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Nuclear Competence Building

Summary Report

NEA No. 5588

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996); Korea (12th December 1996) and the Slovak Republic (14th December 2000). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full member. NEA membership today consists of 28 OECD member countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, the Republic of Korea, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities also takes part in the work of the Agency.

The mission of the NEA is:

- to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge 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.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

FOREWORD

Several years ago a number of studies were undertaken to examine the concern that nuclear education and training is decreasing, perhaps to problematic levels. The NEA study *Nuclear Education and Training: Cause for Concern?* concluded that a failure to take appropriate steps immediately would seriously jeopardise the provision of adequate expertise in the near future. Several recommendations were proffered to governments, academia and industry to help ensure that crucial present requirements are met and that future options are not precluded.

This study is a follow-up to the earlier NEA study. It identifies mechanisms and policies for promoting international collaboration in the area of nuclear education and R&D. The present study aims to address the question of infrastructure as a whole in order to identify good practices and help governments in the process of integrating nuclear R&D and education in an international setting. It was launched by the NEA Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle (NDC) in collaboration with the NEA Nuclear Science Committee (NSC).

The publication was prepared by a group of experts comprising representatives from academia, government agencies and research organisations. The report is published under the responsibility of the OECD Secretary-General.

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INTRODUCTION

The life cycle of the nuclear industry is no different to that of any other industry, indeed to most forms of human activity: birth, growth, maturity, decline, rebirth and renewal or death. The nineteenth century industries such as railways, chemical manufacture, steel production have experienced the full cycle whilst newer industries such as space, aviation and nuclear are only part way through. Depending on economic development and economic needs depends where any industrial sector of a country is found on the life cycle. For the nuclear industry, some countries are at the stage of maturity; some have entered the stage of decline and are contemplating whether to favour renewal or to close the industry; others are just starting out with new build.

Although the life cycle might be a common factor of industrial activity, each industry has its own distinguishing, unique features that set it apart from the others. The nuclear energy sector is characterised by long time scales and technical excellence. The early nuclear plants were designed to operate for 30 years; today the expected lifetime is 50-60 years. When a nuclear plant is closed, decommissioning and decontamination may last as long as its operational lifespan, possibly longer. From cradle to grave may be in excess of 100 years. The rapid technical evolution of the industry would not have been possible without myriad high-quality research and development programmes. Through such programmes and through the associated links with universities and research institutes have come not only technical knowledge but also the technically competent staff necessary for the safe running of the industry.

As a result of the twin facets of long time scales and essential technical competence the industry now faces two problems: how to retain existing skills and competences for the 50 plus years that a plant is operating when the industry in that country may be in a position of maturity or decline on the life cycle and no further build is imminent and how to develop and retain new skills and competences in the areas of decommissioning and radioactive waste management when the latter are seen as “sunset” activities and are unappealing to many young people.

These problems are exacerbated by the increasing deregulation of energy markets around the world. The nuclear industry is now required to reduce its costs dramatically in order to compete with generators that have different technology life cycle profiles to its own. In many countries, government funding has been dramatically reduced or has disappeared altogether while the profit margins of generators have been severely squeezed. The result has been lower electricity prices but also the loss of expertise as a result of downsizing to reduce salary costs, a loss of research facilities to reduce operating costs and a decline in support to the university in order to reduce overheads.

All of which has led to a reduction in technical innovation and a loss of technical competences and skills. However, because different countries are at different stages of the nuclear technology life cycle, these losses are not common to all countries, either in their nature or their extent; a competence that may have declined or be lost in one country may be strong in another. And therein lies one solution to the problems the sector faces – international collaboration.

While previous NEA (Nuclear Energy Agency) studies have focused on nuclear competence and infrastructure in specific areas of activity, such as nuclear safety or nuclear education, this study, launched by the Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle (NDC) in collaboration with the Nuclear Science Committee (NSC), addresses the issues of nuclear infrastructure and competence more generally. The study identifies:

- Progress against the recommendations presented in an earlier study, *Nuclear Education and Training: Cause for Concern?*
- Human resource issues and R&D.
- Mechanisms and best practice regarding international collaboration.

