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Human Resource Development for Introducing and Expanding Nuclear Power Programmes

Summary of an International Conference,
Abu Dhabi, United Arab Emirates, 14–18 March 2010

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Human Resource Development for Introducing and Expanding Nuclear Power Programmes

PROCEEDINGS SERIES

HUMAN RESOURCE DEVELOPMENT FOR INTRODUCING AND EXPANDING NUCLEAR POWER PROGRAMMES

SUMMARY OF AN INTERNATIONAL CONFERENCE ON HUMAN RESOURCE DEVELOPMENT FOR
INTRODUCING AND EXPANDING NUCLEAR POWER PROGRAMMES
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THROUGH THE EMIRATES NUCLEAR ENERGY CORPORATION,
FEDERAL AUTHORITY FOR NUCLEAR REGULATION AND KHALIFA UNIVERSITY
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FOREWORD

Currently, the world is witnessing a resurgence of interest in nuclear power. More than fifty Member States, with support from the IAEA, are considering the introduction of nuclear power, and human resource development is one of the crucial areas in terms of requests for support. The need for human resources in the nuclear sector is not only experienced by countries embarking on new nuclear power programmes, but also by countries with existing programmes that are considering expansion, as many current professionals are approaching retirement age and the number of newly trained staff is generally not sufficient to meet the potential demand.

The IAEA conference on Human Resource Development for Introducing and Expanding Nuclear Power Programmes was held from 14 to 18 March 2010 in Abu Dhabi, hosted by the Government of the United Arab Emirates. This conference was organized to address work force issues faced by countries which are embarking on new nuclear power programmes, expanding current programmes or planning to supply nuclear technology to other countries. The situation is different for each country; some need to develop their own local expertise, while others need to scale up existing educational and training programmes to increase the number of professionals.

The purpose of this conference was to bring together Member States to help formulate country specific policies on human resource development, education, training and knowledge management to help support each country's nuclear power programme. In addition, the IAEA can facilitate better use of other educational opportunities, including research reactors and development of training facilities. These proceedings highlight the key findings and recommendations of the meeting and the conclusions of the chairperson. All papers presented and discussed during the meeting are included on the attached CD-ROM. To access the papers, click on 'Index' on the CD-ROM.

The IAEA officers responsible for this publication were Y. Yanev, T. Mazour, B. Pagannone and J. Parlange of the Division of Nuclear Energy.

CONTENTS

OPENING ADDRESS

Y. AMANO
Director General
International Atomic Energy Agency, Vienna

It is a pleasure for me to open this IAEA conference on Human Resource Development for Introducing and Expanding Nuclear Power Programmes. I am very grateful to the Government of the United Arab Emirates for hosting this important event.

As you know, the world is witnessing a resurgence of interest in nuclear power. The IAEA has projects on introducing nuclear power with no fewer than 58 of our Member States. We expect between 10 and 25 new countries to bring their first nuclear power plants on line by 2030. These are momentous changes.

However, some countries are concerned about a possible shortage of skilled professionals in the nuclear field in the coming decades. The generation of professionals who built and led the nuclear power industry for much of the past 50 years is approaching retirement and in some countries not enough students are coming up through the educational system to take their place.

Naturally, we, at the IAEA, want to do all we can to help Member States address this issue. That is why we have organized this conference.

The situation is different in each country. For countries with expanding nuclear power programmes, the challenge is to scale up their existing education and training in order to have the required qualified workforce on time.

Countries planning to supply nuclear technology to others must not only meet their national human resource needs, but also be able to transfer education and training capacity together with the technology they provide.

Finally, countries embarking on nuclear power cannot become too dependent on their technology supplier and need to develop their own home grown expertise and skills base.

The IAEA would be happy to help interested States to formulate country specific policies on human resource development, education, training and knowledge management in support of nuclear power programmes.

We could also help countries make better use of training facilities, research reactors and other educational infrastructure. We could play a role in ensuring high standards for nuclear education and training and establish a framework for countries to recognize each other’s educational qualifications.

I look forward to hearing the ideas of this very knowledgeable and distinguished audience and wish you every success with the conference.

SUMMARY

The International Conference on Human Resource Development for Introducing and Expanding Nuclear Power Programmes, held in Abu Dhabi, United Arab Emirates, from 14 to 18 March 2010, brought experts, scientists and officials from 62 countries together to share information and ideas on effective ways to attract and train the human resources needed to sustain the current development of nuclear energy programmes worldwide. Over 50 countries have approached the IAEA expressing a serious interest in initiating nuclear power programmes. The IAEA Director General has estimated that between 10 and 25 of these countries will be operating nuclear power plants by 2030. Massive and dedicated efforts will be needed to secure the numbers of qualified nuclear workers to meet these demanding global goals.

Several new approaches to address the human resource challenge were outlined at this conference, including a new emphasis on broadening nuclear engineering and technology curricula to include ‘soft’ sciences, such as risk analysis, law, and social sciences, recognizing that successful nuclear power programmes can succeed only with strong governmental and societal support. Examples included the Nuclear Power Institute Partnership in the USA, where several two-year colleges and six universities are partnering with industry to train and educate the nuclear workforce needed, with programmes spanning from technical training for skilled labour to advanced nuclear engineering degrees. Another is the new nuclear socio-engineering programme in Japan that includes a full spectrum of social and policy disciplines. A third is a new joint programme integrating the UAE with a US university and national laboratory, to develop future national and regional leaders regarding nuclear policies. All are pilot programmes that might be successfully transferred to other regions.

Special emphasis was placed on attracting the younger generation, recognizing that it is the necessary basis for future global nuclear success. Several young nuclear professionals spoke at the conference and articulated the key ingredients needed to attract the best and brightest to the industry — including measures to attract more women.

Much of the conference was devoted to better identifying the roles of government, educational institutions and networks, industry and international organizations in meeting the challenge of human resource development. The conference proceedings are structured to first describe current activities in each of these sectors, then provide examples of what is working well, and finally summarize the challenges remaining. A complete record of all papers and presentations is contained in the attached CD-ROM. To access the papers, click on ‘Index’ on the CD-ROM.

Strong and consistent governmental support is vital to the success of nuclear power. Nearly a century of constant vigil is required for every nuclear power plant (from inception through decommissioning), and the necessary oversight and R&D can be carried out only under a stable government with consistent national policies on nuclear power. Further, nuclear power is now international in scope and the degree of networking necessary between all sectors of the profession will continue to grow. The conference shared examples of maturing and effective networking, to provide ready access both to needed data and to advanced education and training courses. A strong safety culture, so essential for continued success, was emphasized throughout the conference.

Substantial progress has been made in the last decade in focusing on developing knowledge management programmes and a highly qualified nuclear workforce in the numbers needed. However, additional emphasis and dedication is required as the global nuclear renaissance continues to gather momentum. At the conference, a common understanding emerged that an integrated approach to developing the human resources needed for initiating and sustaining a nuclear power programme was extremely important.

A major achievement of the conference was the general recognition by participants of the need to cooperate — locally, nationally and internationally — in building human resources for a nuclear power programme, in overcoming isolationist trends, and in supporting newcomers in a comprehensive manner — to see the ‘big picture’. A human resource development programme needs to be built on the best existing experience, integrating new initiatives into existing ones to close gaps, and ensuring effective use of the of the whole range of available expertise.

To this end, a Global Survey to Quantify Human Resource Needs of the Nuclear Industry is being undertaken. Strong support for this survey was demonstrated by the international organizations cooperating on this conference. There was also considerable interest expressed by conference participants in having the information that such a survey could provide.

