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Human Resource Management for New Nuclear Power Programmes

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HUMAN RESOURCE MANAGEMENT FOR NEW NUCLEAR POWER PROGRAMMES

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HUMAN RESOURCE MANAGEMENT FOR NEW NUCLEAR POWER PROGRAMMES

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FOREWORD

The IAEA's statutory role is to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world". Among other functions, the IAEA is authorized to "foster the exchange of scientific and technical information on peaceful uses of atomic energy". One way this is achieved is through a range of technical publications including the IAEA Nuclear Energy Series.

The IAEA Nuclear Energy Series comprises publications designed to further the use of nuclear technologies in support of sustainable development, to advance nuclear science and technology, catalyse innovation and build capacity to support the existing and expanded use of nuclear power and nuclear science applications. The publications include information covering all policy, technological and management aspects of the definition and implementation of activities involving the peaceful use of nuclear technology.

The IAEA safety standards establish fundamental principles, requirements and recommendations to ensure nuclear safety and serve as a global reference for protecting people and the environment from harmful effects of ionizing radiation.

When IAEA Nuclear Energy Series publications address safety, it is ensured that the IAEA safety standards are referred to as the current boundary conditions for the application of nuclear technology.

For countries embarking on a nuclear power programme, identifying, acquiring and developing the necessary workforce for the first nuclear power plant is a top priority. At the same time, developing the relevant human resource (HR) infrastructure needed to support this workforce across the key organizations involved is an essential undertaking. A number of factors specific to the nuclear power industry, including the unique characteristics of nuclear personnel, specialized demands of the industry and risks related to financing and programme delays, present challenges to HR development. To overcome these challenges, developing an integrated HR management (HRM) strategy is a critical step towards building a competent and sustainable nuclear power programme.

This publication draws on two previous IAEA Nuclear Energy Series publications related to the topic of HR development for nuclear power programmes: Milestones in the Development of a National Infrastructure for Nuclear Power (NG-G-3.1 (Rev. 1)) and Managing Human Resources in the Field of Nuclear Energy (NG-G-2.1). This publication aims to provide Member States with a structured approach to developing an effective HRM strategy, that can be adapted to suit the nature and scope of a national programme. It identifies the four components of an integrated HRM strategy that are particularly relevant for countries developing nuclear power for the first time and examines these issues in the context of each phase of the Milestones approach. This publication identifies the actions related to these issues and presents observations and lessons learned from Member States.

The target audience for this publication is individuals responsible for HRM in countries developing a nuclear power programme for the first time. The information may also be useful for countries considering an expansion of an existing programme, particularly after a significant period has passed since construction last occurred.

The IAEA gratefully acknowledges the work of the contributors to the drafting and review of this publication, particularly, D. Palmer (United Kingdom), B. Molloy (Ireland) and S. Mortin (United Kingdom). The IAEA officer responsible for this publication was M. Van Sickle of the Division of Nuclear Power.

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1. INTRODUCTION

1.1. BACKGROUND

With continued interest in the development of new nuclear power programmes, the IAEA remains committed to providing guidance to support its Member States in this area. One of its publications, Milestones in the Development of a National Infrastructure for Nuclear Power [1] (the Milestones approach) identifies 19 infrastructure issues to be addressed by a Member State considering the introduction of nuclear power. One of these (Issue 10) is human resource (HR) development.

The Milestones approach also describes three distinct phases in the development of a national nuclear power programme, each of which is marked by a specific milestone for the completion of every phase:

— *Phase 1*: Considerations before a decision to launch a nuclear power programme is taken;
— *Phase 2*: Preparatory work for the contracting and construction of a nuclear power plant after a policy decision has been taken;
— *Phase 3*: Activities to implement the first nuclear power plant [1].

The achievement of the infrastructure conditions for each of these phases is marked by a specific milestone at which point the progress and success of the development effort can be assessed and a decision made to move to the next phase. These are:

— *Milestone 1*: Ready to make a knowledgeable commitment to a nuclear power programme;
— *Milestone 2*: Ready to invite bids/negotiate a contract for the first nuclear power plant (NPP);
— *Milestone 3*: Ready to commission and operate the first NPP [1].

The Milestones publication further identifies three key ‘organizations’ involved in the development of nuclear infrastructure:

— *Nuclear energy programme implementing organization (NEPIO).* This may be a stand-alone organization, or it may be a mechanism involving high level and working level committees, with representatives from a range of organizations and departments, to coordinate the work involved in infrastructure development.
— *Owner/operator.* This may be State owned or private, be part of a domestic or international utility, or be another commercial entity. This is the organization responsible for contracting a vendor, overseeing construction and ultimately operating the NPP.
— *Regulatory body (or bodies).* This is responsible for the regulation of nuclear safety, security and safeguards for the nuclear power programme. It may be a new organization or an expansion of an existing body responsible for radiation protection [1].

This publication provides additional guidance on HR development for countries embarking on new nuclear power programmes, addressing this issue in each of the three phases of the Milestones approach. It is to be read in conjunction with the IAEA publication Managing Human Resources in the Field of Nuclear Energy [2], which identifies the different components of an integrated human resource management (HRM) strategy and provides more general guidance on managing human resources in the field of nuclear energy. Other related documents are referenced in the text.

Figure 1 shows the elements of an HRM strategy for countries embarking on a nuclear power programme [2]. Shaded items in the diagram represent the key inputs in the development of the initial HRM strategy as countries move through the phases of the Milestones approach. However, the other

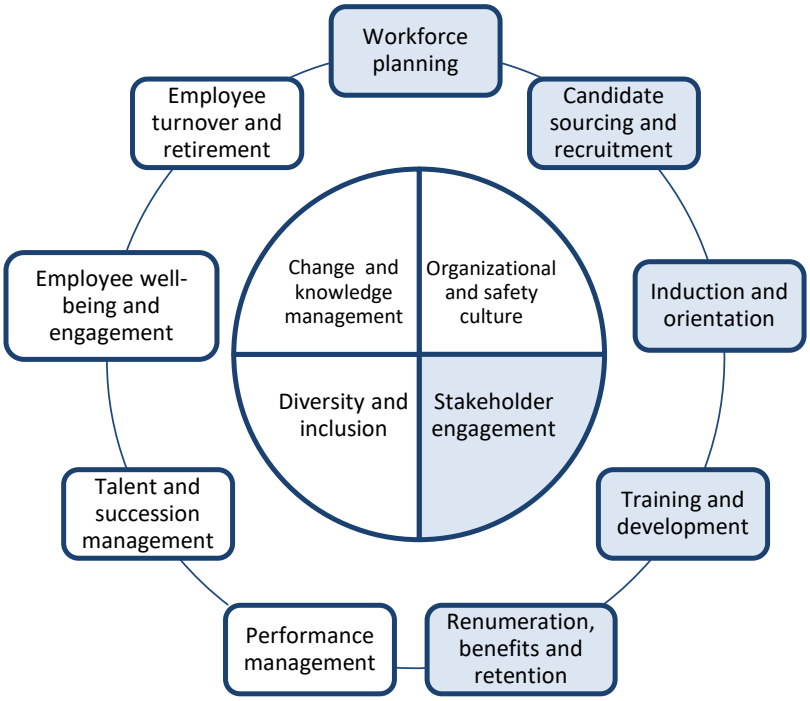

FIG. 1. Elements of an HRM strategy.

aspects of HRM strategy will also need to be introduced at the appropriate time and more details of these components can be found in Ref. [2].

For the purposes of this publication, these key components are as defined as follows:

— *Workforce planning* is the systematic analysis of what an organization is going to need as a function of time, in terms of the size, type and quality of workforce to achieve its objectives. It identifies what mix of experience and competencies are expected to be needed and helps ensure that the programme has the right number of people with the right skills, in the right place at the right time. Further, the term workforce is intended to refer to all personnel, including contractors, involved in the activities. Workforce planning needs to be seen as an integral part of an organization's overall HRM strategy and needs to be aligned and integrated with other HR activities and processes. For example, workforce planning will identify who needs to be recruited and when, and will identify the need for and nature of the training and experience required.

— *Recruitment* includes the preparation of job specifications, including any job specific education and experience requirements, identification of sources of candidates, shortlisting, interviewing and finally selection of staff for particular roles. Following recruitment, induction and onboarding takes place, including medical and security clearances.

— *Education, training and development* include those activities in both the national education system and organization specific systems required to develop an individual's competence for a specific role or task. This area will cover both professional/graduate education programmes and vocational/technical training programmes.[1]

— *Remuneration and retention* include both the direct financial reward (pay and bonuses) and other non-financial rewards intended to attract and retain staff such as subsidized housing, transport, education, and medical cover for staff and their families.

[1] Professional/graduate indicates that the individual obtained a university degree, whereas vocational/technical indicates that the individual has obtained a skill based qualification.

— *Stakeholder engagement* is the process of involving and engaging a wide range of interested parties in the decision making on nuclear power programmes to enhance public awareness, understanding and confidence. While this issue is very important to countries embarking on new nuclear power programmes, it is covered in other IAEA publications and will not be discussed in detail [3].

Member States in Phase 1 of the Milestones approach will be considering an HRM strategy at the national level. As the programme moves into Phases 2 and 3, each organization will develop its own HRM strategy. Hence, the focus of HRM shifts from the national to the organizational level. However, there will still be a need for consideration at the national level of matters such as education and training capability.

As the programme develops, the HRM strategy and associated workforce plans need to be reviewed and developed in more detail. As part of the HRM strategy, it is important to correctly identify the total HR investment required for a nuclear power programme. This may include, among other considerations:

— New education programmes;
— Training facilities and courses;
— International recruitment of staff and/or advisers;
— International training;
— Secondment of national staff abroad;
— Language training.

It is essential that decisions on all these investments are driven by the demands of the nuclear power programme, both in terms of numbers and timing. Member States need to recognize that investment in some of these areas will be necessary prior to the selection of a particular design.

1.2. OBJECTIVE

The objective of this publication is to provide Member States with a structured approach to developing an effective HRM strategy, consistent with the nature and scope of the programme.

It is important to understand the competencies that will be required by the key organizations at each stage of the nuclear power programme, as well as the resources necessary to develop and sustain these competencies. Therefore, this publication will examine each phase of the Milestones approach and discuss the specific HRM activities that are expected to take place. Appendices are included that further describe these competencies.

1.3. SCOPE

This publication was prepared as guidance on the HRM aspects of the development of a national infrastructure for nuclear power. It focuses on those key HRM issues to be considered specifically for countries embarking on nuclear power for the first time. These include:

— Workforce planning;
— Recruitment;
— Education, training and development;
— Remuneration and retention.

These issues were chosen as the focus of this publication as they represent the majority of the effort that will be required in the area of HRM throughout the three phases of the Milestones approach.

1.4. STRUCTURE

In addition to the introduction and conclusions, this publication comprises four sections and four appendices. Section 2 outlines some specificities of nuclear power and the implications for HRM strategy, including observations and lessons learned. Section 3 discusses the considerations of the HRM strategy for each phase of the Milestones approach. Section 4 discusses the use of risk analysis to ensure alignment of strategies to address HRM and programme risks. Section 5 addresses the specific aspect of transition from construction to operation.

1.5. USERS

Expected users of this publication are those individuals with responsibilities for HRM. This may include decision makers, advisers and senior managers who work in governmental organizations, utilities, industry and regulatory bodies of a country with an interest in developing nuclear power.

The publication is aimed primarily at those countries considering nuclear power for the first time. However, much of the information contained may be equally useful to those countries considering an expansion of an existing nuclear power programme, especially if significant time has elapsed since the construction of the last NPP.

This publication will also be of interest to national and international educational and training establishments, suppliers, and research and technical support organizations (TSOs) that may be involved in supporting the development of national nuclear infrastructure.

2. CHARACTERISTICS OF NUCLEAR POWER AND THEIR IMPLICATIONS FOR THE HUMAN RESOURCE MANAGEMENT STRATEGY

A nuclear power programme presents specific challenges related to recruiting, hiring, training and sustaining a suitably qualified and experienced workforce. These challenges are addressed in the following subsections.

2.1. SAFETY, SECURITY AND SAFEGUARDS

The unique aspects of nuclear power related to safety, security and safeguards necessitate an organizational culture and individual attitudes that ensure these issues are given the highest priority. The NEPIO, the organization responsible for coordinating the nuclear power programme, is responsible for promoting this culture at the outset of the programme. However, developing this culture takes considerable time and effort for all the key organizations of the programme, particularly the owner/operator and regulatory body. The staffing and development efforts needed in this regard need to be incorporated in the HRM strategy.

