. Kosilov and T. Karseka, IAEA.

The following is an initial list of support actions related to the WNU (see Ref. [XXIX–1]):

- Provision of high quality training and/or training material to the member universities of WNU network;
- TC-supported fellowships at University networks of WNU and support for WNU-SI fellows;
- Facilitated access to INIS and the IAEA’s library nuclear information resources, made available to WNU students;
- Providing lecturers, where appropriate and especially for key training events (such as major summer school and workshops of WNU).

A non-profit corporation, the WNU pursues its educational and leadership-building mission through programmes organized by the WNU Coordinating Centre (WNUCC) in London under the leadership of a Board-appointed President. These cooperative activities are designed to harness the strengths of partnership members in pursuit of shared purposes.

The WNU President is Ambassador J. Ritch, WNA Director General, whose WNU work is a *pro bono* industry contribution to the WNU partnership. The WNU Board is chaired by Dr. Z. Pate, WANO’s Chairman-Emeritus, a leader widely respected for his pioneering work at the US Institute of Nuclear Power Operations (INPO) and as a co-founder of WANO, the global nuclear safety organization.

A WNU Chancellor and Vice-Chancellor provide leadership in specific WNU programmes and in building public support for the WNU agenda. The WNU’s Chancellor is Dr. H. Blix, the IAEA’s Director General-Emeritus, who headed the IAEA for 16 years and later served as chief of the United Nations Monitoring, Verification and Inspection Commission. The Vice-Chancellor is Dr. R. Hawley, former Chief Executive Officer of British Energy.

Operationally, the WNU is a public-private partnership. On the private side, the nuclear industry provides administrative, logistical and financial support via the WNA. On the public side, the IAEA assists with financial support, from its Technical Cooperation Fund, for certain WNU activities, which has enabled strong participation from developing nations.

Fundamental to the WNU partnership is the staffing of the WNUCC through the assignment by governments and leading companies of internationally experienced nuclear professionals. These experts fulfill a multiple purpose, by:

- Expressing a strong national commitment to the WNU’s mission;
- Empowering the WNUCC with high quality cost-free staff resources;
- Facilitating WNU interaction with major national nuclear establishments.

As of the autumn of 2008, the following nations had seconded staff to the WNUCC: USA, France, Russian Federation, Republic of Korea and Canada. Secondment commitments have been received from India and the UK, and discussions are underway with governments and leading nuclear enterprises in Japan and China. An attractive concept (but unfulfilled) is the placement on the WNUCC secretariat of regionally-supported representatives from Latin America and Africa (see Ref. [XXIX–2]).

The prospect of a steady worldwide growth in the use of nuclear technology — for power generation and in a diversity of applications in medicine, agriculture, and industry — points to the need for a greatly expanded global cadre of nuclear professionals in the twenty-first century. The role of the World Nuclear University partnership is to support this growth by:

- Strengthening education in nuclear science, engineering and law;
- Promoting public understanding of nuclear technology;
- Inspiring and strengthening the development of a new generation of leaders for the nuclear industry.

WNU activities are designed to fulfill unmet educational needs on the transnational level by capitalizing on the diverse strengths of WNU partnership members. These activities fall into five programmatic categories:

— WNU Summer Institute is a unique six-week course which offers an inspiring career opportunity for some 100 outstanding young nuclear professionals and academics from around the world. The WNU-SI programme combines an extensive series of ‘big picture’ presentations from world class experts with daily team building exercises. In the process, WNU Fellows become part of a global network of future nuclear leaders;
— Foster policy consensus on institutional and technological innovation;
— Enhance public understanding;
— Shape scientific and regulatory consensus on issues affecting nuclear operations;
— Strengthen international workforce professionalism.

The flagship programme of the WNU — the Summer Institute for young nuclear professionals, its role in building leadership and transfer of knowledge from the current generation of leading scientists to the next generation and across international boundaries is the subject of this article.

XXIX–2. THE WNU SUMMER INSTITUTE FOR FUTURE LEADERS

The WNU’s creation in 2003 represented only the initial gathering of good-faith commitments — from a variety of inter-governmental, industry, and academic partners — to participate in activities still to be defined. These commitments constituted an essential foundation, but the main task remained: to convert the WNU concept into a successful operational reality.

From the outset, a wide range of WNU activities was envisaged. But the compelling task in the startup phase was to achieve an early and clear-cut demonstration that the WNU partnership could yield valuable innovative contributions to the world nuclear community. The WNU Summer Institute was conceived and developed as this pilot vehicle.

In preparation of the first WNU-SI, the IAEA convened a meeting in December 2004 to coordinate the WNU Summer Institute preparation, follow-up on course outline and contents for the Summer Institute, discuss the preparation of a compendium of existing courses and diplomas and inter-university cooperation and the current WNU activities (see Ref. [XXIX–1]).

The following was discussed and agreed at that meeting:

— Curriculum;
— Faculty;
— Mentoring;
— Evaluation;
— Pedagogical material;
— Selection of students;
— Financial matters.

The meeting also addressed the WNU Business Plan, actions related to the Summer Institute; the educational networks European Nuclear Education Engineering Network (ENEN), Asian Network for Education in Nuclear Technology (ANENT), US Nuclear Engineering Department Heads Organization (NEDHO), and the Canadian University Network of Excellence in Nuclear Engineering (UNENE); exchange programmes; tools for distance learning; compendium on existing courses; identifying the WNU customers needs and the Russian proposal on establishing the WNU Centre of Nuclear Science and Technology in Obninsk, Russian Federation.