1. INTRODUCTION

The International Conference on Human Resource Development for Introducing and Expanding Nuclear Power Programmes was held on 14–18 March 2010 in Abu Dhabi, United Arab Emirates (UAE). Organized by the IAEA, the conference was jointly hosted by the UAE Government, the Emirates Nuclear Energy Corporation (ENEC), the Federal Authority for Nuclear Regulation (FANR) and Khalifa University of Science, Technology and Research (KUSTAR).

The conference was attended by 256 participants and 64 observers, from 62 IAEA Member States and 11 international organizations.

1.1. Expectations for growth of nuclear power

As we begin the second decade of the new century, there is evidence that nuclear power worldwide will continue to grow. Many countries that embarked on nuclear power programmes in the second half of the 20th century, having confirmed the stable and economic performance of their existing nuclear power plants, are now gearing up for new builds. Some that halted their nuclear programmes have recently announced a re-entry into the market. Further, numerous developing countries have expressed a desire to acquire nuclear energy to meet rising demands for electricity and desalinization.

The expansion of nuclear power is evidenced by the approximately 100% increase in the number of units under construction as compared to the trough around 2000 (Figure 1).

History of NPP construction

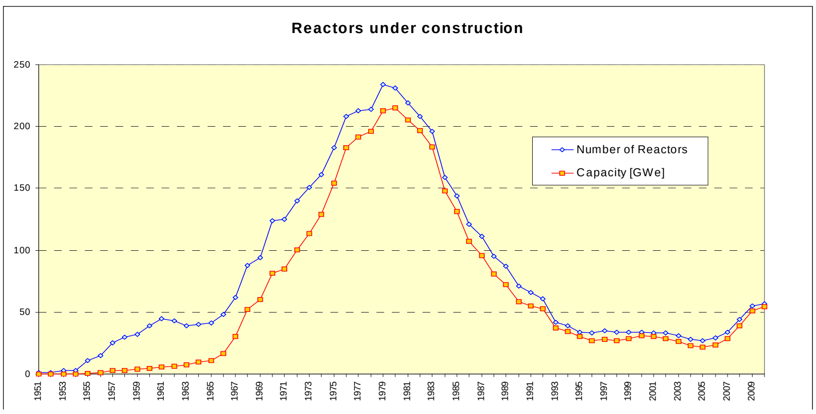

FIG. 1. Fluctuations in growth of nuclear power in 60 years.

Table 1 presents the most recent updated projections for nuclear generating capacity, disaggregated according to regions of the world. In the low projection, nuclear capacity grows from 372 GW(e) in 2007 to 473 GW(e) in 2030. In the high projection it grows to 748 GW(e).

The table shows that the greatest expansion of nuclear capacity is projected for the Far East. Significant expansion is also projected for Middle East and South Asia, the region that includes India. The region with the greatest uncertainty, i.e. the greatest difference between the low and high projections, is Western Europe. Although approximately 20 new countries are included in 2030, the global increase in the high projection comes mainly from increases in the 30 countries already with nuclear power. The low projection also includes approximately five new countries that might have their first nuclear power plants in operation by 2030.

TABLE 1. ESTIMATES OF NUCLEAR ELECTRICITY GENERATION CAPACITY (GW(e))

Region	2007	2010		2020		2030	
		Low	High	Low	High	Low	High
North America	113.2	113.5	114.5	121.4	127.8	131.3	174.6
Latin America	4.1	4.1	4.1	6.9	7.9	9.6	20.4
Western Europe	122.6	119.7	121.3	92.1	129.5	73.9	150.1
Eastern Europe	47.8	48.2	48.3	72.1	94.7	81.2	119.4
Africa	1.8	1.8	1.8	3.1	4.5	4.5	14.3
Middle East and South Asia	4.2	7.6	10.1	12.5	24.3	15.9	41.5
South East Asia and the Pacific	0	0	0	0	1.2	1.2	7.4
Far East	78.5	81.3	83.1	129.2	151.8	155.7	219.9
World total	372.2	376.3	383.1	437.4	541.6	473.2	747.5

The projections by the IAEA have changed over the past few years. In particular, the high projection for the rate of increase in installed nuclear power plant capacity between 2020 and 2030 doubled from the projections done in 2001, reflecting an increase in optimism about nuclear power in some regions. The low projection in 2001 showed declining installed capacity as plants were taken out of service without replacement. Today, even the low projection predicts a continuing small growth in the installed capacity.

The numbers are still well below the peak of construction in the 1970s (Figure 1), indicating that current human resource needs are not of the same magnitude as they were some 30 years ago. However, as shown by the projections (Table 1), growth in 10 to 20 years could be dramatic. Given that it takes 10 years or more from when a young person starts a university degree programme to when they are fully qualified to work in the nuclear power industry, along with the need to replace the workforce that commissioned and operated the plants built in the 1970s, it is clear that now is the time to begin to prepare the human resources to meet this projected growth.

Global climate change issues have caused many countries to recognize the advantage of nuclear power — relative to fossil fuels — as being a source of clean energy. Fossil fuels, though still in adequate supply to fuel a large fraction of electricity generation needs for the near future, are being depleted. Thus, responsible energy planners are considering a long term source such as nuclear with renewed interest for inclusion as a major part of their overall energy portfolio.

The driving forces for this revitalization appear to be population growth, environmental impact (particularly climate change) concerns, and the need for energy security. While the population growth rate is receding in some parts of the world, the quality of life is increasingly recognized to be strongly linked to electricity use (as measured by the human development index of the UN). Accordingly, strong incentives exist for substantial increases in the production of electricity, especially for developing countries. The IAEA has recently received inquiries from over 50 States considering the introduction of nuclear power. At least a dozen of these could be operating nuclear power plants by 2030.

Both India and China are moving ahead with large and ambitious nuclear power programmes. India currently has 16 nuclear plants in operation (3.7 GW(e) total), with six new plants under construction and with the expectation of increasing their capacity with an additional 16 GW(e) by 2020. China is now building 24 new nuclear plants, with plans to go from 9GW(e) nuclear today to 80 GW(e) nuclear by the year 2020. The USA is planning new builds for the first time in some 30 years, and France, Japan, and the Russian Federation are continuing their nuclear programmes with the construction of new nuclear plants. States such as Sweden, Italy, and the United Kingdom (once under a complete nuclear moratorium) have recently announced plans to continue using nuclear power. As indicated in the Statement above, the IAEA Director General predicts that 10 to 25 new entrant countries will have a nuclear reactor on line by 2030.

1.2. The human resource challenge

Given increasing interest worldwide in building nuclear power plants, one obvious constraint is the limited supply of qualified nuclear professionals to design, build, license, and operate such an expanded demand. In fact, the human resource issue may constitute the main challenge in reaching the above mentioned goals.

The nuclear industry is an intensely knowledge based industry, relying on a wide diversity and depth of knowledge. From the mining of uranium, to purification, fuel fabrication, transportation, irradiation, chemical processing, reconditioning, and ultimate disposal of waste, the processes involve many technologic aspects. ‘Soft’ sciences, such as political science and law, as discussed at the conference, should also constitute major components of the entire knowledge base required for the successful deployment of nuclear technology. Further, including the non-power spectrum of radiation applications, such as those in medicine, agriculture and general industry, the impact of nuclear science and technology can encompass nearly every aspect of daily life.

Focusing on nuclear technology for the production of energy, the human resource issues become vital to at least three important groups:

Countries with existing nuclear power programmes, where there is an ongoing need for qualified nuclear professionals to maintain the highest safety standards in operating the current nuclear power plants. Nuclear professionals must be available for approximately 100 years for each nuclear plant brought on line. This becomes clear when we recognize that it requires some 10 years to design, license, and construct a nuclear power plant, then 60 to 80 years to run it, and finally another decade or two to decommission it.

