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Setting up a National Technical and Scientific Support Organization for Nuclear Safety and Security

Report of an international workshop, Oslo, 27 – 29 June 2023

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Emneord

Teknisk vitenskapelig støtteorganisasjon (TSO)

Resymé

Denne rapporten oppsummerer en internasjonal workshop om opprettelse av teknisk vitenskapelig støtteorganisasjon (TSO) for atomsikkerhet. Workshopen ble organisert i samarbeid mellom DSA og IAEA 27.-29. juni 2023 i Oslo.

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Abstract

This report provides a comprehensive record of an international workshop on setting up a national Technical and Scientific Support Organization (TSO) for nuclear safety and security that was organized jointly by the DSA and IAEA from 27-29 June 2023 in Oslo.

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Setting up a National Technical and Scientific Support Organization (TSO) for Nuclear Safety and Security.
Report of a Joint Workshop organized by DSA in cooperation with the IAEA, 27-29 June 2023.

Executive Summary

The International Atomic Energy Agency (IAEA) General Safety Requirements Part 1 includes a requirement that "*The government shall make provision for building and maintaining the competence of all parties having responsibilities in relation to the safety of facilities and activities*". One approach to meet this requirement is the setting up of a Technical and Scientific Support Organization (TSO), defined as "*an organization or organizational unit designated, or otherwise recognized by a regulatory body and/or a government to provide expertise and services to support nuclear and radiation safety and all related scientific and technical issues to the regulatory body*".

To support Member States in meeting this requirement, the IAEA Technical and Scientific Support Organizations Forum (TSO Forum) was set up within the Global Nuclear Safety and Security Network (GNSSN). It provides a platform to encourage open dialogue among TSOs worldwide.

The Norwegian Radiation and Nuclear Safety Authority (DSA) has been asked by the government to support the establishment of TSO functions, and work is underway to develop the optimal national approach. The ambition is to build upon national knowledge and experience through international collaboration, e.g., via the European and Central Asia Safety Network. EuCAS has shared experience on the development, application, and value of TSO support to effective implementation of regulatory responsibilities, including the roles of different partners and organizations that can contribute to solutions.

To build further on knowledge and experience gained to date in establishing a TSO, the workshop presented in this report was jointly organized by DSA and the IAEA TSO Forum. The primary objective was to share experience in setting up national TSOs, including experience within the TSO Forum and EuCAS. Particular focus areas included:

- sharing experience with respect to TSOs and their establishment;
- updating understanding of needs for national TSOs and setting out their roles and responsibilities alongside other organizations;
- identifying and documenting challenges with the establishment and operation of TSOs;
- identification of the scope for saving of technical and other resources through sharing (e.g. regional TSOs); and,
- providing corresponding recommendations from TSO Forum members.

The workshop was organized into six topical sessions that were comprised of presentations and associated discussions aimed at identifying and prioritizing key lessons and the conditions under which they are relevant:

- Session I: Setting the scene for a TSO in the regulatory system;
- Session II: The TSO Self Capability Assessment (TOSCA) methodology;
- Session III: Experiences and case studies from TSO Forum members;
- Session IV: Sub-group discussions on key challenges;
- Session V: Technical and scientific challenges, and
- Session VI: Summary and conclusions

Workshop participants included regulators, operators, TSOs and academics from 16 countries. The wide range of presentations combined with the open and in-depth discussion fully addressed the workshop objectives set out above. The information shared will be very useful to countries looking to develop TSO, providing lessons that guide development and may help to avoid pitfalls.

Twelve countries presented TSO-experience reflecting their individual circumstances, including perspectives from: large and small countries; those with a well-established nuclear program; those that are newly embarking and yet others with no nuclear program at all. Examples show that TSOs can have a significant role even in the latter case, given the wide-scale use of sources of ionizing radiation in medicine, research and industry as well as processes and procedures involving NORM.

The general model for interactions between relevant organizations set out in Figure ES1, is highly relevant. Although their coordination can be complex, those organizations cannot work successfully in isolation. While there can be common topical challenges, there is no one organizational model that can effectively provide that coordination in all circumstances. Clarification of the roles and responsibilities of all these organizations, and how they should interact, is crucial but solutions will be locally dependent.

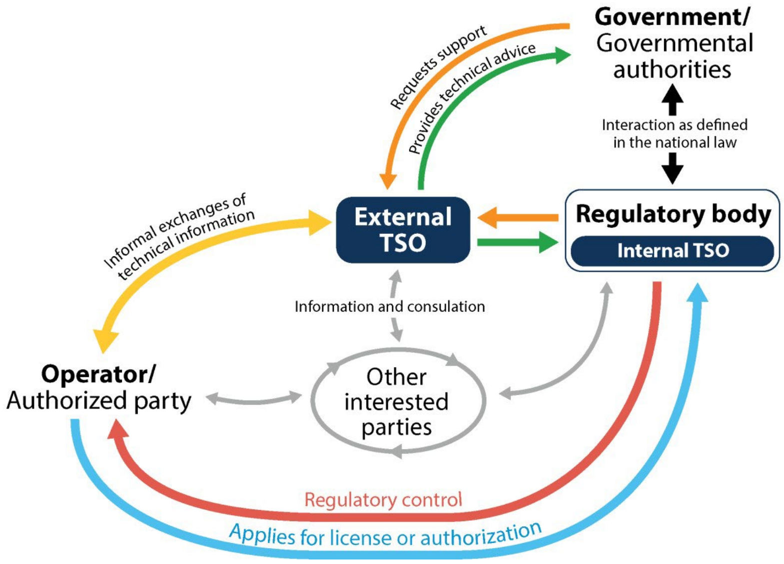

Figure ES1. Illustration of general interactions of the external TSO with the regulatory body and other interested parties in support of regulatory functions in IAEA TECDOC-1835 [IAEA, 2018].

The sharing of knowledge and understanding based on the presentations, including specific case studies, was confirmed by all participants as highly beneficial, providing experience and lessons that can be adapted to the difference circumstances in different countries. Each of the documented presentations has its own value relevant in its own context. Key recommendations and common lessons learned are provided below.

1. When establishing the mandate for a TSO, competencies should be identified and prioritized to ensure that the necessary skills and knowledge are aligned with national policies and nationally relevant needs. Evaluation of such needs is likely to involve a wide range of stakeholders, but a key issue is the legal basis and content of the mandate of the regulatory body.
2. It is important to take a long-term sustainable view of the competencies that will be needed as well as the corresponding staffing level requirements. This applies to providing technical support as well as research.
3. When identifying the requirements of the TSO and the tasks that the TSO will undertake, clear engagement is needed between government, regulators and the TSO that considers the mandate of the regulator. Competencies needed by the TSO to support the regulator in meeting its mandate can then be identified by mapping competencies available against those required. Where competence already exists, judgement is needed to decide if the level of competence is sufficient, or whether

further development is required. Where gaps are identified, thought should be given as to how to close those gaps, through training, hiring or use of external resources. Decisions on which competencies should be held by the regulator and which by the TSO will be dependent on national circumstances. In some cases, changes may be necessary to the legal or regulatory framework under which the regulatory body operates, to allow for the best introduction of the TSO.

4. Determining priorities for improvement of competence or to fill any gaps is an important part of the process and involves a clear understanding of risk management. A holistic view of the risks is suggested that allows multiple hazards to be considered in proportion to those hazards, as well as wider social and economic factors. Advisory committees may have an especially useful role here.
5. Priorities for research that might be carried out by a TSO may be identified by examining the key uncertainties affecting the results of safety assessments. This can be facilitated by making the relevant assessment documentation available.
6. A key challenge in mapping is that competencies need to be linked to a national program that itself may be evolving. For example, it is clear from discussions that several countries are considering the introduction of SMRs. And even without actual SMR development, there will need to be informed discussions on whether such development should take place. Such discussions will need to be informed by input from the regulator, potentially supported by a TSO. In order to deal with such contingencies, it is suggested that a time-step approach be taken to evaluating potential new competency on a regular basis, e.g., examining likely activities and needs on a short- and longer-term basis.
7. There are some events, such as pandemics or armed conflict, that have serious implications and are hard to plan for, so a degree of flexibility in the setting of mandates and interactions among relevant organizations is advised, so far as possible leaving room for appropriate changes in approach.
8. Competence plans should be living documents that reflect progress in line with national programs. Competence mapping should therefore be periodically undertaken both within the regulator and the TSO. Identified gaps in competencies should be communicated, with the TSO informing what resources will be needed to address those gaps, in terms of recruitment and training or by drawing on external expertise, and the associated costs. Knowledge management and risk issues should also be evaluated and prioritized, taking account of the risks associated with not having the necessary competencies and the costs associated with gaining them.
9. While taking account of possible changes in circumstances, it is typically necessary to draw a balance between meeting urgent immediate priorities and long-term interests; this may involve balancing short- and longer-term needs and risks.
10. The mandate for a TSO should include clear mechanisms and processes for interactions between the TSO, regulators and operators, as well as any other relevant organizations, according to local dependencies.
11. In some instances, and particularly for smaller countries, it may be clear that not all the competencies are available. Consideration will then be needed as to whether to look at longer-term training or recruitment from abroad, or some combination. Where there are similar needs in neighboring countries, the establishment of a regional TSO could also help address issues with respect to capacity and capability building.
12. If a TSO is permitted to support other bodies than the regulator, conflicts of interest may arise. This may be a particular issue in small countries where there may be limited expertise available to support both regulators and operators. However, experience presented from countries with established TSOs illustrates that challenges can be addressed by, for example, establishing rules of engagement between the TSO and others. Bringing together the different players has also been demonstrated to be an effective and pragmatic approach to identifying and addressing issues. Nonetheless, careful consideration is needed on how best to arrange expertise in a formal manner to avoid conflicts arising.

13. It has been recognized through various forums that an improved interface is often required between the regulation of nuclear security and the regulation of radiation safety. In some countries TSOs cover security as well as safety and in others, not. Whatever the approach taken, it is beneficial to recognize the synergies between the two fields and the need for an interface to allow engagement when necessary. One complication is that work on security may require some form of clearance and this may deter some from the field. Involving people in the field of nuclear security early in their careers can be a useful approach, enabling security clearance obtained early on with competencies being developed as a career progresses.
14. It has been recognized that the TOSCA methodology might be an appropriate tool to assist national decision-makers in setting up a sound regulatory system with an internal and/or external TSO. This includes self-assessing their national situation and drawing the appropriate conclusions from analysis of strengths, weaknesses, opportunities, and threats and the recommendations and lessons learned.
15. It was noted that the cooperation between EuCAS and the TSO Forum during the workshop was very fruitful and should be further developed in the future, e.g., through joint international and regional workshops or technical contributions to the establishment of national or regional TSOs.

Presentations and discussions during the workshop have proved very useful in providing international perspectives on TSOs for regulatory bodies, including the potential for establishing regional TSOs, for example, in Central Asia. By establishing collaborative platforms, available competencies can be identified at regional level that can be drawn upon as required. Such approaches could prove very useful for emergency response and there is the potential for further promotion of the TSO concept through such platforms. Discussions would be needed between the regulatory bodies within the region to take the concept forward, with EuCAS providing a good platform for starting such discussions. Consideration is also being given to the establishment of virtual TSO Forums that could focus on regional issues.

The TOSCA self-assessment process and TOSCA tool – the TOSCA methodology – have proved useful in those countries in which it has been applied and can support Member States in addressing the above issues. TOSCA was mainly developed for embarking countries on the basis of IAEA TECDOC-1835 and did not focus on how to establish a TSO. However, it was recognized early on that other countries with more developed radiation protection programs also wanted to establish a TSO. Two management and six technical pillars were therefore defined and elaborated to cover the whole range of possible TSO functions and responsibilities. A new TECDOC is now in planning that would cover the establishment of TSOs such that guidance on both 'what' and 'how' are made available to Member States. Suggestions for improvements to the structure and/or content of TOSCA are invited.

Further outreach activities are also planned to help promote the TSO Forum and the work being undertaken. For example, the 5th International TSO Conference is being organized in Vienna in December 2024. Clear messages on the TOSCA methodology and results of the self-assessments undertaken by several countries will be presented. The conference will also provide a platform for wider sharing of experience from other countries on TSOs and lessons learned.

A new cycle of TSO Forum activities is about to begin and new membership is encouraged to allow greater sharing of knowledge and experience. Three core groups have been established with in the forum, comprising TOSCA, research and development and ad hoc. Decommissioning and dismantling and SMRs could be a topic for the ad hoc group and will be discussed at the next forum meeting to determine whether there is scope for working groups to be established.

Abbreviations

CBRN SSA	Chemical, Biological, Radiological and Nuclear Safety and Security Agency, Tajikistan
CERAD	Norwegian Centre of Excellence on Environmental Radioactivity
CEZ	Chornobyl exclusion zone
ChNPP	Chornobyl NPP
CNSS	Centre for Nuclear Safety and Security, South Africa
DD	Danish Decommissioning
DSA	Norwegian Radiation and Nuclear Safety Authority
ENEA	National Agency for New Technologies, Energy and Sustainable Economic Development, Italy
ETSON	European Technical Safety Organizations Network
EuCAS	European and Central Asia Safety Network
FANC	Federal Agency for Nuclear Control, Belgium
GNSSN	Global Nuclear Safety and Security Network, IAEA
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit gGmbH, Germany
IAEA	International Atomic Energy Agency
IRRS	Integrated Regulatory Review Service
IRSN	Institut de Radioprotection et de Sûreté Nucléaire, France
ISIN	National Inspectorate for Nuclear Safety and Radiation Protection, Italy
JRC	Joint Research Centre, European Commission
NDK	Nuclear Regulatory Authority, Türkiye
NMBU	Norwegian University of Life Sciences
NNR	National Nuclear Regulator, South Africa
NORM	Naturally Occurring Radioactive Material
NPP	Nuclear power plant
NRC	Nuclear Regulatory Commission, USA
NSA	Nuclear Safety Authority, France
NÜTED	NÜTED Nükleer Teknik Destek A.Ş., Türkiye
PNRA	Pakistan Nuclear Regulatory Authority
OECD-NEA	Nuclear Energy Agency of the Organization for Economic Co-operation and Development
RW	Radioactive Waste
SAR	Safety Analysis Report
SMR	Small Modular Reactor
SNRIU	State Nuclear Regulatory Inspectorate of Ukraine
SRA RNS	State Regulatory Agency for Radiation and Nuclear Safety, Bosnia and Herzegovina
SSM	Swedish Radiation Safety Authority
SSTC NRS	State Scientific and Technical Center for Nuclear and Radiation Safety, Ukraine
STSO	Scientific and Technical Support Organization to the CBRN SSA, Tajikistan
SÚRO	National Radiation Protection Institute, Czech Republic
STUK	Radiation and Nuclear Safety Authority, Finland
TAEK	Turkish Atomic Energy Authority
TOSCA	TSO Self Capability Assessment
TSO	Technical and Scientific Support Organization
TSO Forum	Technical and Scientific Support Organizations Forum of IAEA
VTT	Technical Research Centre of Finland Ltd
WENRA	Western European Nuclear Regulator Association
WHO	World Health Organization
ZNPP	Zaporizhzhya Nuclear Power Plant

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1 Introduction

1.1 Background

Requirement 11 of the International Atomic Energy Agency (IAEA) General Safety Requirements Part 1 [IAEA, 2015] states that "*The government shall make provision for building and maintaining the competence of all parties having responsibilities in relation to the safety of facilities and activities*". One approach to meeting this requirement is the setting up of a Technical and Scientific Support Organization (TSO), defined as "*an organization or organizational unit designated, or otherwise recognized by a regulatory body and/or a government to provide expertise and services to support nuclear and radiation safety and all related scientific and technical issues to the regulatory body*". TSOs are expected to provide specific research, analysis and testing, independent technical or scientific advice, and competent judgment to a regulatory body. The role can be exercised either inside the regulatory body or as an independent entity and can also support nuclear security and safeguards.

To support Member States in meeting this requirement, the IAEA Technical and Scientific Support Organizations Forum (TSO Forum) [1] was set up within the Global Nuclear Safety and Security Network (GNSSN). It provides a platform to encourage open dialogue among TSOs worldwide, with the objectives to:

- strengthen the roles and technical and scientific capabilities of TSO Forum members, including countries expanding or embarking on a nuclear program and/or facing new challenges;
- promote coordination and collaboration among the TSO Forum members to foster scientific and technical capacity building;
- support the development and application of the TSO Self Capability Assessment (TOSCA) and self-evaluation using the TOSCA questionnaire and relevant IAEA documents; and to
- support preparation of National Action Plans to implement the National TSO development strategy.

There is significant interest in applying these methods in Norway, where the need for scientific and technical support for regulation of decommissioning and waste management is growing following cessation of operations of the Halden and JEEP II research reactors and commencement of their decommissioning. There is also a need to address challenges arising from possible new nuclear and radiation facilities as interest in nuclear power is increasing, and also from the continuing risk of accidents and incidents abroad that could impact Norway.

The Norwegian Radiation and Nuclear Safety Authority (DSA) has been asked by the government to establish TSO functions for Norway and work is underway to develop the optimal approach. There is a strong tradition of research within DSA and within the Norwegian Centre of Excellence on Environmental Radioactivity (CERAD) and the ambition is to build upon this knowledge and experience.

In addition to national experience, international collaboration, e.g., through the European and Central Asia Safety Network (EuCAS)[2], has provided shared experience on the development, application, and value of TSO support to effective implementation of regulatory responsibilities, including the roles of different partners and organizations that can contribute to solutions.

EuCAS, which is supported by DSA, was established in 2016 with the strategic goals of promoting and strengthening sustainable cooperation between member countries, recognizing that challenges and interests are often regionally similar; improve nuclear safety and radiation protection capabilities; develop and coordinate capacity building and contribute to the identification of regional priorities. Since its

[1] https://gnssn.iaea.org/main/tsof/Pages/default.aspx
[2] https://gnssn.iaea.org/main/EuCAS/Pages/About_EuCAS.aspx

inception, EuCAS has developed into one of the largest networks in global safety, with 23 member countries.Several of those countries are looking to develop and improve capacities with respect to nuclear and radiation safety.

To build further on knowledge and experience gained to date, and to share that experience more widely, a workshop on Setting Up a National Technical and Scientific Support Organization for Nuclear Safety and Security, was jointly organized by the DSA and the IAEA TSO Forum. The workshop was held in Oslo, Norway, from 27 – 29 June 2023.

1.2 Workshop Objectives and Scope

The primary objective of the workshop was to share experience in setting up national TSOs, including experience from member states of the TSO Forum and EuCAS network. Particular focus areas included:

- sharing experience with respect to TSOs and their establishment;
- updating understanding of needs for national TSOs and setting out their roles and responsibilities alongside other organizations;
- identifying and documenting challenges with the establishment and operation of TSOs;
- identification of the scope for saving of technical and other resources through sharing (e.g. regional TSOs); and,
- providing corresponding recommendations to TSO Forum members.

1.3 Participation and Program of the Workshop

Workshop participants included regulators, operators and TSOs as well experts with relevant experience from TSO Forum and EuCAS member states. The full list of participants and their affiliations is provided in Appendix A.

The workshop was organized into six topical sessions that were comprised of presentations and associated discussions aimed at identifying and prioritizing key recommendations and the conditions under which they are relevant:

- Session I - Setting the scene for a TSO in the regulatory system;
- Session II: The TOSCA methodology;
- Session III – Experiences and case studies from TSO Forum members;
- Session IV: Sub-group discussions on key challenges, including:
    - How to define and strengthen the technical and scientific capabilities of TSO;
    - The role of a TSO in risk management;
    - Special issues of multiple hazards in decommissioning, remediation and legacy management;
    - Possible conflicts of interest in a TSO serving the regulatory body, operators and other organizations;
    - Communication with stakeholders and the public;
    - Practical aspects of international cooperation for the mutual exchange of experience and approaches in nuclear decommissioning and dismantling;

- Session V: Technical and scientific challenges, and
- Session VI: Summary and conclusions

1.4 Preparation and structure of this report

The report is structured in line with the workshop program, as follows:

- Chapter 2 presents summaries of presentations and discussion from Session 1 on setting the scene for a TSO in the regulatory system
- Chapter 3 summarizes presentations and discussion from Session 2 on the TOSCA methodology
- Chapter 4 outlines presentations and discussion within Session 3 on experiences and case studied from TSO Forum members
- Chapter 5 provides summarized feedback from break-out discussion groups on key challenges (Session 4)
- Chapter 6 summarizes presentations and discussions within Session 5 on technical and scientific challenges
- Chapter 7 provides an overview of the workshop, including lessons learned and key recommendations, as well as perspectives on future plans

Documents are referenced in the text by author and date, and are listed in chapter 8 in alphabetical order.

The report was drafted by DSA and reviewed by participants for correctness of their contributions prior to publication. The information presented is based on contributions provided by participants in the workshop (see Appendix A) but any information or conclusions may not be taken to be representing the policy or views of their respective organizations. Further information is available from presentation files, as made available by the respective contributors.

