Nuclear Knowledge Management Challenges and Approaches

Summary of an International Conference
Vienna, Austria, 7–11 November 2016

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NUCLEAR KNOWLEDGE MANAGEMENT CHALLENGES AND APPROACHES

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

PROCEEDINGS SERIES

NUCLEAR KNOWLEDGE MANAGEMENT CHALLENGES AND APPROACHES

SUMMARY OF AN INTERNATIONAL CONFERENCE ORGANIZED BY THE INTERNATIONAL ATOMIC ENERGY AGENCY IN COOPERATION WITH THE OECD NUCLEAR ENERGY AGENCY AND HELD IN VIENNA, 7–11 NOVEMBER 2016

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FOREWORD

Appropriate technical expertise and experience, along with a strong safety culture, must be developed and kept available throughout the nuclear technology life cycle. Nuclear equipment, installations and facilities may have long life cycles with changing operational conditions. Advanced and specialized knowledge in nuclear engineering and science is required for the safe and effective design, construction, licensing, commissioning, operation, maintenance and decommissioning of nuclear technology based systems. The safe use of licensed nuclear facilities and technologies is dependent on the ongoing availability and maintenance of suitable knowledge and expertise, and an adequate understanding of related safety issues. For organizations using nuclear technology, the ability to take safe decisions and actions can be affected by knowledge gaps or knowledge loss. Appropriate methods and supporting technology are needed to establish and manage nuclear competencies, information and records, work processes, and analysis and verification techniques, and for the interpretation of data.

To further improve awareness of the importance of knowledge management in the nuclear sector, the IAEA organized the Third International Conference on Nuclear Knowledge Management: Challenges and Approaches, held from 7 to 11 November 2016 in Vienna. The conference was a follow-up of the first and second conferences organized by the IAEA on nuclear knowledge management, held in 2004 in Saclay, France, and in 2007 in Vienna. The conference also built on the outcomes of the IAEA conferences on human resources development held in Abu Dhabi, United Arab Emirates, in 2010 and in Vienna in 2014.

Through the presentation and discussion of issues and solutions related to building, collecting, transferring, sharing, maintaining, preserving and utilizing knowledge, Member States had the opportunity to strengthen their capabilities in this area by learning from various stakeholders. Participants shared experiences, lessons learned and practical approaches related to managing nuclear knowledge, which can be used to develop and maintain a strong nuclear knowledge base at the organizational, national and international levels. Various issues were addressed in relation to human resource development, competencies, methodological or process knowledge and technology related knowledge — elements necessary to support the safe and sustainable application of nuclear technology. The conference consisted of both plenary and parallel sessions, combining high level, keynote sessions with more practical sessions. The event also featured exhibitions, forums and panels, as well as tutorials and workshops.

This publication presents the key findings and recommendations of the conference participants, as well as the opening statement of IAEA Director General Yukiya Amano and the conclusions of the conference president. The papers presented and discussed during the meeting are included on the attached CD-ROM.

The IAEA wishes to thank all the conference participants — particularly the Programme Committee, the session lead chairs and co-chairs, and the conference rapporteur, P. Gowin (Germany) — for helping to make this conference a success. Special thanks and appreciation go to the conference president, V. Pershukov (Russian Federation) and Vice Presidents Y. Fanjas (France) and F. Osaisai (Nigeria). The IAEA also acknowledges the generous support of all exhibitors and sponsors. The IAEA officer responsible for this publication was M. Urso of the Division of Planning, Information and Knowledge Management.

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1. INTRODUCTION

The Third International Conference on Nuclear Knowledge Management – Challenges and Approaches was organized by the International Atomic Energy Agency and held in Vienna from 7 to 11 November 2016. The event was attended by high-ranking officials and experts from 61 Member States and 10 international organizations, with 450 officially registered participants and observers. The conference was co-organized by the OECD/Nuclear Energy Agency (NEA).

Background

The programmatic activities of the International Atomic Energy Agency encompass a dedicated sub-programme on nuclear knowledge management which focuses on:

- Developing methodologies and guidance documents for planning, designing and implementing nuclear knowledge management programmes;
- Facilitating nuclear education, networking and experience exchange;
- Assisting Member States by providing products and services for maintaining and preserving nuclear knowledge;
- Promoting the use of state of the art knowledge management technologies and supporting interested Member States in their use.

Organized within this sub-programme on nuclear knowledge management, this was the third IAEA conference on the subject. The first conference was held in 2004 as *International Conference on Nuclear Knowledge Management: Strategies, Information Management and Human Resource Development* in Saclay, France, the second in 2007 as *International Conference on Knowledge Management in Nuclear Facilities*, held in Vienna, Austria.
In addition, related topics, including capacity building, human resource development (HRD), education and training (E&T) and knowledge management (KM) were addressed in a number of other conferences, including the 2010 IAEA *International Conference on Human Resource Development for Introducing and Expanding Nuclear Power Programmes*, held in Abu Dhabi, United Arab Emirates, and the 2014 *International Conference on Human Resource Development for Nuclear Power Programmes: Building and Sustaining Capacity – Strategies for Education and Training, Networking and Knowledge Management*, held in Vienna, Austria.
Since 2002, the IAEA General Conference considers nuclear knowledge management in its resolutions. The 60th Session of the IAEA General Conference of 2016 reiterated earlier resolutions on nuclear knowledge management that request the IAEA to develop and continue corresponding activities.

Objectives

The purpose of the conference was to:

- provide an opportunity to share experiences and lessons learned in the nuclear sector related to managing nuclear knowledge and
- share practical approaches to knowledge management that can be used at the organizational, national, and international levels to develop and maintain a strong nuclear knowledge base.

Various issues related to specific human competencies, methodological or process knowledge and technology-related knowledge that are needed to support the safe and sustainable application of nuclear technology were addressed.

Conference Arrangements

The conference was opened by Y. Amano, Director General of IAEA. V. Pershukov, Russian Federation, served as conference president, P. Gowin, Germany, as conference rapporteur. The Scientific Secretaries of the conference were J. de Grosbois and M.E. Urso, Nuclear Knowledge Management Section, IAEA.
The scope of the conference encompassed eight thematic areas, exploring both cross-cutting aspects in nuclear knowledge management and specific applications of nuclear technologies:

1. Strategic and cross-cutting KM issues in organizations;
2. Managing knowledge for new build projects and programmes in newcomer and expanding countries;
3. Managing knowledge for operating nuclear facilities;
4. Managing knowledge for decommissioning and environmental remediation projects, including in countries with phase-out plans;
5. KM for nuclear regulatory compliance;
6. KM for non-power nuclear science and applications;
7. KM in nuclear technology research, development and innovation; and
8. Issues and approaches for information and records management.

Following the opening plenary session, the eight thematic areas were addressed through one or more topical sessions, plenary or parallel.
To accommodate the broader, overarching nature of the first thematic area on strategic and cross-cutting KM issues in organizations, this was split in different sub-themes, as listed below, which were addressed in dedicated sessions:

1a KM challenges and approaches;
1b Human resource development;
1c Training and competency development;
1d Nuclear education and outreach;
1e Networking and technical communities of practice; and
1f KM methodologies and implementation approaches.

The conference was closed with a plenary session and presentation by the conference president on insights gained, conclusions and recommendations.

About the Proceedings

These proceedings have been compiled and edited by the IAEA after the conference. They document the objectives, arrangements and discussions, insights gained and conclusions made during the conference.
They are based on the statements made during the conference, the papers presented orally or in interactive sessions, the panel discussions at the end of technical session and the discussion at the concluding panel during the closing session.

An overall summary of the Conference is reported in Section 2, while summaries of sessions by topics are provided in Section 3. These are structured according to conference themes and sub-themes, as defined above, but for sessions on closely related topics summaries have been combined.

The opening statement delivered during the initial plenary session by Y. Amano is reported verbatim in Section 4, while Section 5 reports the closing statement delivered by the Conference President.
The attached CD-ROM contains:

- all available conference papers and materials per thematic area; and
- a selected set of references to IAEA publications, tools and services available for capacity building, HRD, E&T, KM and for knowledge networks.

Additional material can be found at the conference website: https://www-pub.iaea.org/iaeameetings/50805/Third-International-Conference-on-Nuclear-Knowledge-Management-Challenges-and-Approaches

2. TECHNICAL SUMMARY OF THE CONFERENCE

This Section contains a summary of the insights, results and lessons learned from the opening keynotes and the different sessions of the conference, including the panel discussions, the question and answer and the final plenary session of the conference.
Overall, the conference put increased focus on the strategic importance of Nuclear Knowledge Management. The IAEA Director General, Y. Amano asserted himself how KM should be core to every type of nuclear programme. The importance of KM in the nuclear safety approach and safety culture was reiterated, along with its essential role in supporting its reliable, economic and sustainable performance in the nuclear sector.
Presentations and discussions indicated that, in general, the awareness and adoption of KM have increased. However, its application varies greatly across different stakeholders. In the context of nuclear power and nuclear safety, owner-operators, regulators and private companies, knowledge management is now broadly adopted and generally well known. Although appreciation on the role of KM has grown in research and development, academia or nuclear power management, more could be done to make full use of it.
In addition, in the nuclear sector, which typically operates for long to very long timespans, in multi-stakeholders environments and with a multiplicity of interfaces, the capture, conservation, transfer and overall management of design knowledge over the technology lifecycle are of utmost importance, as is managing KM across organizational borders and barriers. With a more engrained adoption of NKM, knowledge should be managed in a more pro-active and holistic fashion, covering the full life-cycle. In addition, greater KM coordination could be pursued also at the national level, e.g. by establishing national workforce plans aligned with industrial recruitment needs of different stakeholders and joint qualification standards.
The most significant activities for NKM have still been predominantly developed at the organizational level. However, even if greater maturity in the application of KM is being witnessed, still rare are the cases where KM processes are actually assimilated into the organization structure and become embedded in the daily operational processes, the organizational culture, and the integrated management system.
The next step ahead is to increasingly foster such integration for technical functions, but also for management purposes including governance, monitoring, auditing, transparency & leadership, and so promoting the development of ‘learning organizations’. This is strongly advocated in the emerging ISO KM Standards (part of ISO 9001:2015 and ISO 30401:2016).
Innovation in information and communication tools is being introduced at a very fast pace, with the introduction of ground-breaking technology that has impacted ad has the potential of profoundly changing personal and professional settings. Clearly technology is no longer a limiting factor in KM processes. KM, and particularly data and record management, can

greatly benefit from innovative tools such as semantic approaches, plant information models, 3-D modelling, big data and artificial intelligence, which can tremendously broaden accessibility and timely availability of data. Yet, as much as technology represents a powerful enabler of KM, emphasis should stay on the individual that remains at the heart of knowledge processes. Interpersonal factors, communication and interactions, issues linked to underlying cultures and attitudes play a profound role in KM.

In this respect, the implementation of communication measures and cultural changes, the ability to deal with feedback and the use of error prevention techniques are all central elements to the development of learning organizations.

KM mechanisms that have proven to be effective, and must be further promoted, are based on this human and communicational stance. Increasingly recognized is the importance of active networks, communities of practice and "capability clusters", at the organizational level but also spanning broader nets up to the regional and interregional level. Effective collaborative approaches boost and enrich the creation and sharing of knowledge more than any other asset. Equally, synergies in learning processes are gradually more adopted, for instance by bringing together senior experts and young professionals, and creating learning teams.

Clearly nuclear E&T remain the basis of HRD for any nuclear programme – its adequate provision is a cornerstone to ensure and sustain a suitably qualified and competent workforce. In education, networks and partnerships have been adopted for quite some time and have proven to be of key value to enable collaboration and synergies and help retain and boost MSs capabilities in nuclear E&T programmes, making them more sustainable.

More and more multi- and interdisciplinary approaches are adopted in devising academic degrees and courses, with much attention and increasing integration of elements related to management and leadership.

As the younger generation embraces new technologies and different ways of learning, the delivery of E&T has to keep adaptive, and apply new modes and solutions. We have seen the advent and increasing adoption of e-learning, blended learning and also massive open online courses which adopt learning management systems. Education and particularly training providers develop approaches that give courses higher visual content, greater interactivity and instant access to information.

For many years, the IAEA has accompanied MSs in the challenges and needs they faced across these disparate levels of nuclear knowledge management, providing assistance and guidance in the introduction, adoption and advancements of KM methodologies and practices, through targeted publications and services.

3. TECHNICAL SUMMARIES OF SESSIONS BY TOPIC

The following Section contains a summary of the individual plenary or (partly parallel) technical sessions of the conference, including panel discussions, questions and answers.

Each session summary was prepared through the respective session chair, session rapporteur and support by the IAEA.