The WNU-SI programme consists of many components [XXIX-3–XXIX-4], including:

— Daily morning lectures by international experts on a variety of issues that will influence the future use of nuclear technologies;
— Team-building activities designed to initiate and enhance relationships and teamwork among fellows;
— Afternoon review sessions in small facilitator-led groups to promote sharing of differing perspectives and to discuss major ideas/issues presented by the faculty, including case studies;

— Special invited ‘distinguished’ speaker presentations by persons who have made notable contributions in the nuclear domain, bringing ideas and information related to their achievements in the real world of nuclear energy, painting ‘big pictures’ and encouraging the fellows to think of an exciting career dealing with challenging issues;
— Group presentations (by fellows on topics of interest) dealing with significant nuclear issues with international implications, including:
  - Non-proliferation policy;
  - Reprocessing policy;
  - Limitation of fuel production and enrichment capacities;
  - Issues in initiating or expanding the use of nuclear power;
  - Options for storing radioactive waste (regional or multinational repositories);
  - Role of nuclear technology in addressing global warming;
  - Strategies for counteracting the public’s fear of nuclear technology.

  These presentations provided an opportunity for self-directed intensive teamwork amongst the fellows;
— Field trips to several host-country nuclear and industrial sites, including fuel cycle facilities, heavy components manufacturing plants, geological waste repositories, etc.;
— Receptions, informal social events and group recreational activities to encourage socialization and strengthen relationships among fellows, facilitators, presenters and other Institute participants.

With help from the US Department of Energy, the first WNU-SI was organized by the London based WNUCC and hosted by the Idaho National Laboratory in July–August 2005. From an impressive field of applicants — mostly young professionals in nuclear enterprises — 77 WNU fellows were selected, representing 34 nations, for development as ‘future leaders’ in the realm of nuclear science and technology. The IAEA provided crucial financial aid to facilitate the participation of WNU fellows from developing countries.

The six-week WNU-SI programme combined presentations from a series of world-class experts with a challenging regime of small-group exercises. The entire programme was overseen by a full-time team of senior nuclear professionals acting as Facilitators. The WNU’s founding supporters — IAEA, WNA, WANO and NEA — provided many of the expert presenters. This formula — and its execution — proved an unqualified success, winning virtually unanimous praise both from the WNU fellows and from the experts and facilitators who comprised the WNU-SI faculty.

With this momentum, the second WNU-SI was held in 2006 in Stockholm, hosted by Sweden’s Royal Institute of Technology and the Swedish Centre for Nuclear Technology. Midway through the SI programme, France’s Commissariat à L’Energie Atomique (CEA) provided an extensive tour of French nuclear facilities. Again, the IAEA supplied key financial aid to developing-country fellows.

The 2007 WNU-SI was hosted by the Korea Atomic Energy Research Institute (KAERI) in South Korea (see Ref. [XXIX–3]). The fourth WNU-SI was hosted and supported by a Canadian consortium of nuclear industry and governmental organizations, including Cameco Corporation, Atomic Energy of Canada Limited (AECL), Bruce Power and Ontario Power Generation (OPG). For this 2008 Summer Institute, 99 WNU fellows were selected, representing 36 countries (see Ref. [XXIX–4]). As before, the IAEA role was crucial in supporting WNU fellows from the developing world.

The fifth WNU-SI will occur in the United Kingdom — hosted at Christ Church, University of Oxford — between 5 July and 15 August, 2009.

Some 367 young nuclear professionals from some 58 countries have become part of a growing family of WNU fellowship alumni, who are permanently networked through the WNU web site (www.world-nuclear-university.org) and now through an annual reunion (see Ref. [XXVIII–2]).

In September 2007, a first reunion was held for former WNU fellows in conjunction with the Annual Symposium of the World Nuclear Association in London. The WNU reunion has now become an integral part of this leading yearly event on the calendar of the global nuclear industry.

XXIX–2.1. Knowledge transfer and networking

The WNU-SI is a unique opportunity for future leaders in the nuclear domain to extend their knowledge of nuclear issues and to network with peers from around the world. Instruction in the mornings is provided by some of the foremost leaders in science, engineering and the environment. The curriculum devised by the WNUCC covers the full range of topics relevant to the future use of nuclear technology, including global environment, sustainable development, nuclear-related technology innovation, non-proliferation and nuclear industry practices. In the afternoons, WNU fellows work in teams to analyse the morning's presentations and to pursue case studies and other analytic projects. A corollary of the Institute is the encouragement of networking, benchmarking, and the sharing of best practices.

The presentations cover the full range of topics relevant to the future of nuclear technology and fall into the following categories:

- *Global settings*, including energy supply and demand, global warming and climate change, nuclear technology in sustainable development, lessons in public acceptance, and key political issues and trends;
- *International regimes,* including safety, radiological protection, non-proliferation and security, waste management, transport, nuclear law, and global greenhouse gas emissions control;
- *Technology innovation*, including next-generation reactors, advanced nuclear fuel cycle, hydrogen production, desalination, and nuclear fusion;
- *Nuclear industry operations*, including industry economics, fuel market, knowledge management, comparative risk assessment, social ethics, and operational excellence.

These 'big picture' presentations from industry experts demonstrate a personal commitment to professional expertise and a strong sense of purpose to transfer valuable knowledge to the younger generation. It also helps to attract, maintain and further develop a dedicated cadre of highly competent professionals to sustain nuclear competence.

Lecturers included outstanding nuclear and environmental scientists, as well as industry experts, authors and policymakers. Among them were J. Bouchard, M. Salvatores, T. Isaacs, Y. Yanev, G. Campbell, B. Pellaud, just to name a few.

The lectures were followed by:

- Self-directed study groups to prepare responses to challenging case studies developed by Institute faculty;
- Discussions of case studies with the entire group of Institute participants.

Receptions, informal social events and group recreational activities were also included in the programme to encourage socialization and strengthen relationships among fellows, facilitators, presenters and other Institute participants. The social activities began with a welcoming reception, presided over by the WNU President and host-country industry leaders, and concluded with a special celebratory banquet and graduation ceremony presided over by the WNU Chancellor.

This WNU-SI aims to meet the following: capacity building through training and education and transferring knowledge from centres of knowledge to the younger generation in these centres as well as to centres of growth; attracting and maintaining the young generation to a career in the nuclear field; foster networking in education and training and contribute to the development of educational quality benchmarks; preservation of valuable nuclear knowledge for future use; and the notion that sharing and pooling of nuclear knowledge can contribute to development and innovation.