2 Session 1: Setting the scene for a TSO in the regulatory system

2.1 IAEA Safety Standards and the TSO Forum activities (G. Bracke, IAEA)

2.1.1 Overview of the IAEA Safety Standards

The first IAEA Safety Standard were published in 1958, one year after the IAEA was established. Many more have since been published. The overall objective of the Safety Standards is to provide an integrated, comprehensive and consistent set of high quality, up-to-date and fit-for-purpose safety standards that, together, provide the basis for a high level of protection for people and the environment from harmful effects of ionizing radiation throughout the IAEA Member States. The Safety Standards are primarily aimed at national regulatory authorities and cover all regulatory and operational aspects of nuclear and radiation safety and cover all facilities and (peaceful) activities that can give rise to radiation exposure. The Standards are not binding to Member States but may be adopted by them. They are, however, binding for the IAEA's own activities and on Member States requesting support from the IAEA for operations or entering into project agreements with the IAEA.

The IAEA provide a hierarchy of documents in support of nuclear and radiation safety. The highest level are Safety Fundamentals which cover 10 fundamental safety principles for protecting people and the environment:

1. Responsibility for safety
2. Role of government
3. Leadership and management for safety
4. Justification of facilities and activities
5. Optimization of protection
6. Limitation of risks to individuals
7. Protection of present and future generations
8. Prevention of accidents
9. Emergency preparedness and response
10. Protective actions to reduce existing or unregulated radiation risk

The Safety Fundamentals are supported by Safety Requirements. These are functional requirements that need to be met. They include General Safety Requirements and Specific Safety Requirements. The requirements are detailed in 7 parts. They focus on the governmental, legal and regulatory framework for safety, and also set out the requirement for governments to establish and maintain regulatory bodies which are independent for safety-related decision making [IAEA, 2010]. The Safety Requirements are then underpinned by Safety Guides that provide recommendations and guidance around how to comply with these Safety Requirements.

Another important document is the IAEA Safety and Security Glossary[3] that provides meanings for many technical terms used throughout the documents according to their context, including special meanings

[3] A living document available at: https://www.iaea.org/resources/publications/iaea-nuclear-safety-and-security-glossary

ascribed to common terms. Overall, the Safety Glossary aims to harmonize the terminology used throughout radiation protection and IAEA publications.

There are many players involved in the development of Safety Standards, including the IAEA Secretariat, Member States, the Commission on Safety Standards, the Safety Standards and Nuclear Security Guidance Committees, specialized agencies such as World Health Organization (WHO), international experts and users. Currently there are 134 established safety standards of which 131 have been published. There are also 28 drafts under development that are either new or revisions of previous Standards. The expected total number is 145. At the time of the workshop, 8 standards had been published in 2023 so far and two standards have been posted for official comments by Member States. Beyond the Safety Standards Series publications there are Safety Reports, Nuclear Security Series publications and IAEA TECDOCs available.

2.1.2 Setting the Scene for a TSO in the Regulatory System: TSO Forum activities

The TSO Forum was established by the IAEA in 2010 following a first TSO conference in 2007 with the objectives set out in Chapter 1.1. Currently, 19 Member States are members of the TSO Forum, and Norway is in the process of joining. Partner organizations are the European Commission and its Joint Research Centre (JRC) and the European Technical Safety Organizations Network (ETSON). A resolution was adopted by the IAEA on 30 September 2022 that encourages Member States establish TSOs and to promote cooperation between Member States through the TSO Forum and regional TSO networks, and to assist, if requested, in the use of the TOSCA methodology.

There are many ways of establishing relationships between the regulator, TSOs, operators and other interested parties, and no single model is suitable for all situations. Some case studies have therefore been undertaken within the TSO Forum to illustrate what happened under real situations within a country and the national circumstances and constraints prompting TSO development. Available case studies include reasons leading to the development of TSOs in Pakistan and South Africa and a case study on funding and administrative structure.

The TOSCA methodology aims to help assess the scientific and technical capabilities of a TSO and can be particularly useful for embarking countries as well as those with established capabilities. The methodology centers around a questionnaire developed on the basis of TECDOC-1835 [IAEA, 2018], with an emphasis on evaluating how a TSO is performing its duties. The steps in the methodology are illustrated in Figure 1. The methodology is underpinned by IAEA references and the case study library. A TOSCA Handbook has been developed that describes how the overall self-assessment process can be undertaken.

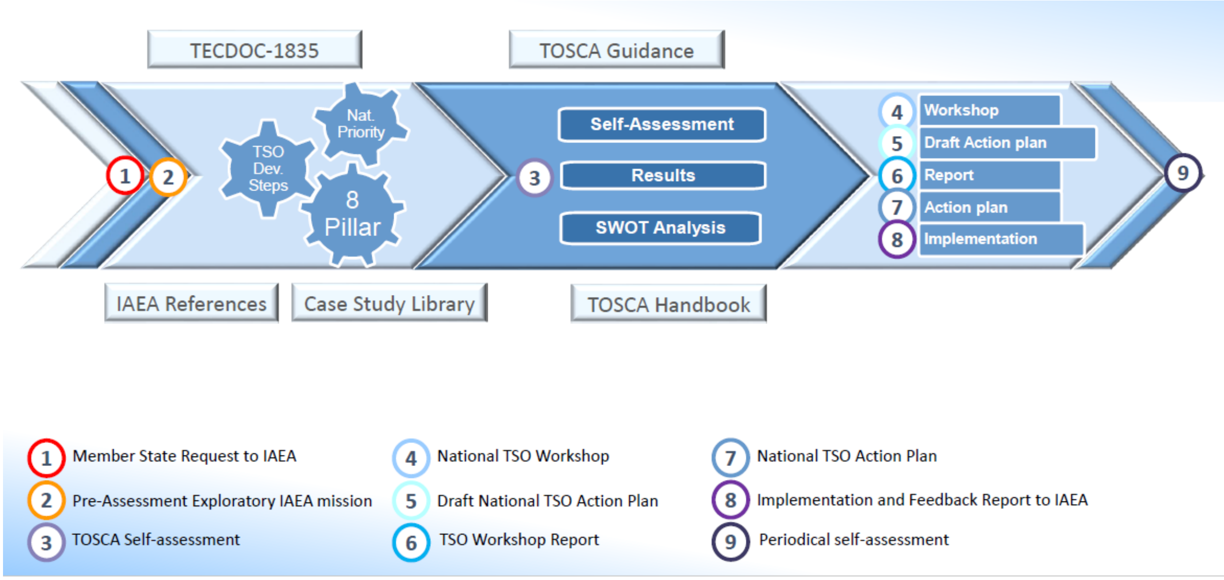

Figure 1. Illustration of the IAEA TOSCA methodology.

Results of the assessment can be presented in various diagrams that illustrate how current capabilities are matched with respect to goals in terms of process and performance. On the basis of experience gained through the case study in South Africa, the TOSCA methodology has been improved and a web-based tool has been developed. Several countries have expressed strong interest in applying the tool. Norway recently embarked on the process. An explanatory mission to prepare for the self-capability assessment has been undertaken, which was followed by a phase 1 self-capability assessment and a workshop to discuss the results.

Following completion of the self-assessment methodology it is recommended that a periodic self-capability assessment may be appropriate. The overall implementation steps are illustrated in Figure 2.

Figure 2. Steps in the implementation of IAEA TOSCA self-assessment.

Discussion

TSOs are primarily aimed at providing support to the regulatory body within a country. Support can also be provided to operators etc., but there can be challenges faced with regards to actual and/or perceived conflicts of interest. In some countries, however, there may be few resources available such that a TSO may need to support both the regulatory body and operators. Where that is the case, conflict of interest issues will need to be addressed.

Membership of the TSO Forum is very much welcomed and any country wishing to join the TSO Forum should email a request to join and provide within that some justification for membership. Additional membership will help further build on the knowledge and experience within the current membership and will be of benefit in the further development of the TOSCA methodology and other topics.

2.2 The TECDOC-1835 approach (K. Ben Ouaghrem, IRSN)

IAEA Safety Standards Series report SSG-16 [IAEA, 2020] on establishing the safety infrastructure for a nuclear program is a useful resource for embarking countries, providing information around the key competencies that need to be developed when developing a nuclear program. IAEA Specific Safety Requirements document79 [IAEA, 2014] then provides guidance on the management of competencies, which is then underpinned by TECDOC-1835 [IAEA, 2018]. This is the key report setting out the core values for organizations providing scientific and technical support to regulatory functions. Additional issues, including legal support, may also be important, but are not within the scope of TECDOC-1835.

The TSO Forum consists of three core groups. One is focused on TOSCA, a second is focused on identifying research topics for countries embarking on nuclear programs and a third is for ad hoc topics identified for which an expert group would be established to address the topic. Conclusions from past TSO conferences included the need to share experience, to develop science-based expertise, to define roles and characteristics etc., and these conclusions formed the cornerstone for the content of TECDOC-1835.

Significant resources are needed to build scientific and technical capabilities. The core characteristics and activities of a TSO may be understood, but the process for developing capacities is less well developed. Case studies can be useful in this respect, providing lessons learned and informing on activities with respect to the organization and political situations in place. A case study in Pakistan illustrates the process for identifying the needs for a TSO. Once needs have been established, the TOSCA self-assessment process follows, to determine how well those needs are being met and better direct further development.

There can be many different activities within a country for which TSO support may be required. A TSO may therefore need to cover a range of different scientific and technical areas in order to provide the necessary services. These different regulatory functions have been covered by the different pillars included in TOSCA (see Chapter 3.1). For each function, lists are provided of how TSOs can provide support to those functions, and what activities can help to develop and maintain those capacities.

There are several different models for TSOs. Where there is an operator requiring authorization, a safety process will be undertaken to develop a safety analysis report and there could be a direct link between the TSO and the operator during this assessment process. Alternatively, the regulator may be the direct contact point for the TSO. In instances where there are links between the operator and the TSO then conflicts of interest may arise. Such conflicts are a key challenge highlighted in GSR Part 1 [IAEA, 2010]. The TECDOC therefore provides some examples of how conflicts can be addressed when a TSO works both with the regulator and operator.

Research supports safety assessment, but it is also necessary to anticipate future needs. This is a key challenge since operational focus is often on the short- or mid-term, but when considering TSO services, it is important to think also in the longer-term, e.g., the implications of climate change on safety assessment. Anticipation is therefore part of the duty of a TSO, ensuring necessary future capacities in assessment and modelling expertise are build and enhanced as required.

The characteristics of members contributing to the development of the TECDOC have been compared and this illustrates the different types of TSO and whether they are internal or external to the regulatory body. Some TSOs are more focused on safety issues whereas other also address environment, while others focus on security issues. Some are directly involved in regulatory inspections, others not. The range of activities of TSOs can therefore vary between countries. Whilst protection of the environment can be an important issue to be addressed by a regulatory body, TECDOC-1835 is focusses only on safety and security.

TECDOC-1835 has proved very useful for those entering the TSO self-capability assessment process and the intention is to further develop and improve the TECDOC to further address issues relating to safety, to better cover the different domains of activities and to improve in terms of IAEA references. Suggestions for improvements to the structure and/or content are invited.

2.3 BOSNIA & HERZEGOVINA: TSO experience, needs and expectations for small non-nuclear countries (Z. Tesanovic, SRA RNS)

Bosnia & Herzegovina is a small country comprising of a population of around 3.5 million people within an area of just over 50,000 km^2. It has a single regulatory body, SRA RNS, that is responsible to the Council of Ministers. The country has been an IAEA Member State since 1995 and received EU Candidate Status in December 2022. The country consists of two entities (the Republic of Srpska and Federation of Bosnia and Herzegovina) and the State district Brčko. Each entity has its own government.

The country has no nuclear power plants (NPPs), research reactors nor uranium mines and is not a nuclear embarking country, but does have sealed and unsealed radioactive materials used in medical, industrial and research activities. There are also a significant number of old lightning rods with sealed radioactive sources installed on various buildings. Management of these sealed and unsealed radioactive materials is the main radiation safety challenge in the country.

A law on radiation and nuclear safety was adopted in 2007 which was followed in 2012 with a policy on the safety and security of sources of ionizing radiation. The country is also a signatory to the Joint Convention on the safety of spent fuel management and on the safety of radioactive waste (RW) management. A strategy on RW management was published in 2014, followed by a regulation on RW management in 2015. The legal and regulatory framework includes the provisions of the Code of Conduct on the safety and Security of radioactive sources as well as applicable EURATOM directives. There is coherence between laws, policies, strategies and other regulations.

SRA RNS is responsible for radiation and nuclear safety, RW safety, transport safety, safeguards, security, emergency preparedness and response, environmental monitoring and the maintenance of national registers. All activities are performed according to IAEA standards and there is no overlapping of regulatory responsibilities with other institutions. SRA RNS therefore performs as an independent regulatory body.

As noted, RW management is the main challenge in the country. There is a policy of safe management of RW in accordance with international standards which requires SRA RNS to establish a regulatory framework for the safe management of RW and to authorize technical services for their safe management, including collection, transport, packaging, handling, conditioning, storage and final disposal. The national strategy for RW is to have a single centralized storage facility, owned by the state, for all institutional and non-institutional waste. Authorization for the central storage facility will be required to be given by SRA RNS to the independent operator of the facility. All wastes generated as a result of past practices, including those currently in interim storage, will be collected in the central store facility for conditioning and storage.

Prior to 1992, all RW and disused sealed radioactive sources were sent to “Vinča institute in central storage” in Serbia, one of the republics in former Yugoslavia. After this, two temporary storage facilities were operated and there were an additional 9 interim stores at user’s premises. These facilities were not, however, secured according to required standards and the situation of the interim storage varies by facility. The inventory of wastes within the facilities is known, but requires verification. Some of the waste has been appropriately conditioned, but some storage areas are occupied by sources that remain associated with equipment. The safety of interim stores is therefore being re-evaluated in line with new regulations.

There are several challenges for RW management in the country. One of the main challenges is that a decision is required on the location for a centralized storage facility, and a committee of 14 people from different institutes having been established to address this challenge. There is also a need to revise the legal and regulatory framework prior to establishing the central storage facility and to revise the safety case in accordance with information obtained from relevant institutions and organizations. The safety case will need to be subject to independent review by the regulatory body prior to licensing the facility and its operator. Continuous training of staff is another challenge faced and it will be necessary to perform a thorough self-assessment of existing gaps in capabilities and competencies.

As a small country, maintaining sufficient staff numbers is a challenge so there can be a lack of experience and expertise. The availability of technical services to support during emergency situations are also limited and there is not sufficient training capacity available in the country. Furthermore, the lack of training means that users of radioactive materials can be challenged in following and applying all the necessary requirements.

The development of a TSO to support the regulatory body and operators could help in addressing challenges, but to achieve this there needs to be a better understanding of the meaning of a TSO in the country and of the difference between a TSO and technical services and centers of excellence. Greater understanding of how a TSO could work, its role, and the availability of staff capacity to be engaged in a TSO within a small country are also needed. It is recognized that similar challenges are faced in other countries in the region and one solution could be to establish a regional TSO, but this would likely be a very complex procedure.

Discussion

It can be difficult to accommodate political decisions in countries. An assessment of the situation needs to be made initially and, from this, an action plan can be proposed. There has been success achieved in developing maintaining national TSOs that serve the needs of the regulator but also supports industry whereby rules are in place that personnel supporting the regulator cannot work on the same issue for the operator.

2.4 SWEDEN: The Swedish research and expert support system (P. Seltborg, SSM)

The Swedish Radiation Safety Authority (SSM) is the organization responsible for nuclear safety, radiation protection, nuclear security and nuclear non-proliferation in Sweden. The organization has missions for knowledge management, regulation, licensing, supervision and emergency preparedness. Licensing includes large NPPs down to dentists using radioactive sources. The nuclear program in the country began in the 1970s and 1980s and currently there are 6 operational nuclear reactors. There is no explicit TSO in Sweden, but there are expert support organizations.

The research and expert support mission of SSM focusses on knowledge management and funding of research to maintain national competence and knowledge development. International research activities are also undertaken.

An IAEA Integrated Regulatory Review Service (IRRS)/Artemis reviews of Sweden has recently been performed with good performance noted. It was recognized that Sweden has a comprehensive regulatory framework for nuclear and radiation safety covering all facilities, activities and exposure situations. Particular good performance was noted with respect to the supervision and optimization of patient dosimetry, the digitization of processes to facilitate source registration, transparent decision-making for licensing and oversight of licensees through annual integrated safety assessments. Other noted good performances related to the mature concept developed for the disposal of spent nuclear fuel and maintaining public awareness of nuclear and radiation safety measures. The main challenge recognized was a lack of qualified staff and knowledge management both for SSM and at a national level with the recommendation made for a distinct national strategy to be developed to address this challenge. Qualified staff are needed by many organizations throughout the country and this need has been further emphasized recently with growing interest for the construction of new nuclear plants. As the regulatory body, SSM will need to develop capacity and capabilities with respect to potential new nuclear build. Extra funding has been allocated to help in readying for potential new build through hiring of new staff, but this has proved challenging; a challenge that is shared with other countries.

In light of the challenges, SSM is working to develop knowledge and national competence through the development of a national strategy for the development of national competence. Whilst competence development has been worked on for many years, there is a need to manage this at a national level and involve many other organizations, including universities and industry as well as the national authorities. Altogether there are around 40 stakeholders involved. The importance of international research activities is recognized and SSM is involved in research programs with various international bodies including EURATOM and the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (OECD-NEA) as well as bilateral research activities.

The vision in terms of a national strategy for competence is that "*secured national supply of competence in the field of radiation safety enables socially beneficial use of radiation and contributes to the protection of people and the environment from unwanted effects no and in the future*". The vision is divided into 5 strategic areas: national coordination; research policy for viable research environments; international research cooperation; education and training for the competence needs in society; and the attractiveness of the radiation safety area. Overall, there are 21 proposed activities across these 5 strategic areas.

A more positive attitude towards nuclear has developed in Sweden in the last few years, and this has resulted in more interest from students to join the nuclear community, but it will take some years for these individuals to develop competence. There will be a need to continue to identify critical subject areas for national competence, investigated the need for infrastructure and funding needs, and to strengthen education programs in nuclear technology and radiation sciences in order to secure national supply of competence.

Increased research funding for radiation safety has been allocated by the government and SSM has received additional funding to hire staff in order to strengthen capacity. Research areas receiving additional funding include reactor safety, nuclear waste management and radiation protection. Reactor safety funding comes from the operators of the NPPs and SKB, the organization responsible for the management of nuclear waste in Sweden, also funds research activities. Research funding is for both basis research, where the main objective is to support national competence, and applied research where the main objective is to support regulatory functions. In addition to additional funding allocated from the government, the Swedish energy agency also provides funding to support nuclear technology and innovation.

There has not been much discussion within Sweden with respect to TSOs but there is an established expert support system. There is internal expert capacity within SSM that could be called, to some extent, an internal TSO capacity but it is necessary to also rely on external capacity. There are strong links with universities throughout Sweden for this support with seven universities being involved in nuclear technology and radiation safety. There are also a number of private/commercial organizations as well as strong international collaboration with Euratom, OECD-NEA and the Nordic countries. For projects within Euratom, normally TSOs would participate but, in the case of SSM, the role taken is both as a TSO and as the regulator.

No decision has been made with respect to new nuclear build in Sweden but there has been new political support and increased funding and SSM has been given a government assignment to prepare for new build. This includes reviewing the legal framework and other measures needed for existing and new nuclear power (e.g., small modular reactors (SMR)). A lot of work remains ahead in order to prepare the legislative process and establish the necessary expert support both within and outwith SSM. As such, SSM is taking part in many different international activities withing the IAEA, EU and OECD-NEA as well as bilateral collaborations with other countries on topics relating to new build and, particularly SMRs.

Key challenges faced with respect to new nuclear in the country include the growing need for personnel and the risk of lack of competence in the short-term and ensuring that radiation protection, emergency preparedness and waste management are not forgotten amongst the new nuclear initiatives. International harmonization and type approval of new reactor designs will also be complicated. Whilst there are challenges ahead, there are also a number of opportunities. There is already a robust and competent nuclear and radiation community in Sweden that can be scaled-up over time, particularly given the increased funding and growing interest for nuclear and radiation science. Sweden also benefits from having a comprehensive regulatory framework in place that can be adapted to new nuclear.

Discussion

The current regulatory framework in Sweden for nuclear power is considered sufficient for SMRs of light-water design, but if more advanced SMRs with different cooling systems are considered then changes are likely to be needed. Scaling up of current capacity and competencies will be needed irrespective of the system of interest and funding has been made available to strengthen internal capacity and to support research activities.

Research collaboration with universities is largely based around funding calls for basic and applied research. Bilateral agreements are also in place with research and technical support organizations. For research institutes there can also be issues around availability of staff so that when funds are made available for research activities and education programs it can take time to scale up.

As in other countries, many people working in nuclear and radiation safety are close to retirement age. There are expectations for new recruits to be able to speak Swedish which can pose a barrier to the hiring of experts from outside of Sweden. There are many international students enrolled in Swedish universities, but it can be challenging to then keep that expertise within the country, which is consistent with challenges faced in many countries.