As the programme develops, the owner/operator and the regulatory body may be supported by organizations from other countries, each with their own language and organizational culture. These diverse backgrounds may create challenges in establishing an organizational culture that gives the highest priority to safety, security and safeguards, and may require a dedicated effort and supporting programmes.

Observations and lessons learned:

— Organizations need to develop and promote their values, behaviour and expectations as soon as they are established;
— The development of leadership programmes is particularly important in the creation of an effective and cohesive organizational culture.

2.2. COMPETENCE REQUIREMENTS

Nuclear power requires a higher level of education, training and experience compared with other energy sources. The job specific training and experience for some positions can add years to the competence development process. For a country embarking on nuclear power for the first time, the options for obtaining experienced national staff are to: recruit nationals who have been working abroad; second staff abroad to develop experience; or recruit experienced staff from abroad and use them to train national staff through mentoring or shadowing programmes. Suitable national staff may also be sourced from any existing nuclear research facilities, such as research reactors. The above issues need to be considered in the recruitment and retention policies of the organizations to ensure that the right staff are attracted to, and retained in, the organization.

The time from recruiting an individual with suitable education for a position to when that individual is fully qualified to work independently in the nuclear sector is longer than for many other fields. This lead-time for certain positions in the owner/operator can be five to ten years (e.g. licence engineer, operational planning, shift supervisor, emergency planning engineer, and plant manager). Therefore, the workforce plan needs to identify when these individuals need to be recruited, taking into account training lead times, and when they are needed to perform their job function. Appendices I and II provide examples of job positions and work functions in the owner/operator, including those with long lead times required for the operational phase of the plant. Additional information regarding competence and staffing of the regulatory body can be found in the IAEA publication Organization, Management and Staffing of the Regulatory Body for Safety [4].

Outreach and engagement programmes with educational institutions — from primary school to university — will help to attract suitable candidates and will also foster greater public understanding regarding nuclear power technologies. These programmes need to be included in the national stakeholder involvement and public communication plans [3].

Observations and lessons learned:

— The IAEA Nuclear Infrastructure Competency Framework [5] assists Member States in planning the activities required throughout all phases of the introduction of a new nuclear power programme, as well as identifying the competencies and capabilities required to implement these activities.
— Lead times may need to consider language requirements (i.e., when the language of the training programmes is different from the national language).
— If enhancements to the national education infrastructure are required, this will add to the overall lead times.
— It is important to ensure that the relevant standards of the national education system are aligned with those required by nuclear training programmes.
— Early engagement with educators in the broader areas of science, technology, engineering and mathematics (STEM) has proven effective in attracting students into nuclear specific careers.

2.3. SECURITY AND MEDICAL SCREENING AND FITNESS FOR DUTY

The term ‘fitness for duty’ is used to cover a broad range of requirements in nuclear operating organizations but has three main elements:

— Initial screening of candidates, including a thorough review and verification of qualifications and experience, as well as criminal records and financial reviews and background/security checks. In some countries, there may be legal constraints regarding security clearances, beyond the control of the recruiting organization, which will impact the recruitment of foreign workers.
— Medical testing and questionnaires, including drug and alcohol testing, are also necessary to ensure general fitness for duty according to the organization’s requirements. Again, some of these may be dependent on the specific country requirements.
— Psychometric testing based on job specific requirements (e.g. control room operators) may also be required. These tests are designed to confirm aspects such as an employee’s suitability to work on shift, effectiveness in stressful situations, approach to safety, ability to work in teams, etc.

Medical and psychometric testing are typically used as part of the initial recruitment process and at regular intervals (e.g. one–three years), as part of job change requirements (promotion, job rotation) and after any extended absence from work, especially if there is a medical reason. This screening and testing can both reduce the pool of potential workers and also lead to higher and unplanned turnover rates, which need to be considered in the HRM strategy [6].

Observations and lessons learned:

— It is important that fitness for duty programmes are designed properly to meet the needs of the organization;
— While portions of the background checks may be performed by governmental organizations, certain elements of the screening process may be outsourced;
— Certain positions may be limited to nationals.

2.4. STAFF RETENTION

The long lead times and specific competences required make the unplanned loss of personnel in the nuclear power industry particularly costly, both in monetary terms as well as maintaining the programme schedule. Therefore, a retention strategy and succession plan are needed to mitigate the risks. For example, when staff receive training overseas, they may be attracted by opportunities in the host country. Incentives or formal agreements may be useful to ensure that staff return following the completion of the training.

Observations and lessons learned:

— The nuclear power programme may be promoted as an opportunity to participate in a national project with the potential to improve the overall quality of life in the country;
— Competitive remuneration, incentives and benefits support staff recruitment and retention;
— It is important to carefully monitor the turnover of personnel and to have processes in place to understand the reasons for leaving and for managing their exit;
— Programme delays can lead to the loss of qualified staff and impact the motivation of new recruits;
— Differences in the level of the salaries for similar positions among the organizations involved in the nuclear power programme can create retention issues;
— Opportunities for career development and promotion will support staff retention.

2.5. KNOWLEDGE MANAGEMENT

NPPs have a lifetime of at least 100 years, from planning, construction, commissioning and operation through to decommissioning. This timescale means that the workforce of the NPP will span several generations. Therefore, the establishment of a knowledge management programme will ensure that specific knowledge and skills are archived and shared throughout the life cycle of the NPP. This will include the initial planning, design, licensing and construction information. It will also include archiving the knowledge of people when they move internally to new positions or leave the organization [7].

These processes are also needed to ensure that knowledge is transferred from external experts to the staff in the organization that will be responsible for the continued sustainability of the nuclear power programme. In particular, it will be important for the owner/operator to establish processes to transfer knowledge from the vendor to its organization. Knowledge related to the design, construction, commissioning, operation and maintenance of the first unit(s) needs to be archived and transferred from the vendor [8].

In addition to normal turnover, organizations need to anticipate situations that may lead to higher rates of separations. For example, some organizations have age demographics that may result in a higher than normal number of retirements. Knowledge management processes need to be configured to anticipate and prepare for such situations.

Observations and lessons learned:

— Procedures for cataloguing and transferring relevant knowledge need to be established by each key organization from the beginning of the programme.
— Mentoring or shadowing programmes may be a useful way to transfer knowledge from experienced personnel to more junior staff. Formal training and relationship building are an essential part of effective mentoring programmes.

2.6. MANAGEMENT OF CONTRACTORS

The nuclear power programme requires the management of experienced and specialist contractors. These contractors are typically used to perform tasks that are of a specialized or temporary nature, such as siting studies. They may also be used to supplement the staff of the owner/operator or regulator and provide training and mentoring to future staff of the organizations. Different numbers and types of contractors will be used throughout the duration of the programme.

There are two key aspects to consider related to the use of contractors. First, the customer (owner/operator or regulatory body) needs to be capable of specifying the work required, overseeing the work carried out and understanding the implications of the results or conclusions. Second, the customer needs to ensure that work carried out by contractors is conducted by personnel who are competent for that purpose and suitably qualified and experienced to perform their duties.

The use of contractors will have a direct impact on the workforce planning of the organizations. For example, using contractors to perform specialized or temporary tasks will generally reduce the total number of permanent staff. Alternatively, when contractors are used to supplement the staff, the total headcount and cost may temporarily increase.

Observations and lessons learned:

— Ensure that the contracting strategy is reflected in each organization’s workforce plans;
— Consideration has to be given to establishing formal training and knowledge transfer requirements as part of the contract.

2.7. GLOBAL WORKFORCE

The global workforce is becoming increasingly mobile. This mobility, combined with the global nature of the nuclear power industry, creates a competitive environment for recruiting and retaining a competent workforce. The implication of this environment is that recently trained and qualified personnel may leave an organization to work in other countries. This mobility, however, may also present an opportunity for an organization to recruit experienced staff. These issues need to be addressed by an organization's recruitment, remuneration and retention policies. The global nature of the industry may ultimately lead to a diverse workforce, and the HRM strategy has to consider the need to ensure that policies and procedures are understood and consistently implemented by all staff.

Observations and lessons learned:

— The development of a glossary of terms may help ensure common communication and understanding among a potentially international workforce;
— A strategy needs to be in place to mitigate the potential loss of staff attending foreign training;
— Induction and orientation programmes need to consider the diversity of staff and the culture of internationally recruited staff.

3. HUMAN RESOURCE MANAGEMENT STRATEGY

While all of the elements discussed in Fig. 1 are components of the HRM strategy, it is recognized that the initial priority for a country embarking on a nuclear power programme is to identify, acquire and develop the necessary workforce for the first NPP project, while also developing the HR infrastructure to sustain this workforce. Therefore, this section will focus on the following four elements, and the actions required for each phase of the nuclear power programme:

— Workforce planning;
— Recruitment;
— Education, training and development;
— Remuneration and retention.

3.1. PHASE 1

The initial HRM strategy is developed at the national level, addressing the HR needs of all organizations involved in the nuclear power programme. It is to be in line with other national policies that will be developed for the programme, such as industrial involvement and contracting. It will also take into account any existing national policies related to worker qualifications, employment rules, etc. The national HRM strategy is normally the responsibility of the NEPIO and may draw on expertise from many national organizations related to education, training, and labour. The initial HRM strategy needs to consider options available for the organizations to use international experts and the need for external support.

The initial strategy may consider:

— Required enhancements to the national education and training infrastructure;
— The availability of skills such as legal, financing, HR, contracting and an assessment of the current capabilities;
— The need for recruiting experienced staff or consultants;
— The potential use of non-national support organizations;

— Plans for gaining international experience, both by secondment of national staff and recruitment of international expertise;
— Recruitment, remuneration and retention strategies to enable the above activities.

At the end of Phase 1, the HRM strategy will form an input to the comprehensive report that, if it were to recommend a positive national decision, defines and justifies a national strategy for nuclear power [1].

3.1.1. Workforce planning

The staffing and workforce requirements for countries embarking on a nuclear power programme for the first time will be influenced by the overall programme goals and objectives. The range of competences needed to license, oversee project implementation, regulate, commission, operate, maintain and eventually decommission an NPP are largely the same for any nuclear power programme. However, the planned scope and goals of the programme, the desired levels of technology transfer, longer term capability, and desired level of self-sufficiency, will all have a major impact on the extent to which these competences need to be developed nationally. The number of reactor units envisioned for the programme, as well as the contractual approach, will also have an impact on the staff and competencies required to support its development.

As stated above, a key objective in Phase 1 is to identify the approximate numbers and range of skills that will be needed to be able to assess whether the current educational infrastructure and vocational training programmes can meet these needs. The challenge for embarking countries is that they may have limited knowledge of these requirements. In order to assist Member States, Table 1 [8] provides an example of the typical number of staff in an owner/operator organization at different stages for an engineering, procurement and construction (EPC) contract based on two 1000 MW units. The numbers in the table include the staff for each work division and are further broken down by the professional and technical staff required for each phase of the project. Administrative staff are not included in these numbers. It is emphasized that these are indicative numbers only. Staffing approaches may vary greatly between plants resulting in total numbers that differ from this table and may reflect a very different balance between professional and technical staff.

The size of the regulatory body workforce depends on the nature of any existing regulatory body, the adopted regulatory approach, the level of specialist independent support available, and the number of NPPs planned. However, for Phase 1 planning purposes, a total staff of approximately 100–150 could be used for a fully functional regulatory body, comprising mostly science and engineering graduates.

TABLE 1. REPRESENTATIVE STAFFING BY WORK DIVISION FOR A TWO UNIT NPP[a]

Division	Project development Phase 2	Construction Phase 3	Commissioning	At operation
Engineering	20/0	60/20	60/20	60/10
Planning and project control	15/5	15/5	35/15	35/15
Material control and management	10/0	20/20	10/10	0
Construction control	10/0	15/15	10/10	
Commissioning		35/15	70/100	
Maintenance			30/70	30/200
Technical support	5/0	15/0	30/70	30/70
Management, HR, training and procurement	15/0	90/35	50/10	70/30
Nuclear safety and quality management	20/0	20/0	30/0	30/0

TABLE 1. REPRESENTATIVE STAFFING BY WORK DIVISION FOR A TWO UNIT NPP[a] (cont.)

Division	Project development Phase 2	Construction Phase 3	Commissioning	At operation
Security and physical protection	5/0	10/20	5/55	5/55
Operators	0	30/30	90/90	90/90
Total	100/5	310/160	420/450	350/470

[a] Numbers in the table indicate professional staff (left number) and technical staff (right number).