XXIX–2.2. Nuclear leadership

An important component of the WNU-SI is a series of special presentations by leaders and pioneers in areas related to Nuclear Science and Technology. These lectures on Nuclear Leadership feature internationally known individuals who have made significant contributions to the development, politics and peaceful use of nuclear science and technology.

Lecture appearances comprised:

- A late-afternoon or morning presentation, some of which were open to the public, lasting about 40–50 minutes, followed by a question and answer session lasting an additional 15–20 minutes;

— A reception and an informal after dinner discussion, at the conclusion of the programme, provided an opportunity for additional interaction between the presenter, WNU fellows and faculty of the Institute for earlier WNU-SIs.

In preparing their presentations, lecturers are offered wide latitude but are encouraged to cover:

— Personal experiences and lessons learned in the nuclear field;
— Issues and challenges they foresee for future nuclear leaders.

Among them were WNU Chancellor H. Blix and renowned global environmental scientist J. Lovelock, author of the Gaia theory. The aim of the lecture series is to provide:

— Vivid insight about notable careers in the nuclear field;
— Realistic perspective on the challenges facing those engaged in applying and advancing the valuable uses of nuclear technology;
— Appreciation — by way of personal example — for the capacity of dedicated individuals to make a substantial difference in our world through a career in the nuclear profession.

The following individuals gave presentations at the last four Summer Institutes:

— J. Ritch (Director General of WNA and President of WNU);
— L. Echavarri (Director General of OECD/NEA);
— D. Klein (Chairman of the US NRC);
— P. Pradel (Director of the Nuclear Energy Division of CEA);
— G. Grandey (President and CEO of Cameco);
— P. Moore (Greenspirit Strategies and co-founder of Greenpeace);
— White (President and CEO of GE New Energy Ventures);
— Lauvergion (CEO, Areva).

XXIX–2.3. The WNU-SI assessments

The WNU organizers believe that it is important to determine the strengths and limitations of the initiatives to contribute to the evolution of the design, development and delivery of future offerings and continuous improvements of the Summer Institute and other WNU programmes. As a result an assessment was designed to provide the many stakeholders of the WNU Summer Institute with summary data and analyses regarding the value and effectiveness of the Institute. This assessment was applied to all WNU-SI and provided the basis for the continuous improvements made in the WNU-SI programme (see Refs [XXIX–1, XXIX–3, and XXIX–4]).

Eight different assessment components (see Ref. [XXIX–1]) were developed and completed during the six weeks of the Summer Institute, in particular:

— Pre-Institute questionnaire;
— Pre-Institute survey of fellows’ knowledge and interest;
— Assessment of session/presenter;
— Importance-satisfaction survey of faculty members;
— Fellows’ mid-Institute assessment of mentor programme and mentors;
— Post-Institute survey of fellows’ knowledge and interest;
— Post-Institute importance-satisfaction survey of fellows;
— Fellows’ action plans.

Assessments of all four Institutes held thus far have shown that the goals of the SI were accomplished and all the participants — fellows, lecturers, mentors (facilitators) — share the same positive appreciation of the event. Two key benefits to the fellows have been stated repeatedly:

— Obtaining a much broader global perspective on many aspects of the nuclear field;
— The opportunity to interact with international peers in the nuclear field that will lead to lifelong professional relationships and personal friendships.

A technical meeting, held in June 2005, reviewed the IAEA support to the World Nuclear University, outlined the current issues, coordinated the WNU actions and, in particular, discussed the latest preparations for the Summer Institute (see Ref. [XXIX–1]). A follow-up meeting is planned for 2009 after the fifth Summer Institute for a comprehensive review of the IAEA's support as well as programme content and the way forward.

XXIX–3. CONCLUSION

Nuclear power alone can not solve the environmental problems and cut excessive greenhouse gas emissions. However these problems can not and will not be solved without the nuclear power. Furthermore, to encourage and support energy growth in less developed countries, nuclear power has to experience a huge expansion. In a number of key areas, including safety, security and environmental impact, the nuclear industry has to maintain the highest standards and to continue learning from experience. All this requires moral qualities in future leaders, and a global awareness of nuclear issues amongst stakeholders. The WNU will be instrumental in raising global educational standards as well as fostering a widely shared sense of responsibility. The WNU-SI aims to facilitate:

— Capture and dissemination of existing educational experience and skills from senior nuclear professionals;
— Develop knowledge bases in various areas of nuclear science and technology;
— Inspire a new generation of future leaders of the industry.

Inter-university cooperation, the Summer Institutes and other programmes being planned will contribute to building a worldwide nuclear community. This community should share moral values such as openness, intellectual rigour and a commitment to sustainable human development. Trust within the community will be a precondition of defining internationally sound regimes covering the areas of nuclear installation trade and operation, nuclear material management, including high level and long lived waste.

The WNU fellows are seen as a growing army of future nuclear leaders. They represent a peaceful force, but one that can make a real impact as we struggle to achieve human advancement around the world while preserving our global environment.

In shaping the Summer Institute's agenda, the main goal was to deepen their (the fellows) appreciation of the pervasive value of nuclear technology in our modern world and to strengthen their ability to explain that reality to their fellow citizens, who need the leadership they can provide.

The IAEA Member States have expressed their appreciation of the WNU. One of the recent resolutions of the IAEA General Conference (GC(52)/RES/12) recalls previous resolutions favouring innovative educational partnerships like the WNU that involve academia, government and industry and expresses confidence that such initiatives can, with the IAEA support, play a valuable role in promotion of strong educational standards and in building leadership for an expanding global nuclear profession.

REFERENCES TO ANNEX XXIX

[XXIX–1] INTERNATIONAL ATOMIC ENERGY AGENCY, The World Nuclear University: New Partnership in Nuclear Education, IAEA Report, IAEA, Vienna (2007).
[XXIX–2] RITCH, J., The World Nuclear University: A Global Partnership for Sustainable Development, (November 2008).
[XXIX–3] SAIDY, M., Highlights of the 2008 WNU Summer Institute, September 2008.
[XXIX–4] SAIDY, M., Highlights of the 2007 WNU Summer Institute, September 2007.