2.5 TÜRKIYE: Establishment and development stages of TSO (O. Altunkal, NÜTED)

The development of the regulatory system in Türkiye began in 1956 with the establishment of the Atomic Energy Commission. The following year, the country became a member of the IAEA, and two research reactors were also commissioned. In 1982, the Turkish Atomic Energy Authority was established and in 2010 an agreement was signed with Russia to build a NPP. The first site license had been awarded for the Akkuyu site in 1976, but the capacity at the site had develop, necessitating a new site report and construction license for unit 1 and a limited work permit for unit 2 that were also awarded in 2010. In 2018, the IAEA advised that an independent nuclear regulatory body should be established, and the Nuclear Regulatory Authority (NDK) was established by Statutory Decree Law No. 702. In addition, NÜTED, a TSO, was subsequently established and a construction license was issued for Akkuyu units 2-4.

The regulator, NDK, is supported by NÜTED as the primary TSO, but other organizations also provide support. Licensees in the country include those operating research reactors and NPPs as well as the technical university. In addition, there are over 50,000 mostly sealed radiation sources in Türkiye that are subject to regulatory control by NDK. Previously, regulatory functions and technical and scientific roles were under one organizations responsibility, Turkish Atomic Energy Authority (TAEK).

NÜTED was established by law but has no responsibility within the regulatory system. The organization can provide support to the NDK on regulatory issues if requested. This could include assistance with respect to authorization review, undertaking assessments and inspections, training and drafting regulations and guides. NÜTED is also an active member of the TSO Forum.

The timeline for the establishment of the company and its development is illustrated in Figure 3. Following its establishment in 2018, several years were required to establish the framework contract and regulations setting out how NÜTED would work with NDK, with the first contract then being signed in 2020 for technical support to inspections for radiation applications. Since this time, contracts have also been signed for technical support on inspections, construction and management of nuclear facilities and for support for the assessment of commissioning permits.

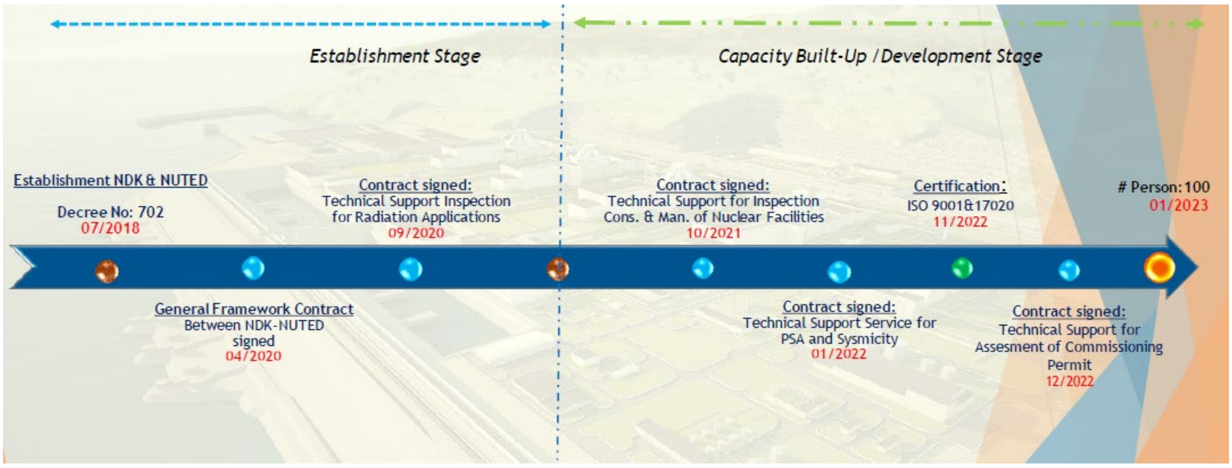

Figure 3. Steps and timeline for the establishment and development of NÜTED.

Within 1.5 to 2 years of establishment, NÜTED has grown to employing around 100 personnel (of which 80% are technical experts with a range of expertise) and it is expected that this will increase to around 150 technical people by around 2025, in line with the development and anticipated operation in of the 4 reactor units currently under construction. The site represents the world's largest nuclear construction site with more than 20,000 workers present and over 400 different companies involved. In addition to work within Türkiye, NÜTED also provides resident inspectors internationally.

Regulatory inspections of at the Akkuyu NPP are carried out by NDK and NÜTED with additional organizations providing support with respect to construction works, nuclear installations and equipment inspections. A graded approach to inspections has been developed with NÜTED providing surveillance and inspection services for site surveillance, NPP equipment manufacturing, on-site inspections and radiation facilities and sources. Records of inspection activities are maintained. Support is also provided to NDK on licensing, analyses and safety review and assessment and approval, training and certification services.

In terms of future plans, NÜTED will support NDK's inspection activities and the licensing process for the commissioning and operational phases. Furthermore, following the commissioning of the NPP, an emergency case coordination center will be required and NÜTED will provide technical and manpower support. Continuous development of expertise is necessary to ensure the necessary capabilities and capacities are available as needed.

The law establishing NDK and NÜTED required that capital investment for the establishment of NÜTED be provided only by NDK. All shares in NÜTED are owned by NDK. Although it is a public company, it can act with the flexibility of a private company with exemptions defined in the Law ruling the establishment of NÜTED and NDK.

Upon its establishment there was no experience on construction, commissioning and operation of NPPs in Türkiye, but there was some regulatory experience and knowledge inherited from the operational and regulatory activities of reactors and radiation sources (TAEK era). As a result of plans for over 50 years for the construction of nuclear power in the country, there was also some nuclear knowledge and, in addition, Türkiye has construction expertise from other large conventional and civil construction projects in Türkiye and abroad.

With these resources at hand, some regulatory experience was also inherited from NDK, both in terms of training and personnel), but this related to the non-nuclear field so it was necessary to develop skills further. Hired experts (in civil, mechanical, I&C, project management etc.) from big industrial projects in conventional fields are motivated to work in the nuclear area. Teams were organized that consisted of NDK experts and NÜTED technical experts that worked together to share experience and develop regulatory and nuclear knowledge. Regulatory personnel were also trained on more technical aspects of work.

Electricity needs within Türkiye keep increasing so it is anticipated that siting for a second NPP will be agreed this year with a third NPP anticipated in the very near future. It will also be necessary to establish new RW facilities. Parallel to these developments, capacity and capabilities of both NDK and NÜTED are expected to increase rapidly, with the acquired experiences from current activities.

Discussion

NÜTED works closely with international experts, including from organizations such as Institute de Radioprotection et de Sûreté Nucléaire (IRSN). Research activities are not undertaken at the current time as there is another separate organization with this function assigned. It could be the case, however, that NÜTED take on more of a research role in the future if required.

In the initial stages of development, NÜTED hired around 10 to 20 personnel with the capital investment provided by NDK, but further expertise was needed. To support the hiring of additional personnel an internal arrangement was put in place between NÜTED and NDK.

3 Session 2: The TOSCA methodology

3.1 Self-evaluation using the TOSCA questionnaire and relevant IAEA documents (C. Eibl-Schwäger, GRS)

The TOSCA methodology was an initiative aimed at establishing a system to support countries evaluate and their TSO capabilities. TOSCA is now in the prototype phase, having been developed as a database from the initial MS Excel file format. The database is only available to countries that apply for TOSCA self-assessment. It is aimed at countries with a regulatory body and TSO either within or outwith that body and for embarking countries where there is a need to assess national capabilities.

TOSCA self-assessment involves a cycle of 9 actions as follows:

1. Member State request to the IAEA for a TOSCA self-assessment
2. Pre-assessment exploratory IAEA mission and preparation of self-assessment
3. Self-assessment phase, with the support of the TOSCA Tool
4. National TSO Workshop, organized jointly by the Member State and the IAEA, with contribution of IAEA TSO Forum Experts
5. Drafting of the National TSO Workshop Report and elaboration (or update) of a draft National Technical Support Development Action Plan
6. Validation of Workshop Report by competent national authorities and by IAEA
7. Finalization, and validation of National Action Plan by competent national authorities after consultation of IAEA TSO Forum Experts
8. Implementation of the Action Plan, and information feed-back to IAEA TSO Forum on implementation results
9. Periodical Self-Assessment – even partly – when appropriate or necessary

The starting point is for a Member State to make a request to the IAEA for a TOSCA self-assessment. This is then followed by a pre-assessment exploratory IAEA mission and preparation of the self-capability assessment where access to the TOSCA tool is provided and the self-assessment phase can progress. It is important when applying the tool to provide context on what the objective is in terms of what is planned to be achieved. This could be, for example, to expand current capacity to address the needs of new energy programs or for emerging countries to establish competencies through the formation of a TSO. The objective is not to illustrate competencies to others, but rather to be honest in terms of where you are currently at and where you want to be.

The scope of the database is deliberately large to be of use to all that are dealing with nuclear safety and radiation protection and is aimed at identifying strengths and weaknesses and opportunities and threats that can then inform the development of national action plan for achieving end goals, with the support of IAEA experts. It is important to recognize when undertaking the assessment that nuclear programs last much longer than a few years, so it is necessary to look beyond political / government cycles.

The TOSCA tool is focused around the following 8 pillars of assessment:

1. Role, characteristics and management
2. Capacity building and outreach
3. Support to safety assessment and inspection

4. Support to the development of regulatory documents
5. Radiation protection and safety of radioactive sources
6. Assessment of operating experience
7. Emergency preparedness and response
8. Research and development

Six of the pillars are therefore focused on technical areas with two being more managerial topics. As the topics are broad reaching it is important to consider who will have responsibility throughout an organization for completion of the different sections of the questionnaire.

Within each pillar there are two types of questions posed, either process-oriented or performance-oriented. Together these aim to cover both the process to be undertaken and how that process is performed on a day-to-day basis.

Pillar 3 on support to safety assessment and inspection is a key pillar for the regulatory body with a TSO often undertaking safety assessments for the regulator. There are at least 18 topics covered within pillar 3 and it is necessary to select which topics are relevant to a country's situation. One approach is to begin with a broad analysis that evaluates the existing or developing process for its adequacy in the context of a TSO and then to look at the performance-oriented questions such as rating resource availability with respect to needs and to rate how experts involved in activities have and maintain competence.

Pillar 5 is focused on radiation protection and safety of radioactive sources, and this has been expanded to a detailed technical level, but only those aspects applicable to the local circumstances should be addressed. Similarly, pillar 6 focusses on operating experience assessment and this will vary according to national programs such that only those aspects applicable should be focused upon. For those coming from a more research background then pillar 8 on research and development will be very important.

For each of the technical pillars there are a series development steps with actions detailed and these can be used to help identify priorities in achieving end goals. Each of the development steps are like an action plan and are worked through much like a road map until the formal launch of a TSO is achieved. The development steps are as follows:

1. Regulatory TSO national capability on agenda for nuclear safety infrastructure
2. A blueprint for national TSO capability (TOSCA pillars 3 to 8 as required) and finalization and blueprint validation
3. Initiate TSO operations
4. National TSO sustainability

Once a blueprint for a national TSO capability has been finalized (step 2) then TSO operations can begin. It is important to consider the sustainability of a national TSO and this is addressed in step 4. There will be movement of people and expertise out of the TSO so work will need to continue to ensure that competencies are maintained.

Process rating scales are provided but it is important not only to focus on the 5-star rating. Brainstorming is a key aspect to completing the questionnaire. Ideally a dedicated person should be assigned to fill out the form, but a team is needed in order to brainstorm, help work through the process and develop understanding of what is needed. The team should cover all levels within the organization with discussion for each topic aiming to identify where improvement is needed.

The TOSCA Handbook is provided along with access to the database. An implementation roadmap and starter kit are also provided to provide background information and guidance to help with communication within a company and more widely as needed. TECDOC-1835 [IAEA, 2018] is also provided.

At the end of the assessment, it is possible to gain an overview of national results and to view the results of the different organizations that have provided input to the assessment. The IAEA provides assistance through various national workshops, including on how to transfer results and develop recommendations. It is possible to focus on particular pillar results and to rate results in relation to an 'ideal situation' benchmark (i.e., the end goal). Figure 4 illustrates the results of a TOSCA assessment. Note that there is no benchmarking against other countries.

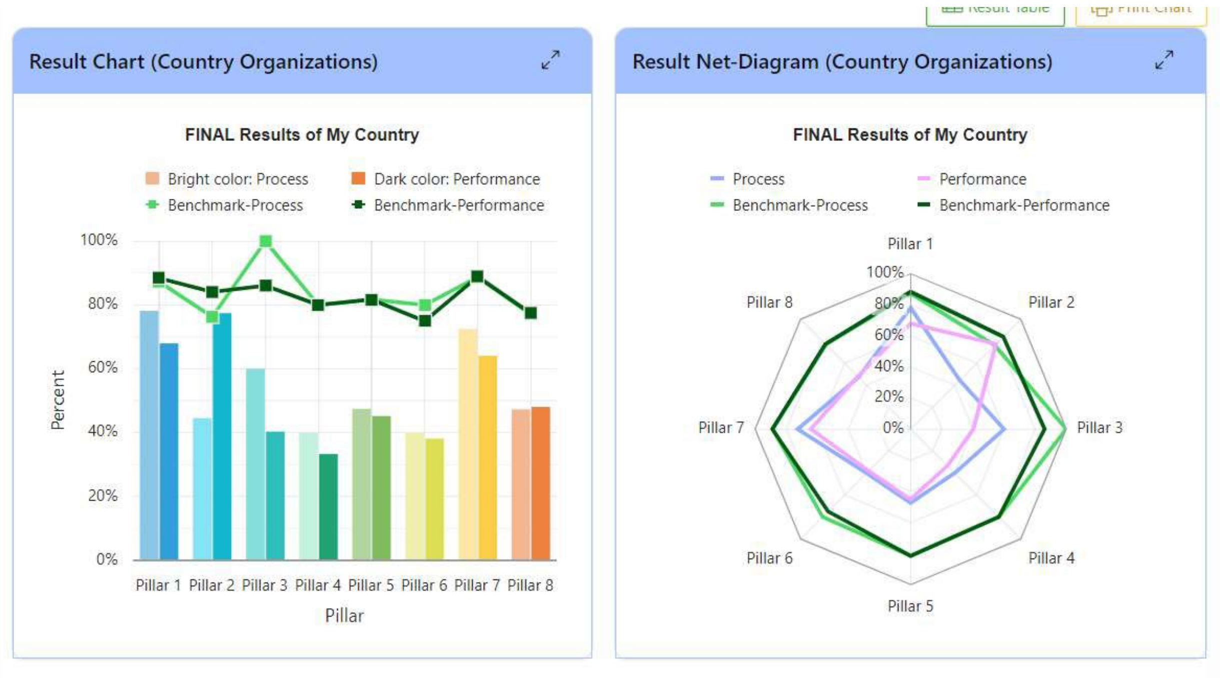

Figure 4. Illustration of results of a TOSCA assessment

3.2 Development and application of the TSO Self Capability Assessment (TOSCA Tool) (K. Ben Ouaghrem, IRSN)

There are various scenarios in which regulatory authorities have to address new challenges in the field of nuclear and radiation safety, such as extensions to licenses for NPPs, development of new nuclear medical applications or radiotherapy units, in the context of legislative or regulatory framework evolution or in response to new national priorities. New nuclear programs are also under development. TOSCA has therefore been developed in a stepwise approach with the aim of ensuring it can be applied to any kind of new program. For embarking countries, it may be necessary to draw on external support, but as internal capacity develops, both within the TSO and the regulatory body, the need for external support should reduce.

Disruptive events (e.g., the Fukushima accident, Covid pandemic, Ukraine war) can also pose additional challenges. This is especially the case for countries that rely on critical competencies from outside the country. New science and technologies can also require support, such as SMRs, advanced reactors and use of artificial intelligence. Changes in society can also have an impact. For example, there has been a considerable change in information exchange with stakeholders being more involved in assessment and decision-making processes. A further key challenge is maintaining competencies as people retire, being able to attract new people to the field and having the appropriate research infrastructure to help in developing necessary competencies.

In spite of the various challenges faced, regulatory sustainability must be developed and maintained. Several strengths must be supported, including strength in terms of independence and in terms of gaining and maintaining the trust of members of the public for which communication and engagement are key strategies. Strength in terms of the funding system and the technical resources including tools and data are also important.

An important strategy for sustainability is to evaluate the current status. Competencies should be mapped and analyzed. Peer review from the IAEA can also be very useful. When considering competencies, there may be different contributors spread between different agencies and in such instances, it is important to develop and maintain appropriate linkages.

It is also important for a TSO to develop effective communication skills to help bridge the gap between scientific knowledge and regulatory terminology. The TSO needs to be able to understand and support the formulation of requirements and authorizations, but also be able to communicate and engage with members of the public. Enabling interactions between the different players can be important in this regard.

Discussion

Decommissioning of older facilities can often be challenging. For example, Norway is currently looking to decommission old research reactors that were not designed to current standards. Complex situations can arise when undertaking such activities that can be challenging both for the regulator and the TSO. In some situations, it may be necessary for regulatory systems to be updated to allow situations to be managed appropriately and effectively.

Operational plants will have process wastes and the hazards associated with these tend to be in line with the normal operating hazards at the plant. However, for a decommissioning site, low level RW can often be associated with other hazards that may be more hazardous than the radioactivity. In such situations, the risks associated with the different hazards need to be a be assessed proportionately to inform on the most appropriate management strategy for the wastes. The regulatory challenges associated with addressing legacies, including the problem of multiple hazards, have been considered by the NEA-OECD expert group on legacy management [NEA, 2020].

3.3 Norway – Experience and lessons learned from the TOSCA and national workshop (A.L. Rudjord & H. Hüttmann, DSA)

The Norwegian nuclear sector is relatively small with just three sites. Kjeller and Halden are permanently shut-down research reactors and there is a combined low and intermediate level waste storage and disposal facility (Himdalen). There is a lot of infrastructure in place for fuel fabrication, wet and dry storage facilities etc. at the research reactor sites that date from the 1950s and 1960s. Whilst the nuclear sector is relatively small, there is wide variation in the facilities and associated challenges as the preparations get underway for decommissioning and waste management. New infrastructure will be required to support decommissioning, including new disposal facilities. New nuclear power is a topic of increasing interest in Norway, particularly in relation to SMRs. There are also challenges presented by nuclear powered vessels that are present around the Norwegian coast.

In order to address the various challenges faced, DSA, as the Norwegian regulatory body for nuclear and radiation safety, needs to develop capacity and competencies. A TSO would build upon current expertise available in the country, including CERAD and should also be active in international research and development and technical cooperation.

Following initial discussions in 2018, DSA investigated how to potential set up a TSO or TSO functions in Norway with funding being allocated in 2023 to support this approach, DSA established an internal working group. Whilst the main focus was on decommissioning and RW management, all sections of DSA were involved, along with the Norwegian University of Life Sciences (NMBU), that partners with DSA in CERAD. The working group decided to request IAEA support in order to include TOSCA to inform the investigations on how best to establish a national TSO.

Project TSO was based on a standard approach for establishing businesses, with a phased approach being employed (Figure 5). The project was supported by TOSCA, which was being conducted in parallel. The output from several workshops, including that reported herein, will also be used to inform decisions.

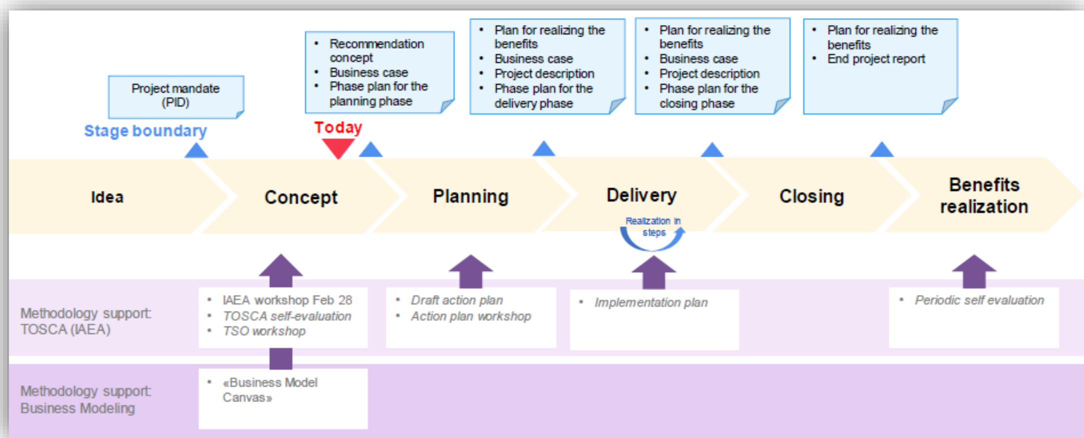

Figure 5. Phased approach to Project TSO to establish a national TSO in Norway.