The majority of the staff for the regulatory body needs to be recruited in Phase 2 in order to define the regulatory framework and be ready to review licence applications related to siting and construction [4]. During construction, the regulatory body has the responsibility for inspections at manufacturers of safety related components, inspections at the construction site, and the review of any design changes. When the NPP becomes operational, the regulatory body has responsibility for oversight, including on-site inspections.

The owner/operator and regulatory body have the largest demand for specialized skills in a nuclear power programme. The HRM strategy also needs to address the potential demand for other skills in the workforce. If the EPC contract stipulates a requirement to source construction skills from the domestic workforce, the HRM strategy needs to ensure that these skills are available. Similarly, it needs to consider the respective roles of TSOs, contractors and supply chains.

Using the numbers cited above, or others derived in a similar way, the next steps for workforce planning in Phase 1 are the following:

— Survey the domestic workforce to determine the availability of competencies necessary for the programme. This survey needs to identify the numbers of existing workers with the necessary education, competencies (if any), and qualifications, and identify domestic industries that use these same, or similar, competencies. There is also a need to consider the availability of such resources, the international mobility of national resources, and any major projects that may compete for skilled and experienced resources over the lifetime of the project.
— Identify and review educational programmes (professional and technical) for each technical area needed for the organizations to ensure their suitability to meet current and future requirements.
— Identify domestic facilities that provide training and experience related to the needs of the programme to ensure their readiness and availability to deliver future training.
— Identify competency gaps that might present a risk to the programme. These may be areas specific to nuclear power or competencies that the nuclear power programme and other sectors both use, which results in a high demand relative to the anticipated national workforce for that specific competency area.
— Evaluate which organization(s) are most capable of taking on the potential owner/operator role.
— Consider how experienced, supervisory and management staff will be recruited and developed to support key organizations.
— Conduct a sensitivity analysis, as required, to consider potential changes in the programme scope or schedule, and the respective impacts on workforce planning.

Observations and lessons learned:

— Define the nuclear power programme objectives early (e.g. the scope of the programme, number of units, contracting alternatives, etc.) so that the workforce requirements are known.

— Several embarking countries are relying on a strategic partnership to reduce the overall burden and gain expertise from an experienced partner.
— Understand the impacts of the contractual approaches on the competencies that will be required for the owner/operator organization.
— Understand the potential impact of this project on the workforce of other planned or existing national infrastructure projects.
— The initial workforce plan needs to consider, at a high level, a timeframe consistent with the Milestones approach (10–15 years) through commissioning.
— The nature and scope of the national workforce plan will evolve through the three phases of the Milestones approach.
— Workforce plans need to be considered as living documents that need to be maintained and updated as necessary.

Several factors are discussed under Phase 2 that need to be taken into account by the owner/operator and regulatory body. However, in Phase 1 the NEPIO needs to be aware of the requirements for the full life cycle of the nuclear power programme and consider the implications for the national HRM strategy.

3.1.2. Recruitment

One of the first activities that will take place is allocating resources for the NEPIO, which is the organization responsible for producing the comprehensive report at the end of Phase 1. As stated in an IAEA publication on the Responsibilities and Functions of a Nuclear Energy Implementing Organization:

> "Many of the NEPIO's capabilities may come from staff within government agencies or other organizations. This could be achieved through secondment or through some other arrangement. As the nuclear power programme advances, NEPIO staff may also rotate into implementing organizations, taking with them personal networks and perspectives fostered in the NEPIO. Consultants and other experts should be used as necessary where domestic expertise is unavailable and impractical to develop for one-time use." [9]

The size and structure of the NEPIO may vary across Member States. However, it is important to ensure that the organization has sufficient resources to be able to address the 19 infrastructure issues that comprise the comprehensive report as well as to manage the overall programme of work.

In order to facilitate future recruitment, it is preferable to begin outreach during this phase of the programme to inform educators and students about the science and engineering needs and opportunities offered by the nuclear industry [3]. The recruitment aspect of the HRM strategy (which is closely tied to the education, training and development strategy) also needs to consider the possibility of recruiting expertise from other countries for skills that may be in short supply in the national workforce.

3.1.3. Education, training and development

It is important that the NEPIO understands and demonstrates the importance of nuclear safety, security and safeguards, and is fully aware of the need to develop an appropriate culture in each of the organizations that will be involved in the nuclear power programme. Training on these topics is available from the IAEA and other international organizations and vendors.

The NEPIO needs to identify potential solutions in case certain skills are not easily available in the national workforce. These solutions may include investment in workforce development opportunities and initiation or enhancement of educational infrastructure and programmes. These requirements are to be based upon the expected demand and timing for graduates and apprentices of various educational and vocational programmes.

Although nuclear power has some unique education and training requirements, some skills are similar to those for other safety significant industries, such as medicine, petrochemicals and aerospace. Hence an embarking country may already have a well developed education infrastructure and vocational training programmes in place, some of which will support the nuclear power programme. However, within any education system, STEM education represents the fundamental building blocks for such a programme. Without this, students will be ill-prepared for any subsequent engineering/technology education and training programmes. Hence, the first step in reviewing the suitability of the existing national education model is to check the content and quality of STEM education. In the event that changes be required to the national education model, in addition to developing specialist nuclear programmes, substantial investment may be required, and it may take a significant amount of time to implement (up to ten years). This may prove challenging in the context of the overall timescales for a new nuclear power programme and will require early decisions.

The NEPIO also has an important role to play in ensuring that the government understands the needs of the nuclear power industry in terms of any additional education and training infrastructure requirements. In this respect, Fig. 2 represents the relationship between the key entities in this process. The employers (owner/operator, regulatory body, other organizations) will recruit staff for the nuclear power programme from the national workforce. The universities and vocational schools provide the pools of resources from which the employers recruit staff. For this process to be effective, the resources developed need to match the needs of the key organizations, and therefore these organizations need to communicate their needs to the universities and colleges. However, in Phase 1, the NEPIO needs to identify these needs.

In turn, universities and colleges rely on the government for educational policy, and often funding, so effective communication between these three entities is essential. In addition, it is important that there is communication between the universities and vocational schools because although their roles are different, they are complementary, and it is important that the full range of educational and vocational requirements of the employers are considered. Potential conflicts between the kinds of resources the nuclear organizations need compared with other employers may also require government leadership to resolve these issues.

Bilateral international agreements may also need to be established to support the development of individuals, including education and training opportunities and secondments. The NEPIO may also consider seconding senior managers to nuclear organizations in other countries.

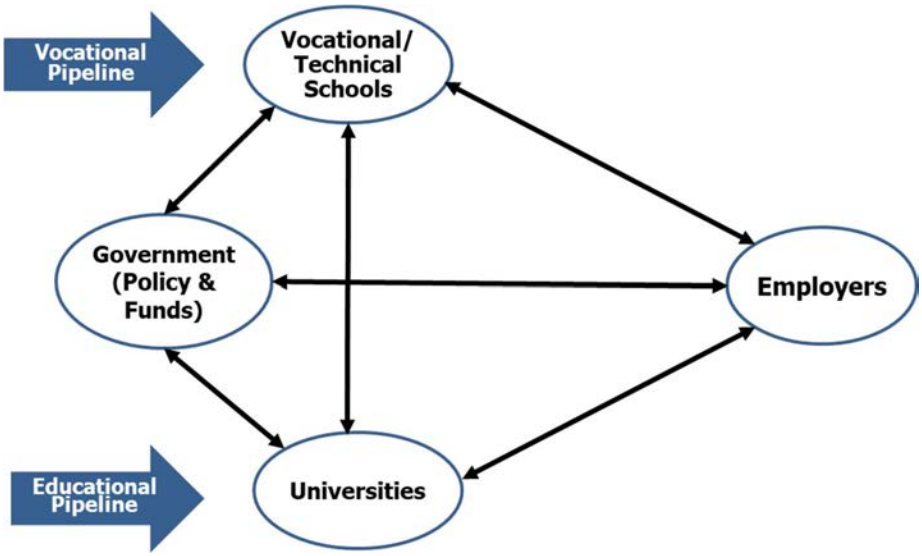

FIG. 2. Relationship between government, vocational schools, universities and employers.

3.1.4. Remuneration and retention

There are key issues related to remuneration (which includes pay and benefits) and retention that need to be addressed, even in Phase 1. These include assessing the adequacy of the existing remuneration structures to attract the staff with the requisite skills, including international experience, and to ensure comparable benefits between the key organizations.

It is also important to consider mechanisms for retaining staff following the completion of costly training programmes. These can include contracts that require a minimum number of years of service, with penalties for early resignations.

3.2. PHASE 2

The regulatory body and the owner/operator are established in this phase if they do not already exist. Therefore, each of these organizations will need to develop its own HRM strategy, including the respective workforce plans and associated priorities. While the national HRM strategy examined workforce needs at a high level, the HRM strategies for these organizations will include job specific requirements for education and experience, define training requirements, and establish strategies for recruiting and onboarding candidates. The HRM strategies of the different organizations need to be coordinated at a national level by the NEPIO.

3.2.1. Workforce planning

As the key organizations are established, each one needs to review the Phase 1 national workforce plan and develop its own workforce plan addressing the needs of Phase 2, Phase 3, commissioning and operation. As stated in Section 3.1, a nuclear power programme will require a wide variety of competencies, both nuclear and non-nuclear, at both the professional and technical levels. Therefore, it is important to understand the difference between education and vocational requirements for particular job positions. The focus of this analysis is to always be on what competencies are required to perform the work.

It is not advisable for the regulatory body or owner/operator to base their planned staffing levels for the first units on mature, stable organizations in countries with operating nuclear power plants. Experience has shown that mature programmes can take very different, although still effective, approaches that have developed over time and are typically unique to individual countries and circumstances. Baseline staffing requirements, therefore, need to be developed using international experience with an understanding of the specifics of the country's programme — for example, the availability of a national TSO, the number of units, and the division between headquarters and station staff. These data then need to be adapted to the specific situations of individual countries.

The regulatory body will need to have available much of its required competence in Phase 2 in order to be able to establish the licensing approach and issue the relevant regulations at the appropriate time. Early in Phase 3, it needs to have the competence to review a licence application and inspect the manufacture of components and the construction of the NPP during Phase 3. It may have agreements with other regulatory bodies or TSOs to provide specialized expertise to assist in the development of regulations and review of the licence application and safety assessment report for the first plant(s). Since the oversight and inspection of manufacturing and construction is a specialized and temporary task, it may also consider the use of external resources to support this need. These support arrangements will clearly have an impact on the staffing requirements of the regulatory body and need to be reflected in the workforce plan.

For the owner/operator, the priority in Phase 2 is to establish the competencies to identify the NPP requirements and review vendor proposals. Towards the end of Phase 2 and beginning with Phase 3, it needs to develop competencies to be able to oversee the EPC contract. These activities require project management skills in addition to technical competencies. The detailed planning for operations will

happen early in Phase 3, in collaboration with the chosen vendor. Appendix III provides detail on the competencies, education and training requirements for different work functions based on the experience of the United States of America (USA).

Some of the senior and specialist posts that the owner/operator will need in Phase 3 and beyond will require long periods of training and experience and will need to be filled in Phase 2 (see Section 3.2.2).

Baseline staffing requirements will be driven by a number of factors including: the scope of the programme; the NPP technology selected; the number of sites and reactors per site; the extent of shared resources and facilities between units; the regulatory framework selected; the approach to staffing centralization; and any outsourcing approaches applied.

Furthermore, there are a number of one time activities in Phases 2 and 3 for both the regulatory body and the owner/operator that require competencies that are either not available in the organization(s) or are not core to the operational phase. These activities would typically be outsourced to specialist organizations. However, due to the experience they gain, some of these personnel may be able to transition to longer term roles in the key organizations, depending on the competencies required.

Examples of significant one time activities include:

— Development of criteria for site evaluation (owner/operator and regulatory body);
— Development of regulations for siting, construction and licensing (regulatory body);
— Development and staffing of the project management organization (PMO) and overall programme development planning and execution (owner/operator);
— Reviewing and qualifying vendor provided materials, procedures and training content (owner/operator and regulatory body);
— Oversight of manufacturing and construction activities, including in-work and on-site inspection and testing (owner/operator and regulatory body);
— Development of potential contractual approaches (owner/operator);
— Applications for the siting, construction and operating licences (owner/operator);
— Review of licence applications, including review of the preliminary safety analysis report (PSAR) (regulatory body).

3.2.2. Recruitment

For the reasons described above, the majority of the regulatory body staff needs to be recruited in this phase. Depending on the national strategy, the regulatory body will either be an expansion of an existing radiation protection regulatory body or a specifically created new organization. The strategy adopted will influence the approach to recruiting staff.