ABBREVIATIONS AND INSTITUTES TO THE ANNEXES

AECL	Atomic Energy of Canada Limited
AEET	Atomic Energy Establishment, Trombay
AEKI	Atomic Energy Research Institute
AELB	Atomic Energy Licensing Board
AFCI	Advanced Fuel Cycle Initiative
AFNI	France International Nuclear Agency
AMF	American Machine Foundry
AN	Romanian Nuclear Agency
ANDRA	National Agency for Radioactive Waste Management
ANDRAD	National Agency for Radioactive Waste
ANENT	Asian Network for Education in Nuclear Technology
ANS	American Nuclear Society
ANSN	Asian Nuclear Safety Network
ATI	Atomic Institute of the Austrian Universities
ATOMKI	Atomic Research Institute
BARC	Bhabha Atomic Research Centre
BAS	Bulgarian Academy of Sciences
BME	Budapest University of Technology and Economics
BMSTU	Bauman Moscow State Technical University
BNEN’	Belgium Nuclear Higher Education Network
BNRC	Berkeley Nuclear Research Centre
BRNS	Board of Research in Nuclear Sciences
BWR	Boiling water reactor
C2FSTN	Comité de Coordination des Formations aux Sciences et Techniques Nucléaires
CAC	Centro Atómico Constituyentes
CAES	Centre for Advanced Energy Studies
CANDU	Canada deuterium uranium reactor
CANTEACH	Knowledge repository that provides high quality technical documentation relating to the CANDU nuclear energy system
CCFSTN	Coordination Committee for education in nuclear sciences and technology
CCMA	Research Centre for Advanced Materials
CEA	Atomic Energy Commission
CEGB	Central Electricity Generating Board
CEN	Committee for Nuclear Energy
CERN	European Organization for Nuclear Research
CHASCENT	CHASNUPP Centre for Nuclear Training
CHASNUPP	Chashma Nuclear Power Plant
ChNPP	Chernobyl NPP
CITON	Centre of Technology and Engineering for Nuclear Projects
CIRTEN	Consorzio Interuniversitario per la Ricerca Tecnologica Nucleare
CNA	Canadian Nuclear Association
CNCAN	National Commission for Nuclear Activities Control
CNEA	Argentina Atomic Energy Commission
CNEN	National Committee for Nuclear Energy
CNS	Canadian Nuclear Society
COG	CANDU Owners’ Group

COLA	Construction and Licensing Application
CONUAR	Combustible Nucleares Argentinos
CRD	Collaborative Research and Development
CSD	Commission on Sustainable Development
CT	Computed tomography
DAE	Department of Atomic Energy
DENER	Department of Energetic
DGFS	DAE Graduate Fellowship Scheme
DipRP	Diploma in Radiological Physics
DMRIT	Diploma in Medical Radioisotope Techniques
DNP	Department of Nuclear Physics
DOE	Department of Energy
DONEEP	Department of Nuclear Engineering and Environmental Physics
DONEP	Department of Nuclear Engineering Physics
DRM	Diploma in Radiation Medicine
ECTS	European Credit Transfer System
EDF	Electricité de France
EMSNE	European Master of Science in Nuclear Engineering
ENEA (former CNEN)	Italian National Agency for New Technologies, Energy and Sustainable Economic Development
ENEN	European Nuclear Education Network
EPR	European pressurized reactor or evolutionary pressurized reactor
EPSRC	Engineering and Physical Sciences Research Council
ERASMUS	European Region Action Scheme for the Mobility of University
ETCS	European Credit Transfer System
FAE	Fabricacion de Aleaciones Especiales
FC	Fuel channels
FCDN	Fundación Centro Diagnóstico Nuclear
FCN	Nuclear Fuel Plant
FEI	Faculty of Electrical Engineering and Information Technology
FFE	Foreign field experience
FNCA	Forum for Nuclear Cooperation in Asia
FUESMEN	Fundación Escuela de Medicina Nuclear
GDF	Gaz de France
GNEP	Global Nuclear Energy Partnership
HAEA	Hungarian Atomic Energy Authority
HBNI	Homi Bhabha National Institute
HPS	Health Physics Society
HRD	Human resource development
HRI	Harish Chandra Research Institute, Allahabad
HUNS	Hanoi University of Natural Sciences
HUT	Hanoi University of Technology
IATE	Obninsk State Technical University for Nuclear Power Engineering
IB	Instituto Balseiro
ICN	Institute for Nuclear Research in Pitesti
ICSI	National Institute of R&D for Cryogenics and Isotope Technologies in Rm. Valcea
ICT	Information and communication technology

IEDS	Instituto de Energía y Desarrollo Sustentable
IFA	Institute of Atomic Physics
IFA	Institute of Atomic Physics
IFIN-HH	National Institute for R&D in Physics and Nuclear Engineering ‘Horia Hulubei’
IGCAR	Indira Gandhi Centre for Atomic Research, Kalpakkam
IIT	Indian Institute of Technology
IMSc	Institute of Mathematical Sciences, Chennai
INEEP	Institute of Nuclear Engineering and Environmental Physics
INIC	International Nuclear Innovative Consortium
INIS	International Nuclear Information System
INLA	International Nuclear Law Association
INPO	US Institute of Nuclear Power Operations
INL	Idaho National Laboratory
INSS	International Nuclear Safety School
INSTN	Institut National des Sciences et Techniques Nucléaires
IoP	Institute of Physics, Bhubaneswar
IPPE	Federal Nuclear Research Centre
IPR	Institute of Plasma Research, Gandhinagar
IRC	Industrial Research Chairs
IRNE	Institute for Nuclear Power Reactors
IRSN	Institute for Radiological Protection and Nuclear Safety
IS	Instituto Sabato
ISNL	International School of Nuclear Law
ISPU	Ivanovo State Power University
ITER	International Thermonuclear Experimental Reactor
JAEA	Japan Atomic Energy Agency
JAERI	Japan Atomic Energy Research Institute
JSPS	Japan Society for the promotion of Science
KAERI	Korea Atomic Energy Research Institute
KAIST	Korea Advanced Institute of Science and Technology
KANUPP	Karachi Nuclear Power Plant
KFKI	Central Research Institute for Physics
KHNP	Korea Hydro & Nuclear Power
KINPOE	KANUPP Institute of Nuclear Power Engineering
KINS	Korea Institute for Nuclear Safety
KJFT	Department of Nuclear Physics and Technology
KNEF	Korea Nuclear Energy Foundation
KNU	Taras Shevchenko Kiev National University
KOICA	Korea International Cooperation Agency
KPS	Korea Plant Service
KSKRA	K.S. Krishnan Research Fellowship
KSU	Nuclear Safety and Training AB
KTH	Royal Institute of Technology
KTU	Kaunas University of Technology
LWR	Light water reactor
MBBS	Bachelor of Medicine and Bachelor of Surgery
MEPhI	Moscow Engineering Physics Institute