Key challenges for technical and scientific support to DSA include ensuring that existing competencies and capabilities are maintained and not only made available for use in a regulatory context today but also tailored toward additional needs in the future. Relevant expert and research groups are vulnerable as a result of limited funding being available for research and development and a lack of experienced technical personnel, which also presents a challenge to establishing a TSO. In order to establish an effective TSO, it will be necessary to determine how the TSO should be organized (e.g., internal, external or a hybrid arrangement) and to identify the scientific and technical areas that are required, and which tasks and services could be provided (e.g., whether the TSO would focus on research and development or also provide additional support functions). Norway is only a small country and there are only a few experts available. These experts are needed to support the regulatory functions, but also to support the operators, the Institute for Energy Technology and Norwegian Nuclear Decommissioning. It will be important, therefore, to ensure that conflicts of interest are avoided.

TSO capacities exist already within DSA, including in knowledge management, emergency preparedness and in undertaking inspections. Agreements are in place with a wide variety of external experts, for example through framework agreements and international consortia, and national experts such as within CERAD. A planned Nuclear Research Center is likely to provide additional expert resource in the future.

Despite being a small country, when working through TOSCA, the pillars were found to be relevant for DSA. Of the topics covered within each of the pillars, consideration had to be given as to whether to do broad or in-depth analysis and it was possible to exclude topics as appropriate (some pillars were very focused toward NPPs). Within each topic, respondents are asked to answer a series of questions that are largely set as 1 process and around 4 performance questions for each topic, and consideration had to be given as to how to address questions when there was no dedicated unit available on that topic. The tool was found to be very flexible, adjustments could be made, and the focus was placed on mapping of the technical capabilities both internally within DSA and external resources.

The TOSCA process was found to be helpful. The tool guides evaluators through the process and helps in developing understanding of TSO needs. Establishment of a TSO or TSO functions will be an ongoing process that is steered by the development step and the national priorities of the TOSCA topics. Reassessment will be needed as development phases are achieved. In working through the first phase, a key lesson learned was that, where there are time constraints, effective communication across the organizations and in line management is essential to ensure all involved in the process are onboard and understand the process, the nature of the tool, expected outcomes and needs in terms of input and over what timeframe. DSA's work with the tool during phase 1 will help with the second stage where additional pillars will be addressed. In establishing a TSO, competencies within DSA and NMBU will be built upon and expanded gradually to meet future needs.

Discussion

A workshop was held between DSA and IAEA prior to DSA undertaking the TOSCA and this was valuable in facilitating discussion and helping to build a strategy for the assessment. There can be different perceptions around strategies, for example between regulators and TSOs and it is useful to understand these different perspectives. Having a blueprint of a potential TSO approach can also help in working through the method.

4 Session 3 – Experience and case studies from the TSO Forum Member States

4.1 Pakistan: Review and assessment of Safety Analysis Report by TSO to support in licensing of Nuclear Power Plant (N. Mughal, PNRA)

The licensing of NPPs is a complex task requiring rigorous review and assessment of many different documents that are submitted to the regulator by the licensee at different stages of the process (e.g., pre-construction, construction, operation etc.). Of the many reports submitted, safety analysis reports (SARs) are the most important. A SAR contains diverse information, and it can be a difficult task to undertake regulatory review, requiring significant time and human resources.

In 2005, the decision was made in Pakistan to establish an internal TSO by hiring around 55 fresh graduates from different disciplines of engineering and physical sciences. There was previous experience available prior to establishing the TSO on review and assessment as a result of previous licensing of research reactors etc. This experience was used to help in training the new recruits with hands-on training being provided in review and assessments of generic pressurized water reactor design SARs that had been reviewed in the years prior to the TSO being established. In parallel, the new TSO recruits also received extensive training in specific technical areas at both national and international levels, under the umbrella of the IAEA. As a result, within a period of 5 years, TSO personnel had gained significant capability to perform safety review of SAR of a similar NPP unit in support of an operating license in 2010.

A staged review methodology for the SAR was implemented. To support planning and scheduling, a review schedule was developed that reflected the timeline for the review and PNRA designated sufficient human resources and allocated suitable time, in mutual agreement between the TSO, the licensing department and the licensee to meet that schedule. The timelines were therefore agreed with the licensee at the outset for the whole review process of the SAR.

A review team consisting of several groups covering the different chapters of the SAR was established. Each review team was structured to include a large number of review team members with a review team leader being designated. The review team leader was responsible for the review team carrying out the review and assessment of their designated technical area and for providing feedback to the regulatory body. Above the review team sat a core team that was comprised of senior officials from the regulatory body that had the objective of improving the review and assessment. An advisory team was also formed that informed on key issues to be focused upon. This team structure was applied to all review tasks for documents submitted by the licensee.

The safety review was carried out against the regulatory framework, including industrial codes and standards and the TSO had an important role to play in informing whether or not acceptance criteria had been met. The regulatory framework provides explicit requirements on licensing that can inform licensees. Licensees can also use applicable IAEA safety standards and safety guides to address any gaps, and can use ‘golden standards’ of other national and international organizations, but must demonstrate that they are applicable and equivalent to others that could apply. For example, the US Nuclear Regulatory Commission (NRC) regulatory guide NRC-RG 1.70 provides guidance on the standard format and content for SARs and this was an important document used by the TSO in reviewing the SAR. The TSO also considered feedback reports from design review and inspections etc. that were accessible from different regulatory bodies.

There were three phases to the review. In phase 1, the SAR was reviewed in accordance with applicable codes and standards to check for any notable gaps, having agreed content with the licensee prior to this.

This constituted around a 1.5 month review cycle. Phase 2 was then a detailed review phase where the SAR was reviewed in detail against applicable regulatory documents, codes and standards, lasting around 8-9 months. Phase 3 then comprised an operational feedback review that focused on national and international operating experience feedback and as-built design verification. The review of operational feedback from organizations such as IRSN was an important aspect of the overall review process and lasted around 4 months.

Throughout the review process, information presented in the SAR was evaluated and reviewers raised queries where missing information was noted with respect to the format or content; where explanation was needed on compliance with requirements of applicable codes and standards; where additional analysis was needed to support results presented in the SAR; and where inconsistencies were noted between different chapters of the SAR. The queries were to be reflected in the licensing document provided to the licensee within the authorization and were therefore very important in providing the basis for licensing. All queries were therefore scrutinized by the lead reviewer for each chapter prior to being discussed and finalized within the core team. Review queries were also scrutinized and discussed with the facility design team and/or the licensee in review meetings. For each query, actions sheets were prepared. The review sheets provide space for responses from the licensee and for signatures from both the TSO and licensee. The review sheets are retained for the lifetime of the facility.

At end of the review process, a safety evaluation report was prepared by the TSO that depicted safety issues identified during the review and assessment process for each chapter of the SAR. The report summarized the whole review process and formed the basis for regulatory decision making, detailing issues to be included as authorization conditions within the license and identified specific areas for performing regulatory inspections to verify compliance. The overall review and assessment process is depicted in Figure 6, which can be tailored to other review process needs.

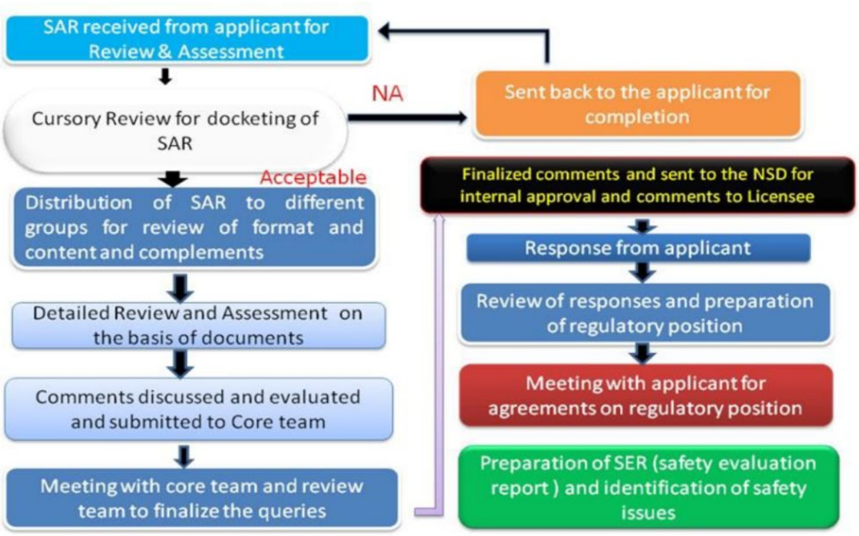

Figure 6. Process flow charge for SAR review and assessment.

The SAR review and assessment process needs to be carried out under the management system of the regulatory body. A licensing contact point was established both in the licensing department and the licensee as the basis for communication between the licensee and the regulatory body. As the overall responsibility for safety rests with the licensee, no meetings of the regulatory body were organized in the absence of the owner.

Review and assessment of a SAR is difficult, and it was therefore possible for the TSO to seek expert assistance from other TSOs where bilateral arrangements of cooperation were in place and important issues requiring external assistance were identified and communicated to the TSO and, in some instances, experts within the TSO would be called upon to act as consultants in formal review meetings.

A wide range of documents were produced as part of the review and assessment process in order to maintain a complete record of the process. These included queries raised by the review team, records of communication of review queries, additional information required as a result of the review, records of internal and external review meetings, including action sheets signed by the licensee, designer and regulatory body, and records of all directives issued by the regulatory body to the licensee.

The TSO has the mandate to carry out independent safety analysis for the purpose of auditing of the licensing analysis presented in the SAR. Such an audit is routinely used by regulatory bodies to check the completeness and consistency of analyses submitted for licensing purposes and to supplement the task of reviewing and assessing the design and operation of NPPs and the IAEA requires that capabilities are developed and maintained to enable independent safety review to be performed.

A design database has been developed based on different documents dealing with plant design, equipment etc. and this has been used to develop an input database for computer codes. The database contains all necessary information on geometry, thermal and hydraulic parameters, material properties, characteristics of control system and set points, and the range of uncertainties in plant instruments and devices, including drawings and other graphical documents. It can be helpful to develop a handbook that can be used for audit analysis against different standards that details methods and simplifying assumptions used in converting technical plant data into code input data and all calculations made. Verification and validation of input data is then required to check for and remove any errors and to demonstrate that the model adequately represents the intended functions of the modelled systems. The overall objective of the independent safety analysis is to check the completeness and consistency of accident scenarios submitted by the licensee to facilitate regulatory decision-making within the framework of the licensing process. Development of in-house capacity for performing such analysis provides greater confidence to the regulatory body during the decision-making process and in communication in discussing issues with the licensee.

An internal TSO can therefore be used as a dedicated organizational unit of the regulatory body where the knowledge base of the TSO is retained within the regulatory body. Recruitment and extensive training are necessary to ensure a sustainable knowledge base over time and this requires sufficient funding to be allocated. This also ensures that competencies on new software can be developed as needed and state-of-the-art knowledge can evolve over time. For any countries embarking on nuclear power programs, it will be necessary to prepare a human resource development plan well in advance for recruitment of staff and their capacity building in order to develop a sustainable scientific and technical knowledge base within a TSO.

Discussion

Radiation protection was included within the scope of the internal TSO. There was national experience stemming from nuclear power in the country for over 10 years and this expertise was included, along with other aspects, such as experience in reviewing radiation facilities in the review. The TSO now provides support to the licensing directorate for other radiation facilities, including medical centers.

There is a requirement on licensees for independent verification of the SAR to be undertaken prior to submission to the regulatory body. Whilst the results of this independent review are often required alongside the SAR, the TSO still undertakes a further independent assessment.

4.2 Belgium: Experience of a TSO in Belgium (S. Vermonter, BelV)

The Federal Agency for Nuclear Control (FANC) is the regulatory body in Belgium for nuclear and radiation safety and Bel V is the national TSO. Bel V is a non-profit organization that is a subsidiary of FANC and responsible for performing oversight of Belgian nuclear installations. Bel V does not have a communication role – that is held by FANC.

Article 14 of the Law of 15 April 1994 states that FANC can create entities for the exclusive purpose of supporting its missions, which is the basis for the formation of Bel V. General Regulations regarding the protection of the public, the workers and the environment against the hazards of ionizing radiation then detail the regulatory missions that can be delegated to Bel V, which includes regular inspections and safety assessments in Class I and IIA facilities. Agreements between FANC and Bel V then set out modalities for performance of the delegated regulatory missions. Key activities of Bel V include oversight and inspection, safety assessment, research and development and training of staff.

There are currently 85 employees within Bel V and 73% are men. The organization is ISO 9001:2015 certified for nuclear inspections, advising authorities on the development of nuclear emergency plans and in performing and evaluating nuclear safety and radiation protection both nationally and internationally. In addition to Bel V providing safety and security support to FANC, it also receives support from other organizations in matters relating to RW management and decommissioning.

Belgium currently has 7 NPP of which 5 are in operation. According to the current situation, the remaining NPPs should cease operations by 2025, but recent discussions between FANC and the operators indicate that at least 2 of the operational NPPs could operate over longer timeframes. In addition to NPPs, Belgium also has a RW treatment and storage center, a research center with research reactors and laboratories, a joint research center with fissile materials and accelerators, and an institute for radioisotope production, primarily for medical applications.

Bel V is formed of two main divisions: a nuclear installations division and a safety assessment division. A department for strategic development then sits between these divisions.

The nuclear installations division has several focus areas, including NPP, other nuclear facilities, support to inspections, projects for NPP and projects for other nuclear facilities. An integrated approach is taken to inspections that comprise performance-based, process-oriented, and reactive inspections with Bel V technical experts providing support in the field during inspections. Safety culture oversight using IAEA-based models is also performed. Safety assessments are undertaken where there are modifications to installations or where incident analysis is required.

Technical project management is an important area. Projects are managed initially by translating contracts into work plans and schedules that are documented as part of the overall project quality and management plans. Project managers are assigned that are responsible for the technical outcome being of the required quality and within the agreed budget and according to the agreed plan. The project manager receives support from technical experts. The projects can be varied and have included periodic safety reviews for the post-operational period and in relation to operations and waste treatment and decommissioning projects for research reactors, reprocessing facilities and facilities producing fuel. Two projects have recently started for the decommissioning of the 2 NPPs that are in definite shutdown. Projects have also included new installations. A storage and treatment facility has recently been built and a facility to transform radioactive residues into low-enriched uranium and to purify them is in the licensing phase. A license has also recently been granted for the construction of a facility for the near-surface disposal of low-level RW and for a spent fuel storage facility.

Within the safety assessment division there are technical responsibility centers and technical branches. The division operates within a multidisciplinary sector so branches are required to work together and technical centers aim to cover all expertise that are needed to perform safety analyses, inspired by the NPP SAR chapters. The centers are not hierarchic but are comprised of a coordinator working with members from across Bel V staff. There is continuous development of expertise through research and development and involvement in various international working groups, such as the Western European Nuclear Regulator Association and ETSON and participation to international research programs under the EC, OECD-NEA and IAEA. Whilst a number of international projects are undertaken, the key focus of activities at Bel V is on providing services in support of Belgian regulatory activities.

Discussion

Inspections at research reactors are performed regularly with inspections often being combined so, for example, the research reactors and laboratories at Mol are inspected at the same time. For decommissioning sites, inspections are undertaken less frequently at present, perhaps being twice per year. At operating facilities, the inspections focus on just one topic at a time for systematic inspections. Thematic inspections are also performed, e.g., for radiation protection, that focus more on procedures and staffing levels and may be carried out once per year.

Whilst Bel V does not have a role in communication in Belgium, FANC receives a lot of questions from politicians and members of the public and Bel V is often required to provide answers from a technical point of view. However, FANC communicates the response.

Capabilities and capacity are maintained through training with around 10% of every person's time being allocated to training. There is a training manager and every year a training grid and report is prepared to identify areas lacking expertise and identifying needs for upcoming projects. Work is then undertaken to address those gaps where possible.

The relationship between FANC and Bel V is set by Royal Decree, and the tasks that can be performed in support of FANC are also stipulated.

4.3 Czech Republic: Czech TSO and current nuclear safety challenges in the Czech Republic (M. Ruscak, SÚRO)

The National Radiation Protection Institute (SÚRO) is a public research institute whose main activity is regulatory research on nuclear safety and protection against ionizing radiation. The basic functions of SÚRO are to provide expert, methodological, educational, information and research activities related to the State Office for Nuclear Safety in the field of nuclear safety protection against ionizing radiation in the Czech Republic. Tasks include research and development in the area of nuclear safety and radiation protection, independent nuclear safety assessment, monitoring radioactivity in the environment, medical exposure, and radon exposure assessment.

SÚRO is not government owned but was established by the regulator. The budget is partially gained from research and development projects that are competitively gained and around 20% is from commercial projects. The remainder of funding is from the government. Research and development accounts for over 50% of the budget.

The nuclear safety group was established in 2012. Initially there were 5 group members, 3 of which were engineers, but this had increased to 50 experts by 2023. The initial approach to recruitment was slow as the company operated as a private research company until 2017 so projects had to be in place to support the hiring of new staff. In 2017 an agreement was signed with the regulator that saw the group join SÚRO as it was established and a strategy was agreed that provided financial support for gaining new staff over a 5-year period. The resultant group is international, comprising individuals from Czech Republic, Slovakia, Italy, Romania, Armenia, Ukraine, Mexico and Spain. There were good links established with various universities and students were invited to train with SÚRO. As the group grew, there was increased interest, with the group now being comprised of around 50% Czech nationals.

By mandate, the TSO aims to grow by around 5 full-time people per year. Grant funding is available for new hires which helps in planning ahead based on the strategy and timeline for what expertise are needed and by when. A key goal in the Czech Republic is to build new NPPs. This will require expertise to be available at particular points in time through the development process which helps in planning recruitment.

When the nuclear safety group initially joined SÚRO it was comprised of a single nuclear safety section with two divisions. This has subsequently been split into three:

- Department of research and nuclear safety assessment;
- Department of nuclear regulation support; and
- Division of nuclear regulation support in the field of radioactive waste.

Within the assessments department, a key challenge has been how to manage an increasing workload with only a few people available, which has required work to be undertaken more effectively. For example, time spent working with data has been reduced by automating the process. With the war in Ukraine beginning in 2022, there has been greater emphasis from the regulator on providing answers with regard to accident scenarios. A single process for direct calculations to be performed for the most common issues was developed by preparing scripts that, with the entry of boundary conditions, will perform all necessary calculations and automatically generate plots and fill tables within a report template. As a result of script development, complex analysis of events, including for severe accidents etc. can be performed within 2 hours. This allows the expertise of people to be applied to analysis rather than undertaking assessment groundwork at computers. SÚRO has been active in the area of severe accidents as a result of the Ukrainian war. Simulation of possible scenarios that could lead to a severe accident at the Zaporizhzhya Nuclear Power Plant (ZNPP) have been routinely performed under varying weather conditions so that if the regulator asks for information on the situation at a particular time, then the information is immediately available. It will be possible to do similar simulations for other NPPs, but a request has so far only been made for the ZNPP.

Within the department providing direct support to the regulator, employees are largely those previously employed by the utilities that have now moved to support the regulatory process. Mostly inspection activities are performed with the TSO department supporting inspectors from the regulator. There are currently about 17 people within this department, and many have decades of hands-on experience of working with reactors and are therefore in a good position to identify any issues during inspections. The department also provides support in the development of legislation and regulatory safety guides and provides expert support to the regulator in negotiations with license holders.

The division of nuclear regulation support in the field of RW management is the smallest department since the regulator has more expertise in this field and less requests for support are therefore made. Currently there are 5 people in this division that provide support in the expected licensing of a deep geological repository for RW, including in the evaluation of documentation for the siting of a deep geological repository. The division also provides support to evaluation of safety documentation of RW facilities, waste acceptance conditions, RW management prior to disposal and the transport of radionuclides. Research and development activities for RW management are also undertaken.

SÚRO is involved in several current Horizon 2020 – Euratom projects, including:

- European Joint Research Programme in the management and disposal of RW (EURAD), 2019-2024;
- PRE-DISposal management of RW (PREDIS), 2020-2024;
- Towards effective radiation protection based on improved scientific evidence and social considerations focus on radon and Naturally Occurring Radioactive Material (RadoNorm), 2020-2025;
- Awareness and resilience through European multi sensor system (ArtEmis), 2022-2026;
- Towards harmonisation in licensing of future nuclear power technologies in Europe (HARMONISE), 2022-2025;
- HARmonised PracticEs, Regulations and Standards in waste management and decommissioning (HARPERS), 2022-2025;
- Partnership for European research in radiation protection and detection of ionizing radiation towards a safer use and improved protection of the environment and human health (PIANOFORTE), 2022-2027; and
- Safety Analysis of SMR with PAssive Mitigation strategies - Severe Accident (SASPAM-SA), 2022-2026.

One of the biggest challenges has been how to undertake research and development and also provide direct support to the regulator with only a few technical experts. The projects are interesting, particularly for younger employees, and help in developing expertise, but do not bring money into the company.

The key nuclear energy challenge in the Czech Republic in coming years is to select a supplier for a new nuclear power plant and to license the selected design and construct the facility. Currently there are 3 candidates for supplying a new NPP: Westinghouse AP1000, KHNP APR1200, and EDF EPR1200. According to the current timeline, the final supplier is to be selected by December 2024 with an application for a construction permit then due by 2026. The construction permit is then due to be granted in 2027 with a construction period then lasting from 2029 to 2035.