Similarly, for the owner/operator, either a new project company, or a project team within an existing utility company or national atomic energy agency, will need to be established. This project team will have the lead role in preparing the specifications, or at least user requirements, for the NPP units that will be used as the basis for either a competitive bid or a negotiated procurement. Most countries embarking on a nuclear power programme have built or are building their first NPP on a turnkey contract basis, where the vendor has the lead responsibility for the design, manufacturing and construction of the entire NPP. While this approach reduces the national resources that will be necessary for the project phase, a competent national project management team will still be required, which will need to be staffed in Phase 2.

If the owner/operator is formed within an existing utility, it is likely that they will have some EPC management experience that can be transferred to the nuclear power programme. They will also have an existing recruitment and induction process. A new company will have a larger recruitment need as they will have to establish the company infrastructure including legal, finance, HR, etc.

While the main focus for the owner/operator in Phase 2 is the first NPP project, it is also important to establish a separate team to begin planning for staffing the organization for commissioning and operation. A key element of this is to consider the initial and continuing training requirements. It is recognized that the detailed organizational arrangements are unlikely to be agreed before a contract is signed, but it is

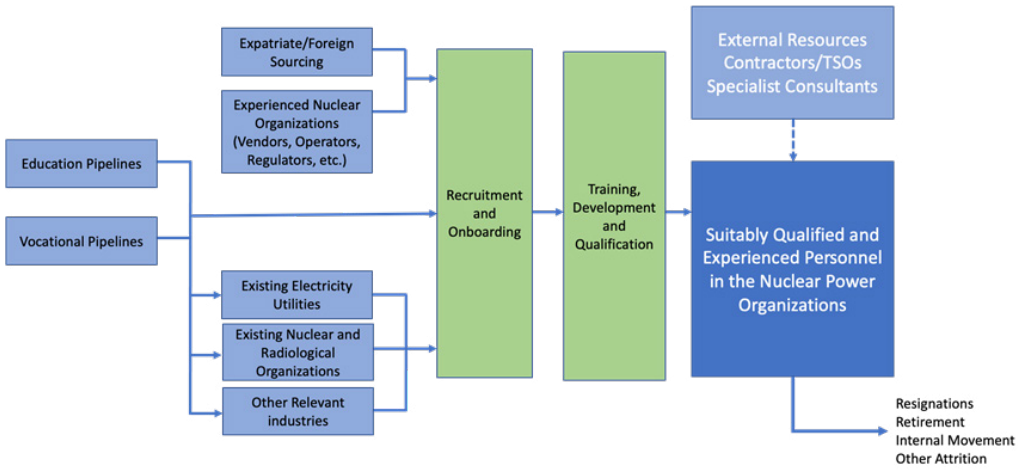

FIG. 3. Recruitment sourcing and staffing life cycle.

important to begin recruitment for the long lead time roles and begin their training sufficiently early to be ready to begin design specific training as soon as the contract is signed.

There are several potential sources for new staff for the key organizations, beginning with the educational and vocational pipelines, as shown in Fig. 3. These pipelines may feed directly into the recruiting processes for these organizations, or they may provide educated and/or trained individuals to other relevant sectors, such as electrical utilities, nuclear or radiological organizations or other large industries. As such, these sectors are to also be considered as valuable sources for recruiting staff.

For Phase 2 activities, it is likely that the country will need to supplement its national staff with foreign experts who have experience in the implementation of nuclear power programmes. This support could be sourced from experienced nuclear organizations, such as vendors, operators or regulatory bodies, or by the direct recruitment of expatriates with industry experience. It is essential that all individuals recruited complete onboarding as well as the specific training and qualification needed to perform their roles. Only after completing this process will individuals become suitably qualified and experienced personnel. In this phase, the organizations may also rely on external resources, such as TSOs or other experienced contractors, to perform specialist roles or supplement its staff, as necessary.

3.2.3. Education, training and development

In Phase 2, plans for any required enhancements to the existing national educational and vocational infrastructure and programmes need to be developed and implemented. These enhancements need to be based upon the expected demand and timing for graduates of various educational and vocational programmes.

As organizations are formed, they will establish their training functions and determine their training requirements, initially to meet the needs of Phase 2 and of early Phase 3. Planning for training needs to consider the time it takes to define the scope of required training, identify potential sources for training, establish and staff a training centre, train the training staff, and conduct training as workers are hired. Thus, planning the training programme needs to start early.

For the owner/operator, it is necessary to identify training needs for the first NPP that will require support from the vendor for inclusion in the bid specification or contract negotiation, which may include the establishment of a training centre within the country. It is important to ensure that those elements of the training system that are not included in that scope are understood and will be supplied through other means.

It is also important that the operator understands the regulatory requirements for the NPP, in particular the licensing/authorization process for staff, although this may not be finalized until early Phase 3.

Typical examples of support provided by the vendor include:

— Job specific training for key plant operations staff, preferably at the reference plant;
— Training personnel on special maintenance, inspection, and diagnostic techniques at the reference plant;
— Assistance in the specification and development of an NPP training facility, including the provision of a full scope control room simulator;
— 'Train the trainer' instruction for those individuals among the owner/operator staff who are expected to be the future national trainers;
— Transfer of technical and training materials to the owner/operator, including the transfer of intellectual property rights related to their use and distribution.

There will also be a need to provide the workforce with training regarding the reactor technologies being considered and the culture required for nuclear power, even for those staff who have nuclear related degrees.

All workers in the nuclear power programme will require introductory training and nuclear fundamentals as soon as they are hired, followed by job specific training. General education in nuclear fundamentals and training may be developed in this phase, regardless of technology selection, whereas more detailed, job specific, training will be dependent on technology and regulatory requirements, determined early in Phase 3. Some roles, such as operators, may require extensive training over several years using specialized facilities. The owner/operator staff will also require training in project management. Leadership programmes for both organizations are to be established in this phase.

The regulatory body will need significant training in Phase 2 to be able to issue regulations and be ready to review the construction licence early in Phase 3. Although they have specific competency requirements, it is appropriate to receive nuclear fundamentals training along with the owner/operator at this time. The regulator may also make use of foreign training opportunities to develop their regulatory competency requirements. Two IAEA reports provide detailed guidance on identifying and developing the necessary competencies for the regulatory body [10, 11].

Sponsoring students through national and international education programmes can be considered as a means for future recruitment. Plans for secondment of staff for training and development to relevant organizations in countries with nuclear power programmes may also be considered for this phase, especially for the future leaders, noting that there will be further technology specific opportunities in Phase 3.

3.2.4. Remuneration and retention

Retention of qualified and experienced staff continues to be a challenge for countries introducing nuclear power. Thus, at an organizational level, particular attention needs to be given to retention strategies, remuneration and other benefits for such personnel, as both the costs and the programmatic impacts of personnel losses could be high.

There is a need to ensure that the remuneration structures for each organization attract the competence needed, enable the recruitment of international experience where required, and ensure comparable benefits between key organizations, particularly the regulatory body and the owner/operator.

It is also important to implement mechanisms for retaining staff following the completion of costly training programmes. These can include contracts that require minimum years of service with penalties for early resignations but also need to include creating job and career opportunities that are attractive to newly trained staff.

Additionally, many NPPs are built in rural areas where the local infrastructure may be inadequate to accommodate the population and services needed to construct and operate the plant. Therefore, it is important to work with local authorities to establish services, access and socioeconomic infrastructure.

Shortages in these services will make it more difficult to recruit and retain the personnel needed to sustain the nuclear power programme. Thus, the HRM strategy needs to ensure that the planning and

development of the local infrastructure considers the needs of the future workforce to avoid difficulties in recruiting and retaining personnel.

3.3. PHASE 3

At the beginning of Phase 3, the owner/operator and regulatory body need to review their HRM strategies in light of the agreed reactor technology and the contracting approach. This will be particularly significant for the owner/operator as the terms specified in the EPC contract will influence the organizational structure, required resources, training strategy and approach to staff authorization/licensing. If a preferred vendor has been selected and is supporting the owner/operator in Phase 2, some of this work could be carried out earlier.

3.3.1. Workforce planning

Early in Phase 3, the owner/operator will need to further develop its workforce plan and the wider HRM strategy, based on the technology selected, the staffing model proposed by the vendor, and the knowledge gained during the negotiating process. Appendices I and II provide a more detailed breakdown of the process areas and work functions required for a typical NPP, based on the experience of the USA, and may assist in determining approximate staffing numbers for an operating plant. Depending on future plans for the programme, the number of units being constructed, and the type of vendor contract in place, the owner/operator will need to develop and implement an HRM strategy and associated workforce plan to form an organization competent to commission and operate the plant. The plan will need to reflect the following factors, which may have an impact on the timing of recruitment and the duration of training programmes:

— The time taken to train and certify personnel;
— The need to recruit staff early so that they can gain knowledge during construction and commissioning;
— The need to second people to other organizations to gain experience;
— The extent of training being provided by the vendor;
— The qualification of staff that requires a licence by the regulatory body.

The plan will also need to take account of the following issues which may have an impact on the total number of staff to be recruited:

— Plans to increase national involvement;
— The extent and duration of secondments from experienced owner/operators;
— Initial failure rates in training due to the required high skill levels;
— Loss of recruits to other relevant industries or other nuclear organizations;
— Additional staff to serve as mentors/advisers;
— Developing capabilities for future projects;
— Having sufficient staff in place to cover the release of other staff for training and development of competencies;
— Self-reliance in areas such as core calculations, safety analysis, etc.;
— Approaches for obtaining technical support.

All of this will require investment in personnel recruitment and training well before the NPP enters into operation and generates revenue.

Similarly, the regulatory body will need to have a plan to support its responsibilities as it shifts from licensing and overseeing construction to overseeing operation. The strategy for this will depend on the number and timing of future units and will include the required training programmes on operational safety.

3.3.2. Recruitment

The regulatory body needs to continue recruiting and training staff to be able to provide adequate oversight of construction, equipment manufacturing and, towards the latter part of Phase 3, commissioning of the plant [12]. The regulatory body needs to also ensure it has sufficient resources and support of TSOs and contractors to review the operating licence application.

In Phase 3, the owner/operator will need to recruit the additional staff identified in Phase 2 to oversee construction. It will also need to recruit the bulk of the operations staff on a timescale consistent with the construction project plan and accounting for the duration of the required training. The construction and commissioning of an NPP provides unique and important learning opportunities for future operating staff. Therefore, early recruitment and involvement of national staff in construction and commissioning are objectives of this phase to maximize learning. Recruitment will thus be a significant activity for the owner/operator in this phase. Where possible, including national staff in the vendor project team from the beginning of the project will support the transfer of relevant knowledge and competencies, and therefore it has to be considered by the recruitment plans of the organization.

The senior management for the operating organization will need to be recruited early in Phase 3 to undergo training and development and oversee the work in preparing for operation. The workload associated with these roles, particularly towards the end of Phase 3, means they cannot be staffed by individuals who are still fulfilling senior roles in the project management organization.

Recruitment plans for both organizations also need to consider the overlap of time needed for shadowing and mentoring to ensure that the experience of external experts is transferred to national staff prior to the departure of the external experts.

3.3.3. Education, training and development

By Phase 3, all required enhancements to the existing educational and vocational infrastructure need to be complete and the NEPIO needs to monitor these initiatives to ensure they are progressing satisfactorily to meet the evolving needs of the programme.

Training and other development activities in Phase 3 will have a dual focus. First, to develop competence in overseeing construction as required in both the owner/operator and regulatory body and second, to develop the competence required for the commissioning and operational phases. It is important to ensure that all technical staff of the owner/operator return to the site by the commissioning phase in order to gain experience and process the lessons learned during commissioning, as discussed previously.

Training for the regulatory body staff will continue during this phase to ensure that there is the necessary competence to regulate an operating NPP. Generally, a new regulatory body will establish an agreement with its counterpart in the vendor country which will assist in developing its competence. However, this will need to be agreed bilaterally between the countries as it will not form part of the vendor agreement.

Phase 3 also provides opportunities for all staff to learn from observing construction and working with experienced staff. For the regulatory body (and any future national TSO), review of the licence applications provides a unique opportunity to learn from experienced organizations supporting the process, such as an experienced regulator or TSO. Similarly, for the owner/operator working with the vendor and any owner's engineer organization will provide opportunities for learning that will not be available in the operational phase. Secondment of staff to other nuclear organizations can also be continued in this phase, but the timing of this needs to also take into account the benefits of being on-site for certain periods of construction and testing.

In addition to the regulatory body and the owner/operator, educational institutions and industrial standards organizations may also benefit from international cooperation with the vendor country organizations. Such partnerships may provide specialized training opportunities for national staff.