Suppliers, where a full contingency of nuclear professions, including designers, fabricators, regulators, administrators and attorneys, must be engaged to meet the needs of both countries desiring to increase their current nuclear capacity with new builds and entrant countries importing new nuclear capacity.

New entrants, where a new cadre of nuclear professionals must be educated and trained in basic nuclear technology in order to set up the domestic structures necessary for successful entry into the nuclear field. Safeguards to prevent the non-peaceful use of nuclear energy need to be applied. A strong safety and security culture is essential and must be developed and internalized by every nuclear professional well before any nuclear facility is put into operation. Whereas most new entrant countries will necessarily be dependent upon supplier countries for the first set of nuclear plants, they must have their own regulatory body in place and functional before any operations are allowed.

1.3. Perspective and structure for this report

In recognition of this global human resource challenge, the IAEA has organized several conferences and workshops to address nuclear knowledge management and human resource development. Two recent ones were:

Managing Nuclear Knowledge: Strategies and Human Resource Development, September 7-10, 2004, Saclay, France; International Conference on Knowledge Management in Nuclear Facilities, 18–21 June 2007, Vienna, Austria.

The CD-ROM included with these Proceedings contains links to the material related to both the above mentioned workshops.

The current conference, the International Conference on Human Resource Development for Introducing and Expanding Nuclear Power Programmes, focused on the challenges of developing the human resources needed for new entrant countries. Since these challenges coincide with those faced within the current nuclear industry, a wide spectrum of global human resource issues was addressed.

This summary of key points was gleaned from the 67 papers presented in the conference plenary. The complete set of contributed papers and their accompanying presentations, and the 87 interactive presentations that were also shown, are included in the attached CD-ROM.

In an attempt to capture the spirit of the conference, the following section presents two benchmarks that highlighted the meeting. The first describes the integrated approach the UAE has to introducing its nuclear programme. The second is a focus on some new programmes that are striving to integrate the full spectrum of educational needs, required both for attracting the necessary numbers of young people to the profession and for providing them with a background broader than the basic technical training.

Section three focuses on the basic challenges inherent in passing nuclear knowledge on to the next generation, applying new strategies to meet these challenges, and efforts to encourage young people to join the nuclear profession, with emphasis on attracting women.

The following four sections focus on the roles of government, educational institutions and networks, industry, and international organizations in meeting the challenges of developing the human resource base, essential to sustaining the nuclear renaissance. Each section comprises a summary of general observations concerning the current facts, a description of what seems to be working well, and a statement of the challenges that remain to be met.

Finally, a concluding section on the path forward is offered to help set the stage for follow-on activities.

2. BENCHMARKS

2.1. New entrants: UAE example

It was most appropriate that this conference was held in the UAE, given the strong commitment by this country to become one of the first new nuclear entrants. Whereas it is well known that the UAE has vast petroleum resources, it is likewise known that such resources are finite and will not last forever. This fact, combined with the environmental issues associated with burning petroleum, has motivated the UAE to move from being solely an oil based economy to becoming a knowledge based economy as well. Hence, it is the policy of the UAE to introduce nuclear energy as a long term source of electricity, and also as an energy source for desalination. Since the UAE lacks indigenous fresh water resources, desalination of ocean water has become an energy-intensive necessity. Nuclear power presents an opportunity to meet both electricity and fresh water needs.

2.1.1. Approach in the UAE

To meet the growing energy needs in the UAE, a contract has been signed with the Republic of Korea to import four nuclear reactors, with the first scheduled to go on line by 2017. The contract provides for a turnkey project with all associated training and technical services, in recognition of the fact that the UAE is starting with no nuclear capability. However, the UAE is keenly aware of the need to develop a capable cadre of nuclear professions within its borders and is, accordingly, investing in a 'fast track' effort to develop the human resources needed for their nuclear programme. Selected students (35 from an application pool of 700) are currently working to obtain baccalaureate degrees abroad, in countries with solid nuclear education programmes in place. A new university, the Khalifa University of Science, Technology and Research (KUSTAR), has been established in Abu Dhabi with a nuclear engineering department currently being structured to offer a Master of Science (MSc) degree in nuclear engineering. KUSTAR intends to have this degree programme in place in about a year. ENEC is the agency established to coordinate the development of human resources, and FANR is the organization established to provide the necessary nuclear regulatory function.

2.1.2. Lessons learned to date

Lessons learned by the UAE to date include:

Start early — Developing nuclear capability takes time. Hence, it could take a decade or so of concerted effort to develop the domestic nuclear capability required for a successful nuclear programme.

Learn the rules — Building a successful nuclear programme is now a global undertaking. International regulations must be recognized, understood, and adopted. The IAEA has provided several guidelines for new nuclear entrants, but this is only a start to becoming a viable member of the global nuclear community.

Build your team — There is no substitute for developing an indigenous nuclear capability. In addition to an internal capability, strong international ties must be developed to ensure success.

Develop an integrated strategy — Plan for short, medium, and long term goals. The nuclear business is complicated, consisting of many interlocking disciplines and all cannot be achieved at once. An orderly plan to develop the resources needed, on a timely basis, is essential.

Start with as much information as possible —In recognition of the complexity of the nuclear profession, the UAE team is amassing everything the IAEA has to offer concerning new entrants. Also, they endeavour to participate widely in international conferences and are hiring international nuclear experts to assist them.

Grow the organization — The UAE has made extensive plans to build their nuclear organization according to the steps needed for eventual full-scale operation of several nuclear facilities. The base in growing this organization is firmly planted in safety culture, as illustrated in Figure 2.

FIG. 2. Growing the Organization.

Collaborate as you go forward — International collaboration is vital to any major nuclear endeavour. The nuclear profession is now global by nature. It is impossible to conduct a successful nuclear programme in isolation.

Several members of the conference suggested that the UAE might serve as a good role model for nuclear entrant countries, on several measures. The approach in the UAE is well organized and there is a clear recognition for building their nuclear infrastructure from a nearly zero base to one where the operation of a commercial nuclear plant may be possible within about a decade. Moreover, the UAE is in the fortunate position of having the extensive financial resources necessary to purchase both hardware and the human resources required for a fast track. Few other potential entrant countries possess such resources, so caution must be exercised regarding any attempts to transpose the time scale of the UAE to other countries. An exceptionally strong financial base is essential for such accelerated entry to the nuclear world.

2.2. Integrated workforce development

Substantial new work is being conducted worldwide in response to the critical need of developing the new human resources needed to sustain rapid growth in nuclear power. Much of this was reported at the present conference and will be summarized in Sections 3 through 7. However, some examples merit special attention. The unique aspect of the three programmes summarized here is that they attempt to encompass a broad segment of the community, well beyond the more focused technical aspects that form the core of a nuclear educational endeavour. The other major development in integrated education is the high degree of networking that is now taking place. Elements of both these advances are described below.

