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Nuclear Education and Training: From Concern to Capability

Executive Summary

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Executive summary

Background

In 2000, the OECD Nuclear Energy Agency (NEA) published *Nuclear Education and Training: Cause for Concern?*, which, for the first time, drew attention to the likelihood of insufficient human resources being available to support current operations, foreseeable developments and the decommissioning of shut-down nuclear facilities. Several measures were proposed in the report to encourage urgent intervention by key stakeholders. Progress against the recommendations was assessed in 2004 in a follow-up report on *Nuclear Competence Building*. A number of outstanding problems were highlighted, in particular as regards the time required to accumulate sufficient skills and knowledge to achieve competence. The situation was made worse by a loss of existing experience, a contraction in research and training facilities, and reduced university funding. Although greater awareness of the overall future skills deficit had been achieved, it was concluded that the response was geographically variable, and that there had been no breakthrough in addressing the downturn in the skilled nuclear workforce.

Since then, the political and technological landscape has changed considerably with the potential for greater deployment of civil nuclear power driven by increased demand for energy, the need to address climate change, concerns over security of supply, the more attractive economic prospects for nuclear energy in the context of carbon pricing and the desire for long-term stability in energy prices. Such changes bring about a demand for expansion of the skilled nuclear workforce. Furthermore, over the last ten years, nuclear education and training has evolved against a more nuanced understanding of how nuclear skills need to be addressed.

This study assesses the current state of nuclear education and training for the development of nuclear skills, the remaining gaps and the actions that are now required to address corresponding development needs across NEA member countries. Programmes and instruments for human resource development have been analysed in three parts by looking at the provision of specialist nuclear education for nuclear professionals: 1) through a review of initiatives that have been taken over the last ten years by the various actors internationally; 2) through a parallel survey on the use of research facilities for education and training; and 3) through the development of a framework for classifying and typifying a selection of nuclear job profiles.

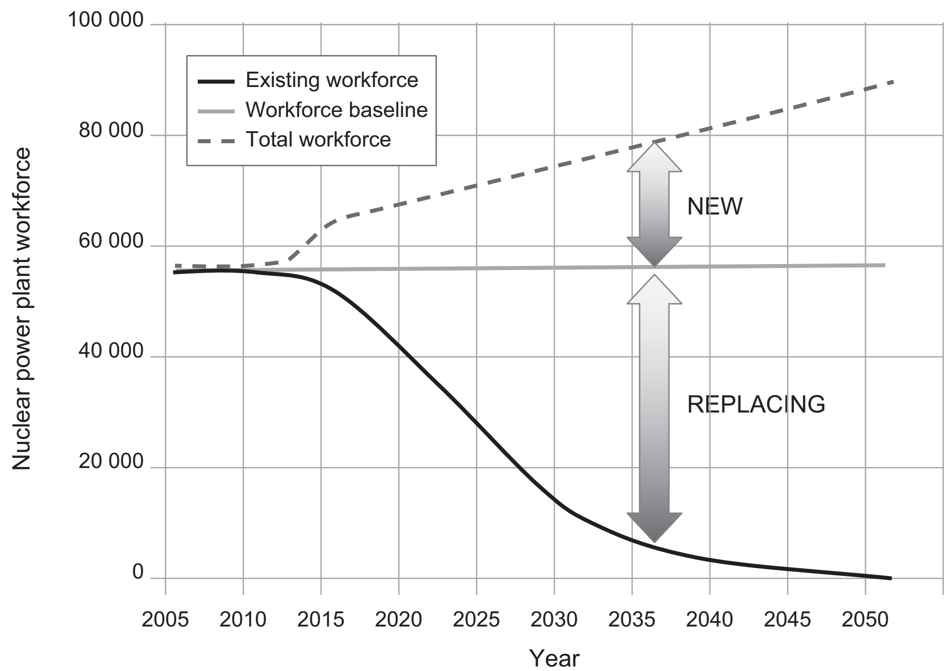
The continuing need for human resources

The distinctive characteristics of nuclear energy and its fuel cycle give rise to special requirements for education and training. In all countries with a nuclear programme, even before new build is taken into account and regardless of national policies, there exists a substantial nuclear estate to be safely operated, maintained and in time decommissioned. An essential element in the implementation and safe operation of all nuclear facilities as well as nuclear technology research and development is a knowledgeable and skilled workforce.