Knowledge Management Challenges and Approaches

The management of knowledge is deeply entrenched within specific perspectives, contexts, approaches and purposes, which render knowledge management (KM) a complex and multifaceted discipline, and make absolute and general statements and techniques difficult to draw. Therefore, when assessing knowledge management in the nuclear sector, it is important to understand the wider context in which the sector operates, taking stock of its current status and prospective role. The contribution that nuclear power can offer in addressing increased demand for energy and concerns over climate change and security of supply is still substantial. The achievement of the proposed 2°C increase limitation of the global mean surface temperature above that of pre-industrial times, as agreed by the parties of the United Nations Framework Convention on Climate Change (UNFCCC) at their COP21 Paris Accord, poses tremendous challenges.

Despite questions and setbacks raised in the aftermath of Fukushima, nuclear technology is set to maintain an important role globally, both for future energy generation as well as all other applications.

Also, importantly, non-power applications of nuclear technology and materials will continue within most Member States for a widespread array of industrial, scientific and medical purposes.

Each country's situation and history with nuclear technology application is different, and NKM strategic issues and immediate priorities depend on national contingent contexts.

However, regardless of the type of programme and its degree of maturity or the specific applications, the safe and sustainable deployment and use of nuclear technology will always be heavily reliant on a highly trained and specialized workforce. The nuclear industry is highly regulated, with stringent standards for performance and competence. Therefore, preparing and developing specialists in the field requires considerable time and effort.

Looking at the current status of operating nuclear fleets, over the last decade the trend towards lifetime extension has continued, increasing the expected lifespan of nuclear power plants (NPPs) up to 80 to 100 years. This entails the participation in NPP design, construction, operation and decommissioning of three or four generations of nuclear workers.

In addition, in countries with mature NPP programmes, a considerable proportion of plants have been shut-down or are approaching the end of their design-life. The sizeable decommissioning programmes and environmental remediation, along with the management of spent fuel and radioactive waste resulting from these, pose unique challenges for NKM, particularly severe in phase-out programmes.

Necessary competencies must be retained over long to very long timescales. The existing talent-base in nuclear technology and science has been established since the mid-20th century. The pioneering generation is now long retired and the generation they trained during the growth period of nuclear technology is also close to retirement.

On one hand, knowledge accrued during the pioneering period must be preserved. Scientific research reports, design documentation and other publications support the preservation of such knowledge, which is, in part, also reflected in university training programmes. On the other hand, there is still apprehension on how the skill base can be sustained.

The ageing of the nuclear workforce is still an issue for countries with established programmes, where age distributions typically exhibit bi-modal patterns, with prevalent staffing of experts at the more senior level, impending retirement, and a lower peak at the junior level.

The need to address inter-generational knowledge transfer is still very prominent and can be exacerbated by the reduction in government funding, major shifts in energy policies and programmes, or transitions in the life of nuclear facilities, further weakening student interest and enrolment in science and engineering programmes.

This is particularly critical for the pool of researchers and scientists in applied science and technology, which can be nurtured through challenging activities such as research and advanced technology development projects.

These intertwined issues pose challenges that are very demanding to address even for the major and best-funded national programmes. Noteworthy efforts need to be made to uphold sufficient skilled workforce and attract new talent, in order to ensure long-term sustainability.

In this respect, collective work at the international level can be a catalyst for creating innovative ideas, attracting new talents and establishing networks of technical leaders. International research programmes can provide stimulating opportunities for scientists to contribute meaningfully as part of a large, multidisciplinary and multinational effort. Such efforts facilitate the capture and transfer of state-of-the-art know-how to the next generation of emerging scientists and engineers, and, if practically oriented, can also contribute in solving real-world problems.

Transnational and international collaboration and support are of particular relevance for developing countries with limited educational training infrastructure, even for nuclear science and technologies uses exclusively oriented towards non-power applications. For such countries, building the requisite manpower and national capacity, as well as managing and preserving knowledge, to efficiently secure the benefits of nuclear technology in the different sectors can be very demanding. Whereas the accountability for increasing the critical sectoral manpower in the areas of applications may lay with the mandated national institutions, the respective national atomic energy commissions could play a key role in setting out the national agenda and strategy, and laying the foundation for building the human resource base critical for a successful and sustainable programme implementation.

Besides retaining the necessary competencies, the adequate nuclear knowledge base must also be sustained over long to very long timescales. The capture, conservation, transfer and overall management of design knowledge over the technology lifecycle are very important issues that require careful consideration to ensure both the economics and safety of nuclear facilities over their lifetimes. This is important in lifetime extension and refurbishment projects, but also for decommissioning and environmental remediation (D&ER), to ensure that critical knowledge is preserved and activities are undertaken and implemented in a responsible and cost-effective manner.

It is however vital that design knowledge management (DKM) is adequately undertaken right from the onset of a new-build project.

Countries gearing up for new build construction are facing other specific challenges, having to bolster the required workforce and competencies to ensure readiness for construction and commissioning schedules, as well as for future operation. New-build projects are being undertaken in increasingly more complex, international environments. These are sometimes coupled with mid-project changes, new partnerships and alliances, while new facility ownership and business models are progressively being introduced.

Outsourcing services, with an increased reliance on non-domestic expertise, has become a common practice, not only in new-build projects.

Such new models and paradigms call for different KM approaches to guarantee that critical knowledge is accessible and preserved across organizational boundaries.

The construction project of Olkiluoto 3 NPP in Finland showcases interesting lessons-learned, among others, on the importance of understanding the evolution of the design and its implications in terms of knowledge management. The management of the plant's design data, and the approach adopted in relation to design compliance in Olkiluoto 3 have played a key role in the project, demonstrating how the assessment of the range, scope and impact of design changes deserve special consideration. In order to guarantee a reliable set of design documentation, clarity, focus, consistency, precision and accuracy of the information content are fundamental. Information quality also represents an important defy: the design and its enactment must be compliant with regulatory requirements and the definition and realization of design requirements must be traceable and verifiable.

Building adequate technical competencies to support the plant during start-up and operation was also of central concern. A systematic approach to training was implemented, which is oriented towards building clusters of competences. One of the strategies adopted was to promote “capability clusters" whereby plant staff are cross-trained, developing the ability to act as back-ups for one other.

Capability clusters are an important element of organizational learning. The concept of learning organizations is a more nuanced notion increasingly acknowledged in KM, essential for nuclear organizations as for any other organizations operating in high-reliability industries.

Organizational learning is achieved, first and foremost by enabling paradigm shifts in the culture of the organization and the individuals, towards robust communication and knowledge sharing. Personal attitudes must be continuously safety-minded and self-reflected, while response, feedback and confrontation with others are required to improve one's personal skills and boost learning processes. Elements that favour effective knowledge sharing include: an open leadership climate, the capacity to learn from failure, good information quality, satisfaction with change processes, performance orientation and a vision for change. Structural changes are only of subordinate significance compared to cultural changes.

To facilitate the free flow of information and ideas that fosters organizational learning and to remove existing barriers to knowledge sharing, EDF Energy Nuclear Generation established an organizational learning portal. The transfer of existing data from legacy systems onto the portal required considerable effort, but was important to ensure that information and knowledge was preserved and available for future use.

Knowledge portals are only one example of different networking solutions that have proven successful in learning organizations. Networks, centres of excellence, and communities of practice can enable collaborative learning and provide effective tools to transfer good practices, share knowledge and programmes, and support nuclear training and education services. Research in the area of collaborative learning in the community of scientists carried out within the scope of a doctorial project from the University of Liege (Belgium) demonstrated the benefits of such networking solutions.

However, key factors for their success are the staff willingness and active involvement in sharing knowledge and ideas.

Technical Communities of Practice (TCoP) that focus on specific knowledge domains can help the successful implementation of initiatives and programmes; national stakeholder networks can benefit strategic capacity building, while wider networks can foster regional and interregional cooperation.

Numerous notable examples of networks and TCoPs are already benefiting the nuclear industry on multiple levels, including individual, organizational, national, regional and international.

At the regional level, the European Nuclear Education Network (ENEN) strives to develop a more harmonized approach for education in the nuclear sciences and nuclear engineering in Europe.

The European Atomic Forum (FORATOM) and the European Nuclear Society (ENS) established a joint taskforce dedicated to education, training and knowledge management issues in nuclear with the main purpose of strengthening the link between industry, research institutes and education and training stakeholders at the European level.

IAEA fostered educational networks: ANENT (Asian Network for Education in Nuclear Technology), LANENT (Latin American Network for Education in Nuclear Technology), AFRA-NEST (African Network for Education in Nuclear Science and Technology) and STAR-NET (The Regional Network for Education and Training in Nuclear Technology) promote activities related to knowledge sharing and dissemination among educational institutions in different regions, with the aim of strengthening education, training and outreach.

The NKM Section was encouraged to continue efforts to promote TCoPs for NKM practitioners and support regional nuclear education networks, helping them strengthen their sustainability and leverage strategic benefits. Equally, the NKM Section works to promote the establishment and effectiveness of national stakeholder networks for human resource development and knowledge management.

The IAEA, as a major international organization in the nuclear area, is itself a knowledge organization. In order to support Member States in a wide area of activities related to the peaceful uses of nuclear energy applications, the IAEA works effectively and efficiently and manages the organization's knowledge through a systematic approach to corporate knowledge management (CKM). During the last decades, several KM mechanisms and tools, which constitute the IAEA's CKM system, have been established and used to manage knowledge at the IAEA. The CKM system aims to provide a coordinated, one-house approach to KM and its related activities, ensuring that they remain a part of results based and quality management activities in the Secretariat, ultimately enhancing the effectiveness and efficiency of programme delivery.

Human Resource Development

The nuclear industry relies heavily on a highly trained and specialized workforce for its safe, economic and sustainable development and operation. The management of human resources is particularly critical in the industry, due to the very high standards required in terms of performance and competencies of nuclear specialists, whose development, accordingly, requires considerable time and effort. In addition, issues related to attrition and succession planning remain a challenge for many nuclear organizations, including operating utilities. Thus, proactive strategies and systematic implementation of effective programmes for human resource development (HRD), along with adequate measures to protect against critical knowledge loss, are of the essence.

The sessions held around the central theme of HRD addressed such concerns and ideas that have been recurrent in the industry, along with other considerations emerging from concrete experience. These were conveyed through a variety of examples and notable initiatives currently seen in different Member States as well as at the IAEA.

Topics covered included workforce planning, competency management, knowledge transfer required to cater with impending retirements, training and continued professional development (CPD), along with performance monitoring and improvement. Presentations and discussions also addressed impacts of societal changes, consequences and expectations of an increasingly more global and mobile workforce, the benefits of ongoing and potential international co-operation, and, not least, the call for an enhanced and sustained alignment of education with the industry needs.

Managing essential knowledge as a strategic organizational asset is a factor of high relevance in today's nuclear organizations, and competencies are seen as critical carriers of knowledge.

Several presentations highlighted the importance of appropriate competency management through the establishment of models or systems in nuclear organizations. These are vital to manage effectively and efficiently the present nuclear human capital, and to forecast competences necessary in technical, scientific, and managerial areas.

In order to be effective, competency-based models or systems have to be fully designed and integrated within the strategic organizational infrastructure. Appropriate competency models could aid capturing the present reservoir of explicit and tacit knowledge related to specific functions or organizational areas. They could also be used to characterise new or alternative designed functions or to determine the needs for future positions.

Notable in this respect is the system adopted for training and development by Amec Foster Wheeler (now Wood plc (Nuclear)), which encompasses a competency assurance system (CAS) towards an effective management of competencies. This modern system enables full integration of core-business systems such as HR, finance and training, to monitor qualification and skills of staff. A system of competency grading from one to four allows (potential) employees to effectively sell their capability to the nuclear industry. Some of the reported advantages of CAS include providing a method to assign, verify and demonstrate competency of staff to clients, a way for managers to obtain an overview of the health of the organization's capability. This can assist in carrying out performance reviews and in managing knowledge by capturing experience and critical knowledge of staff. CAS can help manage the 'Age Gap' and 'staffing margin' that allows to have a pool of new trainees in place, which would be available when the need arises, acting as a feeder tank to the loss of industry workforce. While constituting an interesting method to help overcoming the demographic challenges experienced by the UK nuclear industry, the 'staffing margin' concept requires robust cost-benefit analyses.

Exemplar programmes of workforce planning and KM have been developed at Palo Verde NPP in the USA to support future competency needs of the organization. These are centred on organizational proficiency and the concepts of 'independent competent worker' and 'expert worker' in the KM continuum, and span HRD needs of employees at the start of their career in the industry, their development during the first four years of employment, through to their mid-career, and into the retirement phase.

The programmes cover also roles and responsibilities related to HR and leadership functions within the nuclear organization. The role of an established 'People Health Committee' in the NPP was mentioned as strategic in looking ahead and ensuring effective planning.

Another notable initiative is the 'Tournament of Young Professionals', a programme deployed by Rosatom across their nuclear workforce. The programme is aimed at promoting knowledge sharing and transfer across Rosatom's broad range of technical nuclear experts to reach new recruit and future cohorts of graduates joining the Russian nuclear sector. The tournament has an important role in supporting the strategic HR objectives of staff development and NKM activities. This initiative has proven that the employee selection process yields knowledge that is of actual and practical importance to be reused and applied on the nuclear industry sector scale. It has also demonstrated that mentoring is not only quintessential in the transfer of knowledge, but that it is a two-way road where the expert mentors are also enjoying experience dividends by working with young talents. Finally, the initiative has clearly shown that maturity and culture is required on the side of the enterprise (or rather, on the side of the industry as a whole) allowing relevant knowledge to be recognized, held and managed.