2.2.1. Addressing full scope needs

The first programme introduced at the conference that might be used as a model for encompassing the full scope of needs is the Texas Nuclear Workforce Development Initiative, signed into law by the US state of Texas on 23 April 2007. This initiative is a state-wide response in order to build the workforce needed in a state where up to eight new nuclear plants are in the planning stages for construction. A new programme, called the Nuclear Power Institute Partnership (NPIP), was organized by Texas A&M University in response to stated utility needs. A polling of the utilities revealed that they need to begin hiring staff at least nine years prior to plant operation. Furthermore, the required staff would need skills at all levels, not only advanced degrees in nuclear engineering. Accordingly, the programme was developed to include several two-year community colleges, six universities and several internships at participating nuclear utilities. The community college portion is being undertaken because about two-thirds of the workforce needed can be sufficiently trained at this level (the basics for many of the needed trades such as welders, electricians and metal workers). Graduates of the two-year programmes receive an Associate of Arts degree, but they also earn a certificate that records their specialty in nuclear technology. As a result of extensive interaction with numerous high schools in the state, a total of 200 students are now enrolled in the programme and 31 have already benefited from intern experience at one of the nuclear utilities. Six thousand teachers from Texas high schools and community colleges have attended a teacher's conference where the NPIP programme has been presented and many of these teachers have subsequently spent a summer on the Texas A&M University campus, with some spending a month at a local nuclear utility. Students then have the opportunity for a four-year engineering degree in any related nuclear programme (e.g. nuclear, mechanical, chemical, electrical). The response to this fully integrated approach to building the necessary nuclear workforce has been very rewarding. It provides the educational training needed and encourages young people to enter the profession in sufficiently large numbers.

The second programme potentially serving as a role model is the new Master's Programme in Nuclear Engineering now being offered at the University of Tokyo. A relatively standard track is offered for those wishing to specialize and progress on to a PhD and research, but a new parallel, five-year nuclear socio-engineering track is being offered to give students a broad perspective of how nuclear technology fits into the social and political aspects of modern life. Training covers international treaties (such as the Non Proliferation Treaty (NPT) and other non-proliferation agreements), IAEA safeguards, international fuel cycles, risk analysis, professional ethics, and public communication skills. Some students spend part of their time at either the IAEA in Vienna or the University of California, Berkeley. The Government of Japan has provided considerable funding for this new programme in recognition of the social and public communication aspects of a successful nuclear power programme.

A third new initiative is tied directly to the UAE through an arrangement between Khalifa University (in Abu Dhabi), Sandia National Laboratories (Albuquerque, New Mexico) and the Nuclear Security Science & Policy Institute at Texas A&M University (College Station, Texas). The programme, called the Gulf Nuclear Energy Infrastructure Institute (GNEII), is designed to bridge cultural gaps regarding international policy. Students need the equivalent of a baccalaureate degree for entrance, but it is open to all qualified students in the Gulf Region. A key requirement of the students graduating from this programme is that they stay in the Gulf region to help 'nuclearize' it, rather than succumb to the temptation to join the 'brain drain' and use their new skills abroad. Two 15-week semesters include technology & policy fundamentals, and a capstone module in which the student knowledge gained is applied to real world issues. While the current programme is focused on the UAE, once experience has been acquired it could be used as a model for other entrant countries.

2.2.2. High degree of networking

A number of nuclear education networks are active worldwide. Starting with only fragmentary outlines less than a decade ago, several networks are now highly developed and frequently used. Their prime purpose is to integrate and coordinate the best programmes for the region being served, in order to offer quality courses and educational breadth on nuclear topics.

Examples include:

ANENT (Asian Network for Education in Nuclear Technology; http://www.anent-iaea.org/). This network consists of 16 countries in Asia, Australia and New Zealand. Its objective is to promote, manage and preserve nuclear knowledge and to ensure the continued availability of talented and qualified human resources in the nuclear field in the Asian region.

ENEN (European Nuclear Education Network; http://www.enen-assoc.org). Established in 2003, this network was built in response to the decline in nuclear interest in Europe and was initially focused on constructing a European MSc in nuclear engineering. It has now expanded into training and nuclear knowledge management activities. With 60 members in 18 European countries, and extensive networking with other such groups, it has emerged as a very effective educational network.

UNENE (University Network for Excellence in Nuclear Engineering; http://www.unene.ca/). As a means to offer a quality MSc degree in nuclear engineering in Canada, UNENE was formed as a network of seven industrial/governmental partners and 12 Canadian universities. Approximately 100 students are now enrolled in the system. As a tangible measure of its success with industry, the network is now funded at about $50 million, having started at only $5 million.

Other networks are being built (referenced later in this report), of which several are focused primarily on connecting institutions within national borders. Two other networked organizations, offering more specialized education, are ICTP and the WNU:

ICTP (International Centre for Theoretical Physics; http://www.ictp.it/). This centre, located in Trieste, Italy, has a rich history of advanced scientific education and has become a destination site for scientific conferences of all types. In addition to its wide variety of technical specialization, it now offers a three-year course in nuclear management, and it will soon offer courses in nuclear security and science communication.

WNU (World Nuclear University; http://www.world-nuclear-university.org/). The WNU was founded in September 2003 as a global partnership committed to enhancing international education and leadership in the peaceful applications of nuclear science and technology. The founding partners are the World Nuclear Association (WNA), the World Association of Nuclear Operators (WANO), the International Atomic Energy Agency (IAEA), and the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (OECD-NEA). Among its various programmes, the Summer Institute has emerged as the flagship programme. Some 100 of the brightest young nuclear leaders throughout the world, selected by their employers, spend six weeks together each summer with leading thinkers and educators to gain a broad overview of nuclear issues of strategic importance. After concluding the 5th Summer Institute last summer in Oxford, 467 fellows from 65 countries are now graduates of this nuclear leadership programme.

Some delegates at the present conference expressed the need for a global network to tie all these networks together in a user-friendly fashion. Whereas such a system, developed with the user in mind, could be very helpful, it is not clear at this time which entity might take on such a task. A more realistic goal might be more communication and coordination among existing networks, leading to more clarification of the purpose of the individual networks and more integration from the user perspective. Another matter brought to the floor, stimulated by the growing number of new nuclear education networks, was the question of developing an international certification process so that employers could readily ascertain the skill set embodied in a student graduating from one of the many centres of learning throughout the world. This was noted to be difficult and delicate, but potentially a worthwhile task.

3. KNOWLEDGE TRANSFER CHALLENGES

3.1. Basics

As pointed out in the opening plenary of this conference, rapid growth in nuclear power generating capacity is possible only when the knowledge base and a capable human resources pool have been established. Continuity in growth is the key to nuclear knowledge management. Difficulties arising when nuclear knowledge is not wisely managed become manifest during, for example, the launching of a new nuclear power programme, stagnation in nuclear power growth over an extended period, or the introduction of a new design.

These difficulties can be confronted primarily through cooperation via regional or international networking, as noted by the discussion in the previous section.

The ageing workforce is normally an incentive to take an interest in nuclear knowledge management since many nuclear organizations are faced with retirements over the coming years. An example is the US Nuclear Regulatory Commission, where 50% of their current workforce is eligible for retirement within the next five years. Similar situations are occurring in many other established nuclear institutions.

As noted in the literature, both explicit and tacit knowledge need to be transferred between generations of nuclear workers. Explicit information can be transferred relatively easy through written material (e.g. documents, books, reports) and included in databases that can be readily be referenced. Tacit knowledge is the result of long-term experience and expertise in the subject matter, and is more difficult to pass on to newly qualified staff.

Perhaps the most extensive database containing explicit nuclear knowledge is the International Nuclear Information System (INIS) at the IAEA. This system currently contains over three million bibliographic citations and abstracts of journals, books, reports, and web documents, all accessible with powerful search engines. Other examples of databases gaining increasing use include the Alsos Digital Library for Nuclear Issues (Washington and Lee University, Lexington, VA,), and Lakshya, a database created at the Bhabha Atomic Research Centre (BARC) in India, which has extensive access to full text journals, eleven databases, and six encyclopaedias.

Progress in recovering tacit knowledge is being made at many sites. One seemingly effective approach was presented by AREVA, a partner in setting up the European Nuclear Energy Leadership Academy (ENELA) to provide high-potential professionals with the background needed for nuclear leadership positions. The AREVA presentation also described a complementary programme to conduct extensive interviews with senior professionals two years before their expected retirement, and encourage close interaction between them and new recruits.