Establishing an adequate and effective training system to support the operation of the NPP is itself a major project. The owner/operator will need to work with the vendor to finalize and implement its training

plans specific to the job functions for the operational phase of the NPP. The training and qualification requirements need to be defined and developed, taking into account the NPP design, management system and vendor country experience and practices. Regulatory requirements regarding the qualification and licensing of certain staff will also have an impact on the overall training and qualification arrangements.

The training model used throughout the nuclear industry is the Systematic Approach to Training (SAT); detailed guidance on the application of SAT can be found in Ref. [13]. The owner/operator, as well as the regulatory body and relevant organizations, will need to ensure that all staff involved in developing and implementing the training model and programmes are competent in the use of SAT. The content of the initial and continuing training programmes will be determined using the analysis phase of the SAT model, which will also identify the appropriate training delivery environment (classroom, laboratory, workshop, etc.) and appropriate training tools, including mock-ups, models, and simulators.

A key element of a SAT based system is the provision of a full scope simulator which replicates the control room and accurately models the behaviour of the plant systems. The availability of a full scope replica control room simulator for training operators is typically a licensing requirement for NPPs. However, with advances in technology, PC-based or compact simulators are also being increasingly used to support a variety of training needs, e.g. classroom training on operating principles, systems engineering training and training for emergency management. Experience has demonstrated that the control room full scope simulator needs to be constructed, commissioned and operational at least 18 months prior to fuel loading in order to train and qualify control room operators and other relevant staff. It is to be noted that minimum shift staffing, and full emergency response capability will be required once fuel arrives on-site.

The provision of the main elements of the training system together with the design, construction and equipping of a training centre are typically included within the scope of the NPP vendor's services. The vendor will then be responsible for the delivery of the training system infrastructure, necessary documentation and full scope simulator, together with the provision of training to support the qualification of the NPP operational staff. The vendor can also be requested to train the operating organization's trainers. However, even in these circumstances, the owner/operator needs to have the competence to verify these requirements and commitments as part of the contract deliverables. This is necessary to ensure that the NPP vendor's personnel involved in the training area are knowledgeable and experienced in deploying and delivering a SAT based training model and have applied SAT in the development of the training deliverables [13].

The main blocks of training, and their indicative durations, required by all technical staff are illustrated in Fig. 4. All training programmes need to consider the time needed to authorize/qualify plant personnel for fuel loading and initial critical operation.

It is recommended that on the job training is provided at a reference plant for the staff assigned to operate or supervise the plant operation for the first time. The expectation for NPP staff is that they are formally qualified for their positions based upon their education, training and demonstration of required tasks (competence).

Authorization is a formal recognition by the owner/operator and/or the regulatory body (depending upon national regulations) that an individual is competent and authorized to perform his/her tasks. The contracted training of operations and maintenance teams by the vendor need to be implemented at the reference plant or plants of similar design to the plant under construction.

For construction and project personnel, in addition to their job specific training, it is important to train them on aspects such as foreign material exclusion, quality standards and requirements, and to reinforce the importance of these subjects to ensure long term plant safety and reliability.

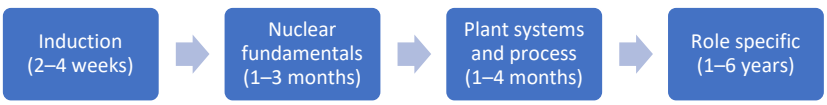

FIG. 4. Durations of typical training programmes.

In a two unit NPP, the typical core training personnel is between 40 and 60 persons. This may be influenced by the number of outsourced and contractor instructors, as well as the selected technology. Experience from operating units and recent new build projects indicates that the owner/operator will probably not have sufficient staff with the capabilities necessary to perform the full range of required training activities, i.e. full scope nuclear simulator instructors. Hence, consideration is to be given to options for increasing training resources and support during Phase 3.

In established nuclear power programmes it is also common practice for senior managers to be directly involved in delivering training, both to show their commitment to training and to give them the opportunity to establish standards and expectations in terms of behaviour and performance. For a country embarking on a new programme this may be more challenging as many managers themselves will still be training in Phase 3. However, to the extent possible, managers need to be actively involved in training.

Even in the case of vendor supply, significant resources will be needed to review the extensive amount of training documents, lesson plans, student texts, etc., all of which will have to be reviewed and accepted by the operator, often on tight timescales. In these circumstances, it is recommended that NPP instructors are recruited from the start of development of the training model to allow sufficient time to gain the necessary capability and experience, either through vendor training or other training/development exchange programmes with other operating countries.

3.3.4. Remuneration and retention

In Phase 3, mechanisms for ensuring appropriate remuneration and retention need to continue. Each organization needs to monitor staff recruitment and retention to ensure that the remuneration structures attract the competence required, enable the recruitment of international experience where required, and ensure comparable benefits between key organizations, particularly the regulatory body and the owner/operator.

It is also important to monitor the success of the different mechanisms put in place to retain staff.

The HRM strategy needs to also ensure that the improvements in the local infrastructure, planned in Phase 2, are implemented and achieve the objectives of recruiting and retaining personnel.

4. RISK MANAGEMENT

Two significant risks that are to be considered by the HRM strategy are programme delays and the potential lack of funding for developing a competent workforce. Experience has shown that embarking on a nuclear programme takes at least 10–15 years. This timeframe may increase depending on several factors, such as political or public support for the programme, the availability of financing, development of the legislative framework, or the time necessary to sign a contract. During this period, it is crucial to identify mechanisms to retain competent staff. Therefore, countries need to be realistic about the timeframe required, and plan the hiring and training of the workforce accordingly, as any delays may have a significant impact on HRM.

Potential impacts may include:

— Reductions in the necessary workforce;
— Departure of newly trained and qualified workers;
— Difficulties in recruiting qualified national staff from abroad due to uncertainties about the future of the programme.

As stated previously, a significant investment in recruitment and training is required well before the NPP generates any revenue, and any reduction or lack of government funding will also impact HRM by limiting the ability to:

— Upgrade education and training infrastructure;
— Recruit and develop new staff;
— Recruit and retain experienced staff from abroad.

If suitably qualified and experienced workers are not available, the nuclear power programme will be adversely impacted. Conversely, if the nuclear power programme experiences delays or significant changes in scope, a country may produce workers when the programme is not ready to hire or train them, creating retention challenges. Therefore, the HRM strategy needs to include standard programmatic risk practices such as a risk log to assess these and other risks, taking into account the risk analysis of the overall nuclear power programme. An example of some risk analysis is included in Appendix IV. Reference [14] provides further guidance on the overall approach to programme risk management.

5. CONSIDERATIONS FOR COMMISSIONING AND TRANSITION TO OPERATIONS

Plant testing, handover and commissioning often take two years or longer. The process begins with pre-operational tests for individual components and systems and goes through the completion of hot functional tests and turnover of responsibilities from the commissioning organization to the owner/operator. Once nuclear fuel is delivered to the site, all programmes, processes, and procedures subject to regulatory requirements need to be in place and approved. These will include having sufficient competent staff (licensed where necessary) to provide 24 hour operations shift cover and emergency response capability. While this does not require all the operational shift teams to be trained and licensed by this time, typically a minimum of three teams would be required to cover 24 hours working for 7 days a week.

The owner/operator needs to be sufficiently staffed and functional prior to the beginning of commissioning in order to take full advantage of the learning opportunity that it provides. The workforce plan needs to reflect this.

Commissioning activities will be coordinated amongst the commissioning team, the owner/operator, and the regulatory body. The commissioning team will typically be provided by the vendor, and the level of involvement from the owner/operator needs to be specified in the vendor contract. There is a need to establish a steering committee to oversee the commissioning process with representation from the vendor and owner/operator. This committee will be stood down after commissioning is complete.

The transition from construction into commissioning and subsequently operations has a significant HR impact in terms of both the potential movement of personnel into new or different roles (or out of the organization) as well as the cultural change that occurs when the owner/operator shifts from project oversight into operations. This needs to be appropriately reflected in HR planning and change management programmes and HR staff will need to support the senior leadership in managing the transition.

It is important to note that the continuing training programme will need to be in place from an early stage of commissioning due to the following factors:

— Initial training may be performed at the time when not all the NPP documentation is in place and just-in-time training may be needed to bridge the gaps;
— Plant modifications and design changes may occur during commissioning that have an impact on training;

— Commissioning needs be considered as a valuable learning experience and feedback has to be provided to all operations and commissioning staff;
— There may be delays in the commissioning of the plant that will require refresher training.

The regulatory body has a significant workload during the commissioning process to provide oversight, inspections and review of documents and the results of commissioning tests. Any additional demand for regulatory body involvement during commissioning may be met using TSOs and specialist contractors.

6. SUMMARY AND CONCLUSIONS

An effective national HRM strategy and its implementation through HR processes in each organization is critical to the success and sustainability of a nuclear power programme. Significant investment is required to ensure the availability of a competent workforce for each phase of the programme.

The initial HRM strategy developed in Phase 1 needs to look ahead 15 years or longer to the operation of the first plant. The commitment to an effective HRM strategy continues as the NPP moves towards operation, although the focus of this responsibility shifts from national to organizational, with the NEPIO maintaining an oversight role.

This publication has outlined the key characteristics of the workforce for a nuclear power programme, including development of a safety and security culture, the long lead times for recruitment, the investment required for education and training, the need to ensure retention of competent staff, and the need to build experience. It includes some current observations and lessons learned from Member States.

A Member State embarking on its first nuclear power programme will have to review the existing educational and vocational infrastructure, availability of relevant skills and other competing projects and organizations as part of a comprehensive report which will be used to inform a decision regarding the introduction of nuclear power.

The regulatory body needs to carry out most of its competency development in Phase 2, focusing first on developing relevant regulations and guides, including those necessary in the various steps of the licensing process, and those requirements that need to be known for siting and for the bidding/contracting process. By early in Phase 3, it would be at nearly full capacity for effectively regulating the NPP programme, focusing first on the issues related to the design, then manufacture and construction of the NPP, and then operation.

The owner/operator will need to develop initially as a project management organization, and, even with a turnkey approach, will need significant resources and competence to negotiate the required contracts and oversee construction. Early in Phase 3 it will need to start developing staff for the operational phase.

A country embarking on a nuclear power programme also needs to carefully consider how it will secure experienced staff for the programme. This is likely to include a mixture of the early secondment of national staff abroad to gain experience and the recruitment of staff who already have experience from organizations in other countries.

Plans for the long term sustainability of the programme will need to address any enhancements needed in the education system, the establishment of a national training capability and shadowing or mentoring programmes to develop national capabilities. A wide range of technical competencies (both nuclear and non-nuclear) are required to initiate a nuclear power programme. It is also important to recognize that leadership, general management and specific project management competencies will be needed to successfully implement such a programme.

Appendix I

EXAMPLE OF OWNER/OPERATOR STAFFING NUMBERS BY PROCESS AREA

This appendix provides approximate staffing levels from 67 operating North American and European nuclear power plants. They include different one and two unit nuclear reactor designs. Some of the plants achieved commercial operations in the 1960s, and some came on-line as late as the 1990s. Some of the plants are in a 'fleet', where one operating organization runs more than one nuclear site, while others are the only NPP operated by a particular utility or operating company (see Table 2).

The data do not reflect significantly different approaches to staffing levels that are driven by regulatory, cultural and operating organization preferences/requirements. This means that the approximate value shown may be significantly different from the minimum or maximum level at a particular NPP. The history of staffing approaches varies widely. Some NPPs had significantly lower staffing levels at startup that grew over time with operational experience and regulatory development. Other NPPs began commercial operations with very high staffing levels because they retained many of the architect/engineering/construction staff after startup and then slowly reduced staff over long periods of time. The data in Table 2 do not address many of the variables that affect staffing levels in other regions or for technologies other than those represented in this sample. Thus, the staffing data shown is only to be used as a general guide for new organizations contemplating deployment of a new NPP, and not for developing specific target staffing levels. The numbers shown represent the staffing numbers of mature nuclear operating organizations and are not to be considered as near term targets for first NPPs, which may be higher.