Several factors were considered that influence how effectively knowledge transfer can take place. Very important are inherent national behaviours, together with social dispositions, cultural norms, and their evolution over time.

Strictly linked to societal changes are new ways of learning that have emerged in recent years. To effectively meet its needs, the industry ought to grasp the changes and potential benefits deriving from the advent of new technologies. It has to adjust its HRD strategies to both new opportunities and threats that the tremendous leaps in digital evolution can bring about.

Different learning behaviours and needs emerge, with the younger generation of recruits exhibiting different learning affinities and carrying different backgrounds. With the dramatic changes in the profile of today's learners, the use of "traditional" teaching materials and methods can result in poor knowledge transfer and retention. Classroom teaching and 'talk and chalk' approaches become outdated and limited, and 'one size fit for all' courses prove ineffective to cope with differences in learning abilities.

A more interactive learning environment helps engaging students, facilitating their memorization and enabling the creation of links between the subject being taught and actual experience.

For this new breed of learners, it becomes increasingly important to encourage the adoption of new ways of learning, like the use of blended learning, to include greater use of technology. This includes the use of self-learning, instructor mentoring, collaborative learning, digital tools such as gaming and virtual-reality training tools, which are all part of the SMART group of learning techniques. Many organizations are increasingly adopting SMART digital tools to enhance existing training programmes or support the establishment of new training programmes for newcomer countries. Gaming and simulation is also being used as a tool to support nuclear business leadership training.

As an example, an executive management team game was presented, in which a team of trainees were requested to adopt a position on a nuclear facility executive issue and to role-play through some of the nuclear safety and commercial challenges faced by the nuclear industry. While not being a new concept, the blending of commercial challenge and changing electricity markets gave it a unique flavour. All these novel strategies could result also in financial benefits, in addition to support personnel retention goals.

L-3 MAPPS in Canada has devised learning tools that focus on the "Practice-by-Doing" principle. New or improved video-materials that incorporate interactive exercises in the courses are expected to bring value to the entire education process.

Tecnatom in Spain is pushing the use of advanced technology in nuclear knowledge creation and transfer. It is enabling an enriched learning environment and adding important learning functionalities, such as flexible tutoring and mentoring, self-monitoring and self-assessment, peer evaluation and formative feedback, as well as learning by inquiring, exploring, collaborating and practicing.

Obviously, the role of tutors, counsellors, and work mentors remains key in all learning processes, but the use of intelligent support systems can provide tremendous aid to the process, e.g. by facilitating online informal support and community managers and facilitators for students, as testified by the extraordinary growth observed in the adoption and use of learning management systems (LMSs) and platforms (for the administration, documentation, tracking, reporting and delivery of educational courses or training programmes).

A remarkable LMS example is the Cyber Learning Platform for Network Education and Training (CLP4NET) facilitated by the IAEA. Examples of CLP4NET wide implementation include its integration within the computer network system at the Technical University of Sofia (TU-Sofia) in Bulgaria; at the National Research Nuclear University "MEPhI", in Russia; and at the Nuclear Training and Safety Centre (KSU) in Väröbacka. The CLP4NET project in Bulgaria is intended to build a National Nuclear Network of Competency and to facilitate and stimulate collaborative, distance and self-learning. The use of CLP4NET offers numerous benefits, including: extensive reach of participants - from anywhere and at any time - to a common LMS; the implementation of a systematic e-learning approach within the nuclear energy education programmes of TU-Sofia; and the simplification of selection processes, assignments. The versatility of such e-learning programmes allows flexibility in complementing daily activities of face-to-face education.

The role of the NKM Section in establishing CLP4NET and bringing it to its current level of use and penetration was acknowledged, and its continued support towards the delivery and management of eLearning content through the provision of platforms was encouraged.

It is recognized that, in order to better address challenges connected to the HRD and capacity building, close alignment between university education, industry demands and training schemes is important. A system engineering initiative for undergraduate education programmes established by the Nuclear Power Institute (NPI) in the USA has focused on student development through real-life project related work activities sponsored by government and industry. The programme encompasses a range of nuclear engineering projects directly related to the type of plant engineering problems actually faced by operational organizations. Students are supported by an industry mentor and their activities include a 'near-peer' outreach programme into schools to provide information and advice on career opportunities in Science, Technology, Engineering and Math (STEM) within the nuclear sector. This approach has proven beneficial, e.g. in allowing students to gain real world research experience, and network with industry/government representatives, invaluable opportunities that would enhance their job marketability.

In the Middle East important efforts by Khalifa University in the UAE include the development of a regional hub for nuclear education. The university's nuclear engineering department has been instrumental in developing qualified nuclear engineers to support the nuclear new build project. The need to develop a sustainable indigenous workforce for the project has been a significant undertaking for the UAE, and the university sees itself as a key provider of future nuclear engineering capability both within the country and in support of the regional demands.

Important initiatives fostered by the IAEA in addressing managerial competency needs in the nuclear sector are the Nuclear Energy Management Schools and the Master's programme in Nuclear Technology Management, and the International Nuclear Management Academy (INMA).

A network of universities constitutes the INMA partnership, which has developed the programme, having assessed its potential role to bridge gaps in nuclear managerial competencies. The structure of the programme consists of four blocks, with the leadership and management block forming an essential part of the programme. Industry leaders and managers are directly involved in the devising and delivering modules as part of a collaborative approach with academy. The main purpose of the programme is to strengthen depth and breadth of managerial competencies, ensure high quality management education and improve managerial decision-making; all of which would bear long-term benefits of improved safety, performance and economics.

INMA is seen as a very high impact and sustainable programme, for which the facilitation and support of the IAEA's NKM Section has been instrumental. Envisioning an increased collaboration with the IAEA Technical Cooperation Department could help making INMA programmes and fellowships available, especially to countries with established or embarking nuclear energy programmes.

Likewise, the NKM Section was encouraged to continue to support the increasing needs of Member States for Nuclear Energy Management Schools requested through established mechanisms.

Nuclear Education and Outreach

There is a great need for robust strategies, sustainable programmes and shared materials for the improvement of the entire education process in the field of nuclear science and technology, and for the preservation of academic knowledge and expertise, which have been created over decades and that are now at stake. In this regard, efforts towards developing outreach strategies, advancing education and training systems and encouraging international cooperation are paramount. At the same time, there can exist a disconnect between academia and industry, science and practice; and emphasis was given to the importance of bridging these gaps and striving for a good alignment between demand and supply, and ensuring that theoretical knowledge is complemented with practical science and technology skills, and that technical expertise is integrated with socio-economic considerations and managerial skills. All these are fundamental elements to establish a new group of nuclear professionals so that the large wave of retirements can be offset, and nuclear activities can be safely maintained and expanded to embrace new countries and reach broader scopes (e.g. in relation to the growing decommissioning programmes).

A number of innovative programmes have been spurring around the world to address these issues; and exchanging experience gained and good practices developed is of great value. Examples on experience and good practices of educational institutions in establishing practical educational and outreach programmes were shared during this session and some are discussed below.

Outreach efforts are very important to achieve communication with students at an early stage. This can help build a community-based support for nuclear power programmes, and stimulate interest in future careers in nuclear technology, including in fields such as decommissioning.

The role of international organizations to support MSs in developing sustainable approach and initiatives to strengthen educational outreach on nuclear energy to high schools was noted. This is one of the medium-term objectives of NKM Section at IAEA, in conjunction with other departments and sections.

Among the academic institutions that presented their programmes, Texas A&M University's Nuclear Power Institute illustrated their long-established involvement in various education and outreach activities. NPI's mission is to develop human resources for the future of the nuclear industry, with an emphasis on the disciplines beyond nuclear engineering. This is achieved through partnerships with the industry, universities, community colleges, high school and junior high, students, teachers, communities and key civic and elected leaders. Working with industry, NPI creates academic and outreach programmes to stimulate interest in the nuclear field and in broader STEM disciplines. In the NPI approach to outreach, different levels of education (from primary students through to PhDs) are integrated, as well as different types of educators (teachers, counsellors and administrators). Educational and educator programmes involve the public (elected leaders, community leaders, families, organizations, government and industries). These programmes can be adopted in whole or in part to support the development of nuclear energy in established and newcomer countries.

A notable example of NPI outreach initiatives is the Science on Saturday (SOS) programme that helps creating interest in future careers in nuclear technology. Participants of such initiatives and associated activities can gain a better understanding of both the industry and student career opportunities in the field.

Another example of strong national collaboration in the USA is the nuclear education programme developed by the Florida International University (FIU) in collaboration with the US Department of Energy (DOE). This established workforce development programme has a focus on STEM minority students that will enter DOE's workforce. This has proven effective in enabling professionals' development and their fundamental accrual of practical experience.

Current challenges specifically experienced at the European level were highlighted. All EU stakeholders, from policy-makers, academia, research organizations, regulators and industry are unanimous in asserting that 'a common pan-European approach in nuclear E&T is the way forward, benefitting from Euratom Fission Training Schemes (EFTS), European Credit Transfer and Accumulation System (ECTS) and the European Credit System for Vocational Education and Training (ECVET) in combination to 'Open Access to key or world class infrastructures'.

It was recognized that, in order to further scientific and technological excellence at the European Union (EU) level, improved governance for E&T and better schemes for qualification and transfer of knowledge are necessary, as well as the pursuit of improved expert mobility to promote the growth of skills and competences.

There is a need for an up-to-date E&T system based on the combination of traditional learning paths and innovative ones (e.g. virtual classrooms and MOOCs). A system that is based on mutual trust, transparency and pan-European integration, which aims to increase the number of highly skilled trained nuclear professionals in the field. Towards this end, Euratom has developed numerous roles and activities in the field of nuclear safety, contributing to the support of European nuclear E&T programmes in collaboration with international and regional networks, industry, and universities.

With specific relation to decommissioning, the European Commission Joint Research Centre and interested partners have launched an initiative to consolidate existing training programmes, through e.g. the ELINDER project, which is aimed at 'pooling' decommissioning training initiatives for European learning ways in this area. The objective is to provide modular courses for vocational and hands-on training on nuclear decommissioning, in cooperation with European universities, research organizations and other partner organizations. Some of the benefits from this joint approach would include: enhanced clarity on the outcome and quality of the anticipated training; increased visibility; and promotion for interested employers and trainees.

In nuclear E&T programmes in general and outreach programmes in particular, synergies between experienced nuclear countries and developing countries are very important. The prominence of internationalization in education programmes and related mobility of students and teachers was emphasized, with the increase in international exchange of PhD students and the offering of co-education programmes with university partners worldwide, which should be further promoted. Education and training programmes should also aim to improve the scientific and practical skills of teachers through trainings at competent national and international organizations.

Recent initiatives of the young Arabian generation in Europe for E&T in the field of nuclear and renewable energy were presented. These encompass the Arab-European Summer School on Energy Education, an Arab-European Forum on Energy Education, an Energy Week of the Arab Schools, and the Energy Network of Arab Schools.

Another instance of a nuclear education programmes designed in collaboration with relevant international institutions and scientific associations is the one rolled-out by the Ibn Tofail

University in Morocco. This nuclear education programme has been improved with up-to-date pedagogical techniques, material and styles, including new approaches in coaching, mentoring and ongoing evaluation of student works.
International elements are embodied also in E&T programmes in China. For a country like China with a rapidly expanding nuclear industry, the strong link between the education programmes and employment in the nuclear industry is essential. To better meet the industry requirements, E&T programmes are being introduced not only for students who do not have previous working experience, but also for professionals in their mid-career development. Flexible ways of learning, such as part time and e-learning are being offered, along with professional training programmes, with a more practical slant.