3.2. Passing the torch

Many nuclear sites foresee an overlap of one to two years where a mentor (one about to retire) spends quality time with an apprentice (a new worker) so that both explicit and tacit information can be passed on. In an operating nuclear power plant, an example would be going through at least one refuelling outage, where numerous tasks must be synchronized to allow the outage to be conducted in the safest possible fashion in the shortest possible time.

The nuclear knowledge to be passed on will vary, however, depending on the roles and activities involved. In a nutshell, the three categories are: 1) know what to do, 2) know how to do it, and 3) know why to do it. Table 2 (compiled from the International Nuclear Safety Group (INSAG) discussions) contains a summary of these needs.

TABLE 2. KNOWLEDGE REQUIREMENTS AND TRANSFER

Type of knowledge	Typically required by
Know-what Understanding what is needed for effective decisions	Managers, plant owners, policy makers
Know-how Application of knowledge	Operators, regulators, suppliers, constructors
Know-why Generation of knowledge	Designers, developers, national laboratories, universities, vendors, regulators

Key messages

Managers, plant owners and policy-makers need to understand what is needed to make effective decisions (including a broad understanding of stakeholder needs and concerns) but they do not necessarily need to know technical details and they certainly don't have to generate fundamentally new knowledge.

Plant operators, regulators, suppliers, and constructors need to be able to apply relevant technical knowledge but they do not necessarily have to deal with policy makers or generate new fundamental knowledge. On the other hand, dealing with the public is a skill that all nuclear workers should develop because of the high degree of misinformation that still exists among many members of the public. Our profession can provide the benefits of nuclear science and technology to society only if society understands it well enough to overcome the fears that are still widely harboured.

Finally, designers, developers, vendors, and scientists and engineers in the national laboratories, universities, and regulatory agencies need to be able to discover and develop new technologies, while understanding the need for such advancements. These people generate new knowledge and disseminate it in a form for others to use.

Whereas these categories are quite general, and there are many cases where overlap is both helpful and necessary, this categorization can be useful in managing a knowledge transfer programme.

To effectively pass the torch, it is essential to train the trainers. In doing so, the proven adage attributed to Confucius comes to mind: *Tell me and I will forget; show me and I will remember; involve me and I will know*. The latter approach illustrates effective knowledge transfer.

3.3. Attracting the new workforce

To generate the human resource base needed for the future, it is desirable to attract the best possible people into the profession. Transferring nuclear knowledge is impossible if there is no one on the receiving end! To meet short term goals, several nuclear entities have been able to attract workers from other fields, particularly in regions where economic circumstances have led to widespread, local unemployment. However, the best long-term supply is the next generation. The sections below review steps that have been taken to attract young professionals into the nuclear field, with particular emphasis on increasing the proportion of women in the profession.

3.3.1. Next generation

Several young nuclear professionals were invited to attend the conference and one session was entirely devoted to the needs and aspirations of the next generation. Several key elements play a part in attracting the best and the brightest young people to the nuclear sector, rather than losing them to banking, marketing, computer science, and other professions.

Whereas competitive salaries are necessary to attract young professionals, money alone is not sufficient to bring in the types of young people the profession needs. Rather, the opportunity to really make a difference plays high as an appeal factor and here nuclear technology has a distinct advantage. Given the global needs for expanded and long-term energy sources that are compatible with environmental stewardship, a career in the nuclear profession is relatively easy to sell.

Additional incentives to students and graduates include being able to work with international colleagues, working with and solving difficult challenges, being able to work on a variety of tasks, having flexible work hours, and having opportunities for life-long learning. Disincentives to the younger generation include bureaucratic obstacles, and an environment resistant to change.

It was pointed out that young people would like their employers to provide an opportunity for more social interaction. They would also like to have their formal university curriculum include courses dealing with the social and political aspects of the nuclear profession.

Networking at the earliest possible point in their career is highly desirable. Networks such as the European Nuclear Society (ENS) Young Generation Network are of benefit to European Students whereas NAYGN (North America Young Generation Network) is of particular value to Americans.

3.3.2. Women

Women in Nuclear

Women in Nuclear (WiN) is an international organization focused on featuring the effective roles that women can play in the nuclear professions. This organization is growing rapidly in Europe but also globally. It is interesting to note that men are allowed membership in this organization, with IAEA Director General Emeritus Hans Blix being the first male member of WiN.

The WiN chapter in the USA has a strong nuclear advocacy component, recognizing the fact that women in support of nuclear technology can have a substantially more positive effect on the general public and policy makers than their male counterparts. Also, considerable efforts are being made to mentor young women entering the profession.

The IAEA, which currently has only about 22% women on its staff, ran a small recruitment booth at the conference to promote opportunities for women at the IAEA. Discussion, networking and information sharing on recruitment initiatives and lessons learned took place with other human resources representatives from the private sector and government organizations.

Panel discussion

The panel discussion that addressed the underutilization of women in the nuclear workforce noted some gains, but indicated that progress in this area is still lagging.

Various presentations illustrated this lag. In Brazil, women constitute approximately 30% of the nuclear workforce, but only 4% occupy high level management positions and the pay for women is considerably less than for men. The French presentation noted that only 13% of 2200 nuclear employees of ONET (the Office Nouveau du Nettoyage) Technologies are women. Of that 13%, only 18% are engineers or upper management, while 45% work as administrative staff.

Things appear a bit brighter in the Republic of Korea, where the Women in Korea organization (part of WiN) started with only 80 members in 2000, but now has 2800 members. A key thrust of the Korean WiN branch is to work with very young students (earliest grade school level) to interest them in nuclear science.

Sweden has been under a moratorium on nuclear technology since the Chernobyl accident in 1986. To keep the technology from disappearing, the Swedish Centre for Nuclear Technology (SKC) was founded 15 years ago with a strategy of bringing nuclear technology education into standard courses wherever possible. The programme has attracted about 50% women, and the result has placed Sweden in a position to re-emerge in the world of nuclear technology, now that the political winds have shifted in favour of moving ahead with nuclear power.

As stated above, the IAEA has only about 22% women on its professional staff, despite efforts to increase that number. In the UAE, KUSTAR has a co-educational programme for nuclear technology and it has been moderately successful in attracting women to participate in this programme.

4. ROLE OF GOVERNMENT

4.1. Observations

Substantial government support is necessary for any nuclear programme to be successful. The principal reasons for this are the following:

The time frame for any commercial nuclear reactor project is likely to be much longer than that of most, if not all, non-governmental institutions. Noted earlier was the fact that a century is the timeframe for a reactor project, given a decade or so of design and construction, an operating life of 60 to 80 years, and another decade or two for decommissioning.

Only national governments are in a position to fund the high risk, long-term projects essential for major advancements in technology. There simply are not sufficient incentives for such investments within the private sector.

Safety, security, and safeguards, often viewed and regulated on an international basis, can be implemented only by national governments.

A fully successful programme can exist only when a strong, visionary policy is advanced by the government such that national laboratories, educational institutions, and industry are all working together in an integrated fashion.

4.2. Positive trends

When strong and steady support is provided by the government, nuclear technology can thrive. Sustained national support, combined with a consistent policy framework and a clear vision, has resulted in:

- a strong R&D technology and safety base;
- the ability to manage through economic fluctuations;
- a rapid and steady deployment of nuclear power plants;
- effective transition from national to international prominence, and attraction of a wide variety of human resources.