Significantly different NPP designs such as Gen IV NPPs and small modular reactors (SMRs) will likely have significantly different staffing requirements than those shown in the appendix. For the owner/operator, experience has shown that for countries embarking on nuclear power programmes, the workforce requirements for the first NPP will be driven by the following five key issues:

— *NPP technical design.* There are differing requirements between designs with more passive or modern safety systems. They will have different requirements for operations, maintenance, and engineering personnel.
— *NPP site layout and number of units*. The geographical arrangement and contents of the site, structures, buildings, and infrastructure will also have an impact on staffing requirements.
— *Regulatory requirements*. There are different regulatory models, requiring different levels of activity and reporting. These have impacts on many staffing functions.
— *Outsourcing*. The degree to which the NPP owner/operator uses external, or contractor support will have a direct impact on staffing. In some cases, it may also be possible to share outsourced functions with other NPPs or non-nuclear generating facilities, which typically also realizes staffing efficiencies through economies of scale.
— *Centralization.* The NPP owner/operator may share, or centralize, some activities with other NPP sites, or with other electrical power generation or corporate head office functions. As they do so, staffing requirements are typically lower for the NPPs owner/operator. Examples include IT support, human resources and financial management, and supply chain functions such as procurement and contracting. Other examples include non-nuclear generating organizations, which share some maintenance and engineering functions with NPPs operated by the same parent organization.

TABLE 2. MEDIAN STAFFING LEVELS FOR DIFFERENT NUCLEAR WORK FUNCTIONS IN PROCESS AREAS FOR NUCLEAR POWER OPERATING ORGANIZATIONS

Nuclear work function	Nuclear plant staffing	
	One unit median	Two unit median
Admin/clerical	25	42
As low as reasonably achievable	4	4
Budget/accounting	7	9
Chemistry	17	26
Communications	2	2
Computer engineering	3	4
Contracts	1	3
Decontamination/radioactive waste (radwaste)	11	12
Design	5	7
Document control/records	11	12
Emergency preparedness	5	5
Environmental	3	3
Facilities	21	27
Fire protection	1	2
Health physics/radiation protection applied	17	28
Health physics/radiation protection support	8	10
Human resources	4	4
Information management	13	14
Licensing	7	9
Maintenance/construction	119	186
Maintenance/construction support	22	39
Management	30	35
Management support	2	2
Materials management	3	4
Modification engineering	22	33
Nuclear fuels	4	7
Nuclear safety review	6	6
Operations	74	122
Operations support	20	20
Outage management	5	7
Plant engineering	33	47
Procurement engineering	5	6
Project management	7	11
Purchasing	4	7
Quality assurance	8	11
Quality control/non-destructive examination	7	7

TABLE 2. MEDIAN STAFFING LEVELS FOR DIFFERENT NUCLEAR WORK FUNCTIONS IN PROCESS AREAS FOR NUCLEAR POWER OPERATING ORGANIZATIONS (cont.)

Nuclear work function	Nuclear plant staffing	
	One unit median	Two unit median
Reactor engineering	4	5
Safety/health	2	3
Scheduling	11	15
Security	119	128
Technical engineering	19	31
Training	32	43
Warehouse	9	14
Total	732	1012

Appendix II

WORK FUNCTION DEFINITIONS

This appendix provides a brief definition of each of the 43 work functions, or areas/groups, for the 67 NPP units from North America and Europe that were the basis for the data in Appendix I. This information is provided to help the reader understand these data or to compare a given situation or plan with these functions. It is not intended to endorse this particular identification of workforce functions, as there is considerable variability among organizations around the world based upon such factors as technology, national norms and culture, labour rules and laws, and industry practices.

The work functions included in each of the process areas shown in Appendix I are identified below:

— *Configuration control:*
  - Design;
  - Engineering: Modifications;
  - Engineering: Procurement;
  - Engineering: Reactor;
  - Nuclear fuels.

— *Equipment reliability:*
  - Engineering: Computer;
  - Engineering: Plant;
  - Engineering: Technical;
  - Quality control/NDE.

— *Loss prevention:*
  - Emergency planning;
  - Fire protection;
  - Licensing;
  - Nuclear safety review;
  - Quality assurance;
  - Safety/health;
  - Security.

— *Materials and services:*
  - Contracts;
  - Materials management;
  - Purchasing;
  - Warehouse.

— *Plant operation:*
  - Chemistry;
  - Environmental;
  - Operations;
  - Operations support.

— *Support services:*
  - Administration/clerical;
  - Budget/finance;
  - Communications;
  - Document control;
  - Facilities;
  - Human resources;
  - Information management;

- Management;
- Management assistance.

— *Training.*

— *Work management:*
  - As low as reasonably achievable (ALARA);
  - Decontamination/radwaste processing;
  - HP applied;
  - HP support;
  - Maintenance/construction;
  - Maintenance/construction support;
  - Outage management;
  - Project management;
  - Scheduling.

II.1. ADMINISTRATION/CLERICAL

This group includes all secretaries, clerks and clerical pools. It also includes administrative assistants who provide administrative support in a function but who themselves are not functional professionals. Also included are staff performing administrative support functions such as conference coordination, graphics work and non-technical analysis of data. Supervisors of clerical pools are included in the function, as are telephone receptionists. This group also includes persons maintaining site-wide procedures.

II.2. ALARA/RADIOLOGICAL ENGINEERING

Persons planning and controlling the ALARA programme are part of this group. Their duties include carrying out and evaluating radiation dose and shielding calculations, as well as reviewing complex radiation work permits.

II.3. BUDGETING/FINANCE

This group is responsible for operation of budget and accounting systems under nuclear group control. It disseminates accounting and budget information and organizes budget input. It also: oversees preparation of budgets; provides ongoing accountability reports to managers; prepares nuclear group business plans; and interfaces with joint owners.

II.4. CHEMISTRY

Included in this group are chemistry technicians for normal and emergency shift functions such as chemical additions and chemical/radiochemical analyses. It also includes persons: coordinating all aspects of the chemistry programme; providing guidance on chemistry standards; conducting evaluations of plant chemistry programmes; and addressing and resolving chemistry operating problems. Also included are personnel responsible for the radioactive effluents programme.

II.5. COMMUNICATIONS

Media representatives, internal communications and tour guide staff are included in this function. Also included are those persons serving as community contacts, answering local questions, organizing publicity projects and operating or providing tours at plant visitor/information centres.

II.6. COMPUTER ENGINEERING

Staff in this group are responsible for hardware and software engineering associated with plant process computers, radiation monitoring systems and other operational and support computers and systems. The group includes personnel who provided similar services for the training simulators.

II.7. CONTRACTS

This group coordinates the placing of bids and awarding and monitoring of performance on contracts for labour and services. Staff control contract changes and associated claims, coordinate administration and enforcement of contract terms and conditions such as bonus/penalty clauses and cost-plus provisions.

II.8. DECONTAMINATION/RADWASTE PROCESSING

All persons carrying out decontamination and cleanup inside the power block are included in this group, as well as those responsible for dry radwaste systems, and for the packaging and transport of contaminated materials.

II.9. DESIGN

Staff members in this group perform manual and computer aided design and engineering functions. They also resolve field questions and maintain piping, instrument and electrical power line diagrams. Other responsibilities include preparing stress isometrics and performing simple calculations.

II.10. DOCUMENT CONTROL/RECORDS

This group receives, prepares, archives and indexes nuclear records and drawings, and controls and distributes station documents. It also coordinates other aspects of document processing, records management, and central files and libraries. Clerical personnel performing records duties are included in this category.

II.11. EMERGENCY PLANNING

This area's responsibility is to develop, implement and maintain the emergency preparedness programme. Group members train and qualify emergency exercise participants. The group is also responsible for emergency preparedness facilities, including the emergency operations facility (EOF) and tactical support centre (TSC). The group is also the focal point for local, state and federal legislation on emergency preparedness issues.

II.12. ENVIRONMENTAL

This area includes persons responsible for the non-radiological environmental monitoring programme and related requirements such as environmental licences and permits, audits and thermal monitoring.

II.13. FACILITIES

Persons directing and performing routine preventive maintenance, corrective maintenance and predictive maintenance activities on non-power block buildings, systems and components other than substations are members of this group. It also includes persons responsible for general yard work, telephone systems and vehicle maintenance.

II.14. FIRE PROTECTION

This group administers the fire protection programme, including surveillance. It is also responsible for fire protection programme inspections, and includes personnel who serve on full time fire brigades.

II.15. HEALTH PHYSICS APPLIED

This group comprises radiation protection technicians are involved with activities such as routine and special surveys, and data reading and analysis. It also includes persons collecting and analysing radiation system samples.

II.16. HEALTH PHYSICS SUPPORT

These people are responsible for technical oversight of the health physics programme. The group includes persons involved with respiratory protection, radiological environmental and dosimetry programmes, including clerical staff maintaining dosimetry records.

II.17. HUMAN RESOURCES

This group is responsible for the implementation and operation of HR and personnel programmes and systems such as appraisal, benefits, compensation, vacancy selection and promotion. It coordinates employment and equal employment opportunity activities, as well as managing development training. The group typically includes the central point of contact for union relations.

II.18. INFORMATION MANAGEMENT

The people in this area are responsible for software and hardware support for business and management applications and database management for nuclear group systems. The group provides software related system design, revision and user information services. It also provides operations and system administration resources for hosts and servers, as well as system hardware design, revision and user information services. Finally, it responds to technical and information requests from internal and external sources.

II.19. LICENSING/REGULATORY AFFAIRS

Staff in this area serve as the primary contact for licensing and other regulatory issues with the national regulatory body (regulatory body). They coordinate and review responses to routine and special information requests from the regulatory body, including licensee event reports (LERs), notices of violation and generic letters. They also coordinate the annual Final Safety Analysis Report update process.

II.20. MAINTENANCE/CONSTRUCTION

Personnel in this area carry out maintenance and construction work within the power block. This includes routine preventive, corrective and predictive maintenance of plant components. The installation of minor and major modifications and metrology work is also in this area. Persons who directly supervise these activities are also included in the function, which includes mechanical, instrumentation and control (I&C) and electrical maintenance staff and their supervisors.

II.21. MAINTENANCE/CONSTRUCTION SUPPORT

Staff in this area are involved in job package development and assembling, completing and reviewing documentation associated with the maintenance effort. They include: non-engineering degreed maintenance technical experts; non-engineering degreed staff developing maintenance strategies and resolving maintenance rule issues; personnel coordinating with plant engineers on the development of corrective maintenance procedures and other technical matters; and full time maintenance procedure writers. Also part of this group are personnel who support plant modification work such as coordination of contractor labour, and cost and schedule estimating. Tool room attendants are included in this group, though it does not include schedulers, designers or plant engineers.

II.22. MANAGEMENT

This area includes all management personnel above first line supervisors in each organization up to and including the company's chief nuclear officer.

II.23. MANAGEMENT ASSISTANCE

This group comprises personnel assigned to multifunctional special projects supporting managers. It includes persons supporting organizational or plant wide projects.

II.24. MATERIALS MANAGEMENT

Included in this area are individuals responsible for inventory control, disposal of surplus materials, and management and operation of inventory reorder point programmes. Their responsibilities include assigning stock numbers, consolidating stores inventories and maintaining ordering information.

II.25. MODIFICATION ENGINEERING

This function includes modification engineering services and ensures design integrity for:

— Civil/structural engineering, including site buildings, roads, bridges and waterfront structures. Personnel perform soil and foundation analyses and reviews, and approve hanger and support locations. In addition, they carry out stress analysis and support evaluation services, as well as architectural and site layout services.
— Electrical/I&C engineering, including high, medium and low voltage distribution systems (including DC and instrument power), related components (including motors, circuit breakers, transformers, batteries, chargers and inverters) and I&C systems and components.
— Mechanical engineering, including primary, secondary and auxiliary systems, and associated components, including piping, insulation and hangers.

II.26. NUCLEAR FUELS

In this area, staff perform and/or review reload safety evaluations, reload design analyses, and thermal, hydraulic and transient analyses. They provide support to operations for core analysis, support fuel licensing and fuel management activities and managing and monitoring the nuclear fuel acquisition process.

II.27. NUCLEAR SAFETY

This area is responsible for off-site and on-site safety activities. Staff review operating abnormalities and advise management on the overall quality and safety of operations. They also review operational and regulatory related documents such as LERs, and changes to licence and technical specifications. Other responsibilities include: reviews of plant and industry event reports for applicability and lessons learned; coordination of contacts with the Institute of Nuclear Power Operations (INPO) and with activities involving the Independent Safety Engineering Group (ISEG); coordination with dedicated corrective action programme personnel; and human performance programme activities and the employee concerns programme.

II.28. OPERATIONS

This includes on-shift staff, supervisors and shift managers responsible for operating primary, secondary and liquid radwaste systems. If performed by shift staff, this area includes preparing or reviewing responses to operating events and associated inquiries from other organizations.

II.29. OPERATIONS SUPPORT

The personnel working in this area include non-shift personnel supporting the operations staff, plus dedicated procedure writers, scheduling coordinators, technical specialists and training coordinators. Also included are persons in licensed operator training classes.