Other important challenges are to urgently license fuel from new suppliers since the Czech Republic no longer imports fuel from Russia following the war on Ukraine, and to accelerate site selection for a geological repository for nuclear waste with the aim of starting construction by 2050. All these issues need to be addressed whilst maintaining the safe operation of current NPPs and ensuring there is sufficient growth in competent human resources.

Discussion

The use of AI to support in safety reviews has been a topic of interest and there are student volunteers working on this topic. In particular, AI could prove useful in speeding up the creation of scripts rather than being relied upon more directly in assessments.

The ability to secure project funding can be a challenge when there are not staff in place to demonstrate expertise and where the funding received from a project is needed to support recruitment of those expertise. It is important to plan in advance the expertise that will be needed and plan accordingly.

4.4 South Africa: Development of a national TSO to support regulatory body under challenging conditions (S. Nhleko, NNR)

The 1948 Atomic Energy Act established the Atomic Energy Board that later became the Atomic Energy Corporation. In the early 1980's, this body was made fully responsible for all nuclear matters and the Council for Nuclear Safety was established as s a fully independent regulatory body responsible for regulating the safe use and handling of nuclear materials. In 2000 NNR superseded the Council and is the current independent regulatory body for nuclear safety. The Centre for Nuclear Safety and Security (CNSS) has been developed as a research and training center and is the TSO to NNR on matters relating to regulation of the NPP program, research reactors, mining, and other Naturally Occurring Radioactive Material (NORM) related activities.

In the southwest of South Africa is the Koeberg site that houses two NPP units. A research reactor site is located in the northeast that is used for radioisotope production. A RW disposal site is also operational and new sites are being investigated to extend the nuclear power program in the country.

In addition to licensing, there are a number of key projects to be undertaken, including the replacement of steam generators to support design-life extension. Associated with that project is a proposal to extend the storage capacity for spent nuclear fuel. The NPP was designed with only limited storage capacity for spent fuel and high level RW so that capacity will need to be extended if the plant continues operation beyond the planned lifetime of 40 years. South Africa is undergoing an energy crisis due to population demand and nuclear energy forms part of the strategy to address those energy needs. A licensing process is therefore underway for a new build project.

The mandate of NNR is to regulate the use of nuclear energy, to implement international commitments on the peaceful use of energy under the IAEA, and to disseminate information to the public on matters relating to nuclear safety. To achieve the mandate, the regulatory approach used by NNR is based on science, which is the field in which CNSS operates. Where no inhouse expertise are available, other organizations are partnered with.

The establishment of CNSS began in June 2014 with the development of a business case and strategy. and was formally launched by the Minister for Energy in September 2016. The center is located within an academic institute in order to have the necessary facilities for undertaking specialized research and training. CNSS operates an in-house training program, undertakes research and development, provides technical and scientific support to NNR including provision of expert opinions, analysis and modelling capabilities. Resources are concentrated on supporting the regulatory body, with additional resources drawn from universities. Key capabilities are identified for internal staff and, where there are no plans to keep such capabilities in house, there is collaboration with other institutions.

The next stage of development was the operational phase, involving a pilot and incubation stage with deliverables including a business strategy and a sustainability strategy. These then provided the basis for developing a business plan, setting out the funding model and longer-term strategy for development. Pilot projects were launched to validate the long-term sustainability of CNSS and a panel was appointed to advise on the TSO development project from an external perspective. As part of this phase, a TSO capability self-assessment was conducted using the TOSCA tool to ensure that activities were aligned with the development project for a TSO. Currently, work is being undertaken to implement the recommendations that came out of that assessment. CNSS program evaluation will be the main output from this phase, which will then feed into phase 3 which is to move from an incubation stage into long-term operation.

The business plan for long-term operation and the funding model for CNSS will be validated using the outputs from the pilot phase and, in the longer term there will be dedicated scientific committees formed for different areas rather than the current single pilot panel.

A key lesson learned from the development of CNSS to date is the importance of setting a strategic vision and communicating this to all stakeholders. Both top-down and bottom-up approaches were employed in developing the vision. It is also important to focus on the correct priorities for the development stage. In the journey to developing a TSO there can be conflicts arising between priorities such as focusing solely on servicing clients rather than also building appropriate and credible capabilities – a balance needs to be achieved. It is also important to remain adaptable so that new business principles and practices can be adopted to take account of the unique circumstances of the nuclear industry. Leveraging partnerships is also important for building capacity. Currently CNSS has active projects with the EC, IAEA, IRSN and the World Institute for Nuclear Security.

Advisory panels are also important and should be put in place from the outset rather than bringing in to troubleshoot problems that have already occurred. By putting panels in place from the beginning, development can be based around appropriate advice from the outset. Disruptions should also be expected from the outset. For example, a target of 5 years was set for the pilot phase of CNSS, but this was disrupted as a result of the Covid pandemic that lasted almost 2 years. The ability to adapt to disruptions is important.

TSOs have a number of roles, including supporting regulatory decision-making, contributing to the independence of the regulator and helping to identify and assess the significance of emerging issues. Prior to the formation of CNSS, it was necessary for NNR to rely on advice from international organizations. With the formation of CNSS, procurement issues have been removed which has helped in ensuring the independence of NNR. In terms of nuclear waste management, CNSS will help in developing the knowledge base, but will still need to rely on external support to some degree as internal capabilities are developed.

Discussion

Freedom of movement can be an important factor for capacity building within the regulatory body and TSO. staff from industry often have extensive experience and movement of staff from industry into regulatory or TSO roles can be an important means by which knowledge is transferred. Freedom of movement also allows the continued development of the skills of individuals, supporting continued strategic growth.

4.5 Tajikistan: Scientific and Technical Support Organization's Activities in Tajikistan (B. Barotov, STSO)

There is no nuclear power in Tajikistan. Sources of ionizing radiation used in the country include medicine (e.g., diagnostic and interventional radiology, radiation therapy and nuclear medicine), industry and research (e.g., use of radioisotope instruments), plus other activities including luggage inspection, veterinary radiology, research work, RW management and NORM. The relevant regulatory body is the Chemical, Biological, Radiological and Nuclear Safety and Security Agency (CBRN SSA), previously called the Nuclear and Radiation Safety Agency. The scope of activities of the Scientific and Technical Support Organization (STSO) to the CBRN SSA include:

- Support in licensing for the use of sources;
- Support in inspections and verification measurements at sites and in the field;
- Provision of technical support for exposure dosimetry;
- Environmental monitoring of uranium production sites;
- Provision of a mobile expert support team for nuclear security events;
- Support in nuclear forensics (e.g., in the case of illicit trafficking of radiation sources);
- Provision of an education and training unit to provide training to users of radiation sources and X-ray machines;
- Research and development in the field of radiation protection; and,

- Provision of an identification center for chemical, biological, radiation and nuclear materials.

An example of review of a remediation project was presented concerning the “Yellow Hill” tailings in Istiklol (Taboshar), see Figure 7. The project required tailings characterization, development of a remediation solution including water disposal and monitoring during the remediation activities and after the work had been completed via monitoring wells. All stages of the remediation project were reviewed and analyzed by the STSO. This was the first remediation project undertaken and support was provided by the IAEA.

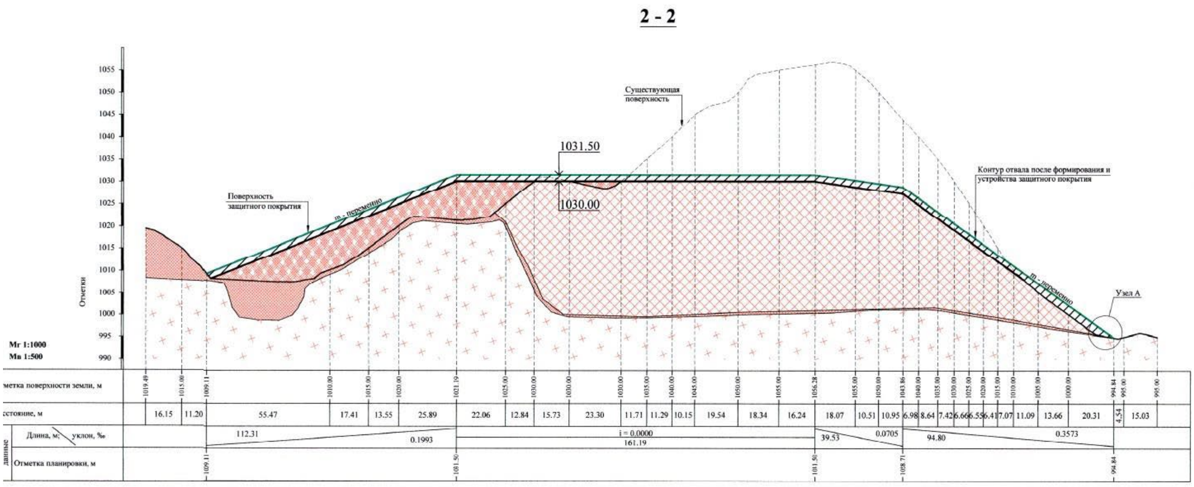

Figure 7. Covering scheme of “Yellow Hill” in Istiklol (Taboshar)

Verification measurement support services provided by the STSO include validation of sources, uranium enrichment measurements and dose rate measurements in workplaces. Checks on the acceptability of shielding materials and contamination checks are also performed. To support this function, a laboratory was established in 2011 as a technical support, achieved ISO17025 accreditation in 2016 and became a member of IAEA Analytical Laboratories for the Measurement of Environmental Radioactivity[4] network from 2017. There are currently 19 staff at the laboratory, but this will soon increase by a further 20 staff as a result of additional work requirements. The laboratory undertakes analysis of radioactivity and also provides services on radiation safety. A new building for the laboratory is due to be operational from September 2023. Equipping the laboratory has been supported through IAEA national technical cooperation projects.

Technical support on radiation safety includes calibration of dosimeters, services to hospitals in checking the quality of X-ray machines and other devices. Workplace monitoring is also performed, along with environmental monitoring such as undertaking gamma surveys and measuring radon around legacy tailings areas. Tailings areas are close to a transboundary river so are a priority for monitoring to avoid contamination reaching the river. In situ measurements are performed and uranium and thorium series radionuclides are analyzed in soil and water samples in the laboratory. Measured concentrations are used to inform decisions and make recommendations on the use of water and land and on remediation of contaminated areas. The STSO also holds a database of radiation sources and materials.

A Mobile Expert Support Team plays an important role in supporting controls at borders. The Team operates a mobile laboratory that includes a portable gamma spectrometer and dosimeters etc. to help in detecting nuclear and radioactive material being illegally transported across borders. In terms of support in nuclear forensics, the laboratory has the means to determine uranium enrichment, heavy metals, minerals, rare and earth elements etc. in samples provided from crime scenes.

[4] https://nucleus.iaea.org/sites/ReferenceMaterials/Pages/ALMERA.aspx

The science and research unit has undertaken work to address contaminated water arising from mines, including purification of water through uranium extraction. Research has been undertaken into different sorbents that can be used to remove uranium.

The sustainability of the laboratory is achieved through provision of services to private companies and the public as well as supporting the regulatory. The laboratory also participates in different national and international projects and involves students in sample preparation and analysis.

A training center began operating in 2011. The center provides regional and national training for different audiences, receiving the status of a regional training center in 2018. The center is equipped with modern equipment and covers a wide range of services for education and training in the field of nuclear security and radiation safety, non-proliferation and export control through, for example, training at national customs border crossing points on monitoring and inspections. Over 500 specialists are trained annually, including employees of the CBRN SSA and law enforcement agencies, as well as from industrial, medical and educational institutions that use radiation sources in their activities.

Discussion

When the CBRN SSA began inspection and licensing activities there was no supporting organization available, and many experts left the country as a result of a civil war. In developing the STSO, efforts have been made to use different individuals for providing support to the regulatory body and for supporting operators. Staff have attended training programs to develop knowledge on the use of equipment and analysis and retention of staff is supported by involving them in national and international projects and through increased salaries supported through funds raised from the provision of services. Being very active internationally also helps improve confidence as well as competence. Both the CBRN SSA and the STSO have taken benefit from bilateral regulatory cooperation with DSA.

The portfolio of services offered are wide and the activities provided are valuable for general radiation safety in the country and for the government. The CBRN SSA established the STSO. This now operates as a separate organization, but remains under the regulator. There is some conflict of interest but, overall, the arrangement works. There has been discussion around moving the STSO to become a national institute for radiation protection, but as Tajikistan is a small country with few activities in the field of nuclear safety and radiation protection, it will remain as is for the time being. Should the program of activities increase in the future then a move to a more separate institute may be taken forward.

4.6 Denmark: TSO Activities: an Operator’s Perspective (M. Øberg, Danish Decommissioning)

There is no TSO in Denmark; the presentation therefore reflected views from the perspective of an operator, Danish Decommissioning. There are several co-located facilities in Denmark, the majority of which are decommissioning. Those that are still operational are due to end operations within a few years. Facilities include 3 research reactors, hot cells, a fuel fabrication plant, a waste management plant and waste storage facility plus several laboratories. Danish Decommissioning (DD) is the only operator in Denmark so is responsible for dealing with other sources of RW, such as medical waste. Continuous operation of the waste management plant is therefore necessary to address all waste streams whilst also addressing decommissioning activities.

DD is a state enterprise that, as an operator, works independent from the government. There are currently around 90 employees, including radiation protection officers and people trained in modelling. The company is ISO 9001/17025 certified in waste management, decommissioning and clearance.

There are over 2000 licenses in Denmark issued for the use of closed sources, 540 for the use of open sources and over 1200 for radiation generators. DD holds two licenses that cover dismantling and decommissioning. DD operates the only clearance laboratory in the country and is responsible for RW management in the country. When waste is received from others, the funds received to address the wastes is less than the costs incurred as DD is not permitted to earn money from waste handling activities. Overall, DD holds > 90% of the radioactive waste in the country at its site.

In terms of radiation workers, there are over 10,000 associated with the medical sector, over 800 in veterinary practice and over 2,500 in industry, giving a total of around 15,700. In comparison, DD has around 70 radiation workers, but is responsible for managing 15000 people per year with dosimeters.

The Danish government has two ministries responsible for nuclear and radiation safety – the Ministry of Health and the Ministry of Defense. All radiation protection, with the exception of emergency preparedness and safety, falls under the Ministry of Health. This ministry also manages the Radiation Protection Act, while they cooperate in managing the Nuclear Installations Act; both are used in the regulation of DD. Radiation protection regulations and laws are implemented by the Danish Health Authority, which undertakes all regulatory functions and statutory duties related to radiation protection. DD then holds a 70-page license to operate in conjunction with a 280-page safety assessment which, on the whole works very well, but issues can arise if there are political discussions and disagreements between the Ministries and the Health Authority.

Legislation is in place that defines radiation protection for all uses of radioactivity across the country, but more specific legislation on RW management is needed. Some elements of TSO's are available in that there is an environmental laboratory, a personal dosimetry laboratory and a standard dosimetry laboratory within the Health Authority.

An IRRS mission was held in 2021 from which 5 recommendations were made. It was recommended that the regulator develop guidance documents, including on the format and content of documents submitted by applicants in support of authorization applications, revise the policy and strategy for RW management to include all types of RW and establish regulations for the development of RW disposal facilities. Overall, policies were considered to be too broad. Whilst legislation in place works well for single source use, more specific guidance and regulations were needed for different waste management and decommissioning areas. A suggestion was also made in relation to knowledge management and development of competencies. Denmark has plans for new waste management facilities and it was recommended that the competencies required for the review and assessment of such facilities be identified and efforts made to ensure those competencies are available when needed, by the government establishing a plan to increase the number of qualified experts in the country. However, as a non-nuclear country, relevant university courses are no longer run which leads to real issues for recruitment.

An Artemis mission in 2022 provided more specific recommendations. It was recommended that the regulatory body establish requirements and guidance documents for the development and authorization of waste management facilities in the different stages of their life-time (i.e., siting, design, construction, operation, closure and post-closure or decommissioning). The need for specific and detailed regulations can vary according to stage. For example, during early phases it can be useful to have broad legislation so that discussions can be held with the regulator to optimize approaches etc. whereas when dealing with longer lifespans, more specific regulations and guidance are needed.

The Artemis mission further recommended that the government ensure management and control over all RW and designate waste management organizations that are obliged to accept all types of RW, and the National Program be updated to include appropriate interim targets and end states for the monitoring of program implementation for all types of RW. Currently in Denmark there is no strategy plan for the management of low activity NORM waste. DD does not accept NORM waste. As such, large volumes of low activity wastes are awaiting a management solution.

DD is the only nuclear site in the country and is therefore the main national competence with respect to radiation issues. However, DD is state owned and, as such, is not permitted to make money or to offer advice or direct to others that could provide advice. A formalized strategy on how to be a national competence center (i.e., a TSO) on radiation safety issues is therefore needed, and is currently being developed with regards to TSO-work directed at national non-regulators.

The Artemis and IRRS missions have shown the need for dedicated resources on decommissioning and waste management and preparation of guidance documents recommended to be developed as a result of those missions will help operators meet deliverables. The formation of a TSO could help address many of the issues faced and liberate regulator resources.

Discussion

There have been various discussions around the definition of NORM wastes, and, without an agreed definition, it is difficult to agree on a waste strategy. Many NORM wastes pose more of a chemical than a radiological hazard. If a TSO were to be established in the field of nuclear and radiation safety, proportionate management of NORM wastes would benefit from dialogue between the radiological TSO and other TSOs dealing with non-radiological risks.

A current challenge that also relates to the management of NORM as well as decommissioning wastes is that there is a lack of legislation in place covering the storage of large volume waste, since the focus has been more on laboratory-scale wastes. A timeline has been set for achieving decommissioning of the research reactors, but the timeline could be extended if waste storage or disposal facilities for larger volume low activity wastes were to be included.

It can be challenging to move from operations to decommissioning and waste management. Following the completion of decommissioning activities, around half the staff at DD will no longer have work to undertake. Some young people are being trained in the nuclear field and formalizing training in the country could help in providing the necessary capabilities for establishing a TSO, when combined with staff from DD. There can be difficulties in hiring experts internationally; discussions are underway to decide whether non-Danish speakers could be hired.

4.7 Germany: Best Practices for Organization and Implementation of Technical Support (C. Eibl-Schwäger, GRS)

Gesellschaft für Anlagen und Reaktorsicherheit (GRS) is a non-profit, non-governmental, impartial and independent research and expert organization. GRS has been the leading expert organization on all topics relating to reactor safety, radiation and environmental protection and nuclear waste management since 1977 and is the central TSO in nuclear safety for the Federal Government. A particular strength of the organization is the consistent linkage of research and development with safety assessments.

GRS currently employs around 400 staff of which around 320 are technical-scientific experts with a broad range of expertise including engineering, physics, chemistry, geology, hydrology, meteorology, etc., that, together, provide all necessary expertise around nuclear safety and radiation protection. A GRS academy has been developed as an effective training concept for training and recruiting new personnel. Technical staff are well mixed in terms of age (the average age of staff is 42) and gender with over half of management positions being held by women.

GRS receives funding from Federal Ministries but also has various international contracts, the volume of which continues to increase. The organization does not replace all retired experts but also continues to remain stable in terms of staff with new hires initially receiving a one-year contract. Most then move onto permanent contracts. GRS operates within an integrated management system and has several accreditations, which are mandatory for many customers. Accreditations include ISO 9001 (quality management system), ISO 27001 (information safety) and ISO 17025 (accreditation laboratory – geochemical).

GRS technical divisions are structured in departments, including a strong project management department and a project management agency that manages the funding of all the different projects. Within the reactor safety research department there are around 60 full-time equivalent staff with a greater proportion (around 90 full-time equivalents) working on reactor safety analyses and operational experience. There are then around 50 full-time equivalents working on radiation and environmental protection and around 40 on final disposal research. A particular challenge can be shifting personnel between divisions and between topics as interest areas change.

There are several technical advisory committees that GRS sits on, alongside other stakeholders, including industry. There are government advisory committees on reactor safety, radiation safety and final disposal.

Responsibility for inspections is held by Technical Inspection Agencies that work alongside authorities to support inspection activities. GRS maintain close exchange of information links with these Agencies.

In Germany, the decision has been made to phase out all nuclear power plants with the last reactor having been shut down in April 2023. However, whilst nuclear power is being phased out, nuclear research is continuing to ensure competence is maintained. This is in line with national and international framework conditions and obligations and to ensure communication to the public on nuclear and radiation safety topics. The Ministries have fewer technical staff on nuclear and radiation safety and therefore rely on TSOs on these topics. As such, GRS has been a key contact point in relation to the war in Ukraine, providing interviews and messages to the public, in close cooperation with the Ministries.

GRS, as a TSO works both as a research organization and an expert organization. Tasks as a research organization include providing independent and state-of-the-art analysis tools for safety assessments for reactor and repository safety as well as performing in-situ investigations and laboratory experiments. Tasks as an expert organization include providing support to the federal ministries on questions on nuclear safety, operating the emergency center, development of assessment methods, further development of nuclear safety regulations and providing support in international cooperation and participation in expert groups.