The Republic of Korea represents an example of what can be done with consistent governmental support. The entire Korean infrastructure was destroyed in the early 1950s by the Korean War. With able leadership and strong, consistent national support, the Republic of Korea has now emerged as a world leader in nuclear technology. As such, it has been chosen to provide the first new builds in the UAE (quite likely to be the first nuclear emergent country). The Government of the Republic of Korea has served as a catalyst to coordinate their nuclear human resource development. The major players include KEPCO (Korea Electric Power Corp.), KINS (Korea Institute of Nuclear Safety), KAERI (Korea Atomic Energy Research Institute), KOPEC (Korea Power Engineering Company), and numerous universities. Solid governmental support and an ongoing building programme have facilitated attracting young people to the profession and the transferring of nuclear knowledge management.

France, with constant national support for its nuclear programme, has maintained nuclear generated electricity at a level of 80% of its total supply. Japan has also maintained relatively steady growth in nuclear technology due to its commitment to long-term planning. China and India have enjoyed relatively consistent national support and they are now leading the world in nuclear growth, each striving to improve the standard of living for their vast populations by integrating all aspects of its nuclear programme.

4.3. Challenges

There are numerous examples where wavering support, lack of a long-term energy policy, or opposition to nuclear energy at the national level has stifled nuclear growth. When funding dries up at the governmental level, stagnation quickly sets in, directly reducing necessary R&D activities and greatly diminishing enrolments in nuclear engineering and technology programmes. Countries with such a past have, in many cases, lost both global nuclear leadership and the benefits of modern nuclear technology.

New entrant countries are dependent upon vendor countries to deliver the ‘full nuclear package’. Until they are able to develop indigenous nuclear talent, they are ill equipped to manage and regulate nuclear projects, all of which require special professional attention. If strong and consistent governmental support is lacking, they have no viable basis for entering the nuclear field.

5. ROLE OF EDUCATIONAL INSTITUTIONS AND NETWORKS

5.1. Observations

Strong university nuclear education forms the backbone of successful nuclear programmes. However, the human resource needs of the nuclear industry reach far beyond the specialized education received in a typical nuclear engineering programme. Over 70% of the human resource needs for an operating nuclear power land are not engineers or scientists with advanced training. Rather, they involve highly skilled technicians such as certified welders, electricians, and metal workers. The new Nuclear Power Institute in Texas has taken an integrated approach towards providing all personnel needed for a nuclear programme.

Because of the need to provide quality nuclear education to young professionals on a much wider scope than in the past, more attention is being paid to distance learning and internet courses than in the past. This technology, though arguably less effective than face-to-face learning, has the capacity for a substantial extension of influence of the existing experienced faculty. It has the further advantage of being delivered to places and times considerably more convenient for the recipient.

It does appear, however, that the distinction between traditional educational institutions and industry is blurring. AREVA, for example, has set up an institution sometimes referred to as ‘AREVA University’, where employees are encouraged to attend a variety of classes to improve required skills. Some 500 courses currently exist for employees. They support a dozen training centres around the world where approximately 100 trainers turn out several thousand students per year. Electricité de France (EdF), likewise, offers 650 courses and supplies some 1.5 million hours of annual training.

5.2. Positive trends

A strong movement in the recent past is the trend towards much greater cooperation between educational institutions and industry. Most industrial organizations are acutely aware of their need for young talent to replaced retirees and gear up for the expanded nuclear market. Hence, they are often willing to provide support for universities to attract bright students and offer special nurturing (such as scholarships and internships) to speed up the process of acquiring a well-educated workforce. There is a trend towards including practical experience in both education and training programmes.

Another effective way for educational institutions to work together is in setting up teachers' workshops with government cooperation. Such programmes, which may provide the only contact teachers have with nuclear topics, can be a cost effective way to attract young people to seek employment in the nuclear industry. In many cases, the teachers completing such a workshop are motivated to include nuclear technology in their course curricula, thus exposing students to information on opportunities in the nuclear industry.

Whereas traditional academic institutions still supply the basic needs for an educated nuclear workforce, the accelerated need for more nuclear professionals is causing even the established institutions to find new ways to meet the challenge. For example, in France a new entity, the French Council for Education and Training in Nuclear Energy (CFEN), was created in 2008 to assess the adequacy of the graduate output. The CFEN consists of governing members from academia, industry, government, and R&D institutions. It has estimated that about 1200 nuclear trained engineers per year will be needed for at least the next decade. However, the output from about 20 engineering schools and universities in France offering related curricula at the master's level was only 300 students in 2006. This number rose to 600 by 2008 and the enrolment at present is up to 886 students. In an effort to further increase these numbers and ensure academic quality, a new international MSc in nuclear energy was established in Paris in 2009. Its courses will be taught in English and open to the global community. The goal is about 200 students per year (half of them French) to augment their traditional programme output. The French focus on nuclear human resource development was further indicated in March 2010, when French President Sarkozy announced the creation of an International Institute for Nuclear Energy (I2EN). The aim of this institute is to serve as an international centre of excellence.

Despite the relatively steady rise of the Japanese nuclear power programme, student enrolments in engineering have been declining in recent years, including those in nuclear sciences. This, combined with retirements in both industry and academia, is a cause for concern. The country has responded by forming an integrated government, industry, and academic team to launch an aggressive nuclear education and training programme, which defines three conditions to ensure safe and reliable nuclear power operations; namely hardware, software, and 'humanware', with special emphasis on the human element. Additional emphasis is being placed on adding non-technical components to the core curriculum (e.g. law construction practices, safety, rad waste, public communications) as exemplified by the new nuclear engineering track at the University of Tokyo described earlier. The Japan Atomic Energy Agency (JAEA) has traditionally played a strong role in Japan's nuclear education and training via the Nuclear Technology and Education Centre (NuTEC). NuTEC has graduated a nuclear cadre of 110 000 in its 53 years of existence. Working with seven universities for base programmes, 20 universities and technical colleges in a cooperative agreement for graduate school programmes, and the Japan Nuclear Education Network (JNEN) with 6 universities, NuTEC is aggressively seeking to increase the output of quality nuclear specialists to meet the growing needs.

The Russian Federation has experienced a drop in nuclear interest similar to that in Japan. Over the last 15 years, the number of nuclear personnel in the 25–30 year age bracket has dropped by half and the number of nuclear personnel over 60 years of age has doubled. To prepare for the emerging global nuclear renaissance, the Russian nuclear educational system has been modernized into the National Research Nuclear University (NRNU) or 'MEPhI'. This new Russian centre for the preservation and expansion of nuclear knowledge opened in July 2009. It has united five specialized universities, including three MEPhI branches, and 13 secondary professional schools. The new course format will follow the Bologna Process[1]. The teaching staff now consists of 2380 personnel (including 1135 associate professors and 485 professors), 22 000 students at the BSc or MSc level, and approximately 1000 students at the PhD level. The International Centre for Nuclear Education has been created within the NRNU to network the entire system with international networks such as ENEN and ANENT.

[1] The Bologna Process unites 47 countries, all parties to the European Cultural Convention, and aims to create a European Higher Education Area (EHEA), by making academic degree standards and quality assurance standards more comparable and compatible throughout Europe. It is also intended to encourage international cooperation and academic exchange that is attractive to European students and staff, as well as those from other parts of the world.

India has a well-established system for educating its nuclear workforce. Annually, more than 20 000 high school students apply for about 300 open positions in the five nuclear training centres in India. Once selected, these elite students are assured of a job in one of the nuclear installations upon graduation. The first year at the graduate level consists of science and engineering orientation courses, followed in subsequent years by specialization in a topic of the student's choice. The uniform curriculum and strong connections with global networks ensure the quality of their education.