II.30. OUTAGE MANAGEMENT

This area includes persons planning and coordinating all outage activities. It is the central contact point for refuelling and maintenance outage planning and management, and forced outage management. It also includes dedicated outage work window managers.

II.31. PLANT ENGINEERING

In this area staff evaluate system and component performance, as well as monitoring system operating performance parameters (system health). They provide engineering assistance in the development of corrective maintenance actions; develop and review procedures and technical reports/responses; and review surveillance, modifications and system related studies generated internally and externally. They are also responsible for coordination and review of post-maintenance and post-modification testing and surveillance testing programmes, and for conducting and reviewing the local leak rate test (LLRT) and integrated leak rate test (ILRT) programmes. This area serves as the site point of contact for technical and procedural system and component testing issues, and includes component and field engineers.

II.32. PROCUREMENT ENGINEERING

Personnel in this area are responsible for materials qualification processes, including parts substitution. They identify and resolve supplier non-conformance, manage and carry out commercial parts dedication testing, and support 'like-for-like' replacement analyses.

II.33. PROJECT MANAGEMENT

In this area staff direct, control and monitor contractor and in-house design packages and other work in support of engineering functions. They review products to ensure high quality work and participate in developing bid packages. Other tasks include: establishing and monitoring milestone schedules for assigned work; assisting in reviewing contractor proposals; recommending contract awards; and coordinating the resolution of technical questions directed to or originated by contractors.

II.34. PURCHASING

The purchasing function includes buyers, expediters and other procurement personnel responsible for obtaining contracted materials and services by evaluating and processing purchase requisitions and proposals. Personnel in this area are responsible for managing the return of damaged goods and for liaison with the primary vendors.

II.35. QUALITY ASSURANCE

The quality assurance (QA) function ensures implementation of the approved QA programme through periodic audits and surveillances. Staff follow up in areas of concern identified by the audits; analyse the status and adequacy of operational QA programmes and establish QA policy for management's approval. They also develop and maintain required QA procedures and manuals. This area includes persons who operate the vendor audit programme, and who support and review organizational self-assessments.

II.36. QUALITY CONTROL/NON-DESTRUCTIVE EXAMINATION

Staff in this area implement the inspection hold-point programme and conduct associated inspections of ongoing activities. They review work activities to ensure compliance with QA programme requirements, and conduct receipt inspections for QA programme materials. This area includes personnel who perform NDEs, including radiography/sonography of welds and fittings.

II.37. REACTOR ENGINEERING

Personnel in this area analyse fuel performance, conduct core performance monitoring and trending, and provide support and technical direction to operations during refuelling, startup and shutdown.

II.38. SAFETY/HEALTH

This area is the focal point for the US Department of Labor's Occupational Safety and Health Administration (OSHA) requirements and contacts. Staff manage and maintain the industrial safety programme. They are also responsible for medical examinations and emergency medical assistance.

II.39. SCHEDULING

In this work area, persons schedule non-refuelling outage work for operations, maintenance and surveillance activities. It also includes work week managers as well as staff who coordinate with maintenance, construction management and engineering for daily schedule review and update. In addition, there are staff members who prepare system outages and forced outage schedules.

II.40. SECURITY

The security area provides physical site security. A staffing estimate is not included here due to significant variations in regulatory and legal approaches in Member States. Responsible for the development of security plans and procedures, the staff address technical issues pertaining to security regulations and requirements. Staff members are also responsible for site access control and fitness for duty programmes.

II.41. TECHNICAL ENGINEERING

Staff in this work area research and analyse technical engineering issues but do not perform modification design package development. They also provide support to modification engineers and plant/system engineers, monitor dispositions, non-conformances and other issues, and respond to design basis and configuration control issues and questions. They serve as technical consultants on engineering issues, and respond to technical inquiries and information requests from internal and external sources. Finally, they are responsible for engineering services and key programmes in specialized technical areas not included in other engineering functions, such as equipment qualification, configuration management, in-service inspection, fire protection engineering and probabilistic risk assessment, as well as ensuring design integrity for specialized areas.

II.42. TRAINING

The training area conducts and/or coordinates all formal training for nuclear staff including all accredited programmes. Personnel coordinate training schedules and produce training reports. They conduct instructor training and development, as well as instructional system design and implementation, and operate plant simulators.

II.43. WAREHOUSE

Personnel directly associated with physical inventories, including those performing materials inspection, tracking and maintenance belong to this work area. They may deliver materials from the warehouse or other storage locations to staging points in support of maintenance/construction or modification activities.

Appendix III

EXAMPLE OF QUALIFICATION AND TRAINING REQUIREMENTS BY WORK FUNCTION

Table 3 is intended to clarify the information provided in Appendices I and II regarding staffing levels and functions or work areas. This information is based on the education, experience and training requirements/practices in the USA. Note that there is considerable variability in these requirements/practices in other countries that currently have operating NPPs. For example, in the USA there is no requirement for NPP control room operators to have a bachelor's degree in science or engineering, whereas there is such a requirement in other countries with operating NPPs. The table also shows the reliance upon national standards/norms (such as the American National Standards Institute's ANSI 3.1).

TABLE 3. QUALIFICATION AND TRAINING REQUIREMENTS BY WORK FUNCTION/AREA

Nuclear work function/area	Competencies/experience requirements	Educational requirements	Training requirements	Lead time required
Administrative/ clerical	Basic computer software competence (word processing, presentations, etc.).	Secondary/high school diploma or equivalent.	NPP general employee training (GET).	n/a[a]
ALARA/radiological engineering	Basic computer competence; experience at commercial nuclear power plants; health physics experience.	Bachelor's degree in sciences, health physics or related discipline.	NPP GET.	Five years.
Budget/finance	Basic computer competence; financial and analytical capabilities.	Bachelor's degree in business, finance, accounting, or related field.	Government and/or NPP owner requirements for account reporting systems	n/a
Chemistry	Three years of work experience in the chemistry field.	Secondary/high school diploma or equivalent, university level chemistry and mathematics.	Certification such as ANSI 3.1 1978 Chemistry, NPP plant specific systems training.	Three months (plus three years of work experience).
Communications	Excellent written and verbal communication skills; knowledge of local language and grammar, human relations, internet technology and industry trends.	Bachelor's degree in journalism, public relations or related field.	NPP GET.	n/a
Computer engineering	Basic computer competence; NPP experience; technical understanding of nuclear plant process computer and full scope simulator.	Bachelor's degree in engineering or a related technical field	Plant technical training	Two years.
Contracts	Basic computer competence; knowledge of contracting concepts; good communications competence; financial analysis skills; negotiation skills.	Bachelor's degree.	Government and/or NPP owner requirements for contracting and contracts reporting systems.	One year.
Decontamination/radwaste processing	Two years of radwaste process experience.	Secondary/high school diploma or equivalent.	Radwaste worker course, waste treatment and radwaste operator's course.	One month (plus two years of work experience).

TABLE 3. QUALIFICATION AND TRAINING REQUIREMENTS BY WORK FUNCTION/AREA (cont.)

Nuclear work function/area	Competencies/experience requirements	Educational requirements	Training requirements	Lead time required
Design/drafting	Basic computer competence; experience with reading and interpreting schematic drawings.	Secondary/high school diploma or equivalent; some requirements for bachelor's degree in a technical field.	Plant technical training; computer aided design (CAD) systems training.	One year.
Document control/records	Basic computer competence; understanding of document control and records management.	Secondary/high school diploma or equivalent.	Government and/or NPP owner requirements document control/ records management systems	Three months.
Emergency planning	Experience in operations and/or radiation protection, and emergency planning.	Bachelor's degree or professional certification.	NPP GET; operations certification required in some cases.	Five years.
Environmental	Experience in environmental science, sample collection, and reporting requirements.	Bachelor's degree or professional certification.	Government and/or NPP owner requirements for environmental safety and reporting requirements.	Six months.
Facilities	Physical fitness; basic mechanical competence.	n/a	NPP GET.	n/a
Fire protection	Knowledge of fire protection engineering principles, including fire hazard analysis, fire protection technology, fire system design, codes and regulations.	Bachelor's degree in engineering technology or a similar discipline.	NPP GET.	One year.
Health physics applied	Physical fitness requirements; understanding of physical sciences.	Secondary/high school diploma or equivalent.	Radiation worker training.	One month.
Health physics support	Understanding of physical sciences.	Secondary/high school diploma or equivalent.	Radiation worker training.	One month.
Human resources	Basic computer competence; experience with retirement plans and health and welfare benefits; familiarity with national labour laws.	Bachelor's degree in human resources, business, mathematics, or finance.	NPP GET.	n/a

TABLE 3. QUALIFICATION AND TRAINING REQUIREMENTS BY WORK FUNCTION/AREA (cont.)

Nuclear work function/area	Competencies/experience requirements	Educational requirements	Training requirements	Lead time required
Information management	Advanced computer competence; experience with computer hardware and software systems, including database administration, cyber security, and network administration.	Bachelor's degree in computer science, information management, or related field.	NPP GET.	Three months.
Licensing/regulatory affairs	Two plus years of experience in the nuclear industry; basic computer competence; nuclear engineering.	Bachelor's degree in a technical field.	NPP GET.	Six months.
Maintenance/construction	Physical fitness; basic mechanical competence; good communication skills.	Secondary/high school diploma or equivalent.	Apprentice, journeyman, master level discipline skill level training required (mechanical, electrical, instrumentation and control); certification training for non-discipline craft such as crane and rigging operators, forklift operators, scaffolding and insulation, etc.	Varies (for discipline craft): some national governments require a three year apprentice training programme prior to initial work at the nuclear plant; others allow on the job training provided by the plant owner with initial training times as short as six weeks prior to the training.
Maintenance/construction support	Planner: Experience in NPP operations and basic computer competence. Other support roles: Experience in basic plant operations and industrial safety.	Secondary/high school diploma or equivalent.	On the job training within a specific area, i.e. scaffolding assembly and disassembly, insulation removal and replacement, work package plan development, etc.	Planner: Five years. Other support roles: one–three months.

TABLE 3. QUALIFICATION AND TRAINING REQUIREMENTS BY WORK FUNCTION/AREA (cont.)

Nuclear work function/area	Competencies/experience requirements	Educational requirements	Training requirements	Lead time required
Management	Understanding of design and operation of power plant systems.	Bachelor's degree normally required.	Supervisory, management and/or leadership training, typically provided by the NPP owner.	Years, when considering hiring a new employee and developing that employee to fill a position of responsibility at least one level above first line supervisor.
Management support	Varies according to the role defined by the NPP owner; may include basic computer competence, good communications skills, project management experience, etc.	Secondary/high school diploma or equivalent; some positions require a bachelor's degree.	NPP GET; some will require operations training or engineering technical training.	Varies, but typically less than one year.
Materials management	Experience with inventory management approaches and systems.	Secondary/high school diploma or equivalent.	NPP owner provided training for the NPP's/owner's supply chain inventory management systems.	1 month.
Modifications engineering	Understanding of design and operation of power plant systems and knowledge of applicable codes, standards and environmental regulations; experience with project management often required.	Bachelor's degree in mechanical, electrical, or civil engineering.	Plant technical training, professional engineer licence often required.	Three–five years.
Nuclear fuels	Engineering economics or other formal financial experience; nuclear fuel cycle and financial analysis experience.	Bachelor's degree in engineering, business administration, or a related field.	Plant technical training.	Five years.
Nuclear safety review	Experience with root cause analyses, human performance evaluations, collection and analysis of industry operating event reports.	Secondary/high school diploma or equivalent; some positions require a bachelor's degree.	Plant technical training.	Five years.

TABLE 3. QUALIFICATION AND TRAINING REQUIREMENTS BY WORK FUNCTION/AREA (cont.)

Nuclear work function/area	Competencies/experience requirements	Educational requirements	Training requirements	Lead time required
Operations	Basic mechanical and computer competencies.	Generally requires a secondary/high school diploma or equivalent; some governments and/or NPP owners require a bachelor's degree.	Plant equipment and NPP control room operations training, typically provided by either a government agency or the NPP owner.	Two–five years, depending on job position.
Operations support	Basic mechanical and computer competencies; NPP experience.	Bachelor's degree engineering or other technical discipline; or two year college/ technical degree with additional direct job experience; or secondary/high school diploma or equivalent with several more years of additional direct job experience in NPP operations.	Initial operator training, or reactor operator training, or senior reactor operator trains.	Six–ten years, depending on educational background.
Outage management	Basic computer competence; NPP experience; technical understanding of nuclear generation principles and operations.	Bachelor's degree in engineering or other technical discipline.	NPP owner provided training in plant scheduling systems.	Five years.
Plant engineering	Basic computer competence; NPP experience; technical understanding of nuclear generation principles and operations.	Bachelor's degree in engineering or a related technical field.	Plant technical training.	Two years.
Procurement engineering	Basic computer competence; NPP experience; technical understanding of nuclear plant equipment and design.	Bachelor's degree in engineering or a related technical field.	Plant technical training.	Two years.
Project management	Basic computer competence; project management competence; good communications and negotiation competencies; data analysis competence.	Bachelor's degree in a technical or management related field.	Basic project management training course.	Three years.