Information on the three aspects cited above was obtained by means of a questionnaire prepared and issued by the NEA in 2002. Responses were received from 15 countries: Austria, Belgium, Canada, Finland, France, Germany, Hungary, Italy, Japan, the Netherlands, Slovenia, Spain, Sweden, the United Kingdom, the USA and from the European Commission. However, some of them contained very limited amount of information and, in general, the responses to the R&D section of the questionnaire, whilst providing a lot of factual information, failed to adequately quantify either human resources or facilities engaged in this activity.

PROGRESS MADE IN THE FIELD OF EDUCATION AND TRAINING

The OECD/NEA report *Nuclear Education and Training: Cause for Concern?* published in July 2000, quantified, for the first time, the status of nuclear education in member countries. It confirmed what many had long suspected: that, in most countries, nuclear education had declined to the point that expertise and competence in core nuclear technologies were becoming increasingly difficult to sustain. Although the overall situation appeared bleak, some encouragement could be gained from the diverse range of initiatives that were identified. If they were not responsible for an expansion in nuclear education and training, they were at least arresting its rate of decline. With the objective of building on these existing initiatives and stimulating new ones, the report made a number of recommendations to government, universities, industry and research institutes.

The reaction of governments has been varied. Some have launched, or supported, a variety of initiatives, often based on their own further studies of nuclear education and manpower requirements. Others have not undertaken any initiatives at all. This may be because they prefer to let the nuclear sector respond to market forces, or because there is a moratorium on nuclear power or simply because adequate programmes already exist.

There is considerable evidence to indicate that the two recommendations made to universities, namely that they should provide basic and attractive programmes and that they should interact early and often with potential students, are being pursued. How much of this impetus is directly attributable to the NEA report and how much is a reaction to market forces is unclear but it is indisputable that the outcome of the many initiatives currently undertaken by universities is an increase in the number of students undertaking nuclear education.

The report made two recommendations to industry: to continue to provide rigorous training programmes and to work together better with universities and research institutes to attract the younger generation. There is no doubt that the first is being pursued, although it would seem to be more out of self-interest and in response to regulatory requirements than by the recommendation of the NEA report. As regards the second, there is clear evidence that the industry, universities and research institutes continue to work together but whether more effectively than before is not apparent from the information received.

Research Institutes (RIs) are facing similar recruitment problems to those of the industry. In addition, the financial situation of RIs is deteriorating in many countries due to cuts in public funding and to tough competition in the niche market in which they sell their services and products. This makes it difficult for the research institutes to fulfil the recommendation that they should attract the best students and employees by developing exciting research projects of relevance to the industry.

HUMAN RESOURCES

Faced with possible demographic downturns in their nuclear industries, many NEA member countries have undertaken studies to define the extent of the problem. In spite of the myriad initiatives underway in the area of nuclear education and training, these national surveys show that more engineers and scientists having nuclear knowledge are required than are graduating.

The continuing antipathy of students in many countries towards science, engineering and technology subjects has meant that the proportion of those graduating in these areas has fallen in recent years. As fewer and fewer high quality technical graduates become available, the competition for them is ever greater and there are signs already that the nuclear industry is losing out. This is of concern to the nuclear industry as the majority of the scientists and engineers working in it do not have nuclear specialist education.

As well as losing out directly the industry loses out indirectly because this also means that the ability of organisations to circumvent the shortage of graduates with a sizeable nuclear component to their degree by hiring good quality technical graduates and training them in house is compromised.

As it has reached maturity, the nuclear industry has developed areas of expertise that are transferable to other industries. There has thus been a flow of personnel from the nuclear sector into other sectors. This was convenient when the industry was consolidating and wished to reduce staff numbers. Now that it cannot afford any further reduction in existing competences and needs to develop new ones in the areas of decommissioning and clean up, attracting young blood, retaining staff and attracting experts from other sectors in the face of competition from industries perceived as more attractive is proving problematic in many countries.

Many of the aforementioned problems can be countered through diverse and dynamic R&D programmes. Within companies R&D is as important for training staff as for technical advancement. Where industry collaborates with universities and research institutes it is also an important source of recruits. In addition, such collaborations provide a reservoir of qualified and experienced personnel, which can service both the industry and the regulatory bodies on an ad hoc basis. Further, R&D performed in universities revitalises the education system by paving the way for new courses, providing topics for theses, and encouraging academics to become positively engaged with the industry.