Knowledge Management Methodologies and Implementation Approaches

Effective implementation of a KM programme requires proper alignment between people, process and technology involved, ensuring, on one hand, availability of competent personnel able to make effective use of knowledge in the right context, and, on the other hand, accessibility of the right knowledge at the right time in the right place, through adequate processes and tools.
For successful KM it is very important that focussed objectives are fixed and defined. The simple, ultimate goal of KM should be increasing and facilitating employees' access to the information and knowledge needed for the efficient performance of their duties. KM should allow capturing and storing, to the fullest possible extent, employees' knowledge that is critical to the company's operations and decisions, with the fundamental aim of instilling a culture of information and knowledge sharing within the organization.
It is a well-known, and sometimes concerning fact, that many KM projects either fail outright or do not live up to the expected outcomes. Some of the inner causes of these failed attempts can be easily identified. Among them, there are macroeconomic changes that can constrain an organization's new project funding, as well as the change of ownership or senior management with new ideas and disdain of older projects. Some of these factors are beyond the control of the KM implementer.
In this pursuit, understanding the business objectives is the first step in devising KM initiatives, to determine adequate success criteria and metrics and select proper technology.
Other major steps are: a thorough analysis for the identification of critical knowledge areas and subject matter experts to ensure knowledge is retained and shared, good understanding of strategic and process requirements, and how KM will be embedded in the daily organizational processes, commitment and ongoing support of the management, as well as adequate and sustained training and communication.
Strong leadership and thorough communication are certainly needed for the success of KM programmes. Creating buy-in, understanding and a culture of openness is vital to ensuring that the right knowledge is made available from and to the right people.
Managing critical knowledge that is at risk of loss, and enabling adequate and effective knowledge capture and retention are among the key objectives of KM programmes. In this regard, it is essential to direct efforts towards knowledge-sharing on a day to day basis and to integrate KM into daily processes. KM programmes should not be rolled-out in isolation but, as already noted, as a part of an integrated management system (IMS – see definition in IAEA Safety Glossary). At present, however, even in nuclear organizations with more mature KM programmes a comprehensive implementation of KM in the IMS has not been achieved. The IAEA NKM Section has undertaken efforts to assist Member States' nuclear organizations to advance towards a mature KM programme through their integration in the management system and the development of relevant indicators The Nuclear Knowledge Management Institute (NKMI) in Vienna has been working to develop a simple and easy to understand approach for implementing KM in the Management System of nuclear regulatory organizations. Its purpose

is to complement the IAEA guidance and to provide an efficient model of managing knowledge and competence in different IMS processes.

To facilitate the transfer and measure effectiveness and impacts, systematic knowledge retention plans should be put in place, with focused knowledge transfer targets and actions. In the effort towards knowledge transfer and retention, the IAEA's Safeguards Division of Concepts and Planning (SGCP) has developed a model to draw out and capture critical knowledge and make it available for use by others. This "person-centred" approach involves face-to-face interviews with staff members, co-workers and/or customers to identify the critical job-related knowledge. Through the efforts for safeguard-relevant knowledge retention and transfer, SGCP has raised the visibility of knowledge retention activities in the department.

The Russian operating organization Rosenergoatom has established a programme for KM implementation in the organization, as part of ROSATOM State Corporation KM activities. This includes activities, both in the framework of the classic KM cycle, i.e. detection, preservation, retention, sharing and transfer, as well as the creation of new knowledge such as training programmes for the new-build of NPPs. The approach embraces key techniques overviewed in IAEA documents on KM, and ROSATOM strategical focus on the commercial use of R&D results and corporate knowledge. The key goal of ROSATOM's KM implementation in this respect is to promote innovative technologies, reduce the overall duration of innovation cycles and assure the growth of ROSATOM technologies' commercial applications. This is achieved through continuing knowledge detection and capturing, and intensive knowledge sharing, as well as circulation via effective cooperation of all internal and external users (provision of data, information and knowledge to ROSATOM employees and the establishment of effective mechanisms for commercial knowledge usage).

The importance of having methods in place to quantify and qualify improvements achieved in day to day processes through the implementation of KM initiatives and to evaluate their long-term impact was also discussed. An interesting example is provided by a method adopted by the Argentine Atomic Energy Commission (CNEA) for developing a Balance Scored Card (BSC) linked to a certain nuclear knowledge domain. The purpose of this BSC model is to determine the role and added value of KM tools from different angles, ideally accounting for each stakeholder's perspective by quantifying and qualifying the improvements achieved in day to day processes through the implementation of KM initiatives. The application of KM BSC may also be a useful tool to communicate the strategy across the organization.

The nuclear industry faces challenges with utilizing years of valuable knowledge and information stored in distributed repositories that are often difficult to access. A suite of tools should be available for KM programmes to address the risk of knowledge loss; including online portals or databases, knowledge loss risk assessment matrixes, and audit processes. Having the right technology in place to support KM initiatives is important. In this regard, knowledge discovery tools powered by semantic search technologies are proving powerful in uncovering answers from unstructured data, providing smaller IT footprint and faster time to access 'critical' knowledge. The search time as well as data gathering can be considerably reduced with the help of such technologies, as multiple repositories can be accesses through a single access portal simultaneously.

As for other processes, products and systems, standards can provide significant support to organizations towards the implementation of KM programmes, fostering efficiency and quality and ensuring consistency and comparability. Until recently there has been a dearth of coherent guidance and standards on knowledge management, and KM was included only in some National Standards (e.g. 2005+ Standards Australia). Lately, in the transition of one of the principal International Quality Standards, ISO 9001 from 2008 to 2015, the International Organization for Standardisation (ISO) has put great emphasis in organizational knowledge. Knowledge management has now become a core part of ISO 9001:2015, against which different businesses worldwide are audited. In addition, since 2014, ISO has directed efforts towards the development of the new KM Standard – ISO 30401:2016. This new ISO Standard, which is integrated within a suite of other standards, is now close to being issued. The

emerging KM standards are no longer prescriptive, but principle driven. Therefore, they do not explain "how to do" but rather highlight the underlying KM principles.
In general, it is recognized that the increased use of standards helps facilitating KM through efficient ways of identifying, transforming, developing, sharing and preserving the highest quality knowledge and international practices worldwide, as testified by the International Electrotechnical Commission (IEC). The nuclear industry is also encouraged to increasingly use standards, including IEC, and enhance its participation in standards development. This can have a direct impact on safety, which makes KM one of the critical processes in the safe and successful operation of the nuclear industry at large.

Knowledge Management for New Build Projects and Programmes

Nuclear knowledge management for nuclear new build, particularly in newcomer countries, carries yet different challenges.
The successful implementation of a national nuclear power programme requires meticulous planning and the management of enormous resources. The greatest challenge is building-up capabilities in future operating organizations and regulatory bodies of countries, capturing and transferring the necessary knowledge from the vendor country and other partners.
This is at the heart of the IAEA Milestones Approach, addressed among the issues of Management and Human Resource Development.
The need for the provision of an information package on KM to newcomer countries (i.e. awareness and educational information) was also voiced, which would help raising awareness on existing issues and available IAEA resources.
In this respect NKM is fundamental, and initiating a national KM programme involving relevant organizations right from the outset of the project is highly desirable in order to capture, retain and distribute knowledge, while helping prevent its loss.
In the case of embarking countries, it is important to note that the implementation of KM initiatives does not necessarily entail the establishment of complex, full-blown programmes, nor does it require the use of very expensive tools. At first it can be achieved through the adoption of effective practices that do not carry heavy burdens of any sort, neither financial nor time-related. The use of shadow training involving junior staff experienced in problem-solving, and managing staff turnover are examples of such simple practices.
In addition, while typically handover of relevant technical knowledge for the preparation to the operational phase is included in the contract signed with the vendor, the scope of knowledge and capabilities that newcomer countries have to gain for the development of the new-build programme is much broader, encompassing e.g. the establishment of adequate institutional frameworks, and notably competencies for the regulatory body. In this respect, it is important that the regulatory body of the newcomer country sets up partnerships with experienced TSOs to 'gain' the necessary knowledge.
Information needs to be captured at the initial stages of the programme roll-out and the early adoption of a robust information system is key. To achieve this in an efficient manner, KM processes and tools need to be assimilated into the organization structure and become part of the organizational culture and the daily operational processes, aiming towards an integrated management system. What is helpful for the working level staff will naturally turn them into knowledge providers and will not be perceived as a burden.
In order to reach successful integration of NKM processes into the IMS, it is important to first define a clear strategy and then work on the processes. Placing the focus squarely on tools, or information technology cannot provide straight solutions, if objectives have not been clearly established.
Leadership is essential in order to implement NKM processes, but such processes should be designed with the input of the people who will make use of them. A balanced combination of a top-down and bottom-up approaches is a key success factor in NKM programmes.

Overall, a holistic approach to KM is required in any organization; and a culture of knowledge sharing, supported by management at all levels, is an essential step before looking at costly tools.

NuGen, UK shared a conceptual knowledge model and high level guiding processes adopted at NuGen's Moorside project to develop and manage critical knowledge assets, along with the oversight of arrangements taken to help monitor and steer knowledge activities as the project develops. Given its relative infancy, the Moorside project presents both a challenge and, at the same time, a significant opportunity for KM to make a real contribution to the successful delivery of a safe and effective plant. The importance of proactive KM embedded throughout the business is clearly understood and this is reflected in their decision to develop and drive a KM strategy from the outset.

Likewise, EDF Energy Nuclear New Build (NNB) considers its Hinkley Point C project a unique opportunity to set KM behaviours, culture, and standards from project inception, instead of working to change them, as it could be the case in an operational site. Lessons were learned in relation to the assessment of end-user requirements and ongoing engagement in the KM programme. This was considered useful, but ultimately led to solutions which were perhaps too complex to implement, considering budget and resource availability. The company benefited from this journey through KM and refocused on a simpler approach. EDF is able to provide its partners with experience accumulated over its forty years of operating its nuclear fleet. The "EDF Nuclear Performance Model" was developed for this purpose.

In terms of human resources, a serious issue faced by newcomer countries is brain-drain. All too often personnel sent overseas from newcomer countries for training is lost to better opportunities abroad. A number of expedients have been envisaged to reduce this type of attrition. For instance, trainees can be requested to commit to work for the entrusting organization for a minimum number of years. Naturally, the best motivation to keep staff on board is offering fulfilling prospects within programmes that actually move forward.

In South Africa, after the PBMR project was stopped, expertise became fragmented and some experts even left the country. A number of training and research facilities that completed their research cycle are in the process of being decommissioned.

With the renewed interest in nuclear technology, a knowledge gap has been identified and there is the urge to capture, consolidate and revive nuclear expertise, education and research. SAN-NEST, the South African Network for Nuclear Education, Science and Technology for South Africa and the African continent, has been established with the main objective of supporting the South African nuclear education system to form suitably qualified and experienced personnel to better meet future demands of national nuclear science and technology programmes.

In terms of technology, as for the operating phase, also during construction tools like simulators can aid moving knowledge from theory to applied practice and can provide cost effective and versatile solutions.

The use of full-scope simulators starting at the earliest stage of the plant construction can enable the identification of system design and Instrumentation and Control (I&C) data voids originating from different sub-suppliers, at an early stage of the design process. It can also help in the validation of the plant operation documentation, in accordance with the plant construction schedule and safety authority requirements, reducing potential significant risks of delay during construction.

The use of full-scope simulators, however, requires specialized and dedicated teams of I&C and system engineers, responsible for testing complex systems and disseminating expertise among other colleagues, with a certain level of awareness of simulation technology. Enhanced training exploiting the advanced capture, retrieval and presentation approaches of new technological tools has proven useful in transferring knowledge and skills of expert workers to less experienced personnel.

Knowledge Management for Operating Nuclear Facilities

The operating lifetime of a nuclear power plant spans several decades, during which the plant may undergo design changes brought about by experience feedback, new knowledge and requirements, or the results of safety reviews. Staff turnover, outsourcing, modifications and extension of plant and equipment design-basis can create knowledge loss and mismanagement, and first-of-a-kind (FOAK) situations. To ensure safety and cope with such situations, changes must be carried out with a full understanding of the design intent, and without compromising it at any stage. Achieving this objective requires efficient DKM all along the lifetime of the plant, within and across all the different organizations involved, while giving full authority and responsibility to the licensee. The operator must identify critical knowledge, including tacit knowledge, and adopt processes and tools that support risk analysis and ensure knowledge capture, retention and transfer.

Particularly critical for the facility operators is the need to keep knowledge of the plant design basis accurate and current from the outset to the end of its life. Records and knowledge of the original design and its intent must be transferred from the original vendor and responsible designer, and all changes thereafter must be carried out with full understanding of the design intent, ensuring that any risk of this being compromised is averted. Plant configuration must be carefully controlled over time, transferring related records and information. In addition to these, however, also the “know-why” and “know-how” must be preserved, so that overall performance and safety are continuously ensured and remain optimized in the long-term.

Efficient control and transfer of design knowledge (DK) must be ensured across all different organizations involved throughout the plant lifecycle. As already mentioned, full authority and responsibility of DKM remains with the licensee, that will give due consideration to the context and make the final decisions.

An efficient and successful DKM requires a well-established KM system, since knowledge has to be passed across successive generation of professionals within operating organizations, as well as within and among other organizations involved (e.g. designers and vendors).

DKM is clearly paramount to ensure successful life-extension programmes, where operating utilities need the support of an effective overarching industry KM capability. Proactive KM steps are essential, both specifically at the level of the facility operator as well as industry-wide, across organizations that have contributed to individual life-extension projects. The operating utility needs the support of an effective industry KM capability to succeed in a life-extension initiative. The overall national institutional base, including the facility operator, regulator, owners’ group, R&D organizations and universities, all play a part in meeting the DKM challenge. These points were emphasized in the presentation of the activities jointly conducted by the Ministry of Economy, Trade and Industry (METI) and the Atomic Energy Society of Japan (AESJ) to construct a Roadmap for Light Water Reactor Safety Technology and Human Resource. The Roadmap focuses on future safety research and development, HRD and KM for the continuous improvement of light water reactor safety, including through the enhancement of management systems, procedures and communication between various stakeholders throughout all stages of the lifecycle of a nuclear power plant and its systems. The roadmap was prepared by a special AESJ committee, based on concerted efforts and communication with all Japanese stakeholders, which are expected to benefit from HRD and KM.