TABLE 3. QUALIFICATION AND TRAINING REQUIREMENTS BY WORK FUNCTION/AREA (cont.)

Nuclear work function/area	Competencies/experience requirements	Educational requirements	Training requirements	Lead time required
Purchasing	Basic computer competence; knowledge of category and supply management concepts; good communication skills; data analysis and negotiation competencies.	Bachelor's degree in engineering, business administration, or a related field.	Government and/or NPP owner requirements for procurement and procurement reporting systems.	Three–five years.
Quality assurance	Experience in NPP design, operations, maintenance, or other nuclear related activities; experience in QA programmes and concepts; senior reactor operator licence or certification preferred for operations area; design or system engineering experience preferred for engineering area; maintenance or work control experience preferred for the maintenance area.	Bachelor's degree in a technical field.	Government and/or NPP owner requirements for QA reporting systems.	Six years.
Quality control/NDE	Physical fitness; basic computer competence; general knowledge of QC and NDE inspection techniques.	Secondary/high school diploma or equivalent.	ANSI qualification training programme: combination of classroom training and field work.	Varies by level of certification: up to eight years for a Level IV certified inspector.
Reactor engineering	Basic understanding of physical sciences; advanced computer competence; understanding of nuclear and reactor physics.	Bachelor's degree in engineering.	Nuclear plant reactor-specific training (PWR, BWR, CANDU, AGR, VVER, etc.).	Two years.
Safety/health	Ability to interpret, implement and communicate occupational health codes and standards; demonstrated skills in the application of personal protective equipment, industrial hygiene monitoring and sampling, risk assessment and mitigation of workplace safety, health and environmental issues.	Bachelor's degree in environmental science, engineering, industrial hygiene, public health or other physical science.	Industrial safety training programme; first aid/first responder training.	Six months.

TABLE 3. QUALIFICATION AND TRAINING REQUIREMENTS BY WORK FUNCTION/AREA (cont.)

Nuclear work function/area	Competencies/experience requirements	Educational requirements	Training requirements	Lead time required
Scheduling	General power plant experience in maintenance, operations or engineering including plant system knowledge; good communications competence.	Bachelor's degree in a technical field.	NPP owner provided training in plant scheduling systems.	Eight years of NPP experience in maintenance, operations, or engineering.
Security	Physical fitness and/or agility; psychological testing/fitness, if required.	Secondary/high school diploma or equivalent.	Basic plant operation principles; firearms training may be required.	Three–six months.
Technical engineering	Basic computer competence; NPP experience; technical understanding of nuclear generation principles and operations.	Bachelor's degree in engineering or a related technical field.	Plant technical training.	Two years.
Training	Detailed knowledge of plant procedures and regulations in assigned area; detailed knowledge of plant systems and processes; working knowledge of computer software programmes supporting assigned area.	Secondary/high school diploma or equivalent; senior reactor operator certification for operations training; Master's level competency in required discipline (mechanical, electrical, or instrumentation and controls) for maintenance training; Bachelor's degree in an engineering field for engineering/ technical training.	Instructional training.	Five years, due to on the job experience requirements.
Warehouse	Physical fitness; heavy lifting safety.	Secondary/high school diploma or equivalent.	Industrial safety training; forklift operations.	One month.

[a]n/a: not applicable.

Appendix IV

RISK MANAGEMENT

Each organization will have its own risk management process with defined procedures. The HRM risks need to be incorporated into the overall project framework. Some will be monitored at company level; others will be monitored within the HR function. An IAEA publication describes an approach to risk management and includes some examples [14]. This appendix is intended to illustrate an approach to managing some of the HR risks. As such, it only includes enough information to illustrate the principles of risk management and uses a simplified approach to that proposed in Ref. [14].

Tables 4 and 5 outline steps 1 and 2 of a risk management strategy.

TABLE 4. STEP 1: EXAMPLE OF IDENTIFYING AND CHARACTERIZING THE RISK

Category/description	Project consequences (1–5)	Likelihood (1–3)	Ranking	Owner
1. Staff leave: Staff sent abroad in Phase 2, to gain experience, return from secondment when the programme has not progressed sufficiently. As a result, they leave the project for another national project or leave the country.	2 (depending on the exact role they are intended to fulfil).	2	Low (4/15)	HR Manager: Only shown in HR risk log.
2. Insufficient staff with experience: Unable to attract experienced staff from abroad.	4 (likely to result in major programme delays or inability to obtain operating licence).	2	Medium (8/15)	HR Manager: Also shown in project risk log.
3. Staff do not return: Staff do not return from training but get a job in another country.	2 (depending on the exact role they are intended to fulfil).	1	Low (2/15)	HR Manager.
4. Cannot recruit suitable staff: Unable to attract suitable graduates into the industry.	4 (if the programme strategy is to staff mainly with national staff).	2 (will depend on the perception of nuclear power in the country)	Medium (8/15)	HR Manager: Also shown in the project risk log.

TABLE 5. STEP 2: EXAMPLE OF IDENTIFYING TECHNIQUES AND STRATEGIES TO REDUCE OR MANAGE THE SPECIFIC RISK

Risk description	Risk reduction	Risk management
1. Staff leave.	1. Keep staff informed of project progress. 2. Seek to extend their secondment. 3. Arrange additional experience on other national major projects or in the power industry. 4. Give them a suitable role to drive the project forward. 5. Include a requirement to return to work on the project for a minimum time.	1. Send more staff than are required. 2. Have an ongoing programme of sending staff abroad. 3. Put the secondment programme on hold. until the project direction is clearer.
2. Insufficient staff with experience.	1. Develop agreements with countries/organizations to provide experienced support.	1. Extend the programme timescales to allow national staff to gain experience.
3. Staff do not return.	—	—
4. Cannot recruit suitable staff.	—	—

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Milestones in the Development of a National Infrastructure for Nuclear Power, IAEA Nuclear Energy Series No. NG-G-3.1 (Rev. 1), IAEA, Vienna (2015).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Managing Human Resources in the Field of Nuclear Energy, IAEA Nuclear Energy Series No. NG-G-2.1, IAEA, Vienna (2009).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Stakeholder Involvement Throughout the Life Cycle of Nuclear Facilities, IAEA Nuclear Energy Series No. NG-T-1.4, IAEA, Vienna (2011).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Organization, Management and Staffing of the Regulatory Body for Safety, IAEA Safety Standards Series No. GSG-12, IAEA, Vienna (2018).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Nuclear Infrastructure Competency Framework, (2017), https://nucleus.iaea.org/competency-framework

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Assessing Behavioural Competencies of Employees in Nuclear Facilities, IAEA-TECDOC-1917, IAEA, Vienna (2020).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Knowledge Loss Risk Management in Nuclear Organizations, IAEA Nuclear Energy Series No. NG-T-6.11, IAEA, Vienna (2017).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Initiating Nuclear Power Programmes: Responsibilities and Capabilities of Owners and Operators, Nuclear Energy Series NG-T-3.1 (Rev. 1), IAEA, Vienna (2020).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Responsibilities and Functions of a Nuclear Energy Programme Implementing Organization, IAEA Nuclear Energy Series No. NG-T-3.6 (Rev. 1), IAEA, Vienna (2019).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Managing Regulatory Body Competence, Safety Reports Series No. 79, IAEA, Vienna (2014).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Methodology for the Systematic Assessment of the Regulatory Competence Needs (SARCoN) for Regulatory Bodies of Nuclear Installations, IAEA-TECDOC-1757, IAEA, Vienna (2015).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Establishing the Safety Infrastructure for a Nuclear Power Programme, IAEA Safety Standards Series No. SSG-16, IAEA, Vienna (2012).

[13] INTERNATIONAL ATOMIC ENERGY AGENCY, Systematic Approach to Training for Nuclear Facility Personnel: Processes, Methodology and Practices, IAEA Nuclear Energy Series No. NG-T-2.8, IAEA, Vienna (2020).

[14] INTERNATIONAL ATOMIC ENERGY AGENCY, Risk Management: A Tool for Improving Nuclear Power Plant Performance, IAEA-TECDOC-1209, IAEA, Vienna (2001).

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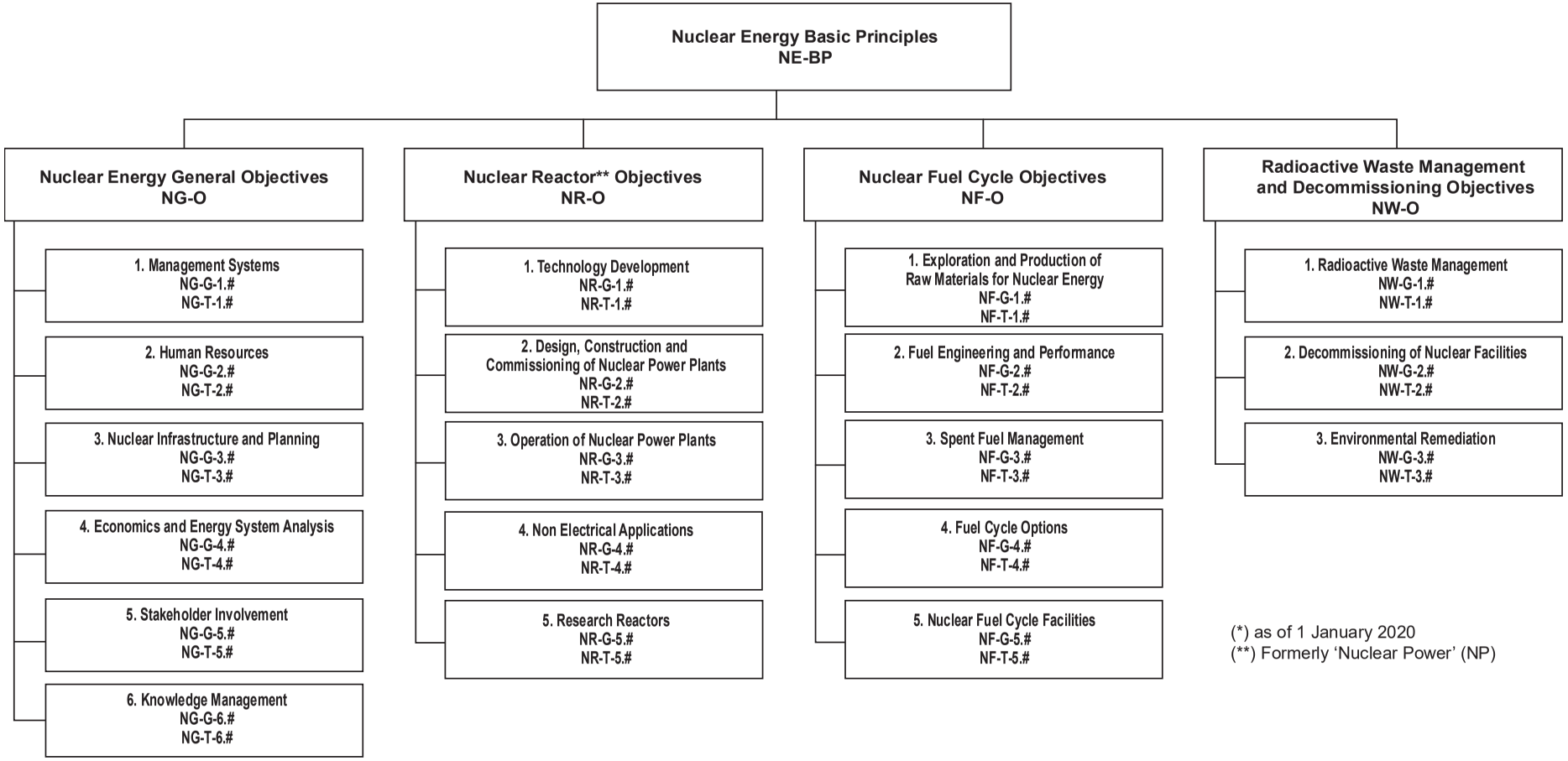

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