MNSR	Miniature neutron source reactor
MOET	Ministry of Education and Training
MOSTI	Ministry of Science, Technology and Innovation
MoD	Ministry of Defence
MoU	Memorandum of Understanding
MOX	Mixed oxide
MPEI	Moscow Power Engineering Institute
MRWS	Managing Radioactive Waste Safely
MSNE	Master of Science in Nuclear Energy
NAA	Neutron activation analysis
NAG	Nuclear Analysis Group
NCNDT	National Centre for Non-Destructive Testing
NDA	Nuclear Decommissioning Authority
NDT	Non-destructive testing
NE	Nuclear education
NEA	Nuclear Energy Agency
NEDHO	Nuclear Engineering Department Heads Organization
NEEP	Nuclear Engineering and Environmental Physics
NEPTUNO	Nuclear European Platform for Training and University Organizations
NERAC	Nuclear Energy Research Advisory Committee
NET	Nuclear education and training
NGO	Non-governmental organization
NIA	Nuclear Institute for Agriculture
NIAB	Nuclear Institute for Agriculture and Biology
NIBGE	National Institute for Biotechnology and Genetic Engineering
NIFA	Nuclear Institute for Food and Agriculture
NKM	Nuclear knowledge management
NMTC	Nuclear Maintenance Training Centre
NPEI	Nuclear Power Education Institute
NPT	Non-proliferation treaty
NRC	Nuclear Regulatory Commission
NRNU ‘MEPhI’	National Research Nuclear University ‘MEPhI’
NRU	National research universal reactor
NRX	National research experimental reactor
NSAN	National Skills Academy Nuclear
NSC	National Science Centre ‘Kharkiv Institute of Physics and Technology’
NSERC	National Science and Engineering Research Council of Canada
NSSS	Nuclear steam supply system
NSTU	State Technical University (Nizhny Novgorod)
NTC	Nuclear Training and Education Centre of KAERI
NTEC	Nuclear Technology Education Consortium
NTUU ‘KPI’	National Technical University of Ukraine ‘Kyiv Polytechnic Institute’
NUC	National University Consortium
NUCENG	Nuclear Engineering
OAH	Hungarian Atomic Energy Authority
OAS	Organization of American States
OCES	Orientation Course for Engineering Graduates and Science Post-Graduates
OCGS	Ontario Council of Graduate Studies

OECD	Organisation for Economic Cooperation and Development
ONPU	Odessa National Polytechnic University
OPAL	Open Pool Australian Light Water Reactor
ORNL	Oak Ridge National Laboratory
PAEC	Pakistan Atomic Energy Commission
PERN	Pakistan Education and Research Network
PESS	Planning and Economic Studies Section
PET	Positron emission tomography
PGEC	Post-Graduate Education Course
PHWR	Pressurised heavy water reactors
PIEAS	Pakistan Institute of Engineering and Applied Sciences
PINSTECH	Pakistan Institute of Nuclear Science and Technology
PNN	National Nuclear Programme
PSA	Probabilistic safety analysis
PT	Pressure tube
PWR	Pressurized water reactor
QA	Quality assurance
RAP NIS	Russian-American Programme in Nuclear International Security
RCA	Regional Cooperative Agreement for Research
REFIN	Romanian Network of Excellence in Nuclear Physics and Engineering
RF	Russian Federation
RNIC	Russian Nuclear Innovative Consortium
ROMAG	Heavy Water Plant
RP&AD	Radiological Physics and Advisory Division
RRCAT	Raja Ramanna Centre for Advanced Technology, Indore
RSO	Radiation safety officer
RUCT	Russian University on Chemical Technology after D.I. Mendeleyev
SAT	Systematic approach to training
SCAE	State Corporation on Atomic Energy
SCK CEN	Belgian Nuclear Research Centre
SCWR	Supercritical water cooled reactor
SE	Slovenské elektrarne
SINP	Saha Institute of Nuclear Physics, Kolkata
SISERI	Information system of supervising of the exposure to ionizing radiations
SKC	Swedish Nuclear Technology Centre
SNEN	Slovak nuclear education network
SNN	State company Nuclearelectrica
SNUNE&I	Sevastopol National University of Nuclear Energy and Industry
SPbSPU	St. Petersburg State Polytechnic University
STA	Science and Technology Agency
STP	South Texas Project
STU	Slovak University of Technology
SUNPP	SouthUkraine NPP
TEMPUS	Trans-European mobility scheme for university studies
TIFR	Tata Institute of Fundamental Research
TLD	Thermo-luminescent dosimeter
TMA	Training and Methodological Associations
TMC	Tata Memorial Centre, Mumbai