The nuclear workforce of the 21st century is a significant international, commercial and research community. Although there is a lack of detailed numerical data at the national and global level, existing surveys conducted in a number of countries suggest that future demand for global employment in nuclear-related activities are in the tens to hundreds of thousands of skilled workers. This is attributable, to a significant extent, to the expected retirement rates of the existing workforce.

A recent study by a Los Alamos National Laboratory team (Li *et al.,* 2009) simulated human resource development needs for several scenarios in the Russian Federation and the United States. Figure E.1 shows the magnitude of the prospective demand for operations personnel (i.e. operating staff retained for plant operations following the construction phase) for the United States case where additional plants are built to retain market share. Starting from the 56 000 United States workforce (as of 2006), the graph shows separately staff needs to replace retiring personnel and to cater for additional capacity, indicating a demand, by 2030, of approximately 19 000 new positions and a total of 63 000 new hires (19 000 + 44 000 to replace retiring employees). The main outcome from this analysis is that there will be a large need for education and training of new employees.

Figure E.1: Estimates of the operating personnel needed for retaining market share in nuclear power in the United States



Source: Li *et al.* (2009).

In general, the demand for nuclear skills set against a generally ageing workforce implies that significant intervention will be required to maintain an adequately skilled and competent workforce, and the required flow of new recruits for long-term sustainability. Policy decisions need to be made now to ensure that adequate nuclear education and training infrastructure is available in the decades ahead. Delays and changes in policies will have detrimental effects on sustaining an effective workforce.

Research and development in nuclear technology are increasingly taking place across international borders. Concurrently, civil nuclear deployment and its associated supply chain have undergone internationalisation. As a result, the need has emerged for a more global nuclear workforce.

A key resource – a competent workforce

The nuclear industry is characterised by a requirement for high overall skill levels and a high degree of safety. Safety is a pre-eminent concern in the nuclear industry not only for its own sake, but also its sensitivity in term of public perception and, formally, because of national and regional regulations and international agreements. The importance of education and training in maintaining safety cannot be understated. For all these reasons, safe behaviours are regarded as critical skills in parallel with the specific technical competencies for the job. Managers and leaders have a key role to model appropriate behaviours and to support nuclear education and training in order to generate and maintain a robust safety culture.

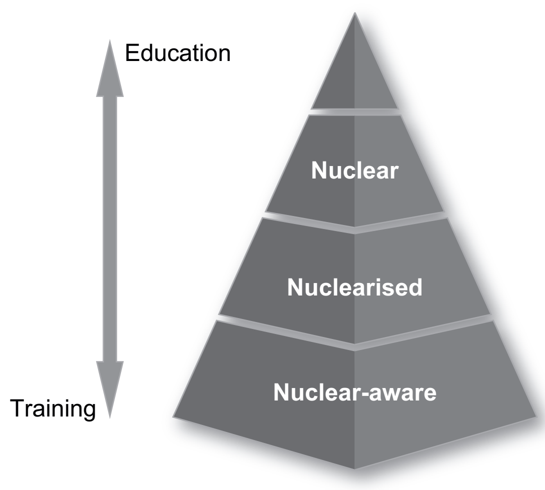
It is useful to recognise that there are various degrees of "nuclearisation" within the industry, that is, the extent to which specific nuclear skills and safety culture training are needed to complement other engineering or management skills. Throughout the workforce, general nuclear awareness is a prerequisite, with more specialised nuclear expertise being required by fewer personnel, depending on the specific job requirements.

A threefold categorisation of the competencies necessary to run a nuclear power plant can be drawn, which includes:

- "nuclear" people with a specialised formal education in nuclear subjects (e.g. nuclear engineering, radiochemistry, radiological protection, etc.);
- "nuclearised" people with formal education and training in a relevant (non-nuclear) area (e.g. mechanical, electrical, civil engineering, systems) but who need to acquire knowledge of the nuclear environment in which they have to apply their competencies;
- "nuclear-aware" people requiring nuclear awareness to work in the industry (e.g. electricians, mechanics, and other crafts and support personnel).

This can be visualised in terms of the pyramid of competence in Figure E.2. Generally there will be a larger number of employees from top to bottom.

Figure E.2: The pyramid of competence



Typically, as one moves from the base to the tip of the pyramid, the acquisition of competencies shifts from training focused on a particular job, task or set of tasks, towards education, developing more in-depth underlying principles that, when properly acquired, can be applied to a less predefined set of circumstances.