Another noteworthy development emerging in this Session is the increasingly widespread application of modern computer-aided design and engineering systems to design and construct new nuclear facilities, adopting multidimensional modelling and design information sources such as data, databases and electronic documents. As a result, new facilities can be provided with a computer-based information environment that is amenable to be transferred, integrated and interoperable with the computer-based information environments of the organizations that own and operate them. Such computer-based information environment can also offer significantly increased potential for multi-stakeholder knowledge capture, integration and transfer.

In general, however, different stakeholders rely on different computer-based information environments, which consist of one or more plant information models (PIMs), and which present minimal standardization and information interoperability.

It is envisaged that the development of a knowledge-centric PIM could leverage and better support a seamless exchange and transfer of design information and knowledge throughout the nuclear facility life cycle and across stakeholders. It is hoped that in the near future major NPP vendors, object-oriented operating as well as IT system vendors will help to develop a knowledge-centric PIM. Subsequent possible “Commercial Off-The-Shelf” (COTS) solutions would be automatically information interoperable with other systems developed or purchased during the lifetime of the plant. This can, in turn, make even the process of selecting and implementing applications for the new NPPs easier and more cost effective.

In this respect, the use of ontologies and semantic technology also plays an important role.

Following the Action Plan on Nuclear Safety (GOV/2011/59-GC (55)/14), the IAEA was requested to assist Member States in strengthening and maintaining the effective management and use of nuclear design basis knowledge and information over the entire life cycle of licensed nuclear facilities. In support of this request the NKM Section identified the key part that PIMs could play in strengthening and maintaining effective management and use of DK throughout the NPP life cycle. This could be effectively achieved by drawing full benefit of standardized plants through cooperation between the licensee, the responsible designers and operators’ groups.

As a part of this initiative a series of IAEA technical reports is planned to provide guidance on information modelling of nuclear facilities, along with the development of a generic prototype PIM for demonstration purposes.

Japan’s Tokyo Electric Power Company (TEPCO) described the benefits of establishing systematic design control / configuration management processes to enhance engineering capability, fostering a sustained understanding of the design requirements and their basis and enabling informed decisions of the responsible licensee. In TEPCO’s experience, this can also enable effective training of new employees, providing easy access to comprehensive design information.

Hitachi-GE Nuclear Energy, Ltd. (HGNE) also continues to develop plant engineering and plant construction systems based on experience and lessons learned. Currently, these systems are integrated in a variety of knowledge bases using the latest information technology. Their performance is continuously validated in the recent NPP constructions. HGNE consider such systems essential to achieve on-time and on-budget-goals in NPP construction projects.

The World Nuclear Association (WNA) ‘CORDEL’ holds a privileged position to contribute to global DKM. CORDEL working group and particularly its Design Change Management Task Force, have the aim to promote international standardization of nuclear reactor designs. For an efficient DKM throughout the life of new plants, this WNA initiative promotes a large cooperation between owners of similar designs, ensuring the continuous involvement of the original designers.

With particular reference to the ongoing construction of modern NPP designs, emphasis was also given to the importance of implementing new methods for transferring knowledge to operators, maintenance personnel, technicians and engineers, and to ensure that these professionals become proficient in their tasks to safely operate and maintain the plants. Existing nuclear training programme methods and processes, in some instances, do not fully contribute to worker task performance proficiency, and instead rely on time-based experience. In this regard, more effective approaches exist for the capture, storage, transfer, and exchange of systematically derived plant-specific information. An example was provided, where a USA nuclear utility had captured and transferred the knowledge possessed by proficient workers to new workers through the use of the VISION learning content management system. This system provides a means for the capture, storage, transfer, and exchange of systematically

derived plant-specific information, which can be used by new build NPP organizations to accelerate worker proficiency.
An interesting example of application of knowledge loss risk assessment leading to the selection of appropriate methods for acquiring knowledge was reported for Cernavoda NPP, in Romania. Lessons learned from the process pointed towards the need of establishing an effective database design from the outset, in order to ensure proper storage and dissemination of the information gathered from interviews and actions resulting from the retention plans. This database should contain information about employees who possess identified critical knowledge and skills, and the actions taken in order to transfer these, together with data about the employees' departure date from the organization, risk factors, etc.
Advice and specific guidance drawn from validated international best practices in the development and implementation of KM programmes can benefit nuclear organizations wishing to become more effective 'learning organizations'. In this regard, the NKM Section has been active in developing and sharing approaches for the integration of KM into the management system. For NPP operating facilities, such integration helps assuring the sustainability of KM processes, identifying interfaces and links with other business processes, monitoring and measuring the effectiveness of KM processes on a regular basis, and clearly defining responsibilities and duties of individual actors through internal guiding documentation.

KM for Decommissioning, Environmental Remediation and Radioactive Waste Management

With the growing number of nuclear facilities and sites having reached or nearing the end of their service life, the scale of D&ER activities globally is already very sizeable and expected to increase. This represents a challenge for many countries.
KM applications discussed so far have been widely recognized to support optimization of operations and enhanced safety in nuclear facilities. These, however, are generally focused in maintaining steady-state conditions, or achieving incremental progress in current practices. In contrast, when nuclear facilities and sites transition from routine operations to D&ER, including related radioactive waste management (RWM), there is a need to reconsider knowledge objectives, methodologies and tools in order to ensure that these are relevant to the incipient activities and can provide solutions to the novel challenges posed in these different phases.
D&ER activities are typically project-based and are characterized by rapidly changing environments and long-term tasks. These might extend for decades, or even centuries (e.g. in the case of RWM programmes), requiring knowledge to be transferred across organizations and throughout generations. Thus, the management of data, information and knowledge for D&ER and RWM presents some distinctive challenges and constraints and calls for robust and agile KM approaches and different maturity models.
The necessity to develop lifecycle wide KM in D&ER was again emphasized. However, KM approaches must be adapted to the phases of the facilities lifecycle. It is crucial to understand lifecycle phases also as phases to which KM systems have to adapt. D&ER require more agile KM systems and specific tools to cope with a quickly changing environment. KM requirements for D&ER may also go beyond the organizational level usually covered when managing knowledge during the operational phase, necessitating eventually regulatory approaches and information repositories.
It was highlighted that applying KM prior to the commencement of any D&ER is a crucial part of a site overall management strategy. Nonetheless, since it is often very challenging, when even possible, to re-create or replace previously acquired knowledge, it is clearly beneficial that KM systems are developed early in a site's lifetime.
Operating facilities and sites which transition to D&ER are faced, in the first place, with the need of transferring critical knowledge, which, by and large, differ from that needed during the

operational phase. This is also the case for skills and expertise that are required for such activities and have to be created or outsourced.

Remarkable in this respect is the experience accrued and reported by the Finnish company Posiva Oy in establishing a first operational Deep Geological Repository (DGR), after extensive work on the R&D concept and design. This project is a “first of a kind” and knowledge from many lessons learned and best practice has been accrued as part of the process. In transitioning the spent fuel disposal facility to an operational mode, Posiva Oy is establishing the supply chain and the project management processes and tools that will support the DGR future mission. Importantly, a strategy/vision is being developed for HR to support the changes in positions inside the company. This includes individual career planning for the workforce and other initiatives to promote KM, knowledge transfer and training of Posiva Oy staff and the supply chain.

Various other examples and case studies of practical NKM tools already developed and used for D&ER and RWM programmes worldwide were presented, including innovative KM approaches that adopt artificial intelligence expert systems.

Looking at complex remediation processes that span very long operating periods, the establishment of comprehensive data, information and KM systems is essential.

Exemplar is the technical database developed by the German federally-owned WISMUT GmbH, which has been remediating legacy sites left behind by former uranium ore mining and processing operations in Eastern Germany for the past 25 years. The established technical database named AL.VIS/W serves as platform for the storage, search and exchange of data and information, including that required to fulfil post-remedial long-term tasks and institutional control.

Sometimes, an organization-based approach is not sufficient, knowledge transfer and sharing may be necessary across organizations and even across states and regions, underscoring the importance of international collaboration and approaches.

International organizations (IAEA, OECD/NEA) have directed their efforts in support of NKM solutions for D&ER and RWM programmes through cooperative projects.

For instance, OECD/NEA presented the concept of the key information file (KIF) on waste repositories as introduced by one of the active working groups within OECD/NEA. This collects records, knowledge and memory (RK&M) on radioactive waste. KIF is aimed at deriving measures against human intrusion as well as raising societal awareness about DGRs. It contains key information about repositories in a simple, accessible language, while pointing to additional records for greater detail.

In order to help conducting safety assessments of repositories in a transparent manner and enable informed decision-making, a tool has been developed under the aegis of IAEA with the cooperation of several partners: SAFRAN. This tool takes into account IAEA standards as well as national regulations. Its application allows the comparison of different approaches for safety assessments, notwithstanding differences in individual national jurisdictions and regulatory backgrounds.

Through the collaboration between the IAEA Division of Nuclear Fuel Cycle and Waste Technology and the NKM Section, a repository and portal for D&ER projects knowledge organization system (DER-KOS) has been created, and efforts continue towards its development.

D&ER and RWM operations are expanding and present tremendous challenges, but they are often perceived as not so appealing by the young generation. Another recognized challenge in the mid-term and long-term is attracting new talents towards these activities. Particularly acute, and further emphasized in the wake of the Fukushima accident, is the global need for E&T to form professionals and to raise awareness on the remediation of radiologically-affected sites, including the many legacy mines.

As the IAEA, the European Commission Joint Research Centre is also supporting MSs in the provision of specialised education and training. The EU Community Acquis includes key legislation such as the recent Council Directive 2011/70/EURATOM establishing the community framework for the responsible and safe management of spent fuel and radioactive waste, which sets the legal obligations for adequate funding, financial security and transparency applicable to the national waste management systems. A clear global positioning of the EU will stimulate the export of know-how to other countries, especially those having a large nuclear programme, and will promote the highest safety levels.

Another example of cooperation in this area are the regional training courses organized by the IAEA in the Russian Federation, within the frame of a Technical Cooperation project conducted in collaboration with ROSATOM. The courses focused on transferring managerial abilities to cope with mining facilities. The significant number of attendants and successful outcome of the courses have made it possible to further extend the programmes' activities.

As experience in Fukushima has shown, along with training and education, outreach and stakeholder involvement play a key role in D&ER projects. The knowledge and information that is generated during the decommissioning and remediation / clean-up activities are important not only for record keeping in Japan but also for sharing with the international community, enabling the application of technologies and methods at other sites and in different contexts.

Knowledge Management for Nuclear Regulatory Compliance

The role of a regulatory body (RB) with regard to KM is quite unique, in that it also has to cater for all interfaces with the overseen organizations, ensuring consistency in decision-making. Having to support internal RB functions, on one hand, and, on the other, to provide oversight of licensees' KM activities, knowledge management for regulatory bodies plays a dual role.

KM is a cross cutting discipline, whose importance towards safety has been widely acknowledged. More and more regulators are recognizing the need for KM and providing, accordingly, a measure of oversight and accountability for licensees in relation to KM, which is considered an important step to further improve safety.

This cross-organizational character of KM for RBs becomes particularly important in new-build projects, where the transboundary relationship between the regulatory body of the vendor and buyer countries is crucial. In these cases, establishing a viable, country specific mechanism for knowledge transfer is of utmost importance.

The UAE Federal Authority for Nuclear Regulation (FANR) offered some recommendations to RBs in newcomer countries on the establishment of their own NKM systems. A fundamental step is assuring a minimal contingent of resources with the necessary skills and competencies in RB areas (with the advice that at least two to three experienced and skilled employees are to be available). These can be developed or seconded from other experienced international regulators or the IAEA. Staged approaches are desirable, starting with a pilot project which integrates KM methods within a small number of processes before rolling-out full-scale programmes. Of crucial importance is ensuring that the organization management knows the exact impact of not having KM in place throughout the nuclear programme phase.

In relation to KM programmes in support of internal RB functions, considerations generally applicable to other nuclear organizations are also valid; notably, e.g., the need to identify critical knowledge and avert risks of knowledge-loss; the importance of ensuring strong leadership and thorough communication in rolling-out KM programmes; the necessity of addressing cross-generational knowledge transfer by means of comprehensive and systematic HR processes. With particular reference to the latter, it was noted that new RB recruits require a solid education in nuclear engineering at a Bachelor or Master level. This is generally a necessary starting point for new employees of a regulatory body. However, several ad-hoc training programmes should be arranged during the professional life of RB employees in order to continually improve their knowledge and to focus it on specific fields.

Notable examples were exposed, which illustrated efforts made in these directions.