TMC	Training and Methodology Commissions
TPU	Tomsk Polytechnic University
TR	Training reactor
TS	Training School
TSO	Technical support organization
UB	University of Bucharest
UKAEA	United Kingdom Atomic Energy Agency
UKM	National University of Malaysia
UM	University of Malaya
UMLRR	UMass-Lowell Research Reactor
UNCu	Universidad Nacional de Cuyo
UNENE	University Network of Excellence in Nuclear Engineering
UniTEN	University of National Energy
UNSAM	Universidad Nacional de San Martín
UOC	University ‘Ovidius’ in Constanta
UPB	University Politehnica Bucharest
UPIT	University of Pitesti
USTU	Urals State Technical University
UTM	University of Technology Malaysia
VECC	Variable Energy Cyclotron Centre, Kolkata
WANO	World Association of Nuclear Operators
WNA	World Nuclear Association
WNU	World Nuclear University
WNUCC	WNU Coordinating Centre
ZEEP	Zero-energy heavy water moderated research reactor

CONTRIBUTORS TO DRAFTING AND REVIEW

Ambrosini, W.	University of Pisa, Italy
Aro, I.	Radiation and Nuclear Safety Authority (STUK), Finland
Artisyuk, V.	Obninsk State Technical University for Nuclear Power Engineering, Russian Federation
Aslam, M.	Pakistan Institute of Engineering and Applied Sciences (PIEAS), Pakistan
Beeley, P.	Khalifa University of Science Technology and Research (KUSTAR), United Arab Emirates
Billowes, J.	University of Manchester, United Kingdom
Boeck, H.	TU Wien-Atominstitut, Austria
Bredimas, A.	E.ON Kernkraft GmbH, Germany
Brown, G.J.	University of Massachusetts Lowell, United States of America
Clark, G.E.	International Nuclear Energy Academy (INEA)
Daures, P.	European Commission Joint Research Centre — Ispra, European Commission
De Regge, P.	European Nuclear Education Network (ENEN) Association
Del Nevo, A.	University of Pisa, Italy
Di Tigliole, A.B.	University of Pavia, Italy
Domanski, R.	Warsaw University of Technology, Poland
Duan, P.V.	Hanoi University of Technology, Vietnam
Falcon, D.S.	Unidad de Formacion Presencial, Spain
Faucitano, A.	University of Pavia, Italy
Ferrer, M.	European Commission Joint Research Centre — Ispra, European Commission
Galan, J.M.	OECD Nuclear Energy Agency, France
Galchenko, V.	National Technical University of Ukraine, Ukraine
Garland, W.	University Network of Excellence in Nuclear Engineering (UNENE), Canada
Gowin, P.	International Atomic Energy Agency
Greyvenstein, G.	North-West University, South Africa
Hascik, J.	Slovak University of Technology, Slovakia
Jaracz, P.	National Atomic Energy Agency (PAA), Poland
Jovanovic, S.	University of Montenegro, Montenegro

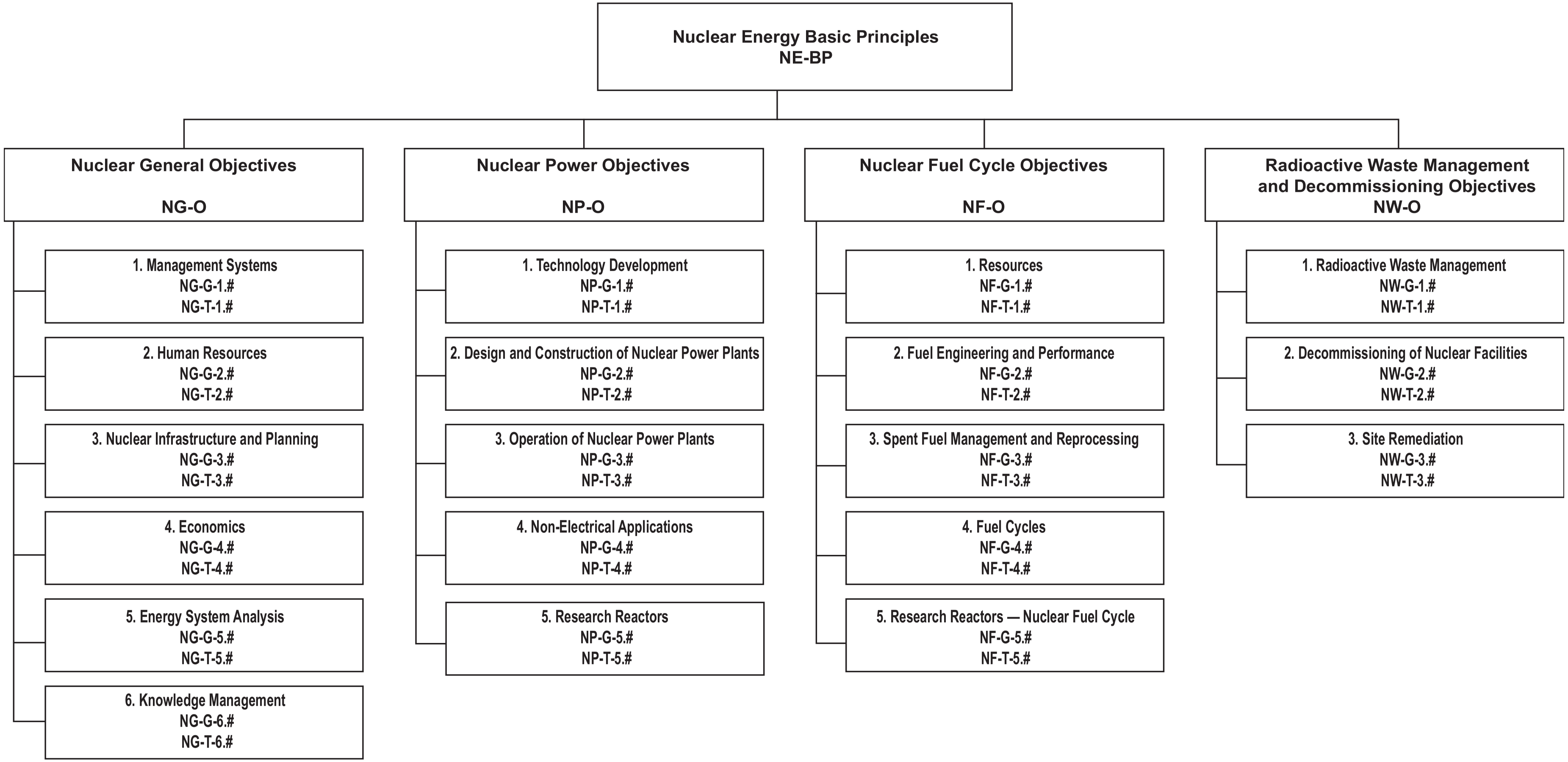
Khalid A.	Malaysian Nuclear Agency, Malaysia
Khan, R.	TU Wien-Atominstitut, Austria
Klein, A.C.	Idaho National Laboratory, United Stats of America
Kosilov, A.	International Atomic Energy Agency
Kryuchkov, E.	Moscow Engineering Physics Institute (MEPhI), Russian Federation
Kusumi, R.	European Nuclear Education Network (ENEN) Association
Kvockova, A.	Nuclear Power Plant Mochovce, Slovakia
Lolich, J.	Balseiro Institute, Argentina
Mazour, T.	International Atomic Energy Agency
Min, B-J.	Korea Atomic Energy Research Institute (KAERI), Republic of Korea
Minguez, E.	Universidad Politecnica de Madrid, Spain
Molloy, B.	International Atomic Energy Agency
Peddicord, K.L.	Texas A&M University, United States of America
Puri, R.R.	Bhabha Atomic Research Centre (BARC), India
Ramamurthy, V.S.	Homi Bhabha Inter-University Accelerator Centre, India
Roberts, J.W.	University of Manchester, United Kingdom
Rouben, B.	University Network of Excellence in Nuclear Engineering (UNENE), Canada
Safieh, J.	Institut national des sciences et techniques nucléaires (INSTN), France
Saidy, M.	International Atomic Energy Agency
Saito, M.	Tokyo Institute of Technology, Japan
Schäfer, A.	ISaR Institute, Germany
Strikhanov, M.	Moscow Engineering Physics Institute (MEPhI), Russian Federation
Sukosd, C.	Budapest University of Technology and Economics, Hungary
Szabo, V.	Nuclear Regulatory Authority, Slovakia
Szymanski, P.M.	The Andrzej Soltan Institute for Nuclear Studies (IPJ), Poland
Van Goethem, G.	European Commission
Villa, M.	TU Wien-Atominstitut, Austria
Vorobieva, I.	Obninsk State Technical University for Nuclear Power Engineering, Russian Federation
Waltar, A.E.	Pacific Northwest National Laboratory, United States of America