Education and training, sometimes viewed as two distinct processes, are intertwined for the preparation of a competent nuclear workforce. Traditionally, vocational entrance has been associated with a stronger training component, while professional routes employ a more educative approach. Pathways are now less rigidly separated, with a necessary degree of interchange to match the development needs of employees. Industry has, in some instances, reacted to the shortage of the technical workforce by recruiting people with adequate competencies in relevant areas but without a nuclear background, which has been imparted to these new recruits through specific training. Industry has also supplemented staff with increasingly large contractor supply chains, in which there is a pressing need to establish and maintain a strong safety culture. This issue is a matter of continual review by safety authorities, as reported in the 2009 NEA Committee on the Safety of Nuclear Installations (CSNI) Technical Opinion Paper on *Improving Human and Organisational Performance*.

Nuclear professionals at the top of the pyramid are crucially important for the research, development and design leading to the safe operation of nuclear installations. This top stratum (which was the focus of the *Cause for Concern* report) is where most nuclear power plant managers can be classified. They are essential for transmitting nuclear safety culture to the entire workforce. For this category, education in nuclear engineering and/or nuclear physics, or experience in non-power nuclear applications (e.g. nuclear navies), are typically a prerequisite. This education is often provided by higher education institutions through bachelor's or master's programmes. In addition, depending on the role, training on simulators (e.g. for reactor operators) and other forms of specific on-the-job training are also required before reaching full professional competence.

Doctoral programmes are necessary to educate a number of specialists and to develop researchers in nuclear science and engineering, and are indispensable for supporting research and development in the industry and research institutions as well as for university teaching.

Since the 2000 NEA report, further concerns were subsequently uncovered with respect to an insufficient supply of operators and technicians to support existing nuclear power plants through their (extended) lifetimes. In the United States, for instance, industry workforce surveys indicate that this constitutes the greatest near-term US workforce need. With prospects of new build and as a part of the growth of nuclear industry on a global scale, even greater attention will be required for the training of the larger part of the nuclear workforce, often transient, forming the base of the pyramid.

Bearing in mind the long lead times generally required for nuclear education and training, the establishment and preservation of an adequate nuclear workforce supply calls for systematic planning decades ahead. In this respect, contradictory energy policies can have grave effects. A deteriorated global context caused by the persistent financial crisis and the negative sentiments in the wake of the Fukushima Daiichi accident heighten uncertainties and may exacerbate existing shortcomings. Indeed, shifting or deferred government decisions act as deterrent mechanisms in investment and employment, and have deleterious repercussions on the interest and engagement of younger people in the industry.

Coherent intervention by governments, industry, universities and research and development organisations thus remains vital to avert the risk of human resource shortages in some countries and to maintain the stock of skilled and competent workers. It is also necessary in order to ensure a flow of new recruits which is sustainable in the long term and adequate, in particular, to offset impending retirements.

Ten years on – the developments

Looking at developments over the past decade, evidence from countries suggests that, in response to persisting concerns and new market conditions, stakeholders have taken actions, albeit not immediate and often driven by external forces. Challenges have been acknowledged and progress has been achieved in addressing certain issues and recommendations raised in the 2000 NEA report. However, overall, concerns remain that a process for providing a sustainable human resource supply has not been achieved in all areas or in all countries.

Governments

In many countries, the educational system is shaped by governments. Hence, while actions by other stakeholders are important, without strong government participation there is limited ability to change the educational system. However, across the board, governments have, in general, done very little of a longer-term and more strategic nature.

Experience shows that active monitoring of demand and supply capacity is a fundamental step for human resource development. However, for it to bear effective and long-lasting benefits, it should be conducted on an ongoing basis, with assessments undertaken regularly and frequently for systematic planning.

In several countries, governments have commissioned workforce assessments. In some cases, the results and recommendations drawn from such surveys triggered significant government actions to address emerging gaps. National councils and bodies have been established (e.g. in France, Japan and the United Kingdom) to undertake labour market research and workforce planning, which has often proven effective for the initiation of government actions in favour of human resource development.

Some governments have provided specific support to university programmes and research, which has contributed, in a few instances, to reversing the declining trends of subscription in nuclear engineering. In many cases, fluctuating policies or lack of long-term strategy for existing programmes contribute to producing human resource development approaches and systems that are deficient, inconsistent or inadequate, if not completely absent.

Recommendation 1

Governments should show a continuous and stable engagement in human resource development planning for the long-term timescales that transcend fluctuations in economic cycles. Government involvement should include regular, active monitoring of demand and supply capacity, as well as allocation of funds to support educational programmes which provide a means of developing and maintaining specialist expertise.