The French Technical and Scientific Support Organization (TSO), 'Institut de Radioprotection et de Sûreté Nucléaire' (IRSN), described tools and actions for the development of their global KM system, which constitutes a corporate objective. To achieve it, IRSN consider necessary to share the KM objectives within the organization, and establish an efficient process in terms of management and tools. KM correspondents are appointed in the various units, as levers to federate the identified important and priority actions. Diagnosis by domain and the respective shared strategic KM action plans are deployed gradually. Functioning of the action plans with good visibility and added value for staff is important. Emphasis of the action plans should be on "quick wins" on real and operational projects, with visible objectives and motivated people relying on proven methodologies. The overarching ambition of IRSN is "enhancing nuclear safety", for which enhancing knowledge is seen as an essential lever. Taking benefit from diverse sources of knowledge and know-how, and ensuring a sustainable turn-over of generations from the first breed of professionals involved in the original construction and operation of the French nuclear fleet are considered by IRSN as key ingredients to enhance nuclear safety, both requiring effective KM systems.

The UK's nuclear regulatory body, the 'Office for Nuclear Regulation' (ONR), also shared its experience to date in establishing and consolidating KM practices. KM activities at ONR have matured over time, covering now organizational culture and environment, and all aspects of organizational resilience. Benefits are apparent, and, to date, they span a clear understanding of core knowledge requirements, better specifications for recruitment and training, and the ability to deploy new regulatory approaches. It was recognized early in the initiative that the transfer of tacit knowledge was key. A major challenge was establishing the best methods to elicit this tacit knowledge. Past experience in using KM techniques to capture and codify knowledge had not produced usable output. External expertise was sought to establish a suite of techniques that could be used focusing on people to people transfer but also improving explicit knowledge such as regulatory training courses and guidance. Major lessons were learned from rolling out this KM initiative. Not unlike those noted by IRSN, success factors identified for effective KM implementation are:

- Clearly identifying the aims for KM and ensuring consistent senior level ownership for KM, especially during periods of organizational change;
- Engaging the whole organization - this is best achieved by identifying activities that enhance KM and are seen to add value in day to day tasks;
- Transfer of tacit knowledge to ensure the resilience of a regulatory body, which in turn requires a people-centred approach to KM.

The Belgian TSO, highlighted the importance of utilizing tools such as the Knowledge Critical Grid (KCG), a model implemented by the organization to assess risk of knowledge loss. This is central for a knowledge driven organization as a TSO for which knowledge challenges are connected to identifying what essential knowledge is at risk and which solutions are useful to address knowledge retention issues. The KCG model is intended to determine the appropriate actions to mitigate the knowledge loss risks and to develop knowledge recovery initiatives. The assessment of knowledge loss risk is a pivotal step of a KM system. KCG assists in dealing with three fundamentals K-loss questions corresponding to three central managerial steps, helping to identify what key knowledge may be lost, how critical the knowledge is, and which are the best relevant knowledge recovery initiatives. While recognizing some of its limits, the KCG enables identifying key positions and knowledge domains where a potential loss is foreseen. The assessed knowledge domains are not only academic ones, but address necessary technical domains in which the TSO is expected to perform its duties.

It is recognized that one of the important functions of the TSOs is to develop and maintain well trained experts in the respective technical and scientific fields using well established and robust KM processes.

Moreover, TSOs are especially well placed in supporting international efforts in implementing and evaluating country specific KM structures. TSOs are able to assist in developing unique methodologies; provide analysis of organizational needs through training, technology transfer, and KM specific tool developments. The main benefit of the regulatory and technical cooperation in improving the KM capabilities of the TSOs is the improvement in regulatory and technical capabilities both at regulatory bodies and TSOs. As noted in the contribution of the US Nuclear Regulatory Commission (NRC), the future challenge in supporting further development of KM capabilities is to ensure that the cooperation between the NRC and foreign regulatory agencies responds to the country specific regulatory needs and further enhances the capabilities with an overall increase in the safety of the nuclear facilities.

An IAEA Safety Report currently under preparation will provide practical advice on introducing and running KM programmes in RBs and related TSOs. In the report, statutory functions of RBs, regulatory process for facilities and activities, and RBs' functions for emergency preparedness and response within national emergency management systems are addressed.

Furthermore, the IAEA offers a number of KM resources which are highly useful to RBs in Member States, including documents such as TECDOC 1757 – Methodology for the Systematic Assessment of the Regulatory Competence Needs (SARCoN) for Regulatory Bodies of Nuclear Installations; TECDOC 1586 – Planning and Execution of Knowledge Management Assist Missions for Nuclear Organizations.

Other relevant IAEA services include KM Assist Visits, and training through the Nuclear Knowledge Management School.

Importantly, the IAEA is fostering the Global Nuclear Safety and Security Network (GNSSN). International safety knowledge networks are seen as an essential resource base to facilitate national capacity building. Networking is efficient not only to build bridges throughout geographical boundaries, i.e. through regional networks, but also to promote cross-organizational collaboration, e.g. among regulators, agencies, technical support organizations, as well as thematic safety groups. In this regards GNSSN is a very good example of practical networking.

Knowledge Management for Non-Power Nuclear Science and Applications

This session was of singular importance since it allowed, for the first time, to bring the fore on the role of KM in non-power nuclear science and applications.

Discussions centred on this topic succeeded in increasing awareness among the scientific community and various organizations on the key role that effective KM can play in the non-power related applications within the nuclear sector. 'Setting the spotlight' on this important theme is crucial in order to obtain the greatest impact and serve the purpose.

Between 2010 and 2016, around 35 laboratories that operate neutron activation analysis (NAA) world-wide were assisted by the IAEA in assessing their analytical performance through inter-laboratory proficiency exercises, as well as the implementation of a Coordinated research project (CRP) on automation enhancement. One of the key gaps identified then was the lack of knowledge preservation and knowledge transfer following the retirement or departure of experienced staff. The "Living Book", a novel e-learning tool was created as a solution to address the issue. The "Living Book" has a modular structure that enables the integration of practical cases which would never be known otherwise.

The Centre National de L'Energie, des Sciences et des Techniques Nucléaires (CNESTEN), along with the Lebanese Atomic Energy Commission experienced an important evolution of staff throughout their history. Efforts were invested to preserve and strengthen knowledge related to safety, security and radiation protection through co-operation with universities and the IAEA.

Ensuring a healthy pipeline of experts in nuclear non-power related applications is at the heart of a rich umbrella of university programmes run in Cuba. Here, a basic university course with a strong theoretical component oriented towards medical physics is offered within the Cuban Master in Sciences in Medical Physics (MSMP). This is combined with a stronger practical component closely linked to in-hospital training programmes, along with a more highly academic level of a doctoral programme that helps address the demand for teaching incoming professionals. This inclusive offer is contributing to an optimal and safer introduction of newer technologies in radiation medicine.

According to ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development) there is a growing need to intelligently manage resources and knowledge in the nuclear fusion sector by placing importance on the relevance of data from past experiments, even after the facilities may have closed down. The IAEA can play a role to better co-ordinate the integration of KM in nuclear fusion.

Another aspect emerging in the discussion was the importance of correctly sharing and divulgating information with communities, and the impact that communication with the public can have. Nagasaki University analysed the difference between thyroid tumour incidences detected in Chernobyl as compared with the Fukushima post-accident findings. It was reported that, beside means to prevent unnecessary exposure to internal and external radiation, the most important lesson learned from Chernobyl NPP accident is protecting the public from the fear of increased risk of radiation-induced thyroid cancer. The study raised the importance and influence of emotional reactions on data perception. In the case of Fukushima, it is critically important that radiation protection members and medical professionals share knowledge with the public, e.g. explaining correctly the current prevalence of thyroid cancers in Fukushima as a mass screening effect, with no direct linkage of a radiation-induced epidemic.

KM in Nuclear Technology Research, Development and Innovation

The importance of nuclear research and innovation is being reinforced by the aspirations to continuously maximize the safety of existing nuclear technology and applications, and to promote safe innovative ways of using nuclear energy in order to address the need for environmentally sound and safe energy technology.

This technical session highlighted some KM issues specific to the realms of nuclear R&D and innovation, as well as some of the benefits that adopted KM practices have demonstrated in these fields.

First and foremost, emphasis was placed on the importance of ensuring that adequate physical infrastructure, including research facilities and research reactors (RRs), remains in place and is easily accessible for R&D and E&T. This is considered an issue of primary concern.

The IAEA offers several schemes to enhance the access to such infrastructure, such as, for instance, the IAEA designated International Centre based on Research Reactor (ICERR) scheme.

International collaboration among research institutes is becoming increasingly important and it is encouraged and promoted. A wide array of interesting initiatives were reported, which promote effective collaboration, networking and sharing of good practices among different stakeholders in the area of nuclear technology research, development and innovation.

The Eastern Europe Research Reactor (EERR) initiative is a good example of coalition and networking, which allows hands-on training courses for trainees coming from countries belonging to the network, where research reactors are not available. This programme brings about the value of transferring knowledge between countries and across regions.

Another central element discussed was the need of integrating teams, key infrastructures and science laboratories operating in fundamental and applied R&D, with education and training programmes – including MSc and PhD, teachers, research experts and students.

The impact of organizational knowledge frames and the so called “Triple Helix Dynamics” involving university, industry and government was stressed, in particular as far as innovation management of nuclear knowledge is concerned.

Joint ventures between industries and universities can also give rise to spin-off and start-up mechanisms that can be rewarding instruments for inventors and represent key features to ensure effective research, development and innovation in nuclear technology.
Research reactors that play an irreplaceable role in professional training, notably in preparing both operators and regulatory body inspectors, can also be utilized for nuclear education. In the Czech Republic the VR-1 reactor is a key facility for nuclear education and training. The use of VR-1 reactor is an example of effective professional training and efficient integration of a low-power RR with national and international E&T. In order to keep utilising existing RRs and set effective training objectives and programmes for NPP staff at research reactors there is, however, an increasing need to secure RR staff and lectures.
Interesting cases of innovative systems being developed through R&D that can also be applied for practical E&T uses were presented. An example is that of advanced compact radiation systems which can be adopted for education on radiation protection. These can be made available even for the very young students and can also contribute to the enhancement of public acceptance of power applications.
The Belgian Nuclear Research Centre SCK•CEN provides a remarkable example of partnership with nuclear education and training, both in Belgium and internationally. SCK•CEN, a renowned nuclear research institution with in-depth experience in the field of nuclear science and technology and innovative research, has recently launched its "Academy for Nuclear Science and Technology", with the aim to offer guidance to young scientists, organize courses, provide policy support, and care for critical intellectual capacities. E&T initiatives from the SCK•CEN Academy are fed directly from SCK•CEN research output, experience and expertise.
Collaboration on research, e.g. amongst universities and / or with research institutions can pose, however, a series of legal questions. Delicate aspects to be tackled include questions such as: how to create a research framework, how to protect individual and collective inventions, and how to share the outcomes of inventions. Taking adequate measures to cover all organizations and staff with access to confidential technology is a crucial point, as it is laying down licensing agreements, which are equitable and explicit to avoid future disputes, but flexible enough to embrace the evolving nature of collaborative research.
Rosatom in Russia has implemented a comprehensive intellectual property (IP) management system that covers the full life cycle of IP rights. Such IP system is designed to identify the results of the intellectual activity, select IP protection forms and provide guidance for drafting licensing agreements. The system supports innovation and allows for the timely identification of the IP rights to be used within the collaboration framework. It demonstrates how a robust corporate framework for IP ownership and management plays a key role in arranging agreements to pursue a collaborative project on innovations and to ensure the successful commercial exploitation of the results of the joint effort.
Critical in R&D and innovation is the ability to warrant, on one hand, availability, reliability and integrity of data and research results, and, on the other, their confidentiality, according to new risks and requirements. Ensuring adequate storage and sharing of data is a major issue. A notable example is that of experimental data relevant to the validation of simulation codes, in particular in the area of severe accidents.
At the Fast Flux Test Facility (FFTF) in the USA, a lessons-learned process is utilized with the aim to preserve past R&D results, counter the loss of key infrastructure and expertise, and document the current effort to retrieve, secure and preserve critical lessons learned that could influence advanced reactor designs. FFTF lessons-learned approach has been effective in capturing essential tacit knowledge about key events in FFTF history and in providing a context for interpreting the exiting data and references.
The National Research Nuclear University 'MEPhI' (Moscow Engineering Physics Institute) in Russia highlighted the importance and purpose of the application of databases in the field of nuclear technology within the National Research Nuclear University (NRNU) of MEPhI. Through the use of modern technologies and classification, these can aid in the preservation of

knowledge on nuclear technologies, and result in learning through activities and youth involvement in nuclear subjects. The lifecycle of nuclear knowledge can be influenced by the introduction of nuclear databases in the educational process of specialized universities.

Issues and Approaches for Information, Records and Data Management

It is important to draw a distinction between information, data and knowledge. Data are representations of facts, concepts, observables or instructions in a formalized manner. Processed data that have been organized within a context and translated into a form that has structure and meaning can be considered information. Knowledge is the result of acquiring, understanding and interpreting information, using judgment and scientific principles for a specific application.