5.3. Challenges

Many once strong nuclear programmes have lost capability, due to the lack of national policy embracing nuclear technology. Now that the global nuclear renaissance is under way, many university departments have been struggling to find ways to rebuild and offer the education needed to meet the rapidly growing demand. Many are using networking avenues, forming new alliances with other universities and, in many cases, finding ways to offer quality nuclear courses via internet. This has reinvigorated many programmes and has forged new working alliances that would never have occurred otherwise. Now Master's level degrees in nuclear engineering exist that can be obtained with varying length and depth of courses, residency requirements, and entry qualifications. But in many cases, direct hands-on learning is very thin. This gives rise to the question of overall quality and poses a dilemma for the employer in trying to ascertain the relative skill sets between graduates of various degree programmes.

The question of potentially developing an international certification process so that employers could readily ascertain the skill set embodied in graduates from education and training institutions was noted to be a difficult and delicate, but potentially worthwhile task.

This is the challenge in the United Kingdom, where national interest and funding over the past three decades has dwindled. In response to the recently announced governmental pro-nuclear movement, universities are scrambling to rebuild their nuclear programmes. The Dalton Institute at the University of Manchester has formed the Nuclear Technology Education Consortium (NTEC), in which 12 UK universities participate. To compensate for the lack of complete curricula for an MSc in nuclear engineering, the network has been set up to allow students to enrol in any one of the participating universities and take courses on-line that emanate from one of the other universities where a particular specialization still exists. The courses, either in 'short course' or e-learning format, can be delivered to meet the schedule of the student. Industry has been very supportive of this new approach.

Whereas nuclear networks appear to be thriving in many parts of the world, it was noted that such a network has yet to be developed in the USA. A mini network was formed several years ago, in response to the rapid loss of campus research reactors. The Innovations in Nuclear Infrastructure & Education (INIE) programme consisted of six regional networks where students from any of the participating universities could use a research reactor clustered within the network. This programme was quite successful in that it overcame obstacles to higher education, but it stopped short of allowing students to take courses at other universities and it did not link up distance learning to broaden courses available to students. This remains a challenge within the USA.

Although safety culture must be a core value of anyone working in the nuclear field, it is not clear how to instil this value effectively at university level. Hence, it remains a challenge. Other challenges are attracting more women to the field and offering courses in the non-technical fields such as law, economics, finance, business, and communications.

6. ROLE OF INDUSTRY

6.1. Observations

The nuclear power industry's investment in its workforce, on a per capita basis, is higher than most other industries. As was indicated during the conference, it is typically three to six years from when an individual is hired for a technical position in a nuclear power plant operating organization until they are fully qualified to perform all their duties. In addition, the nuclear industry devotes a greater fraction of its workforce time to continuing training and development than most other industries. For example, the operations staff of most nuclear power plants devote between 10 and 20 per cent of the year to maintaining and improving their competencies. Given this enormous investment in its human resources, the nuclear industry has more incentive than most to retain its workforce, and needs longer lead times to develop replacements when workers leave due to retirement or other reasons.

6.2. Positive trends

The human resource challenge is best met when industry effectively partners with government and educational institutions. Industry depends heavily on universities and training centres for a well-trained cadre of workers, and students graduating from these educational institutions depend heavily on industry for jobs. Stagnation in the job market discourages prospective students, encouraging them to enter other fields. Conversely, a strong job market encourages students to pursue a discipline offering them good employment opportunities.

This support system can manifest itself in many ways. Successful programmes include industry-supplied scholarships, fellowships, internships, support of faculty/student research, teaching (where a particular specialization resides in industry), special student events, and general support in the form of advisory councils.

Because of the complexity of nuclear technology, life-long learning is a necessity. Therefore, many industrial entities have invested considerable capital into developing in-house training centres for their employees. As noted earlier, AREVA and EDF each offer over 500 courses for employees as part of their life-long learning programme.

The NEI (Nuclear Energy Institute) in the USA has collaborated with the Center for Energy Workforce Development in an attempt to attract the younger generation and provide the training needed for employment in the energy sector. The programme targets primary and secondary school age children, along with 52 colleges and includes the training of displaced workers, in order to strengthen their knowledge in science, math and technology.

Another option is to send employees back to university for further education. China, for instance, routinely sends many of its highly valued employees back to university after a few years on the job. This practice is tightly woven into their human resource programme. The National Nuclear Safety Administration (NNSA) in China has assumed overall responsibility to ensure a qualified cadre of nuclear professionals for the safety-related aspects of its nuclear programme. Shanghai Nuclear Engineering Research and Design Institute (SNERDI) carries out the Chinese programme to ensure a full scope of nuclear knowledge management, including web-based education. In order to become a ‘Certified Registered Nuclear Safety Engineer’, the applicant must pass a difficult national exam. Similar requirements exist for the trades, such as welders and Non-Destructive Testing (NDT) examiners.

Given the need for more nuclear workers in the utility sector, the Institute for Nuclear Power Operations (INPO) in the USA is launching a unified curriculum with several two-year colleges to attract and train the technicians that will be needed. This new programme has been recently launched, and consists of over 50 utility/college partnerships. It is too early to measure results, but the indications so far are that the courses offered are attractive to students. This may become an effective way to recruit more young professionals.

WANO, known worldwide for efforts to upgrade nuclear power plant safety operations, is now beginning to address issues for new entrants. The lessons learned from the review of global nuclear power plant operations, though necessarily confidential, can be categorized in generic terms that should be very useful to any country about to start up a new nuclear power plant. This is valuable to new entrants, and also to re-entrant countries, i.e. those previously running nuclear power plants that have suffered a long stagnation period and need to be retrained to use up-to-date best practices.

6.3. Challenges

Although the operation and safety of nuclear power plants has improved in many countries (as measured by indices such as plant capacity factors, the number of unplanned scrams, radiation exposure to workers, plant upgrades, plant lifetime extensions), it must be remembered that an accident anywhere is an accident everywhere. The accidents at Three Mile Island and Chernobyl postponed many national nuclear programmes, even stopping some of them completely.

Hence, a strong commitment to safety culture cannot be overemphasized. The complexity of beliefs, shared values and behaviour reflected in making decisions and performing work in a nuclear power plant or nuclear facility referred to as safety culture cannot be accomplished only through a programme. It must be internalized deeply by every nuclear worker and instilling this commitment from the top to the bottom of every nuclear entity remains a constant challenge.

Several speakers mentioned that the high degree of success in recent years can, paradoxically, be a matter of concern. Complacency can easily set in after years of excellent operation. Some insightful remarks from the session dealing with industry are quoted below:

If you don't learn from operating experience, you are doomed to repeat your mistakes. While benefiting from positive operating experience, one must learn from accidents that have occurred anywhere in the world.

It can't happen here. This has been uttered many times since the Chernobyl accident, but we all need to be aware that we do not know what we do not know. This may sound self-evident, but it certainly is food for thought.

If production is more important than safety, then that organization will fail. This has, indeed, been experienced too often. Better to heed this sage advice than to be wise after the event.

WANO currently has an annual listing of some 1000 reported events per year, most of which occur in countries with long-term operating experience. Such a large number of reports might be interpreted as lack of good operation or, conversely, as diligent adherence to reporting procedure. The nuclear industry continues to emphasize the importance of transparency, i.e. reporting even minor events, as a basis for learning and for assessing one's own operations. It is a vital part of improving competency and if there were to be repercussions from the reporting of such incidents, many incidents of value to the international nuclear power community would remain unreported.

WANO is currently reviewing how it can provide earlier support to those that are initiating nuclear power programmes including peer reviews during construction and commissioning. The lessons learned from events reported to WANO are highly valuable to new entrants. WANO is studying how to best share this data while maintaining confidentiality.