Education

Universities have also striven to make improvements over the last ten years, with some new and advanced nuclear courses being launched in an increasingly global context. In some cases, and notably when assisted by governmental funding and support, academic programmes have succeeded in reversing the declining trend of student recruitments experienced during the 1980s and 1990s. This is exemplified by what has occurred in the United States and in France. Healthier numbers of students have also been attracted by the prospect of new build, or high profile research topics and international projects.

Co-ordination efforts have proved to be an effective means for the promotion or preservation of nuclear education programmes. Academic institutions have achieved this, sometimes in conjunction with other parties (e.g. research centres), through the establishment of networks, the launch of international programmes, or through the amalgamation of courses, which has been vital in countries with fading nuclear programmes or with a small demand for specialists.

Noteworthy is the creation in some countries of inter-university consortia and college partnerships, allowing early interaction with young students. Some universities have engaged with technical colleges to address the increasing demand for craft and technical skills. Some courses have been specifically devised for the "nuclearisation" of non-nuclear professionals.

However, in many countries, supply has not yet reached a sustainable level taking into account future demands.

Recommendation 2

Universities should intensify efforts, in collaboration with industry, to provide a greater range of courses and with greater flexibility in means of attendance by students.

Recommendation 3

Governments should support educational institutions and nuclear technology students at technical colleges to ensure there is a well-rounded workforce available for all of the nuclear careers.

Research facilities

The integration of national research facilities and academic institutes in international frameworks has generally grown. It is widely recognised that strong research programmes, increased participation in international initiatives and greater involvement of government, industry and academia in research and training can considerably improve the attraction of high-calibre students and young researchers in the field and improve their education. This collaborative approach must continue.

Co-ordination with universities and other stakeholders has been pursued by research organisations, namely through direct participation in academic curricula, the promotion and delivery of courses and seminars to a varied audience, the offer of internships, the provision of well-equipped laboratories and guidance to domestic and foreign students for their research, the awarding of prizes, grants and fellowships, and the organisation of visits.

Building on a recent activity developed by the European Union Sustainable Nuclear Energy Technology Platform, a survey was undertaken across NEA countries to measure the availability and level of use of nuclear research infrastructure for education and training. Owners or operators of facilities were requested to provide information by means of a questionnaire. This survey indicated a concern over the number and utilisation of research reactors in some countries. Thermal-hydraulic loops are less susceptible to obsolescence and hence there is much less concern over availability and ageing. However, they also appear to be largely underutilised for education and training. Full advantage should be taken of these existing facilities, including available industry research infrastructure. The following recommendations are based on the outcomes of this investigation.

Recommendation 4

Access to research facilities suitable for education and training purposes should be widened and international co-ordination for such uses should be enhanced. Efforts should be made by governments to financially support existing infrastructure.

Recommendation 5

Research and academic institutions offering laboratory sessions, including computer simulations, should take new initiatives for the collection and preparation of pedagogical materials (books, software) in support of such sessions.

Computer models and computer simulations do not replace laboratory sessions but can enhance theoretical understanding. The role of simulators in training is mandatory in some countries and is becoming increasingly widespread. Nonetheless, the general view remains that their use in training and education is still to be considered complementary to hands-on training.

Recommendation 6

Research facilities should work with industry and academia to create opportunities for more effective use of research facilities so as to enhance education and training.

The NEA report on *Nuclear Competence Building* testified to the deterioration of the financial situation of research institutes, in many countries due to cuts in public funding and to tough competition in the niche market where they sell their services and products. Although this outlook seems to have improved in a few countries, with funds being directed to research and development and the support of research infrastructures, concerns have been raised over the fact that many expensive and unique facilities were put into operation in the 1960s. Some of them have already been shut down as will a substantial number of others in the next few years.

Recommendation 7

Special attention should be directed to the needs of universities for access to relevant nuclear instrumentation and critical facilities, including research reactors to perform research and enhance education. Infrastructure support should be provided to maintain existing nuclear facilities, where these can be refurbished, or to replace them when they are obsolete.

In this regard, the example of the United States is noted, where the Department of Energy supports over 20 university research reactors and has funded nuclear energy research and equipment upgrades at US colleges and universities.

Industry

The engagement of industry has generally been consistent and vigorous across the board. In the past few years, in view of a prospective nuclear renaissance, major industrial players succeeded in ramping up their recruitment rates worldwide.