To some extent the human resource situation can be ameliorated through the mobility of researchers and experts. This is often viewed as an important part of the education and training of the individual on the one hand and an effective way of coping with a temporary peak in workload or effecting knowledge transfer on the other. However, in reality the mobility of researchers may be rather limited. It seems that some research organisations are more prepared to accept researchers than to part with their own.

RESEARCH AND DEVELOPMENT

Measured in terms of man-years, all responding countries devote significant resources to radioactive waste management. In contrast, although R&D in decommissioning is pursued by all the countries responding to this study, it is an area that generally attracts few R&D resources. Plant design is an important area of research activity in many countries. This is usually aimed at improving both the safety and the efficiency of operation of existing plant rather than innovative plant design. Perhaps as a consequence, in the majority of countries, research in material development is not a leading area of activity. The commitment to research in the nuclear fuel domain varies considerably from country to country and the studies cover a wide range of uses: improving the economics of existing plant, facilitating waste management and commitment to innovative plant design.

Trends common to all countries are difficult to discern in respect of industry funded R&D. Overall, though, it would seem that there is more emphasis on operating reactors than future systems. National projects predominate over international ones. Projects embrace the short, medium and long-term; there is no common denominator. As might be expected of industry funded research, economic drivers are important but in no country are they more important than safety. The nuclear industry in most countries funds open research and very often this complements the public funding of research. Whilst the acquisition of technical knowledge is important, there is no doubt that supporting open research is a way of ensuring the continued availability of experts in key areas at universities and research centres: such experts being crucial to the independent assessment of important issues such as the reliability and safety of plants.

In recent years, publicly funded nuclear R&D has experienced a dramatic reduction in most countries. The main focus has been, and continues to be, the safety of existing nuclear power plants and waste management issues. However, in a few countries, programmes for innovative, future reactors are becoming evident. Public funding is not confined to supporting domestic R&D; increasingly it is being used to fund international collaboration. In all countries there is recognition of the need to maintain core skills and competences and this is an underlying theme of public funding. However, given that it has decreased in most countries in recent years, this responsibility is increasingly falling to the industry.

INTERNATIONAL COLLABORATION

The decline in recent years of many nationally funded nuclear research programmes and the associated loss of facilities and expertise has encouraged countries to seek international collaboration. Although bilateral arrangements continue, increasingly multi-lateral programmes between many countries and research institutes are favoured in order to maximise the use of facilities and expertise as well as to share costs. Agencies such as the NEA, EC and IAEA play an important role in both promoting and co-ordinating this type of collaboration and, moreover, ensuring that collaboration is open to as diverse range of participants as possible. The NEA has adopted a strategy aimed at maintaining essential types of research facility through these collaborative arrangements.

While nuclear research centres can look back over a long history of international collaboration, the same is not true for universities. It is only recently that some regional collaborative networks have been created in both Europe and Asia. The same principles apply to maintaining teaching expertise on nuclear related topics as to maintaining research capabilities, especially in those countries where such expertise may be in short supply. In this area more can be done at the national level to develop co-operation between universities; at the international level the recognised agencies have a key role in promoting and co-ordinating co-operation between countries.

Naturally, collaboration between industrial companies is limited by commercial interests. Some companies have merged and their internal activities are, as result, no longer restricted to national boundaries. However, overall, it is necessary to recognise that industrial collaboration will always be subject to limitations.

Collaboration, information exchange and even exchange of personnel have always been an integral part of the development of nuclear power – inasmuch as political constraints have allowed. It is largely as a result of international collaboration that nuclear power has become a reliable energy source within a single generation, accounting for a significant proportion of the electricity produced in many countries today. That it may continue to do so in the future will depend even more on international collaboration but as long as there are initiatives such as the NEA Halden project and the Generation IV International Forum there will be grounds for quiet optimism.

CONCLUSIONS AND RECOMMENDATIONS

In spite of the ambivalent situation vis-à-vis nuclear energy, where and some countries have decided to build new reactors, some countries hesitate and some others avow their intention to phase out nuclear facilities, nuclear energy still accounts for a significant proportion of capacity throughout the world and particularly in OECD member countries. In so doing it saves precious fossil fuels and reduces greenhouse gas emissions. Furthermore, nuclear technology is far wider than electricity production. It covers a wide range of applications from medical diagnosis and treatment to the examination and testing of materials. With this holistic view in mind, the following recommendations are made. They are intended to help preserve and develop nuclear competences, no matter what their ultimate peaceful applications may be.