Yanev, Y.	International Atomic Energy Agency
Zenov, V.	Sevastopol National University of Nuclear Energy and Industry, Ukraine
Zhang, L.H.	Tsinghua University, China
Zhou, Z.	Tsinghua University, China
Ziedelis, S.	Kaunas University of Technology, Lithuania

Technical Meetings

Vienna, Austria: 10–14 December 2007
Pavia, Italy: 17–20 June 2008
Vienna, Austria: 04–08 May 2009

Structure of the IAEA Nuclear Energy Series



Key

BP:	Basic Principles
O:	Objectives
G:	Guides
T:	Technical Reports
Nos. 1-6:	Topic designations
#:	Guide or Report number (1, 2, 3, 4, etc.)

Examples

NG-G-3.1:	Nuclear General (**NG**), **G**uide, Nuclear Infrastructure and Planning (topic **3**), **#1**
NP-T-5.4:	Nuclear Power (**NP**), Report (**T**), Research Reactors (topic **5**), **#4**
NF-T-3.6:	Nuclear Fuel (**NF**), Report (**T**), Spent Fuel Management and Reprocessing, **#6**
NW-G-1.1:	Radioactive Waste Management and Decommissioning (**NW**), **G**uide, Radioactive Waste (topic **1**), **#1**

No. 22

IAEA
International Atomic Energy Agency

Where to order IAEA publications

In the following countries IAEA publications may be purchased from the sources listed below, or from major local booksellers. Payment may be made in local currency or with UNESCO coupons.

AUSTRALIA
DA Information Services, 648 Whitehorse Road, MITCHAM 3132
Telephone: +61 3 9210 7777 • Fax: +61 3 9210 7788
Email: service@dadirect.com.au • Web site: http://www.dadirect.com.au

BELGIUM
Jean de Lannoy, avenue du Roi 202, B-1190 Brussels
Telephone: +32 2 538 43 08 • Fax: +32 2 538 08 41
Email: jean.de.lannoy@infoboard.be • Web site: http://www.jean-de-lannoy.be

CANADA
Bernan Associates, 4501 Forbes Blvd, Suite 200, Lanham, MD 20706-4346, USA
Telephone: 1-800-865-3457 • Fax: 1-800-865-3450
Email: customercare@bernan.com • Web site: http://www.bernan.com

Renouf Publishing Company Ltd., 1-5369 Canotek Rd., Ottawa, Ontario, K1J 9J3
Telephone: +613 745 2665 • Fax: +613 745 7660
Email: order.dept@renoufbooks.com • Web site: http://www.renoufbooks.com

CHINA
IAEA Publications in Chinese: China Nuclear Energy Industry Corporation, Translation Section, P.O. Box 2103, Beijing

CZECH REPUBLIC
Suweco CZ, S.R.O., Klecakova 347, 180 21 Praha 9
Telephone: +420 26603 5364 • Fax: +420 28482 1646
Email: nakup@suweco.cz • Web site: http://www.suweco.cz

FINLAND
Akateeminen Kirjakauppa, PO BOX 128 (Keskuskatu 1), FIN-00101 Helsinki
Telephone: +358 9 121 41 • Fax: +358 9 121 4450
Email: akatilaus@akateeminen.com • Web site: http://www.akateeminen.com

FRANCE
Form-Edit, 5, rue Janssen, P.O. Box 25, F-75921 Paris Cedex 19
Telephone: +33 1 42 01 49 49 • Fax: +33 1 42 01 90 90
Email: formedit@formedit.fr • Web site: http://www. formedit.fr