Sometimes industry initiatives have also led to commendable examples of collaboration with universities and other parties, such as the funding of chairs and the sponsoring of educational and research programmes, the direct involvement in the development and delivery of courses, the offer of internships and, in some cases, the opening of research infrastructure to students.

In some countries, the industry has also been engaged in the monitoring process of human resource demand and supply and has fruitfully partnered with local universities and community colleges to address emerging gaps across different levels. Of particular note is the industry participation and initiative in the establishment of multilateral education networks. The partnership between US utilities and technical colleges has created the Nuclear Uniform Curriculum Program to address the supply of technicians in the United States. Some existing networks such as the University Network of Excellence in Nuclear Engineering and the European Nuclear Education Network are considering expanding their scope to train technical personnel, which is fully supported.

Recommendation 8

Networks such as those developed for educational programmes should be expanded to cover technical training as well.

Most major industrial actors have developed and maintained strong internal vocational training processes to prepare their personnel and to ensure re-staffing. In some cases, large training centres and programmes have been set up to satisfy the high and diverse recruitment needs. However, as discussed above, attrition is still acute and in some countries the industry has been unable to retain professionals and has suffered a drain of nuclear skills towards other sectors or, in an increasingly globalised context, towards other countries.

Typically, if favourable conditions are instated, careers in the nuclear sector offer the appealing prospect of highly secure and long-term employment, which represents a point of strength of the industry.

Recommendation 9

In order to attract and retain high-calibre young professionals and avert cross-sector and cross-boundary attrition, the industry should provide competitive remuneration, career opportunities and recognition.

One continual challenge facing the nuclear industry is maintaining and continuously enhancing safety culture, which is difficult to measure. A further challenge comes from the fact that the few multinational suppliers are confronted with many different standards and codes, as well as the diversity produced by a global supply chain.

Internationalisation

A general tendency characterising the sector has been the significant and increasing internationalisation. With a consolidated market of few global technology vendors and progressively more research and development projects developed across national borders, recent years have witnessed an increased globalisation of the civil nuclear industry and its supply chain. Nuclear power has become an international business bounded by international agreements. Greater emphasis has been placed on international collaboration for regulation, basic research and development, as well as the intricate global supply chains involving utilities, vendors and contractors in manufacturing, engineering, construction, operations, maintenance and decommissioning.

In connection with the increased internationalisation, new questions and issues have emerged, such as student and human resource mobility, quality control of education and training, greater understanding of different nuclear job profiles, and the need for a set of transferable nuclear competencies and safety awareness that support an international supply chain.

This has prompted many international initiatives. The various new programmes of international and intergovernmental bodies have given rise to means by which organisations may source or collaborate on research, education, training and knowledge management at a range of levels internationally, and instruments by which they can also draw from and contribute to labour market research on the supply and demand of human resources in nuclear energy.

Global partnerships committed to enhancing international education and leadership in the peaceful application of nuclear science and technology have been established in the last few years, such as the World Nuclear University and the European Nuclear Energy Leadership Academy. The role of the European Commission in supporting human resource development has been particularly noteworthy and has resulted in many new initiatives such as the European Nuclear Education Network, the European Fission Training Schemes, the European Human Resource Observatory in the Nuclear Energy Sector and the European Nuclear Safety and Security School.

Recommendation 10

Governments should strongly encourage and support international initiatives and programmes, which foster consistent quality of the education and training being delivered in different countries and overall contribute to enhancing human resource development capacities.

In this new context, in addition to the duties of countries with respect to existing national programmes, there is the emerging responsibility of providers and vendors to develop a competent workforce in recipient countries. Various bilateral and multilateral agreements have been established at different levels (institutional, academic and industrial) and numerous transnational education and training projects have been initiated in several countries. Yet, even with the international components emerging in the nuclear industry and increasingly in education, the responsibility for national education ultimately remains with individual governments.

Countries with strong national nuclear activities, facilities and resources have initiated programmes to “train the trainers”, which complement similar programmes conceived by international organisations (notably the International Atomic Energy Agency). These are implemented in close co-operation with interested countries and specifically tailored to their needs and local education systems with the aim of forming a strong pool of indigenous human resources.

The uptake of transnational programmes as well as regional and national networks has often benefitted from improved technological means. Novel communication systems and IT instruments can be more appealing to new generations, and their dissemination has allowed the development of effective and innovative learning methods. Increasingly, web-based resources as well as distance learning are embraced as common practices both by education and research institutions as well as industry training programmes. This has helped to enlarge the pool of prospective students. Through distance learning, students can take courses even when these are not available at their own university, during a semester when they may not be taught, or, importantly, when physical or geographical obstacles would prevent their physical attendance or make it significantly more onerous. However, this raises the issue of consistency and certification.