Research topics are very broad. A lot of research is undertaken in relation to plant safety and repository safety. Many different simulation codes having been developed, for advanced reactor technologies, simulation of behavior of passive safety systems and fuel element assemblies. For repository safety, contaminant transport modelling and modelling of thermodynamic processes are important research areas. GRS has been a consortium partner of the Mont Terri project in the Swiss rock laboratory, undertaking experiments on disposal of high level RW in clay rock formations.

Following the Fukushima accident, an emergency center was built and operated by GRS. The Centre provides an interdisciplinary emergency team that is available 24 hours a day. Following Fukushima and, more recently in response to the war in Ukraine, the center has undertaken extensive work to support the Federal Radiological Situation Center. The center also plans and measures performance of safety drills, provides training courses for authorities and develops emergency preparedness concepts and decision support systems.

GRS has provided continuous technical support in the development of national regulations for several decades, considering international requirements and lessons learned. GRS has also been involved in the assessment of generic safety issues including the effects of changing boundary conditions in the European grid on NPP operation and is involved in several international projects. This includes projects financed by the European Union and international institutions, including the IAEA and NEA-OECD, as well as bilateral projects aimed at developing competence within foreign authorities and TSOs, and close cooperation with specialist institutions in around 25 countries. A key objective of the many international projects is to harmonize safety assessments and exchange information on best practices and lessons learned.

GRS was one of the founding members of ETSON[5], which was founded in 2006 and currently has 16 members. The objectives of the network are to develop common approaches for nuclear safety assessments and share technical and scientific knowledge and experience among TSOs. ETSON, together with the IAEA, established the TSO Forum which aims to support newly developing countries to build up TSOs.

In general, regulatory bodies need assistance in maintaining and continuously developing their knowledge base and associated items such as computer codes, methods and data as well as expert advice and support in issues related to nuclear safety and sufficient education and training capacity. GRS provides these services as the national TSO. Support is provided to the regulatory body in decision-making and training and education are provided, not only for GRS staff, but also for ministry staff. It is necessary to ensure that a high technical level is maintained and for work to be undertaken on an international level and in an international context.

Discussion

GRS is the national TSO on issues relating to nuclear safety and radiation protection, but also undertakes work internationally. For example, GRS has worked with NAGRA, the organization responsible for disposal of RW in Switzerland. When working with other country operators, it is necessary to get prior approval from the federal ministry. GRS has also undertaken much work with universities on a wide range of research topics as well as teaching at universities. Close relationships are maintained to support research in the field.

4.8 Italy: ENEA TSO Functions in the Italian Framework (F. Rocchi, ENEA)

The Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) is a public entity operated under the supervision of the Ministry of Environment and Energy Security. The ENEA has around 2200 employees across four main departments:

- Energy technologies and renewables;
- Fusion and nuclear safety technologies;
- Sustainability and territorial productive systems; and,
- Energy efficiency.

The agency also operates three institutes, the TSO functions being based in the Bologna Research Centre.

The department for fusion and nuclear safety technologies contains six divisions: plasma physics (PLAS), research and development for fusion (FUSEN), experimental engineering (ING), technology for fission (FISS), safety security and sustainability (SICNUC) and technology for security and health (TECFIS). The

[5] www.etson.eu

SICNUC division is divided into three laboratories, including one dedicated to safety and security which primarily focuses on safety assessment and supports the regulatory body. There are no operational NPPs in Italy, but there are NPPs close to the border and there is a duty to be prepared to respond to possible consequences of accidents abroad.

The history of ENEA began in 1952 with the formation of the Cimitato Nazionale Ricerche Nucleari. This became the Comitato Nazionale Energia Nucleare in 1960, which then transformed to the ENEA in 1991. Initially the regulator was within ENEA, but it was recognized that this was not sustainable and so the regulator detached in 1994. There were several developments from 1994 until in 2014 the regulatory body National Inspectorate for Nuclear Safety and Radiation Protection (ISIN) was created. ISIN functions as a fully autonomous and independent regulatory body. The histories of ENEA and ISIN are therefore very much interlinked and there has been a lot of knowledge exchange over time as a result of this common history. ENEA technical competencies and skills in the nuclear and radiation field are nowadays within the Fusion and Nuclear Safety Technologies Department and within the Institute for Radiation Protection.

ENEA undertakes research and development in nuclear safety and security and performs TSO functions to ISIN. The official mandate for ENEA was updated in July 2022. Under the mandate, ENEA has no automatic or continuous interactions with ISIN but rather receives specific requests from ISIN as required. As such, ENEA provides an 'on-demand' service. Where ENEA can provide the service, it is obliged to accept the request and provide assistance. ENEA also interacts with other public stakeholders such as civil protection and fire fighters, but interactions are less formalized. There are also interactions with universities with programs in nuclear engineering and support to Masters and PhD students.

Under the mandate, ENEA's official duties include ensuring technical support to national institutions and international representatives on nuclear safety, nuclear emergency preparedness and response, and application of international treaties on nuclear safety, security and non-proliferation. Further duties include:

- representing Italy at Eurofusion, Fusion for Energy, and ITER – the world's largest fusion experiment;
- building a large nuclear fusion test facility near Rome (the Divertor Tokamak Test facility);
- undertaking research and development activities related to SMR and other Gen-IV technologies; and,
- providing support to ISIN on research and development in nuclear energy.

ENEA also provides support to other institutions. For example, from 2006 to 2018 ENEA had a framework cooperation agreement with the Ministry of Enterprises and Made in Italy, on research and development for nuclear safety and for technologies for lead-cooled reactors. ENEA is also head of the Italian delegation to the G7 Nuclear Safety and Security Group, is a member of the IAEA Nuclear Security Guidance Committee and, at the start of 2023, ENEA joined the IAEA Response and Assistance Network[6].

In terms of research and development for safety, both experimental and numerical activities are undertaken. Experimental activities have included testing of large-scale SMR components, code verification and validation as part of international benchmarking activities, and validation of passive safety systems. Numerical activities have focused on light-water reactors, including simulations for neutronics, fuel safety, and simulations of severe accidents etc.

Since 2012, Italy has been a member of the TSO Forum, with ENEA being on the Steering Committee and contributing to the drafting of TECDOC 1835 [IAEA, 2018]. ENEA also represents Italy at the NEA-OECD, particularly on the Committee on the Safety of Nuclear Installations and the Nuclear Science Committee, is a member of the European Nuclear Education Network and the Italian representative to the Generation IV International forum GIF. ENEA also participates in several Euratom projects on nuclear safety and holds

[6] https://www.iaea.org/services/networks/ranet

service contracts to the European Commission. ENEA also has bilateral cooperation activities on various topics in nuclear safety with IRSN and the Alternative Energies and Atomic Energy Commission in France and the US NRC. There are also ongoing discussions around cooperating with the EU JRC on emergency preparedness and response.

In Italy, decommissioning NPPs, research reactors and fuel cycle plants are under the responsibility of the Decommissioning and national Waste Management Organization. Research reactors however are owned by ENEA. Two of the three research reactors are still in operation in the ENEA Research Centre of Casaccia. A third research reactor in the ENEA Research Centre of Montecuccolino, near Bologna, has been decommissioned and dismantled by ENEA to green field. This is the first case in Italy whereby a research reactor has been completely decommissioned, in line with the most recent regulatory requirements. The reactor was owned and operated by the ENEA from 1971 to 1989 after which it was permanently shut down following the Chernobyl Referendum. In 2010, ENEA received a ministerial decree authorizing the dismantling of the reactor with the aim of reaching green field status. A graded approach was applied in the application of rules for decommissioning. Green field status was reached and approved in July 2021.

At present, the main challenges faced relate to the availability of manpower. This stems from retirement of staff, but also competition with the private sector where pay is higher and with the job market abroad. There is also difficulty attracting young professionals. On-the-job training is essential and takes time – at least 5 to 10 years – and maintaining skills and competencies has become more difficult over time. The Government is currently considering whether nuclear energy could once again be introduced in Italy. If this were to occur, a main difficulty faced initially would be to create a good job environment from universities upward that would provide the necessary manpower and skills needed.

Discussion

The issue of manpower availability needs to be solved quickly and will involve working with universities to develop necessary skills in the future workforce. In the past there was a sufficient workforce of nuclear engineers but the numbers enrolling in such courses have decreased. Professors have also retired so there is also a lack of experienced people to educate and train the next generation, another issue to be addressed. One option could be for ENEA and universities to join forces to help strengthen the universities in the field of nuclear safety and radiation protection. However, salaries remain a key issue as better levels are available abroad.

When ENEA receives a request for support from ISIN there is a strong commitment to provide that support if the necessary skills and knowledge are available. As both ENEA and ISIN are public entities, ENEA receives no funds from ISIN for this work. However, funding can be provided if ENEA is required to make purchases in order to respond to the request. In some countries, regulators can charge operators licensing fees that can then be used to obtain technical support as required. However, with NPPs having shut down in Italy over 30 years ago, this funding mechanism is not available.

4.9 Ukraine: TSO in Ukraine (Y. Balashevska, SSTC NRS)

Ukraine emerged as an independent country in 1991. In March 1992, the State Scientific and Technical Center for Nuclear and Radiation Safety (SSTC NRS) began providing support to the regulator, the State Nuclear Regulatory Inspectorate of Ukraine. (SNRIU) so Ukraine has had a national TSO from the outset.

In 2008, SSTC NRS obtained dual subordination status to the SNRIU and the National Academy of Sciences of Ukraine. The mission is to provide comprehensive scientific and technical support to the state regulation of nuclear and radiation safety in Ukraine aimed at protecting the public and the environment against the impacts of man-made ionizing radiation. SSTC NRS is publicly owned and operates as a commercial enterprise (i.e., no financial support is provided from the government). Activities undertaken in support of SNRIU include safety assessment, improvement of the regulatory framework, emergency preparedness and response, training, testing and certification, and publication of the Journal of Nuclear and Radiation Safety[7], with four issues being released per year.

SSTC NRS consists of around 240 staff of which more than half are researchers. There are three research units (a safety analysis unit, a strength and reliability unit and a radiation safety unit) and two subsidiary subdivisions (Center INTENSA and Kharkiv subsidiary). In addition, there is an international projects department and a management systems and nuclear security department.

Various activities are undertaken in support of SNRIU, including support in regulatory inspections and providing expert support on technical requirements for safety assessments. Ukraine has applied to join the European Union and, in support of this, SSTC NRC supports SNRIU to improve the regulatory framework and preparation of internal guidelines. SSTC NRC's is a member of the TSO Forum and associate member of ETSON. Further international support is recognized though bilateral regulatory cooperation with the DSA since 2014, as most recently reported in Sneve et al [2022].

Many staff work within an emergency center of SNRIU that focusses on emergency preparedness and response for various scenarios ranging from acts of terrorism to emergencies around the Chornobyl exclusion zone. Staff at the center are also involved in monitoring when requested by SNRIU.

SSTC NRC also provides a wide range of training that can be tailored to workplace activities. Some staff are also university professors and summer schools are organized for students with the most promising students often being recruited as trainees.

SSTC NRC has an integrated management system that is ISO 37001 (anti-bribery management systems) and ISO 17065 (information processing) certified. ISO 17025 (testing and calibration laboratories) certification is also held with testing and certification activities being provided in support of SNRIU.

4.10 France: Developing Nuclear Research Capacity (K. Ben Ouaghrem, IRSN)

The development of nuclear research capacity and a corresponding research program has been illustrated through a case study from IRSN for the TSO Forum.

For a TSO to be listened to at a high level it needs to have influence and push on priorities. Furthermore, for research to develop within a country, there needs to be suitable infrastructure to support that research – facilities are needed to support programs and can be financed through working with operators and industry that have finances and also common needs. Working with industry and operators also helps in developing an understanding and anticipating possible assessment issues that will need to be addressed in the future and for which research can help find answers and solutions.

The IRSN is a scientific and technical organization dedicated to radiation and nuclear safety and security. It was formed in 2002 and operates totally independently from the regulatory body Nuclear Safety Authority {ASN). IRSN currently has around 1800 staff across nine sites throughout France and 1000 of those staff are specialists in radiation protection and nuclear safety. Around 40% of the annual budget is devoted to research.

IRSN works widely within the field of nuclear and radiation safety and security. The institute works with the civil air agency (e.g., in relation to airline crew dosimetry), is in charge of radiation monitoring in France

[7] https://nuclear-journal.com

with over 450 active monitoring stations and has interactions with the ASN, defense authorities and operators and civil society. An important challenge in working with civil society is finding the right level for communication. All reports sent to the regulatory body are published publicly. IRSN also has many international interactions.

The assessment process usually involves a trinity of ASN, IRSN and the operator with ASN making a request to IRSN for technical assessment and IRSN then having direct technical exchange with the operator. For large topics, an advisory committee of experts from IRSN and international experts can be activated. IRSN then makes the technical assessment with the report being evaluated by the advisory committee. This can be a long process, but it has proven to be effective.

IRSN has various research areas, including nuclear safety. This includes the safety of nuclear installations and safety associated with the use of ionizing radiation. Nuclear safety was the focus of the case study.

Topics within nuclear safety research include fuel behavior, severe accidents, containment, fire and explosions, criticality and neutronics, ageing, human factors, and new technologies such as new advanced reactors and SMRs and accident tolerant fuel. Particular topics of research to address current and future safety challenges include implications of an ageing workforce on long-term operations, external hazards, passive safety systems, safety in time of war and the impact of climate change among others.

Climate change is an important consideration with respect to nuclear safety. Changes in climate can affect safety through factors such as changes in water levels, but there are additional factors to consider such as changes in ecosystems that can have implications for environmental impact assessments. Climate change therefore affects across the different domains of expertise within IRSN.

A new project, PASTIS, has recently begun. Phase 1 runs until 2025 and involves the construction of an experimental platform comprised of two facilities. A second phase is then the realization of experiments and development and validation of models. The first focus area is Natural Circulation Analysis for SMRs. SMRs rely on passive safety systems but they need to be demonstrated as effective and efficient. Studies will focus on natural circulation in a closed loop and pressure drop in various geometrical configurations, and analysis of parameters influencing natural circulation. The second focus area is ‘condensation in a containment model facility’ (CoCoMo) that involves studies on condensation phenomena within an immersed containment, looking at the effects of non-condensable gases on condensation heat transfer and analysis of parameters influencing stratification in large volumes.

The IRSN case study for the TSO Forum focused on research as a driving force of TSO capabilities in France. The study presents the French context, including the necessary split in activities between supporting the regulator and operators. The synergy between research and expertise is also discussed. In undertaking assessments, IRSN provides information to the regulatory body whereas when undertaking research, this tends to be on a longer scale. It is important to link both assessments and research in order to identify what is needed for developing competencies over the longer-term. International cooperation and the projects under each research topics, the research infrastructure to support those projects and simulation tools available are discussed in the case study. There have been several research programs on the prevention of accidents and mitigation of consequences and the case study provides a lot of information on these topics, including details of codes under development. An appendix sets out the priorities for nuclear safety which could be a useful resource for those looking to develop a research program, providing information on criteria and financial requirements. The case study is currently being validated and is therefore only available to TSO Forum members at the present time but could be made more widely available once the validation process has concluded.

It is important to connect with industry when considering the long-term research strategy and to consider a range of questions, including the importance of the science for risk management, the potential for increasing the institutes independence of judgment, the ability to build capacity or maintain strategic skills, potential for generating collaborative partnerships, and the technical and financial risks. In addition to industry, it is important to maintain links with others, both nationally and internationally, and to embrace available knowledge and tools. Through experience gained it is possible to build capacity that can then be used in validating tools and in developing new tools. It is also important to maintain research capacity and infrastructure, supported by linking programs to research infrastructure.

Discussion

Maintaining a good interface with the regulator and researchers is important as there can be a large gap between what research focuses upon and what regulators need. It is important, therefore, for regulators to communicate needs to help target research activities.

5 Session 4: Discussion Session

The discussion session involved participants being divided into two groups to discuss a series of 6 topics. Feedback from both discussion groups on each topic is summarized below.

5.1 How to define and strengthen the technical and scientific capabilities of TSO?

How to define and strengthen the technical and scientific capabilities of a TSO will depend on the situation in the country, including experience, history and status and plans for the use of radiation sources. For example, a country may have a long history of working in the field of nuclear safety and radiation protection or may be a newly embarking country. Overall, the mandate and core functions of the regulatory body will define the necessary capabilities. However, some countries may have more or less prescriptive regulatory styles, and this will affect what the TSO will be required to do and the capabilities that may be required. Developing an inventory of the activities of the regulatory body and of the operators and nuclear technologies in the country could help in identifying needs, which could be achieved by, for example, creating a steering committee tasked with defining needs. Once needs have been defined, it is important to then prioritize those needs.

In some countries the needs of the TSO may be defined by law. However, in this case, it should be recognized that laws may need to be adapted to address changing circumstances (e.g., during a move from operations to decommissioning). Where laws are being developed (e.g., for an embarking country), flexibility should be incorporated to allow for possible changes within the period of applicability.

International workshops can be very useful in terms of sharing knowledge and experience on defining and strengthening TSO capabilities. Regular meetings and sharing experience help in the transparent analysis of performance and operational experience. The same sharing can support regulatory threat assessments, identifying gaps in regulatory systems and developing road maps to prioritize and address those gaps.

TSO capabilities should be maintained to address the identified priorities and achieved through training, education and research, in turn supported by international cooperation. Training and education also build confidence in long-term career development of personnel. To be effective, this requires secure funding over more than one year.

Sustainability is important and this requires continuity of policy and strategy as well as sustained financing. Where a TSO is able to raise funds rather than rely on external budget allocation then this can help in maintaining a more sustainable organization. Clear vision and long-term goals are required to gain funding.

The different roles of a TSO should be clearly defined so that there is no doubt on the roles and relationships and what can and can’t be undertaken in terms of work in the private market. Some flexibility should be maintained, however, to allow discussions to take place.

5.2 Role of TSO and risk management

The role of a TSO with respect to risk management will depend on the situation and the defined roles of the different players and the legislation in place. Gap analyses/threat assessments can be useful in identifying where new or improved rules and guidance are required. The rules and guidance give the regulator the technical authority for their decisions and provide the basis for clear communication on what the TSO then needs to do.

Risk management is a complex combination of (semi-)objective technical evaluations, usually by the TSO, and subjective sociopolitical assessments, more typically an issue for the regulator. Who completes the assessments needed to support regulatory decisions will depend on which TOSCA Pillars are kept with the regulator and which can be covered by the TSO. In most instances, the TSO is responsible for providing technical risk assessment with the regulator being responsible for risk management and related decision-making.

Clear roles for all stakeholders are needed. In some countries there can be different regulators for environment and safety, or for safety and security etc. but there may be just one TSO that supports all regulatory core functions for safety and security and for protection of the environment and human health. One model does not fit all situations.

5.3 Special issues of multiple hazards in decommissioning, remediation and legacy management

Addressing multiple hazards associated with decommissioning, remediation and legacy management will depend on the individual circumstances and roles and responsibilities will vary between countries. For example, in some countries there will be different regulators and/or TSOs for different hazards. Ideally there would be a nominated organization or person with the overarching role of ensuring that the different hazards are managed proportionately, which would require a coordinated effort between the different players, but with one being designated as having lead authority. Stakeholder groups could also be established to discuss and review the process of addressing core functions across operators, regulators and TSOs.

Decommissioning, remediation and legacy management can be very challenging. Often characterization of the situation is inadequate and/or information is limited. It is important to raise awareness of multiple hazards arising different situations and work on this topic has been ongoing within working groups of the NEA-OECD, as illustrated in the following reports that each include a range of case studies:

- Characterization Methodology for Unconventional and Legacy Waste [NEA, 2021].
- Challenges in Nuclear and Radiological Legacy Site Management: Towards a Common Regulatory Framework [NEA, 2020].

5.4 Conflict of interest by serving the regulatory body and utilities

In small countries it may not be possible to avoid conflicts of interest due to limited resources, but measures can be taken to minimize conflicts. For example, knowledge sharing can be separated from drawing conclusions on safety assessments and rules and avoiding the same persons undertaking assessments then being involved in their review.

In larger countries greater separations should be feasible, but it may still be necessary for the TSO to provide services to both the regulator and operators. Such situations could potentially be managed by establishing separate departments for those providing services to operators and those supporting the regulatory body. It is possible for TSOs to effectively work for both the regulatory body and the operators, but clear rules on engagement between the TSO and others are needed and transparency and traceability in records can help in building trust by proving supporting information on data sources and where judgements have been made etc.

Experience from Finland on the challenges for a TSO supporting both the regulator and industry is available in Puska [2014] along with other potentially relevant advice.

5.5 Communication with stakeholders and the public

A TSO may have a role in providing communications on safety and security issues, or the TSO may provide support to the regulatory body that is then responsible for communication. If both regulator and TSO are responsible for communications, the details should be agreed in advance, setting out who will be responsible for communicating on which specific issues, to whom communicated should be made, and the mechanism(s) of communication.