An important tool that has traditionally supported storage and retrieval of data and information are digital repositories, which are crucial in the nuclear sector to help preserving codified knowledge at risk.

According to the European Organization for Nuclear Research (CERN), there is a real necessity of preserving large-scale analyses that underlie much of the experimental physics work conducted in the organization. The data generated in experiments must be progressively reduced and elaborated from their raw form into final publications, through a combination of software and simulations, passing through multiple hands. To manage and preserve high-energy physics experimental analysis packages in support of Open Science, CERN is developing an ambitious new service that relies heavily on the direct engagement of users in each of CERN's experimental groups.

INIS, the International Nuclear Information System, operated by the IAEA in collaboration with over 150 members, hosts one of the world's largest collections of published information on the peaceful uses of nuclear science and technology. Established in 1970, INIS offers online access to a unique repository of non-conventional literature.

The use of a repository and, the ability to information sharing at large, can be significantly enhanced through the development and inclusion of meta-data, i.e. data about data.

In response to needs expressed by national programmes for radioactive waste repositories requiring the long-term management of large amounts of data, the OECD/NEA has launched an initiative called Radioactive Waste Repository Metadata Management (RepMet), to investigate the role of metadata in the knowledge and information management within the national programmes of radioactive waste repositories. The initiative is of use to both existing programmes looking to review their current systems, as well as new programmes looking at developing their own systems.

In the use and management of digital repositories some challenges are however acknowledged: e.g. in relation to repository sustainability, or the diversity of structure and content of existing systems that can affect their compatibility and related data accessibility. Lack of integration can lead to information silos, hindering data sharing.

In this respect, innovative tools and technologies can be powerful enablers. We are witnessing tremendous advancements and very significant changes in information and communication technology, which are deeply transforming our ways of working and interacting. New instruments such as semantic approaches, Plant Information Model (PIM), 3-D modelling, big data and artificial intelligence, have become available and can greatly enhance data and record management, broadening accessibility and timely availability of data.

The adoption of semantic technologies such as machine learning, statistical analyses and fuzzy systems can also provide a means to build up knowledge from information content. Such methods offer an invaluable aid in the evaluation of the correlation between terms and content in information repositories from which one might infer the importance of the relations and hence insight into its value for knowledge.

It is one of the IAEA's aims to advance the development and deployment of eLearning resource taxonomy and metadata management using Pool Party, a semantic suite technology platform.
Among other hands-on applications that were presented, the Open Educational Resources (OERs) provide a practical tool to disseminate and share educational content in knowledge networks. Specific educational metadata ease the re-use and the creation of a community around single content and semantic web technologies, assisting e.g. with searching, sharing, and adding important content. The adoption of a multidisciplinary approach to operate the OER digital repository is deemed essential to address the various technical, pedagogical and discipline issues. Conversely, the use of knowledge organization systems can enhance the application of semantic technology methodologies. Their success depended on the diversity and variance of the content of the information databases from which the techniques were "trained." New regional intelligent KM systems have been successfully established in India with the Indira Gandhi Centre for Atomic Research (IGCAR) and in Malaysia with the Malaysia Nuclear Agency (Agensi Nuklear Malaysia).
Another important issue also flagged during the session is the need to develop common languages. Constructing common glossaries and using a standardized terminology, while respecting the use of multi-lingual terms are vital aspects to communicate information and facts, describing procedures, policies and progress.

4. OPENING STATEMENT

Y. Amano
International Atomic Energy Agency

Dear colleagues,

It is a pleasure to welcome you to the Third International Conference on Nuclear Knowledge Management, which we are very happy to host in cooperation with OECD Nuclear Energy Agency. Effective knowledge management is vital for success in all industries and especially in the nuclear sector. A nuclear power programme requires a long-term commitment of people and resources, and it is essential that specialist knowledge is shared and maintained. At present 449 nuclear power reactors are in operation in thirty countries. Sixty more are under construction, and the use of nuclear power looks to grow in the coming decades. With its ability to produce steady baseload electricity, while emitting very low levels of greenhouse gases, nuclear power can help countries to grow their economies while mitigating the impact of climate change.
Managing and retaining technical knowledge are major challenges, both in countries with established nuclear power programmes - where an entire generation of experts have begun retiring - and in what we call at the IAEA newcomer countries. Even in countries that are phasing out nuclear power, critical knowledge must be maintained in order to ensure that decommissioning and environmental remediation of sites are carried out in a responsible manner.
Ensuring the availability of highly qualified staff to assume responsibility for the safe, secure, and sustainable operation of nuclear facilities in the coming decades is extremely important. We also need to ensure that critical knowledge is not lost when experts retire.
Ladies and Gentlemen, to help the Member States address some of these challenges, the IAEA has developed a number of programmes in Nuclear Knowledge Management. We have been organizing Nuclear Knowledge Management and Nuclear Energy Management schools since 2010. So far, over 800 young nuclear professionals have graduated from these schools. This year alone, five such events took place.

In 2013, the IAEA launched the International Nuclear Management Academy initiatives to address the lack of Master's programmes in Nuclear Technology Management. The University of Manchester, in the United Kingdom, has introduced the first nuclear Technology Management Master's programme under this initiative. The Russian Nuclear Research Nuclear University "MEPhI" is expected to follow in this.
The IAEA has helped to establish regional and interregional nuclear education networks in Africa, Asia, Latin America, and most recently in Eastern Europe and Central Asia. These have proven to be valuable tools in strengthening operation. Over 10,000 users from more than 100 Member States are using our Cyber Learning Platform for Network Education and Training. This offers more than 300 e-learning courses.
Finally, conferences such as this provide a valuable opportunity for nuclear managers, KM specialists, and decision makers to share experiences and lessons learned.
Ladies and Gentlemen, the nuclear sector constantly needs new thinking and fresh ideas. Knowledge management is a broad and complex area but sharing ideas through events such as this one can bring new perspectives on how we do what we do and how to do it better.
The IAEA will continue work closely with all of you to help ensure that the strong nuclear knowledge base is available, in order to ensure the safe and sustainable use of nuclear technology throughout the world. I wish you productive discussions in the next few days, and look forward to hearing about the outcome of this conference.
Thank you very much.

5. CLOSING STATEMENT BY THE CONFERENCE PRESIDENT

V. Pershukov
Russian Federation

Distinguished participants, dear colleagues,

Thank you for participating in this conference.

I am pleased to report that the conference was very successful.

- The conference we are about to conclude is the third nuclear knowledge management conference, and together with conferences about human resources, the fifth. It was organized as a cross-cutting endeavour involving all relevant IAEA departments.
- The first nuclear knowledge management conference was held in 2004, almost 15 years ago. At that time, nuclear knowledge management was a rather unknown approach. Today, it is well established in the nuclear field.
- Our conference was attended by more than 450 participants from 61 countries and ten international organizations, and supported by 25 exhibitors and sponsors. This is a two-fold increase over the last conference. It is also a good demonstration of the leadership role of the IAEA as a focal point for promoting new insights and making them available to all.
- Participation in the conference was also very broad in terms of countries and organizations involved. This shows the importance of nuclear knowledge management for all Member States.
- We had significant participation from outside the traditional nuclear community. We heard a number of high-level speakers who are experts in knowledge management as academics or professionals. Connecting people and connecting professional communities is an important function of the IAEA.

We heard this week that several drivers make knowledge management an important part of the nuclear sector:

- The need for sound economics, the need for safety, the need to maintain technical design knowledge, the desire to preserve our scientific and technical heritage and the need to secure human resources.
- Nuclear organizations are essentially knowledge-driven, for which establishing and maintaining an appropriate knowledge base and ensuring effective knowledge utilization are central.
- It is logical then, that knowledge management should be a part of every type of nuclear programme, be it for power or non-power applications, for commercial or governmental operations, or for programmes on an organizational or national level.

I would like to commend the IAEA for continuously providing opportunities to share and develop topics of overarching importance, providing a platform where the global nuclear community can share views and Member States can benefit from one another – this is international cooperation in the best sense.
The IAEA General Conference in 2016 adopted strong resolutions on nuclear knowledge management that request the IAEA to continue to place a priority on its knowledge management programme and to support Member States by:

- Developing methodologies and guidance for planning, designing and implementing nuclear knowledge management programmes in nuclear organizations;
- Facilitating nuclear education, networking and experience exchange;
- Assisting Member States by providing products and services for maintaining and preserving nuclear knowledge;
- Promoting the use of state of the art knowledge management technologies and supporting interested Member States in their use.

Clearly this week's conference was a big step forward in all of these areas.

Distinguished participants, dear colleagues,
How has the context for nuclear knowledge management evolved?

1. The energy sector is evolving rapidly, and so does the nuclear world. All nuclear activities depend on the availability of nuclear knowledge, and this knowledge won't manage itself. Knowledge is not a self-organizing system.
2. Decisions for new build, new partnerships and alliances, increased internationalization, growing mobility of a global nuclear workforce and increased bilateral cooperation are trends that bring benefits but can also induce difficulties, such as language and cultural barriers. New or developing initiatives in the areas of nuclear safety or nuclear innovations and occasionally also changing priorities in national nuclear programmes make for a complex and dynamic environment.
3. Approaches to knowledge management and the professional knowledge management community are also evolving, with new solutions, new technology and new tools becoming available every year. The nuclear sector needs to stay connected to this development so that it can benefit from the best knowledge management tools and approaches and the most recent lessons learned.
4. Knowledge management has been successfully used by various organizations involved in different stages of nuclear programmes: owner-operators, regulators, government organizations and private companies, but also at the national and global levels.
5. An important lesson learned from Fukushima is that we cannot take our underlying technical knowledge and knowledge-based decision making for granted. We have

understood that nuclear knowledge management must be an essential part of our nuclear safety approach and safety culture.

Distinguished participants, dear colleagues,
Let us look at the insights we gained this week.
From the point of view of nuclear power,

1. Knowledge should be seen as a valuable resource, and should be managed as key asset of a high-reliability industry.
2. Nuclear facility design knowledge needs to be carefully managed over the entire technology lifecycle to ensure the safety of our facilities as equipment ages, or wears out, or is replaced or upgraded. This means we must pay attention to
    a. identifying clear responsibilities for and ownership of this knowledge along the full supply chain;
    b. ensuring that is maintained together with competent staff that can use the knowledge;
    c. ensuring structured knowledge transfer to recipient countries in case of new programmes;
    d. promoting continuous organizational learning and new approaches such as Plant Information Models.
3. However, there are also a number of challenges.
    a. The trend of lifetime extension continues and the lifespan of nuclear power plants is expected to reach 80 to 100 years in the future. Three or four generations of nuclear workers will participate in the design, construction, operation and decommissioning.
    b. New facility ownership and business models and the increased trend to outsource services, and sometimes relying on non-domestic expertise, result in an increased need to manage knowledge across organizational barriers.
    c. Complex international new build projects, both in mature and newcomer countries, sometimes coupled with mid-project changes, are a growing challenge for knowledge management.
    d. There is a continuing need to address inter-generational knowledge transfer. This challenge exists in two directions. We need to recruit and train new staff to preserve and transfer critical knowledge. On the other hand, the young generation also brings in new knowledge, for example about new design philosophies or new technologies, which needs to be integrated.
    e. There is a lack of uniform guidance and standards that could support and govern the use of knowledge management in the nuclear sector.
4. We have heard how nuclear knowledge management can support new nuclear programmes. Three types of organizations are of prime importance: the nuclear energy project initiating organization, the regulator and the vendor. Well-defined knowledge requirements and processes need to be established between them. National human resource and knowledge networks can play a key role in building the necessary competencies needed for new nuclear energy programmes.
5. We recognized that knowledge management for decommissioning, site remediation, spent fuel and waste management poses unique challenges, such as the need to involve many stakeholders, to combine knowledge from many different sources and from many scientific disciplines, and over long to very long timescales. Decommissioning often means that the operating organization is closed or significantly restructured, so that an organizational approach to knowledge management would be insufficient. Appropriately managing post-accident knowledge is an even more complex challenge. We heard several examples of approaches to address such challenges, for example through databases and long-term knowledge preservation programmes.

6. We also discussed knowledge needs for phase-out programmes**.** Here, the emphasis is on need to sustain an adequate nuclear knowledge base long after last shutdown to ensure responsible decommissioning and site remediation.

From a nuclear safety point of view, knowledge management is of paramount importance.