Being able to design, license, and construct new nuclear power plants on a reliable schedule and budget is a major challenge for an industry just coming out of a relative stagnation period. The Finnish experience at Olkiluoto-3 is a reminder of this re-entry challenge. As reported at this conference, the key lessons to be learned from Olkiluoto-3 are that the original schedule was too ambitious, required skills for managing a large, new construction project were inadequate, and the deterioration of the global nuclear infrastructure led to lapses in quality and increases in cost.

Finally, it should be noted that hardware is relatively easy to fix. Human behaviour is considerably more difficult. Incidents that have been reported at operating nuclear facilities are almost always traceable to human error. Attitudes and beliefs are difficult to measure. It is of paramount importance for nuclear workers to develop a questioning attitude, recognizing that there are things they still do not know, and be open and eager to participate in the life-long learning process so important to their personal success and the success of the industry. Empowering employees remains a constant challenge for management.

7. ROLE OF INTERNATIONAL ORGANIZATIONS

7.1. Observations

Among the international organizations most relevant to the nuclear industry, the IAEA occupies a unique role. Every nation that uses any type of nuclear technology is a Member State of the IAEA. Accordingly, the IAEA is expected to provide leadership in those areas of global interest. Given the increasing needs for nuclear knowledge management and the development of human resources, the IAEA is expected to provide guidance on how best to achieve the necessary goals. The IAEA cannot enforce implementation of its guidance, but responsible countries (many of which are directly involved in helping to formulate such guidance) are strongly advised to participate in a constructive fashion in matters of such importance.

The IAEA has taken a strong leadership role in articulating and advancing nuclear knowledge management, along with programmes for achieving the desired goals. As a service to entrant nations, the IAEA published Milestones in the Development of a National Infrastructure for Nuclear Power (IAEA Nuclear Energy Series NG-G-3.1) in September 2007. This publication outlines a three-phase approach to acquiring and operating a nuclear power plant. It covers the human resources required. More than a half dozen documents have been prepared and distributed by the IAEA dealing with nuclear knowledge management and the challenges of human resource development.

Other international organizations, such as WANO and many of the regional networks, are now addressing the knowledge management/human resource development area. The distinction between ‘national’ and ‘international’ is beginning to disappear with regard to human resource development. There is far too much global exchange in today’s world to maintain national isolation in this crucial area, and this is certain to be the trend far into the future.

7.2. Positive trends

7.2.1. Facilitating organizations

Several organizations exist to facilitate and improve human resource development. Examples of these, which include regional, national, and international organizations, are:

International

IAEA (International Atomic Energy Agency)

WANO (World Association of Nuclear Operators)

WNU (World Nuclear University)

Regional

ANENT (Asian Network for Education in Nuclear Technology)

ANSN (Asian Nuclear Safety Network)

AFRA-NEST (Africa Education Network in Nuclear Science & Engineering)

ENEN (European Nuclear Education Network)

National

BNEN (Belgium Nuclear Education Network), Belgium

INPO (Institute of Nuclear Power Operations), USA

INSTN (Institut National des Sciences et Techniques Nucléaires), France

NTEC (Nuclear Technology Education Consortium), UK

UNENE (University Network for Excellence in Nuclear Engineering), Canada

These entities and networks all serve a useful purpose in bringing key nuclear organizations together, and the number of such networks is growing.

7.2.2. Global survey

In an effort to provide a more comprehensive global perspective of human resource needs by various sectors and time frames, the IAEA, along with the other international organizations that participated in this conference, is planning to conduct a coordinated survey of global human resource requirements.

Information collected at the international level is expected to allow relevant agencies to formulate and implement better strategies for meeting this vital need.

7.3. Challenges

With the rapid growth of nuclear power, combined with the increasing need for qualified human resources, heavier demand will undoubtedly be placed on international nuclear agencies such as the IAEA. With over 20 new entrant counties now planning to implement new nuclear power programmes within the 2015 to 2030 time frame, it is clear that additional demands will be placed on the IAEA for assistance in effective ways to start up such programmes. Further, with the addition of more plants, there will be an associated need for more inspections and enhanced safeguards efforts. WANO will also be taxed with an increasing load of requested visits. All of this will require significant resources, both in terms of qualified personnel and funding.

8. PATH FORWARD

8.1. Current status

Significant progress is being made, worldwide, in managing nuclear knowledge, and recruiting and training the next generation of nuclear workers, in order to sustain rapid expansion of nuclear technology in the coming decades. All sectors involved in nuclear power production now recognize the challenges and several new initiatives were reported at this conference that provide hope for meeting the crucial human resource challenges. National and regional networks are helping to organize and foster the sharing of data and educational opportunities.

8.2. Key focus areas

The steps taken so far are only the beginning of confronting what will be one of the most difficult challenges the nuclear industry has ever faced. Perhaps the most effective way to meet the goals for sufficient nuclear knowledge management and human resource development is for governments to recognize the merits of nuclear technology and to institute stable, consistent policy and supportive programmes to ensure success.

Above all, it is essential to keep nuclear plants operating safely. Any significant accident immediately places the entire nuclear industry in peril. That is why a strong safety culture must be internalized in every person involved in the profession. In addition to keeping our plants running safely, it is important to help the general public and policy makers to be aware of the enormous benefits of nuclear technology in power production, medicine, agriculture, and general industry. This is a major reason for the younger generation to be informed about risk assessment and social issues associated with the nuclear profession. This may be a particularly important ingredient to attracting more women to the profession. It was interesting to note that such courses are now being included in some nuclear engineering curricula.

Another key factor in providing the necessary human resources for the future is the recognition that workers at all levels are needed, not just academically educated nuclear engineers. Skilled craftsmen, such as welders, pipefitters, and electricians, are badly needed. Some new programmes described at this conference are focused on this broader range of skills and these continuing efforts should be encouraged.

Networks that combine educational institutions, leading to an increase in the number of quality nuclear science and engineering courses being offered, are now growing. This positive trend provides hope that it may be possible to provide a global educational system sufficient to turn out the human resource cadre needed to serve the nuclear renaissance. Networks that provide ready access to data and those that provide professional linking to enhance leadership skills are also increasing, again providing encouragement that the human resource challenge may be met. The papers presented at this conference demonstrated considerable progress in all these areas, laying a strong foundation for the crucial work ahead.

9. CONCLUSIONS

The conference participants expressed the need for a catalogue listing the various global education and training networks that support nuclear power. It would be useful to find improved ways for these networks to work more effectively together to serve the integrated needs of the industry. These evolutions could be well incorporated into any future network creation.

International cooperation in the area of nuclear education and training is essential and the role played by international organizations in generating exchanges among education and training stakeholders from all over the world is admirable. An increased cooperation among these organisations in the future could allow progress in quantifying global human resource needs and the supply needed to support future nuclear power expansion, possibly through the establishment of cooperative arrangements.

The integrated and cooperative effort established for development of human resources for the nuclear power programme in the UAE is consistent with the recommendations of the IAEA, on workforce planning and human resource development. Of particular note is the establishment of an integrated approach towards this development, led by the UAE Government with active participation by the operating organization (ENEC), the regulatory body (FANR), and education institutions (KUSTAR, the Institute of Applied Technology (IAT), and the Abu Dhabi Education Council). Countries considering or now implementing nuclear power programmes should study this UAE approach and apply the same principles to their efforts, with the particulars to be based upon their own national cultures and education systems.

International and national nuclear industry organizations should establish mechanisms such as conferences and networks to share good practices and lessons learned regarding recruiting and retaining the next generation nuclear industry workforce, including means to increase representation of qualified women in the nuclear industry.

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No. 22

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