The most appropriate means of communicating may depend on the situation. If information is provided directly from the regulatory body, this may be seen as reliable and trustworthy, or the TSO might be seen as more trustworthy as 'independent experts'. The TSO is also more likely to be appropriate for communicating on scientific and technical issues to professional stakeholders, i.e., the science and technical community at conferences, technical meetings etc., whereas the regulator may be more appropriate for communications on a situation to the wider community. Where experts are involved in communications, either to support the regulator in answering technical questions and providing facts or acting independently, care should be taken to ensure that the correct 'experts' are involved and that they are capable of communicating at the right level.

Those responsible for communicating should be prepared to not answer questions outside their remit but avoid appearing evasive as this may erode trust.

5.6 Practical aspects of international cooperation for the mutual exchange of experience and approaches in nuclear decommissioning and dismantling

International cooperation is very important and there are several international forums on nuclear decommissioning and dismantling within which discussions and knowledge exchange can occur. There is also a knowledge database and knowledge sharing platform under development[8]. There could be merit in specific forums being developed that are specific to nuclear decommissioning and dismantling, but at the same time there is a need for integrated consideration, e.g., making the link to RW management. As facilities move from operational to decommissioning status there can be limited experience and expertise available so there can be real benefits gained by sharing technical experience and knowledge through focused forums. Case studies can be very beneficial means for exchanging knowledge and experience, particularly where site visits can be arranged that facilitate discussion among experts about the real challenges being faced.

Exchange of staff between organizations can also help in developing understanding.

Other practical aspects for international cooperation could be the offering of mutual review services and/or sharing of laboratory services through, for example, establishment of joint research centers.

[8] see https://joint-research-centre.ec.europa.eu/scientific-activities-z/eu-nuclear-decommissioning-knowledge-management_en

6 Session 5: Technical and Scientific Challenges

6.1 CERAD Centre of Excellence: a science-based TSO (D. Oughton, CERAD, NMBU)

CERADs mission is to provide scientific knowledge and tools to support better protection of people and the environment from the harmful effects of radiation. The Centre has been funded for the last 10 years by the Research Council of Norway as a Centre of Excellence. CERAD is hosted and run by the NMBU. The Centre collaborates with a number of partners, including DSA, the Norwegian Institute of Public Health, the Norwegian Institute for Water Research (NIVA) and the Norwegian Meteorological Institute. The 10-year CERAD project funding has now completed, but a CERAD Knowledge Centre has since been established by NMBU to maintain knowledge. The Knowledge Centre includes many of the original collaborators, but with DSA taking on a different role.

At its peak, CERAD employed 118 full and part-time personnel. There was a Scientific Advisory Committee, which included international experts. There was a significant focus research leading to PhDs, with over 32 dissertations being completed over a 10-year period. More than 300 scientific publications were also produced.

Research focused on both anthropogenic and natural radioactivity in the environment as well as the effects of radiation in combination with other stressors and covered the whole spectrum from source, transfer, biological responses and risk assessment and communication.

Source term research includes transport modelling from the point of release to presence in environmental media and covers both atmospheric and marine releases. Source characterization includes chemical and physical aspects. The approach to research has therefore been to look at how speciation, the presence of other contaminants, features of the ecosystem and variable climate and chemical conditions in the environment can affect transport, uptake and distribution of radioactivity and uptake into people and wildlife.

Much of CERAD research has been on studies undertaken at a range of field sites, including legacy mining sites, new construction sites and the CEZ. Studies have not only considered radioactivity, but also the effects of multiple stressors, such as road and tunnel construction in alum shale areas in Norway. Leaching from alum shales results in both NORM and heavy metal release to the environment and studies have considered how the presence of different chemicals in the environment affects transfer and impacts. Research has also looked at the different risk drivers as a means of identifying the key contaminants driving overall risk to people and the environment.

The Source to Outcome Pathway (STOP) concept has been an important research approach, looking at cumulative risk assessment for multiple hazards. STOP considers source, transport, exposure, hazard and risk drivers. A wide range of effects are considered from cellular through to population-level effects.

The Centre is home to an exposure facility that can be used to look at the impacts of ionizing radiation on organisms and to research the mechanisms by which effects occur. The facility is licensed for a range of model organisms, including genetically modified organisms and ecosystem interest species. Gene expression and a host of other biomarker responses have been studied.

The consequences of radiation events go beyond the direct effects of radiation. Societal and ethical aspects have also been an important area of research at CERAD, including public perception of risks and stakeholder engagement. Citizen science is another important aspect that has been considered, including the use of new technologies, such as apps on mobile phones for taking measurements, and the ethical challenges they may present.

It has been recognized that programs dealing with all aspects from source term to impacts and risk is too ambitious for any one institution, so a partnership approach is required and the partnership between national organizations and CERAD has been very successful in this respect.

In terms of 'what now?' in Norway, the Government has recently announced an 8-year funding program to support basic nuclear research in Norway. A Norwegian Nuclear Research Centre is being established between the University of Oslo, NMBU and the nuclear operator IFE that will work to increase nuclear competence in Norway. Much of the available funding will be used to support PhD students on science topics needed for the future. 40 study places have also been made available at BSc and MSc levels to meet the growing needs for nuclear competence in Norway. The development of a TSO to DSA is also moving forward. Resources for the TSO have not yet been designated, but already some functions are being provided, including support with respect to emergency preparedness.

Staff from CERAD recently participated with DSA in the TOSCA self-evaluation exercise (see Chapter 3.1). All pillars were completed. The TSO is in the development stage, but it was valuable to go through the exercise to identify what needs to be done and be delivered. It was realized that there are many management procedures in place that can be built on in moving toward building a TSO. Such development will need to be done in collaboration with other institutes in the Knowledge Centre.

Discussion

At the outset, a strategic research agenda was developed for CERAD, and the intention is to expand this to a more national context. Having a long-term research plan is important for planning and to help focus direction.

6.2 CERAD Science Cases of Relevance for a TSO in Norway (O-C Lind, NMBU)

Addressing uncertainties in models has been an important area for CERAD activities, aiming to identify and reduce key uncertainties and to provide better, more reliable estimates of uncertainties. Prospective radiological and other impact assessments use past observations as a means of constructing models, and results are used to support decision-making in many areas, such as: planning for emergency preparedness and response in case of accident and other incidents; management of contaminated sites, and evaluation of proposals for RW disposal. The models used are simplified representations of reality that are associated sometimes with large uncertainties. Research can help reduce those uncertainties and support development of better models, allowing more reliable estimates to be made in support of decisions. In addition, improved model predictions can be achieved using local and regional site characterization data and by considering speciation and chemical characteristics and their dynamics, all reliant on better researched understanding of source terms and ecosystems.

An important example for CERAD concerns impacts in arctic waters. Nuclear powered submarines have been subject to accidents, or directly disposed, and now lie on the seabed. Related to this is the continued presence of nuclear-powered vessels in the region, including the Norwegian coast. Accordingly, an assessment has been made of a hypothetical nuclear accident on board a floating NPP, Akademik Lomonosov. Uncertainties in dispersion following a hypothetical onboard accident occurring close to the Norwegian coastline have been evaluated; illustrative results are presented in Figure 8. It was assumed that the reactor had been running during transport then the accident occurred, leading to an assumed release of around 5E+17 Bq, distributed across different particle size classes. Complete fuel meltdown was conservatively assumed. The study of uncertainties was performed by comparing models applied in Norway and Greece and was very relevant for emergency preparedness, radiation protection and environmental impact assessments.

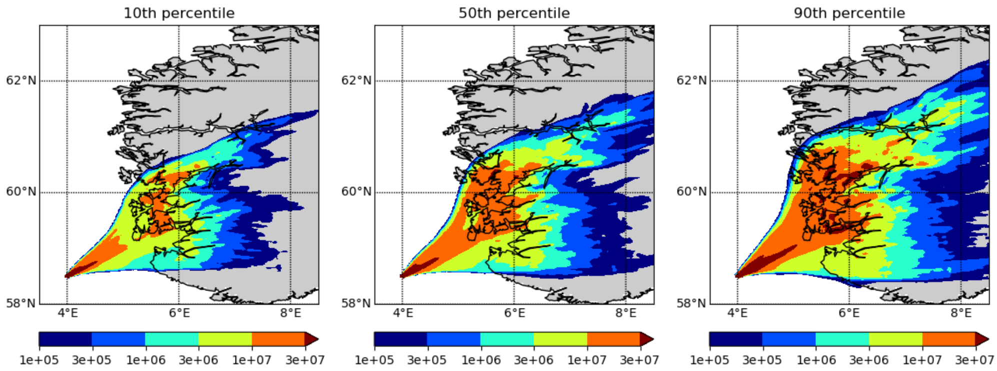

Figure 8. 10th, 50th and 90th percentiles of accumulated deposition over 24 h, Bq/m^2, for a hypothetical NPP accident at sea.

Another important research area has been the influence of chemical and physical characteristics of particles on radionuclide speciation. The influence of colloids and nanoparticles on radionuclide mobility has also been studied. Sophisticated methods have been applied to characterize particles and colloids, including laboratory-based methods such as electron microscopy, micro- and nano-scale x-ray fluorescence imaging and inductively coupled plasma mass spectrometry. Field sampling methods have also been applied to obtain data on speciation *in situ*.

Radioactive particles have featured in many different releases of radioactivity to the environment, including severe nuclear accidents, weapons tests and effluents discharged from nuclear installations. For example, significantly radioactive particles have been detected in the marine environment around Dounreay in Scotland. Research on these particles has allowed the particles to be characterized and to inform on the history of production of the particles when combined with information on the reprocessing processes that were used at Dounreay. The different characteristics and speciation of particles from the Dounreay fast reactor particles and materials test reactors were determined and skin contact dosimetry was studied and used to validate existing models. Radioactive particles released as a result of nuclear detonations at the Semipalatinsk site have been studied and results will be of relevance to nuclear forensics. The information gained during the particle studies should be transferable to other situations, including the dismantling of nuclear reactors.

Wildlife studies have been a further important research area. Most wildlife exposure data are derived from model simulations, but exposure is highly location dependent. GPS-coupled dosimetry has been used to consider uncertainties in model predictions of external dose rates for wildlife with results demonstrating that model-derived external dose rates could be underestimated where averaged soil contamination is used as input to assessment models. The output of this research is of relevance to wildlife dosimetry and environmental impact assessments.

Toxicity tests using daphnia and nematodes as model test organisms have been performed to investigate the biodistribution of radionuclides nanoparticles and the influence of particle composition on biological responses. Whether or not radioactive colloids and nanoparticles can be incorporated into tissues and organs has also been studied. Standard toxicity tests have been performed alongside synchrotron experiments at the PETRA II facility. Both uranium in solution and uranium nanoparticles have been studied with results indicating that uranium in solution is more toxic to the test organisms, but that body burden is higher for nanoparticles. The nanoparticles have been characterized, including their oxidation state, which affects both uptake and speciation. Specific target organs have been identified for uranium nanoparticles as a result of the research. Research has also been undertaken on stable elements such as cerium, zinc and iron as a means of linking exposure to detailed spatial-resolution characterization of accumulation in tissues and organs and live-imaging of antioxidant defenses in nematodes. Results are of relevance to environmental impact assessments and safety assessments.

CERAD research therefore covers a wide scope of topics, including cutting edge technologies and the competencies that have been developed over the last 10 years will be very useful for many coming TSO activities. Reports, publications and further information are available at https://www.nmbu.no/en/research/projects/cerad and CERAD [2023].

Discussion

A further topic of interest with respect to radioactive particles relates to RW management. Very small particles may be present in wastes destined for waste repositories and there is interest in ensuring that these can remain *in situ*. Evaluating the potential for physical movement of small particles in groundwater could be relevant at sites under remediation, and in evaluation of post-closure safety of disposal facilities, such as the Norwegian Himdalen storage and disposal facility. Some geochemical modelling and coupling work have already been undertaken on this topic and work is likely to continue as part of TSO activities.

Transport of radioactivity across the water-atmosphere interface in the marine environment as a result of processes such as resuspension has been on the research agenda but to date, work has focused on non-radioactive pollutants.

6.3 Finland: Development of Funding and Administration Structure of Finnish National Research Programs on Reactor Safety and Nuclear Waste Management (E. K. Puska, VTT)

There are five operating NPP units in Finland that, together, produce 40% of the country's electricity. In addition, Finland is home to the world's first spent nuclear fuel repository that is due to start operations in 2024. The national planning over the next 120 years, includes the operation and decommissioning of the current NPPs as well as operation and closure of the disposal facilities for low- and intermediate-level waste, interim storages for spent fuel and a disposal facility for spent fuel. There are also several smaller scale decommissioning projects and SMR projects. This includes the ongoing decommissioning of VTT's research reactor and VTT's low-temperature district heating and desalination reactor project that is currently moving from conceptual design phase to engineering phase.

The VTT Technical Research Centre of Finland was established in 1942 and currently employs over 2200 employees of which around 250 people work in the nuclear field. VTT is the TSO to the Finnish Radiation and Nuclear Safety Authority (STUK) and also provides support to the nuclear operators Fortum and Teollisuuden Voima Oyj and to the RW management organization Posiva. These roles have been ongoing since the 1970s.

National research programs on NPP safety and waste management safety have been a key component in Finland's and VTT's human capacity building in nuclear. The programs have been running since the 1990's. The programs were run in parallel until recently when they were merged into a single program. Research activities have generally been more focused toward NPP safety than waste management since Posiva has undertaken a lot of research on RW management outside of the national program.

During the first decade of the national programs, funding was primarily from the Finnish government budget with funding being decreased considerably during the 1990's and early 2000's, which resulted in the volume of research programs also decreasing. Then, in 2001, a parliamentary decision was made on the Olkiluoto repository, followed by a parliamentary decision on the Olkiluoto 3 NPP in 2002, which called for regulatory research and fostering of new generations of researchers to increase the workforce and replace those about to retire. This necessitated a new long-term solution for the funding of research that required a change in the Nuclear Energy Act. The change in law was accepted in 2003 and the new funding structure came into force at the start of 2004, enabling research funding to be collected into two separate funds within the State Nuclear Waste Management Fund. The maximum funding varied from 60% to 100% depending on the program, with any gap being filled by the research organization involved. The same funding structure is in place in the current SAFER2028 program, which requires 30% of own funding from the research organization.

When this mechanism was accepted, the Ministry of Finance initially stated that value-added tax would be applied that would have resulted in 24% of the funds collected going to the state rather than funding research. However, successful negotiations meant that the Fund avoided this tax.

Challenges were faced with the new funding mechanism. Under the new arrangement, the nuclear energy companies became responsible for paying into the research fund and it was necessary to gain their acceptance of the arrangement. This was achieved by providing seats in the new administration structures to those that had a duty to pay. In the NPP safety research program, seats were also provided to the research organizations that were obliged to contribute up to 40% of their own funding.

The Nuclear Energy Act sets out what fees are to be collected from nuclear facility and waste management operators and how those funds are to be distributed. The Act also defines who has to pay and sets the annual fees for research purposes. Currently the fees for NPP safety research purposes are set at 390 euros per rated thermal output megawatt given in the NPP license and, for RW management safety research the rate is set at 0.1% of the liability confirmed. How research organizations can apply for funding is also set out in the Act.

The most significant change to the administration structure of programs for NPP safety and waste management was the involvement of research organizations within the program decision making bodies. From 2015, mid-level research area steering groups were included between the management board and reference groups that have responsibility for scientific guidance in respective fields. Due to differences in the size of the programs there was a difference in the administrative structure of the two programs with a three-step structure being in place for the SAFIR research program on NPP safety[9] compared with a two-step structure for the KYT program on RW management research[10]. A third difference was the involvement of research organizations into the highest administration level with research organizations being full members within the SAFIR program whereas research organizations were not represented in the KYT program.

For the current SAFER2028 program, a steering group provides program direction and planning with reference groups then providing the strategic planning and scientific direction of research. The current structure of the program has management and stakeholder groups at the top of the structure, steering groups in the middle and technical advisory groups below, as illustrated in Figure 9.

[9] http://safir2022.vtt.fi/
[10] http://kyt2018.vtt.fi/en/

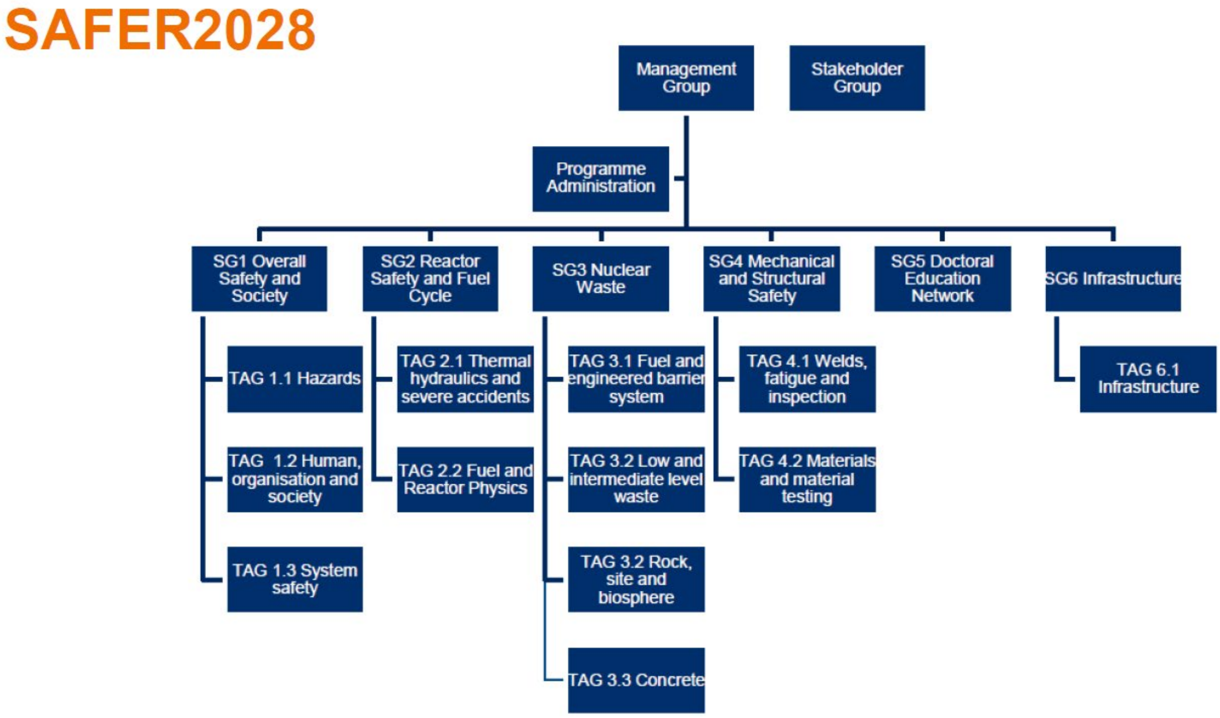

Figure 9. Structure of the SAFER2028 research program.

- The management group has representatives from STUK, the operators and the Ministry of Economic Affairs and Employment and is chaired by STUK. The group is responsible for defining the research area steering groups and technical advisory groups and is responsible overall for the program and its results.
- The stakeholder group consists of representatives from the research organizations and universities and acts as an advisory board to the management group, providing opinions and feedback on management group decisions, but holds no power in terms of making decisions. The group also acts as an information exchange forum between the research organizations.
- The research area steering groups are comprised of representatives from STUK and the operators and follow the compliance of projects with the Framework Plan and are responsible for ensuring that results are achieved in line with budgets.
- Technical advisory groups have representatives from all or some of the management group organizations and the research organizations and universities participating in the projects and are responsible for the scientific and technological guidance of the research.

The SAFER2028 Operational Management Handbook describes the roles and responsibilities of all involved in the program and describes how the planning of the research, follow-up and reporting of project results are done. The handbook also describes the evaluation process and the target of continuous improvement.

The presentation emphasized that each country needs to apply a research infrastructure that is applicable to its current and future situation. Consideration of the future situation is particularly important for those countries with a strong nuclear industry. Steady long-term funding allows for good planning of research activities and the training of young researchers; having a mechanism for funding that maintains independence from those liable to pay helps to ensure that research is independent and doesn't produce only those results that funders want to see. Furthermore, by requiring research organizations to also contribute funds to research, research projects concentrate on the most relevant subjects and target real needs, which also supports longer-term planning. Experience in Finland has shown that an effective funding mechanism for research in a small country can be delivered by gathering all players together. The presentation pointed out that it can be difficult to combine NPP and waste management research within a single program when in the early stages since they can require different kinds of expertise on different timeframes and can also involve different organizations. However, in mature programs, where the synergy between reactor safety and waste management is recognized, it can be worthwhile to consider a single research program, as is the case in SAFER2028.

Discussion

A move to a more combined approach to NPP safety and RW management research is particularly relevant to consider for 'mature' programs. Programs can also be reorganized as different synergies are recognized over time and to optimize programs and make best use of expertise. For small embarking countries, it may be appropriate to start with separate programs on NPP safety and radioactive waste management, gathering the critical mass of specific experts for each program. Bringing together researchers, operators and regulators can be an effective and pragmatic approach to identifying and addressing issues, and could apply to various situations, including the management of legacies.