Job taxonomy

Recognising this emerging internationalisation of the workforce and the overarching priority to ensure safety, and drawing from the experience of a number of countries, the expert group responsible for this study researched and classified a set of job roles with significant nuclear competence that are found across the nuclear industry. This effort laid the basis for the development of a classification system for nuclear job profiles: a job taxonomy framework.

The proposed taxonomic system is of course nominal. It is neither a final nor a unique solution, but it provides a first step to assist the development of classifications.

Nuclear job specifications have been produced for the main activities associated with the construction, operation and decommissioning of commercial and research reactors, drawing up on analyses conducted by a number of companies. These may serve as an initial platform on which organisations or governments can overlay their own specific requirements.

An analysis of commonalities has led to the following findings and recommendations:

- Competence in technical and regulatory matters features consistently and prominently in nuclear job specifications across the globe. Nuclear safety culture is inextricably linked to both.
- Information, advice and guidance on training, especially concerning technical and regulatory competencies, could be improved through accreditation of training, whether provided in-house or outsourced.
- There are limited international occupational standards to guide nuclear training and workforce development,[1] although there are national standards such as those established by the Institute of Nuclear Power Operations in the United States.[2]
- Apart from the National Nuclear Accreditation Board in the United States and the National Skills Academy in the United Kingdom, there are no other independent national bodies for the accreditation of nuclear training.
- Taxonomy as a tool in workforce development can aid workforce planning in elaborating scenarios for the supply and demand of skills, in developing training standards, and as a structure for competence assurance management systems such as nuclear passport schemes.
- Both governments and employers can benefit from access to high-quality labour market intelligence and training standards. This can inform, for example, targeted policy interventions such as directives on training or prioritisation of resources for higher education and research.
- Dissemination of international guidelines for training and competence assurance would assist employers in choosing or designing appropriate workforce development programmes.

Recommendation 11

Drawing from the experience of the National Nuclear Accreditation Board in the United States, it is recommended that:

Consideration should be given to carrying over to training the accreditation and certification culture that is well established in education, and to establishing independent accreditation and certification of training provision and employer schemes.

1. It is noted that at a European level there is a strong drive to structuring training and career development across the EU and to establishing European high-quality “reference standards” with the ultimate objective of creating a European competence passport.
2. It is worth noting that the work done by the Institute of Nuclear Power Operations (INPO) for operators is distributed internationally by the World Association of Nuclear Operators (WANO).

Safety culture permeates nuclear job specifications. In this regard, the proposed taxonomy brings into prominence not only the competence assurance considerations of the previous section, but also the technical and regulatory competencies, both of which relate to safety.

Recommendation 12

There appears to be international consensus on the fundamental components of basic nuclear training covering fundamental technical and regulatory matters to support the production of an outline programme in "basic nuclear awareness" that could have value for the international community. It is therefore recommended that:

Consideration should be given to the provision of an outline for training in "basic nuclear awareness" with content adequate to cover both the range of nuclear sectors and the range of occupational levels.

Reference

Li, N., C. Dale, K. Kern and S. Scott (2009), "Los Alamos Nuclear Enterprise Resource and Infrastructure Model (LA-NERIM)", Los Alamos National Laboratory, Proc. International Congress on Advances in Nuclear Power Plants 2009 (ICAPP 2009), 10-14 May 2009, Shinjuku, Tokyo, Japan.

Nuclear Education and Training: From Concern to Capability

The OECD Nuclear Energy Agency (NEA) first published in 2000 *Nuclear Education and Training: Cause for Concern?*, which highlighted significant issues in the availability of human resources for the nuclear industry. Ten years on, *Nuclear Education and Training: From Concern to Capability* considers what has changed in that time and finds that, while some countries have taken positive actions, in a number of others human resources could soon be facing serious challenges in coping with existing and potential new nuclear facilities. This is exacerbated by the increasing rate of retirement as the workforce ages. This report provides a qualitative characterisation of human resource needs and appraises instruments and programmes in nuclear education and training initiated by various stakeholders in different countries. In this context, it also examines the current and future uses of nuclear research facilities for education and training purposes. Regarding the nuclear training component of workforce competence, it outlines a job taxonomy which could be a basis for addressing the needs of workers across this sector. It presents the taxonomy as a way of enhancing mutual recognition and increasing consistency of education and training for both developed and developing countries.

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