Nuclear Education and Training

Conclusions

Countries have recognised the issues and there has been good progress against the recommendations of the report but more needs to be done.

Three years after its publication, it is clear that, in most countries, there is a high level of awareness of the report *Nuclear Education: Cause for Concern?* More importantly, it is clear that it has been the catalyst for action. There is strong anecdotal evidence to suggest that without it some existing initiatives would have atrophied and that there would not have been the necessary impetus to start new ones. Certainly, the report has prompted a number of countries to conduct surveys in order to quantify more accurately their future manpower requirements. The benefit of these surveys is not limited to the national initiatives that they in turn have prompted. Taken together, they give a much clearer picture of the global situation and have already been the spur for international collaborations. Initiatives are starting to improve the situation but it is still early days and more needs to be done.

While there is a wide range of activities in all countries, there is no evidence of a breakthrough in addressing the demographic down turn; nevertheless, such activities have begun to ameliorate the situation.

The number and diversity of initiatives currently underway suggest that the situation is beginning to improve. However, in spite of the wide range of activities being undertaken by member countries, where demographic studies have been undertaken, they still indicate a shortfall of qualified personnel in the near future. Recruiting and retaining those with specialist nuclear expertise, such as reactor core physics for example, is a particular concern. All the more so if the ability of universities to teach nuclear subjects continues to decline.

The provision of necessary specialist nuclear education is under threat.

Because of its maturity, the demand for specialist nuclear education is lower now than it has been for many years and as a consequence the number of academics delivering nuclear courses has declined considerably. Yet the need for specialist education remains if the safe operation of plants is to be guaranteed.

Recommendations

Countries should seek to borrow good practice from other countries to enhance their domestic programmes.

While all countries have made progress, very often this has been through the logical extension and development of existing activities. One of the objectives of this study is to identify initiatives with the view to sharing good practice. Borrowing ideas from other countries could well be the route to both complementing and maximising the effectiveness of domestic activity.

Countries should widen their knowledge base through national and international initiatives.

There is a limit to the number and diversity of initiatives that countries can undertake on their own. While specific skills and competences might be under threat in one country, they may be far more secure in another. To retain all the necessary nuclear skills and competences of which the industry has need will require a greater degree of international collaboration than has occurred before.

Government, academia, industry and research organisations should collaborate both nationally and internationally to secure access to essential nuclear expertise.

The safe and efficient use of nuclear power demands a certain number of experts in nuclear specific areas: nuclear reactor engineering, reactor physics, radiochemistry and radiation protection, for example. Since the required number of experts in these essential disciplines may be small in some countries there is a danger that the educational provision to supply them may disappear. There is, therefore, a need for government, academia, industry and research organisations to collaborate together in order to secure sustainable groups of expertise. Governments need to provide the strategic direction which ensures that sufficient education resources in critical nuclear specific areas are secured. Where essential expertise is in short supply or unavailable in one country, then access to its provision should be sought within another country.

Human Resources

Conclusions

Conducting manpower surveys is an important way of assessing present and future competence requirements.

Prior to the report *Nuclear Education and Training: Cause for Concern?* few, if any, countries had a clear understanding of their present or future manpower needs. The report confirmed what many had suspected for some time, that nuclear education and training had been in decline for a number of years and there was a serious risk of skill shortages in the near future. The potential insecurity of supply prompted a number of countries to accurately assess their needs and take steps to guarantee that they could be met.

Attracting high quality technical graduates into the nuclear sector is a challenge.

Being a mature industry, the nuclear sector has developed areas of expertise that are transferable to other industries. As a result, the sector has lost personnel to fast expanding sectors such as information technology. Replacing them should not be a problem given that many of the engineers and scientists working in the sector do not have a nuclear qualification and the numbers required represent only a small fraction of the total number of graduates in these fields. Yet, attracting high quality technical graduates into the industry in the face of competition from other industries perceived to be more attractive is increasingly problematic.

Recommendations

To ensure that supply and demand are as evenly matched as possible, it is worthwhile carrying out a manpower assessment every few years.

In a changing world it is evident that the manpower and competence requirements of the nuclear sector of any country will gradually change. Manpower surveys help to ensure that supply will meet demand. Simply identifying areas in which recruitment is proving difficult by talking to recruitment officers in nuclear companies and organisations would help universities and training institutions to develop the appropriate courses.