6.4 UKRAINE: Challenges of Wartime: a TSOs perspective (Y. Balashevska, SSTC NRS)

The full-scale Russian invasion of Ukraine began on the morning of 24 February 2022, with Ukrainians waking to the sound of explosions. From the very beginning, the war was associated with radiation hazards due to the movement of troops through the Chornobyl exclusion zone (CEZ) and the occupation of facilities at the Chornobyl NPP (ChNPP).

In the first day of the invasion, the Ukrainian prime minister reported that the ChNPP had been taken under control of the Russian military with workers held hostage. The next day, abnormal readings were received from the automated radiation monitoring system in place throughout the CEZ. This was followed a few days later by shelling of the Kyiv RADON RW disposal site. Some damage was reported but radiation risks were low. The strike led to the termination of all RW management activities at the site, including transport of radioactive materials. Then, on 4 March, the Zaporizhzhya nuclear plant (ZNPP) was captured with shelling of the site causing damage to the ZNPP-1 reactor building and striking the area where a dry spent fuel storage facility is located. Two days later a Neutron Source nuclear research facility was bombed and damaged.

Toward the end of March 2022, Russian occupiers left the ChNPP. In the months that followed, missiles were launched frequently with some damage being caused to buildings at the Pivdennoukrainska NPP. Extensive missile attacks also targeted critical infrastructure, leading to black outs across the country. The Kakhovka dam was also targeted in June 2023 leading to an increased threat of nuclear incident at the ZNPP that relies on water from the Dnieper River for cooling ponds.

The invasion of Ukraine has led to many new challenges and an increased workload for SSTC NRC. There has been a need to look frequently at different possible accident scenarios to support emergency preparedness and an enormous demand for high quality, clear and timely information to be released to the public on the developing radiation situation. There has also been a need to correct fake and disinformation targeted at the public about the radiological situation as part of psychological attacks.

SSTC NRS performance has had to be uncreased under very difficult and often dangerous conditions. There have been weeks when air raids occur several times per day requiring people to leave workplaces and seek shelter in basements or underground. On return to work there are often black outs that can last for hours, when computers cannot be used. Evacuation and relocation of staff has meant a rapid transition to remote working, with some personnel being relocated abroad or remaining in territories occupied by Russia. Other experts have been conscripted into the Ukrainian armed forces. Where personnel have moved abroad it can be difficult to provide continued support since; if refugee status is gained, they can no longer legally work for the TSO. For personnel within occupied areas, communications can be very limited. Together, these factors have affected the availability of expertise. There is a lack of safe working places, information chains and communications have been affected and continued challenges are faced with respect to power supply that affects the ability to receive and transmit data. Establishment of a stable emergency working center is a challenge currently being dealt with.

The occupation of the CEZ gave rise to an emergency radiation situation. Heavy machinery moving through the contaminated area was not decontaminated, as would normally be necessary, and there was concern about the potential for contamination to have been mobilized and of the consequences of that radiation being transported to new areas. A first phase radiation survey, performed in collaboration with DSA, as part of the bilateral regulatory cooperation program, has been undertaken and a second phase is ongoing. The objective has been to perform a radiation survey of the Kyiv region surrounding the CEZ that may have been affected by the military occupation, to reduce risks of exposure due to contact with radioactive sources and radioactive contamination and to communicate results with the public to reduce public anxiety associated with perceived risks. Typical circumstances in the area and the survey routes are indicated in Figure 10.

Gamma radiation readings from some stations of the automated monitoring system within the CEZ were elevated following the military occupation, up to 30 times higher than prior readings. Furthermore, after these readings were received, connection to the system was lost, causing a lot of anxiety. It was suggested that military machinery could be causing increased dust loadings in air that could explain the readings, but this explanation was doubted. It was not feasible to use drones to undertake aerial surveys and the presence of mines meant that the survey of the region was restricted to movement by road. Measurements were made in homes, schools and hospitals and information was collected by speaking with inhabitants on their experience and knowledge of actions and behaviors of the invading forces. Whilst there was no sign of intrusion within the ChNPP facilities, there was evidence of mass looting of small sources and scrap metal from the laboratories. The radiation survey was performed over around 50 localities and included over 130 private houses, over 130 public places and facilities and over 840 km of roads. More than 400 suspicious objects have been investigated, and two radiation sources have been identified and removed. No additional radiation contamination outside the CEZ was identified as a result of the movement of military machinery. A methodology for conducting radiation surveys in affected areas has been developed as a result of the work undertaken to date. An important feature is engagement with local people and authorities. This approach this will be rolled out to other liberated areas where there are radiation threats. Further information is provided in Balashevska et al (2023).

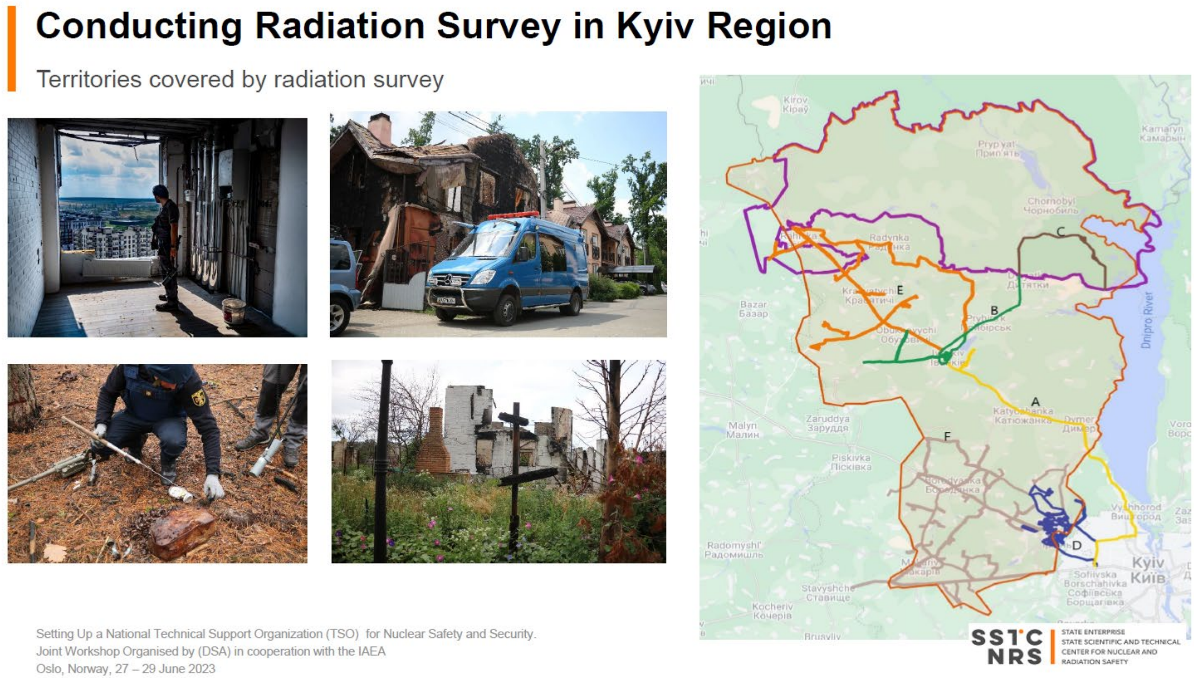

Figure 10. Routes of the radiation survey and examples of circumstances in these routes. The highlighted area refers to the territory that was under the occupation (approx.). The boundaries of the CEZ (approx.) are shown in purple marked with purple

There has also been a need to inform the public based on information gained through monitoring. When there is no information on the development of a situation, it is possible for others to manipulate the situation and to conduct psychological operations and manipulate public moods and opinions. This was particularly an issue for the radiation situation around NPPs. To address this, project RESTORATION was undertaken in collaboration with DSA. The objective of the project was to strengthen the technical support capabilities in the assessment of doses to the public using data from independent environmental monitoring stations with a view to better informing the public about threats. Up to 5 independent radiation monitoring stations will be established solely for use by the regulator and work is being undertaken to identify and justify where monitoring stations should be established and what equipment to install.

Training of licensees, students and specialists has always been an important part of SSTC NRCs activities, but during the war the focus of training and the target audience has changed so the focus now is more on raising public awareness and disseminating crucial knowledge, including actions to take in an emergency. Events have been organized to educate the public and there has been an increased presence on TV.

A lot of work has also focused on fighting disinformation and mitigating the consequences of misinformation. One interesting case was that of misinformation being disseminated around the finding of a ‘radioactive flask’ in an apartment in Bucha in May 2022. The flask was found by mine safety officers that entered homes first to check they were physically safe. It was reported that radiation contamination was higher than expected in the apartment, but this had not been measured. As it was reported by the media the context kept changing slightly until it was being reported that the flask was an item from ChNPP. The item was actually a mercury flask.

In another incident it was reported on the media that the radiation background had increased dramatically following the shelling of the city of Khmelnytsky. Whilst an increase had been observed it was not a large increase (being within the margin of error) and this disinformation needed to be addressed and for the public to be assured that the situation was safe.

The SSTC NRC has also needed to develop specialist training for personnel working on how to understand readings and decontamination measures etc., where the need is much greater than in normal times.

There has been a lot of support from a range of partners internationally. Many TSOs from other countries have offered help in the supply of equipment and training and facilitating SSTC NRC in fulfilling their functions. This also provided the opportunity to test the IAEA Response and Assistance Network (RANET) cooperation. Requests have been submitted to RANET on needs and responses were received quickly with supplies being provided either through RANET or as a result of individual agreements.

There have therefore been considerable radiological aspects to the war in Ukraine. The TSO has needed to ensure that reliable scientific and technical support to the regulator is maintained, and this has benefitted from assistance received from the international community as a whole and particularly ongoing strong collaboration with many specific organizations, including the DSA which has maintained a clear and consistent position, comprehensive support and reliable long-term partnership.

Discussion

There has been a need to rapidly adapt to changing situations. Prior to the war, others in Ukraine would have been responsible for addressing misinformation etc., but many people have been pulled to work in other tasks in defense of the country. SSTC NRC has therefore worked to address the gap.

The ability to address public concerns about radiation increased in the years following the Chornobyl accident, but much of that experience and learning has regressed such that there has been a need to relearn in response to circumstances arising because of the invasion.

Whilst there have been concerns among the public about the radiation situation resulting from the war, this has not affected public opinion with respect to nuclear power in the country. The public are not afraid of nuclear power, but there are fears about nuclear facilities being attacked.

7 Session 6: Overview and Future Plans

7.1 Key Recommendations and Lessons Learned

The wide range of presentations given combined with the open and in-depth discussion fully addressed the workshop objectives set out in Chapter 1.2. The information shared will be very useful to countries looking to develop TSO's, providing lessons that guide development and help to avoid pitfalls.

Twelve countries presented TSO experience in relation to their individual status, providing perspectives from large and small countries, including those with a well-established nuclear program, those that are newly embarking and yet others with no nuclear program at all. Examples show that TSOs can have a significant role even in the latter case, given the wide-scale use of sources of ionizing radiation in medicine, research and industry as well as processes and procedures involving NORM.

The general model for interactions between relevant organizations, as set out in Figure 11, is highly relevant. Although their coordination can be complex, those organizations cannot work successfully in isolation. While there can be common topical challenges, there is no one organizational model that can effectively provide that coordination in all circumstances. Clarification of the roles and responsibilities of all these organizations, and how they should interact, is crucial but solutions will be locally dependent.

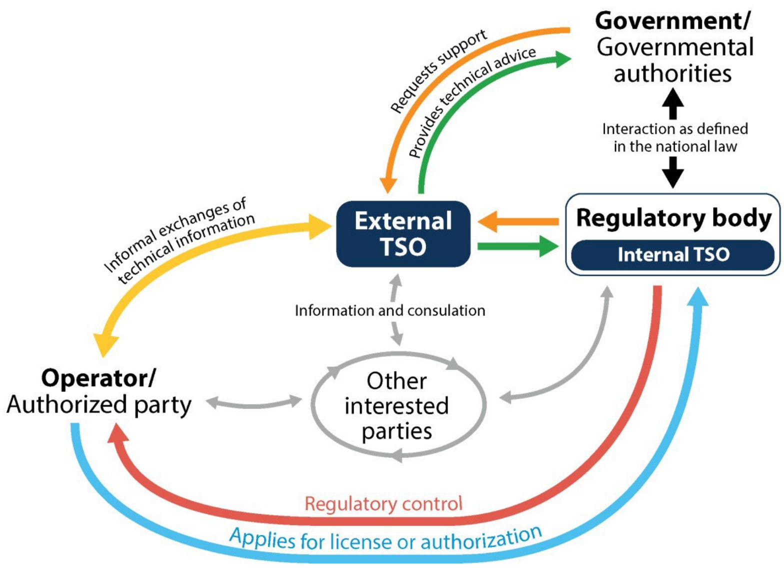

Figure 11. Illustration of general interactions of the external TSO with the regulatory body and other interested parties in support of regulatory functions in IAEA TECDOS-1835 [IAEA TECDOC, 2018].

The sharing of knowledge and understanding based on the presentations, including specific case studies, was confirmed as highly beneficial, providing experience and lessons that can be adapted to the difference circumstances in different countries. Presentations and discussions highlighted the need for continued and enhanced cooperation and coordination at an international level.

Each of the presentations documented above has its own value. Key recommendations and common issues are provided below.

1) When establishing the mandate for a TSO, competencies should be identified and prioritized to ensure that the necessary skills and knowledge are aligned with national policies and nationally relevant

needs. Evaluation of such needs is likely to involve a wide range of stakeholders, but a key issue is the legal basis and content of the mandate of the regulatory body.

2) It is important to take a long-term sustainable view of the competencies that will be needed as well as the corresponding staffing level requirements. This applies to providing technical support as well as research activities.

3) When identifying the requirements of the TSO and the tasks that the TSO will undertake, clear engagement is needed between government, regulators and the TSO that takes into account the mandate of the regulator. Competencies needed by the TSO to support the regulator in meeting its mandate can then be identified by mapping competencies available against those required. Where competence already exists, judgement is needed to decide if the level of competence is sufficient, or whether further development is required. Where gaps are identified, thought should be given as to how to close those gaps, through training, hiring or use of external resources. Decisions on which competencies should be held by the regulator and which by the TSO will be dependent on national circumstances.

4) Determining priorities for improvement of competence or to fill any gaps is an important part of the process and involves a clear understanding of risk management. A holistic view of the risks is suggested that allows multiple hazards to be considered in proportion to those hazards, as well as wider social and economic factors.

5) Priorities for research that might be carried out by a TSO may be identified by examining the key uncertainties affecting the results of safety assessments. This can be facilitated by making the relevant assessment documentation available.

6) A key challenge in mapping is that competencies need to be linked to a national program that itself may be evolving. For example, it is clear from discussions that several countries are considering the introduction of SMRs. Even without actual SMR development, informed discussions on whether such development should take place will need to be informed by input from the regulator, as potentially supported by a TSO. In order to deal with such contingencies, it is suggested that a time-step approach be taken to evaluating potential new competency on a regular basis, e.g., examining likely activities and needs on a short- and longer-term basis.

7) Events, such as pandemics or foreign invasion are hard to plan for, so a degree of flexibility in the setting of mandates and interactions among relevant organizations is advised, so far as possible leaving room for appropriate changes in approach.

8) Competence plans should be living documents that reflect progress in line with national programs. Competence mapping should therefore be periodically undertaken both within the regulator and the TSO. Identified gaps in competencies should be communicated, with the TSO informing on what resources will be needed to address those gaps, in terms of recruitment and training or by drawing on external expertise, and the associated costs. Knowledge management and risk issues should also be evaluated and prioritized, taking account of the risks associated with not having the necessary competencies and the costs associated with gaining them.

9) While noting possible changes in circumstances, it is necessary to draw a balance between meeting urgent immediate priorities and long-term interests; this may involve balancing short- and longer-term needs and risks.

10) The mandate for a TSO should include clear mechanisms and processes for interactions between the TSO, regulators and operators, as well as any other relevant organizations, according to local dependencies.

11) In some instances, and particularly for smaller countries, it may be clear that not all the competencies are available. Consideration will then be needed as to whether to look at longer-term training or recruitment from abroad, or some combination. Where there are similar needs in neighboring

countries, the establishment of a regional TSO could also help address issues with respect to capacity and capability building.

12) If a TSO is permitted to support other bodies than the regulator, conflicts of interest may arise. This may be a particular issue in small countries where there may be limited expertise available to support both regulators and operators. However, experience presented from countries with established TSOs illustrates that challenges can be addressed by, for example, establishing rules of engagement between the TSO and others. Bringing together the different players has also been demonstrated to be an effective and pragmatic approach to identifying and addressing issues. Nonetheless, careful consideration is needed on how best to arrange expertise in a formal manner to avoid conflicts arising.

13) It has been recognized through various forums that an improved interface is often required between the regulation of nuclear security and the regulation of radiation safety. In some countries TSOs cover security as well as safety and in others, not. Whatever the approach taken, it is beneficial to recognize the synergies between the two fields and the need for an interface to allow engagement when necessary. One complication is that work on security may require some form of clearance and this may deter some from the field. Younger people are likely to have fewer issues in obtaining security clearance than older experts. Involving people in the field of nuclear security early in their careers can therefore be a useful approach, enabling security clearance obtained early on with competencies being developed as a career progresses.

14) It has been recognized that the TOSCA methodology might be an appropriate tool to assist national decision makers in setting up a sound regulatory system with an internal and/or external TSO by self-assessing their national situation and drawing the appropriate conclusions from the results of this SWOT analysis and the recommendations and lessons learned mentioned above.

15) It was noted that the cooperation between EuCAS and the TSO Forum during the workshop was very fruitful and should be further developed in the future, e.g., through joint international and regional workshops or technical contributions to establishment of a national or regional TSOs.

7.2 Perspectives and Future Plans

Presentations and discussions during the workshop have proved very useful in providing international perspectives on TSOs for regulatory bodies, including the potential for establishing regional TSOs, for example, in Central Asia. By establishing collaborative platforms, available competencies can be identified at regional level that can be drawn upon as required. Such approaches could prove very useful for emergency response and there is the potential for further promotion of the TSO concept through such platforms. Discussions would be needed between the regulatory bodies within the region to take the concept forward, with EuCAS providing a good platform for starting such discussions. Consideration is also being given to the establishment of virtual TSO Forums that could focus on regional issues.

The TOSCA self-capability assessment process and TOSCA tool have proved useful in those countries in which it has been applied. The tool supports the mapping of competencies and identification of gaps and areas where further development is required to achieve the desired levels of competencies. TOSCA provides a flexible assessment approach that can be tailored to the particular circumstances in a country and is designed to be an iterative approach to help guide the TSO development process, guiding the development of a plan for competence building and providing a means of evaluating progress. In addition to helping guide the development of TSOs, TOSCA can also be used as a means of periodically reviewing capacity needs as national programs evolve.

TOSCA was mainly developed for embarking countries on the basis of TECDOC-1835 [IAEA, 2018] and did not focus on how to establish a TSO. However, it was recognized early on that other countries with more developed radiation protection programs also wanted to establish TSOs. Two management and six technical pillars were therefore defined and elaborated to cover the whole range of possible TSO functions and responsibilities. TOSCA is intended as a flexible assessment approach that can be tailored to the particular circumstances in a country by only addressing those pillars that are applicable. A TECDOC is also planned that would cover the establishment of TSOs and provide guidance on both ‘what’ and ‘how’. Further outreach activities are also planned to help promote the TSO Forum and the work being undertaken. For example, the 5th International TSO conference is being organized in Vienna in December 2024. Clear messages on TOSCA and results of the self-capability assessments undertaken by several countries will be presented. The conference will also provide a platform for wider sharing of experience from other countries on TSOs and lessons learned.

A new cycle of TSO Forum activities is about to begin, and new membership is encouraged to allow greater sharing of knowledge and experience. Three core groups have been established with in the forum, comprising TOSCA, research and development and ad hoc. Decommissioning and dismantling and SMRs could be a topic for the ad hoc group and will be discussed at the next forum meeting to determine whether there is scope for working groups to be established.

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Appendix A. List of Participants

The workshop participants and their affiliations are detailed in the following table.

Surname	First name	Organization	Country
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Øberg	Mikkel	Danish Decommissioning	Denmark
Puska	Eija Karita	VTT	Finland
Ben Ouaghrem	Karim	IRSN	France
Eibl-Schwäger	Carla	GRS	Germany
Rocchi	Frederico	ENEA	Italy
Sneve	Malgorzata	DSA	Norway
Hüttmann	Heidar	DSA	Norway
Strand	Per	DSA	Norway
Skodbo	Sara	DSA	Norway
Rudjord	Anne Liv	DSA	Norway
Frøvig	Anne Marie	DSA	Norway
Hosseini	Ali	DSA	Norway
Celius	Trine	DSA	Norway
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Steinmoen	Hilde	NMBU	Norway
Skipperud	Lindis	NMBU	Norway
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Lind	Ole Christian	NMBU	Norway
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Nhleko*	Sifiso	NNR	South Africa
Seltborg	Per	SSM	Sweden
Barotov*	Bakhtiyor	STSO	Tajikistan
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