1. The availability of adequate nuclear safety knowledge is a must for operators to operate a facility safely and for regulatory bodies to carry out their functions. Nuclear safety knowledge management is thus a strategic responsibility for every operator and regulator and, in general terms, essential for all nuclear facilities and activities, including emergency preparedness and response, as they require a reliable and resilient knowledge base.
2. Consequently, the role of regulatory bodies is very specific, as the knowledge to be dealt with is also complex, distributed and long-term. In addition to managing their own knowledge, regulatory bodies need to provide oversight over the licensees' knowledge base, so that they have a dual role.
3. Safety leadership and safety culture promoted amongst junior, mid-career professionals and future leaders is crucial to achieve sustainable knowledge management programmes for safety. There is an on-going need to educate and train competent nuclear managers to ensure strong organizational and personal safety culture. Culture and human interactions in general are of paramount importance for nuclear safety; as one speaker put it for the aircraft industry: *„Culture eats strategy for breakfast".*
7. Several nuclear regulatory bodies and technical support organizations, including some in newcomer countries, successfully use **c**ompetence and knowledge mapping and criticality assessments. The new IAEA supported national nuclear safety knowledge platforms were reported to be of high value for connecting regulatory bodies and technical support organizations.
8. We also heard about the important nuclear safety knowledge networks, for example the Global Nuclear Safety and Security Network, and other topical or regional networks.
4. The new systemic approach to nuclear safety, which considers human, organizational and technical factors, connects to nuclear knowledge management with its focus on the triangle of "people, process and technology", a triangle that is also emphasized in other industries. Exploring these synergies might be a most valuable next step.
5. In short, knowledge management is and must be an integral part of safety culture.

Nuclear knowledge management is also important for research and technology development.

1. Innovation, research and development should be accompanied by knowledge management programmes to facilitate knowledge creation, for example through international university collaboration and networking.
2. Nuclear knowledge preservation of scientific research in turn can be vitally important to ensure that research results – that would be expensive and difficult to reproduce – remain available if and when needed in the future.
3. Knowledge management for research reactors is another continuing challenge, as such reactors are often operated with a small number of staff with unique and specialized skills, and with minimal budgets, so that effective turnover and knowledge transfer become even more important compared to large nuclear power plants.

Establishing reliable and robust intellectual property management as part of a knowledge management programme is another important objective. It is important

- for protecting nuclear innovations through patents;

- for building a favourable climate for investments into nuclear research and development;
- for allowing effective international cooperation for knowledge transfer and capacity building, in particular to newcomer countries; and
- as secure legal basis for many commercial nuclear activities and cooperation.

Distinguished participants, dear colleagues,
A number of insights relate to the state and use of knowledge management across all stakeholders.
Many activities currently address the important issue of capacity building.

1. For the IAEA's Technical Cooperation programme in particular, delivering assistance for knowledge transfer towards building capacity is an important objective.
2. A good example is the IAEA Education Capability Assessment and Planning methodology.
3. Localization, local participation and knowledge transfer to local recipients are supported through knowledge management programmes involving local research and university centres.
4. Knowledge management can help to ensure that these capacity building activities have a lasting impact in Member States. Knowledge management, if implemented strategically, can make capacity building sustainable.

It is interesting to see that the awareness and use of knowledge management by various stakeholders in the nuclear field varies greatly.

1. While in the context of nuclear power and nuclear safety knowledge management is well known, much more could be done to make full use of knowledge management in research and development, academia or nuclear power management.
2. For the first time, the IAEA included a session on knowledge management for non-power applications, and this has been very beneficial. It covered radiation therapy, nuclear medicine and nuclear techniques in industry. Clearly there are opportunities to further apply knowledge management methods and tools in these areas as well.
3. When considering the three important levels of global, governmental and organizational knowledge management, we noted that the most significant level of activity was on the organizational level.
4. However, additional challenges exist when looking at the national level, for example the need to develop the national workforce to meet the recruitment needs of several organizations, transparent education and training standards, connecting different organizations in terms of structured knowledge interfaces, and overcoming barriers between different cultures or professional communities. Managing nuclear knowledge at a national level also appears to be an area where more could and should be done.

Networking and communities of practice are proven knowledge management mechanisms.

1. University networks have existed for some time and are one of the success stories. To date, the focus of networking has been mostly on education.
2. An interesting perspective is to use communities of practice or networking for other knowledge management activities, for example, as networks for creating knowledge, for archiving knowledge or for knowledge transfer.
3. They help to provide access to key experts, facilitate knowledge sharing and mutual learning, including across organizations, connect science and practice, support career development and long-term knowledge transfer.

At the organizational level, according to the IAEA survey, knowledge management is used with three degrees of maturity: ad-hoc, coordinated or fully systematic. The most advanced organizations come to the conclusion:

1. that knowledge management should be part of an organizations' integrated management system, on the same level as quality management or results based management, and be supported by top management;
2. that knowledge management should be embedded in everyday activities under a process-oriented knowledge management approach;
3. that plant information models, design knowledge management and knowledge loss risk assessments are recommended approaches; and
4. that knowledge management has value not only for technical functions, but also for management purposes in general, including governance, monitoring, auditing, transparency and leadership.

Nuclear education and training is a cornerstone of any nuclear programme: in terms of developing human resources, in terms of handing over knowledge from one generation to the next and in terms of creating new knowledge through young scientists.

1. We heard about the successful establishment of educational networks, most recently, for Central Europe and Eastern Asia, about the good progress made by the nuclear education networks from other regions and about the establishment of new degrees and educational institutions.
2. Academic degrees and courses are increasingly designed with a multi- and interdisciplinary approach, for example, by including nuclear subjects in courses for managers, or vice versa.
3. Education does not start at university level. Education starts in primary and secondary schools, and addressing and including the young generation at an early stage is of prime importance.
4. We also heard about national level human resource demand and supply forecasting – a very beneficial effort for both the educational and the recruiting sectors.
5. Learning management systems, internet based learning platforms or the recently founded International Nuclear Management Academy are good examples of how Member States can benefit from IAEA support. We also heard good examples of how to improve the education and training infrastructure, for example through partnerships with industry or through networks that facilitate access to research reactors.
6. Finally, it is of utmost importance to adapt to new learning modes used by the younger generation who grew up in a different IT environment.

Information and communication technology is evolving at tremendous speed. New solutions become available every year, for example, expert systems, online collaboration, semantic technology and search functions, e-learning and massive open online courses, three-dimensional (and multi-dimensional) modelling and artificial intelligence. Digitalization continues to grow in management, science and engineering and business processes. We need to keep up-to-date with these developments and seek to use them for the benefit of all nuclear activities.

Distinguished participants, dear colleagues,
In closing, I would like to re-emphasize a few key messages:

1. The IAEA has supported its Member States for more than 20 years in using knowledge management for nuclear activities. Interest in this conference shows that this is a success story for the IAEA.

2. I would like to highlight once again the need to manage nuclear knowledge more pro-actively throughout the full life-cycle of all projects and programmes, and always giving equal consideration to all three components: people, processes and technology.
3. It has been emphasized how several drivers make knowledge management an important part of nuclear activities: the economic driver, the safety driver, the need to maintain design knowledge and our joint scientific and technical heritage. As a result, knowledge management should be a part of every type of nuclear programme, be it power, non-power, commercial or governmental, organizational, national or global.
4. I would like to reiterate the importance of coordinated action between governments, industry, regulators and all other stakeholders to promote nuclear knowledge management across all nuclear activities and organizations, and the need to look beyond individual organizations and think on a national and international level.
5. I would also like to emphasize the overarching objective of nuclear safety for all nuclear activities and the important contribution knowledge management makes to both the safety and the economic objectives, leading to overall nuclear sustainability.
6. Knowledge management is not a one-size-fits-all concept, and needs to be tailored to meet the specific needs of individual Member States.
7. The IAEA is to be commended for this fruitful conference and is invited to continue to support Member States in their nuclear knowledge management activities, to provide guidance, support, publications, services and development assistance, in all areas: nuclear energy, nuclear safety, nuclear applications and Technical Cooperation alike.

My thanks go in particular to the conference rapporteur, to session chairs and co-chairs, to all speakers, to the scientific secretaries and to the programme committee.
Our joint thanks also go to the remarkable number of sponsors, who have contributed to the exhibition and helped to make this conference a social event as well.
I also thank all participants for their valuable time, attendance and contributions.
It was your participation that made this conference a success.
Thank you.

LIST OF SATELLITE EVENTS

A number of satellite events were held within the conference; titles are provided in the list below:

- Managing design knowledge over the nuclear lifecycle and The Plant Information Model
- Approaches to long-term KM for nuclear facilities, sites and waste post-operation
- "Errare humanum est" – seminar in developing a learning organization
- KM: current challenges and future perspectives
- Leading in a nuclear business
- NKM School Alumni Reunion - Reunion of the alumni from the IAEA / ICTP Nuclear Knowledge Management School
- Knowledge management for technical communities of practice (TCOPs)
- E-learning in support of education and training
- Strengthening the contribution of women to nuclear: enablers and barriers
- How intellectual property benefits knowledge management
- Workshop on National Nuclear Safety Knowledge Platforms and the Integrated Nuclear Safety Capacity Building Plan
- Nuclear capacity building using research reactors and the Internet Reactor Laboratory (IRL) – a live demonstration
- A practical approach to facilitating sustainable human resource and knowledge development (HRKD) networking
- Attracting, developing and retaining new talents
- Semantic web-technology and KM
- Leveraging the international community of retired nuclear experts

ABBREVIATIONS

AESJ	Atomic Energy Society of Japan
AFRA	Africa Regional Cooperative Agreement for Research Development and Training Related to Science and Technology
AFRA-NEST	AFRA Network for Education in Nuclear Science and Technology
ANENT	Asia Network for Education in Nuclear Technology
BSC	Balanced Score Card
CAS	Competency Assurance System
CERN	European Organization for Nuclear Research
CKM	Corporate Knowledge Management
CLP4NET	Cyber Learning Platform for Network Nuclear Education and Training
CNEA	Argentine Atomic Energy Commission
CNESTEN	Centre National de L'Energie, des Sciences et des Techniques Nucléaires
COP21	Conference of the Parties 21
COTS	Commercial Off-the-Shelf
CPD	Continued Professional Development
CRP	Coordinated Research Project
D&ER	Decommissioning and Environmental Remediation
DER-KOS	Decommissioning and Environmental Remediation Projects Knowledge Organization System
DG	Director General
DGR	Deep Geological Repository
DK	Design Knowledge
DKM	Design Knowledge Management
DOE	Department of Energy
E&T	Education and Training
ECTS	European Credit Transfer and Accumulation System
ECVET	European Credit System for Vocational Education and Training
EERR	Eastern European Research Reactor
EFTS	Euratom Fission Training Schemes
ELINDER	European Learning Initiatives for Nuclear Decommissioning and Environmental Remediation
ENEA	Italian National Agency for New Technologies, Energy and Sustainable Economic Development
ENEN	European Nuclear Education Network
ENS	European Nuclear Society
EU	European Union
FANR	Federal Authority for Nuclear Regulation
FFTF	Fast Flux Test Facility
FIU	Florida International University
FOAK	First-of-a-Kind

FORATOM	European Atomic Forum
GNSSN	Global Nuclear Safety and Security Network
HGNE	Hitachi-GE Nuclear Energy, Ltd.
HRD	Human Resource Development
HR	Human Resources
I&C	Instrumentation and Controls
IAEA	International Atomic Energy Agency
ICERR	International Centre based on Research Reactor
IEC	International Electrotechnical Commission
IGCAR	Indira Gandhi Centre for Atomic Research
IMS	Integrated Management System
INIS	International Nuclear Information System
INMA	International Nuclear Management Academy
IRSN	Institut de Radioprotection et Sûreté Nucléaire
ISO	International Standards Organization
IT	Information Technology
KCG	Knowledge Critical Grid
KIF	Key Information file
KM	Knowledge Management
KSU	Nuclear Training and Safety Centre in Väröbacka
LANENT	Latin American Network for Education in Nuclear Technology
LMS	Learning Management Systems
METI	Ministry of Economy, Trade, and Industry
MOOC	Massive Open Online Course
MSMP	Master of Science in Medical Physics
MSs	Management Systems
NAA	Neutron Activation Analysis
NKMI	Knowledge Management Institute
NKM	Nuclear Knowledge Management
NNB	Nuclear New Build
NPI	Nuclear Power Institute
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
NRNU	National Research Nuclear University
OECD	Organisation for Economic Co-operation and Development
OER	Open Educational Resources
ONR	Office for Nuclear Regulation
PIM	Plant Information Model
R&D	Research and Development
RB	Regulatory Body

RK&M	Records, Knowledge and Memory (of Radioactive Waste)
RR	Research Reactors
RepMet	Radioactive Waste Repository Metadata Management
RWM	Radioactive Waste Management
SARCoN	Systematic Assessment of the Regulatory Competence Needs
SGCP	Safeguards Division of Concepts and Planning
SMART	Specific, Measurable, Attainable, Results-Focused, Time-Focused
SOS	Science on Saturday
STAR-NET	The Regional Network for Education and Training in Nuclear Technology
STEM	Science Technology Engineering & Mathematics
TCoP	Technical Communities of Practice
Tepco	Tokyo Electric Power Company
TSO	Technical and Scientific Support Organization
TU	Technical University
UAE	United Arab Emirates
UNFCCC	United Nations Framework Convention on Climate Change
UK	United Kingdom
USA	United States of America
WNA	World Nuclear Association

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