Industry and research organisations should increase their interaction with university science and engineering departments in order to raise the profile of the nuclear industry so that more students consider it when deciding on career choices.

With the nuclear industry facing fierce competition from other science, engineering and technology industries, it is incumbent upon those working within it to present the challenges and opportunities that the sector has to offer. A particularly important target group is those at university and on the brink of making career choices.

Research and Development

Conclusions

In recent years, publicly funded nuclear R&D has experienced a drastic reduction in most countries.

It is a natural consequence of a maturing industry that the public funding of research and development should decline. In some countries that decline has been accelerated by the decision to let market forces prevail, in others by the decision to phase out nuclear power. Increasingly, industry funds open research as a means of ensuring the continued availability of experts and facilities in universities and research centres.

The main focus of R&D is the safety of existing nuclear power plants and waste management issues. Commitment to innovative, future reactors is far from pre-eminent in most countries.

With the decline in public funding, the burden of R&D has fallen to the industry. Not surprisingly, this has been focussed on issues of immediate importance such as safety and waste management. In an increasingly competitive environment it would seem only limited funds are available to support longer-term issues such as new reactor systems.

Recommendations

Publicly controlled funding of nuclear R&D should not be allowed to decline to the point that the retention of skills and competences are jeopardised.

The underlying theme of public funding or publicly controlled funding, in all countries, is the need to maintain core skills and competences. Yet, given that public funding has decreased in most countries in recent years, this responsibility is increasingly falling to industry. The danger is that the industry will narrowly focus on those skills and competences that it needs for the near-term. Strategic planning is needed to accommodate longer-term needs and this can only be effected in the absence of commercial pressures.

Those responsible for funding nuclear research and development should seek to ensure that education and training aspects are an integral part of activities.

In some countries, funding for nuclear research is dealt with in isolation from funding for nuclear teaching within the same university. In other countries, it is recognised that good teaching and good research go together and a more integrated approach to funding is taken. Although there would be benefit in increasing the funding of nuclear teaching to cover research as well, it is more likely that good research will beget good teaching rather than vice versa.

If nuclear power is to continue to evolve, commitment to developing innovative new plant is required. A mix of industry and public funding would seem an appropriate way forward.

Countries cannot take their nuclear programmes forward, or even merely keep their nuclear option open, without some commitment to innovative plants. Given that the benefits will be both on a national basis and a company basis, it seems appropriate that a mix of industry and public funding should support endeavours in this area.

International Collaboration

Conclusions

International collaboration in nuclear research and skills provision is well established and has become an essential way in which countries are able to meet their responsibilities.

International collaboration among civilian nuclear research organisations dates back to the birth of the industry and links made in the 1950s still exist today. Both bilateral and multilateral collaboration continue to operate effectively but increasingly the nuclear agencies are playing an important role in co-ordinating international activities on both research and skills related issues.

The recent Generation IV International Forum (GIF) is a good example of how countries and organisations can come together to collaborate on an issue in which they have a common interest. In this case the development of future nuclear power plants. However, collaboration by industry beyond the early research stage can be limited by commercial interests.

Large, high profile international R&D programmes enhance the image of the nuclear sector and encourage recruitment.

Innovative nuclear research programmes in the area of Partitioning and Transmutation and future power reactors (GIF), for example, are tangible evidence that nuclear technology continues to be challenging, innovative and considered a long-term option in some countries. As such, research programmes have the potential to influence topics taught at university and to present a dynamic image of the industry to those making career choices.

Collaboration is as important to the industry as it is to the universities. Not only are shortages of expertise averted but so also are the closure of courses. There are good examples both in Europe (ENEN) and Asia (ANENT) where universities are collaborating to establish common platforms for education at the Masters level. Although collaborations need to be driven by the universities themselves, government and industry do have a role in clarifying the educational needs and in providing financial support.

Recommendations

Government, industry and academia should work together to create a functional framework to support education and training through national and international collaboration.

The teaching of nuclear related subjects at universities has declined considerably over the last decade or so. Consequently, a high and comprehensive standard of nuclear education can no longer be guaranteed in all countries supporting nuclear technology. Whilst national and international collaboration between universities can provide the means whereby the collapse of nuclear education may be avoided unfortunately such collaboration is weak or non-existent in many countries.