Lavoisier SAS, 145 rue de Provigny, 94236 Cachan Cedex
Telephone: + 33 1 47 40 67 02 • Fax +33 1 47 40 67 02
Email: romuald.verrier@lavoisier.fr • Web site: http://www.lavoisier.fr

GERMANY
UNO-Verlag, Vertriebs- und Verlags GmbH, Am Hofgarten 10, D-53113 Bonn
Telephone: + 49 228 94 90 20 • Fax: +49 228 94 90 20 or +49 228 94 90 222
Email: bestellung@uno-verlag.de • Web site: http://www.uno-verlag.de

HUNGARY
Librotrade Ltd., Book Import, P.O. Box 126, H-1656 Budapest
Telephone: +36 1 257 7777 • Fax: +36 1 257 7472 • Email: books@librotrade.hu

INDIA
Allied Publishers Group, 1st Floor, Dubash House, 15, J. N. Heredia Marg, Ballard Estate, Mumbai 400 001,
Telephone: +91 22 22617926/27 • Fax: +91 22 22617928
Email: alliedpl@vsnl.com • Web site: http://www.alliedpublishers.com

Bookwell, 2/72, Nirankari Colony, Delhi 110009
Telephone: +91 11 23268786, +91 11 23257264 • Fax: +91 11 23281315
Email: bookwell@vsnl.net

ITALY
Libreria Scientifica Dott. Lucio di Biasio “AEIOU”, Via Coronelli 6, I-20146 Milan
Telephone: +39 02 48 95 45 52 or 48 95 45 62 • Fax: +39 02 48 95 45 48
Email: info@libreriaaeiou.eu • Website: www.libreriaaeiou.eu

JAPAN
Maruzen Company, Ltd., 13-6 Nihonbashi, 3 chome, Chuo-ku, Tokyo 103-0027
Telephone: +81 3 3275 8582 • Fax: +81 3 3275 9072
Email: journal@maruzen.co.jp • Web site: http://www.maruzen.co.jp

REPUBLIC OF KOREA
KINS Inc., Information Business Dept. Samho Bldg. 2nd Floor, 275-1 Yang Jae-dong SeoCho-G, Seoul 137-130
Telephone: +02 589 1740 • Fax: +02 589 1746 • Web site: http://www.kins.re.kr

NETHERLANDS
De Lindeboom Internationale Publicaties B.V., M.A. de Ruyterstraat 20A, NL-7482 BZ Haaksbergen
Telephone: +31 (0) 53 5740004 • Fax: +31 (0) 53 5729296
Email: books@delindeboom.com • Web site: http://www.delindeboom.com

Martinus Nijhoff International, Koraalrood 50, P.O. Box 1853, 2700 CZ Zoetermeer
Telephone: +31 793 684 400 • Fax: +31 793 615 698
Email: info@nijhoff.nl • Web site: http://www.nijhoff.nl

Swets and Zeitlinger b.v., P.O. Box 830, 2160 SZ Lisse
Telephone: +31 252 435 111 • Fax: +31 252 415 888
Email: infoho@swets.nl • Web site: http://www.swets.nl

NEW ZEALAND
DA Information Services, 648 Whitehorse Road, MITCHAM 3132, Australia
Telephone: +61 3 9210 7777 • Fax: +61 3 9210 7788
Email: service@dadirect.com.au • Web site: http://www.dadirect.com.au

SLOVENIA
Cankarjeva Zalozba d.d., Kopitarjeva 2, SI-1512 Ljubljana
Telephone: +386 1 432 31 44 • Fax: +386 1 230 14 35
Email: import.books@cankarjeva-z.si • Web site: http://www.cankarjeva-z.si/uvoz

SPAIN
Díaz de Santos, S.A., c/ Juan Bravo, 3A, E-28006 Madrid
Telephone: +34 91 781 94 80 • Fax: +34 91 575 55 63
Email: compras@diazdesantos.es, carmela@diazdesantos.es, barcelona@diazdesantos.es, julio@diazdesantos.es
Web site: http://www.diazdesantos.es

UNITED KINGDOM
The Stationery Office Ltd, International Sales Agency, PO Box 29, Norwich, NR3 1 GN
Telephone (orders): +44 870 600 5552 • (enquiries): +44 207 873 8372 • Fax: +44 207 873 8203
Email (orders): book.orders@tso.co.uk • (enquiries): book.enquiries@tso.co.uk • Web site: http://www.tso.co.uk

On-line orders
DELTA Int. Book Wholesalers Ltd., 39 Alexandra Road, Addlestone, Surrey, KT15 2PQ
Email: info@profbooks.com • Web site: http://www.profbooks.com

Books on the Environment
Earthprint Ltd., P.O. Box 119, Stevenage SG1 4TP
Telephone: +44 1438748111 • Fax: +44 1438748844
Email: orders@earthprint.com • Web site: http://www.earthprint.com

UNITED NATIONS
Dept. I004, Room DC2-0853, First Avenue at 46th Street, New York, N.Y. 10017, USA
(UN) Telephone: +800 253-9646 or +212 963-8302 • Fax: +212 963-3489
Email: publications@un.org • Web site: http://www.un.org

UNITED STATES OF AMERICA
Bernan Associates, 4501 Forbes Blvd., Suite 200, Lanham, MD 20706-4346
Telephone: 1-800-865-3457 • Fax: 1-800-865-3450
Email: customercare@bernan.com · Web site: http://www.bernan.com

Renouf Publishing Company Ltd., 812 Proctor Ave., Ogdensburg, NY, 13669
Telephone: +888 551 7470 (toll-free) • Fax: +888 568 8546 (toll-free)
Email: order.dept@renoufbooks.com • Web site: http://www.renoufbooks.com

Orders and requests for information may also be addressed directly to:

Marketing and Sales Unit, International Atomic Energy Agency
Vienna International Centre, PO Box 100, 1400 Vienna, Austria
Telephone: +43 1 2600 22529 (or 22530) • Fax: +43 1 2600 29302
Email: sales.publications@iaea.org • Web site: http://www.iaea.org/books

10-39441

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA
ISBN 978–92–0–109010–2
ISSN 1995–7807