The NEA and other international agencies should facilitate transferability of education and skills between member countries especially in critical nuclear specific disciplines.

The strength of international organisations such as the NEA, IAEA and EC lies in their ability to create and secure frameworks in which member countries can work together and collaborate. Much progress has already been made in the areas of nuclear education, training and research and if it is to continue the responsibility of these organisations to facilitate collaborations must be maintained.

EXAMPLES OF BEST PRACTICES

Collaboration between national universities

In Germany, a number of universities have formed a network of competence in nuclear technology. In Belgium, five universities, in collaboration with the Belgian Nuclear Research Centre, have merged two post-graduate programmes into a single one, taught in English.

Use of the Internet

In the United Kingdom, a web site that lists all of the university courses with a nuclear content has been successful in attracting students. In Germany, and several other countries, the young generation interacts with students through their web sites. In Italy, many professors have their own web pages by which they inform students about nuclear courses. In US universities distance learning is well established and the Internet is but one way of delivering courses in a flexible manner. In Japan, it is commonplace to use company websites to promote recruitment.

Training existing staff and recruiting new staff

R&D is an important way of training staff as well as effecting knowledge transfer. Collaboration with universities and research institutes not only encourages an interchange of staff to mutual benefit but also is a conduit for recruitment. One British company has established a number of research alliances with universities that support a university skill base of some 150 people.

Education and training integral part of R&D

Education and training (E&T) is one of the thematic areas of the 6^{th} Euratom R&D Framework Programme. The aim is to develop a harmonised approach to education in nuclear sciences and engineering and to provide support for fellowships, training courses networks and grants for young researchers. E&T is also one of the main objectives of the Finnish national research programmes.

Collaboration between industry, universities and research institutes

A Belgian company works with local universities and technical high schools on specific projects. British companies work with universities to develop new courses and support both new and existing courses through visiting lecturers and by providing work placements for students. The Canadian initiative UNENE – University Network of Excellence in Nuclear Engineering – crosses traditional boundaries to ensure a sustainable supply of appropriately qualified engineers and scientists to meet the needs of the Canadian nuclear industry. In Sweden, industry together with the regulatory body contributes to the funding of the Swedish Nuclear Technology Centre in order to ensure that there is adequate financial provision to replace retiring professors.

Encourage mobility of young generation

At a Belgian university students spend time in a foreign institution as part of their graduate training in nuclear engineering. In Korea, outstanding students are supported so that they can visit an overseas facility. A Hungarian university has developed links with other European universities and research institutes, thereby giving its students the opportunity of pursuing part of their studies abroad.

Preserving expertise and facilities

The funding of R&D by the private sector helps through private funding the continued availability of experts and facilities in universities and research centres. Joint funding is more efficient than single company funding. In the United States, members of EPRI and the Owners Group agree on jointly funded projects. Industry funding for R&D can complement public funding, as is the case in Korea, Japan, USA, Germany, Spain and Hungary. Where there is little or no public funding, industry can act alone. In 2000, the nuclear industry of the United Kingdom had some 250 research contracts with universities worth about GBP 10 million. Since 2004, Finnish nuclear power companies have had to finance national nuclear safety and waste management research programmes to ensure the availability of the expertise for public authorities.

International university networks

Regional initiatives such as The European Nuclear Engineering Network and the Asian Network on Education and Nuclear Training bring together universities in different countries to provide degrees in nuclear subjects that are beyond the capability of any individual university. The World Nuclear

University is an example of government, industry and academia collaborating to support education and training. The mobility of students, teachers and experts is an integral part of such initiatives.

Securing access to nuclear expertise via international organisations

Many European countries encourage their nuclear organisations to participate in the Euratom Framework Programmes in order to enlarge the pool of expertise. International projects, such as NEA Joint Projects, offer a cost efficient option way of obtaining experimental data and of retaining and developing the competences necessary to keep the nuclear option open. Collaboration can also be effected through international organisations such as the NEA – the NEA Halden programme being just one example.

International collaboration

R&D can be accelerated through international collaboration. The Euratom Framework Programmes cover most aspects of nuclear activity from new reactor systems to decommissioning old ones. GIF, relevant for long-term development of innovative reactors, and INPRO, focused on users requirements are two examples of collaborative R&D.

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