Staffing Investigation, New Nuclear in Norway

(Bemanningsutredning Norsk Kärnkraft SU.60368.00993)

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Report that describes staffing, recruitment and training to assess the potential for nuclear power plant in Norway.

Kärnkraftsäkerhet och Utbildning AB answers Halden Kjernekraft AS

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1. EXECUTIVE SUMMARY

The report describes an operating organisation, a high-level plan for requitement and training based on own experience and studies from documents. The documents are mainly from International Atomic Energy Agency IAEA and Word Association of Nuclear Operators WANO together with own experience from many years working in the Nuclear Business.

The report is based on historical data that has been analysed to create a prediction of competence building of new nuclear plants.

The roles that are required for the operating organisation is based on experience data.

SMR design organisations are pursuing new approaches, trying to take advantage of certain benefits of the innovative technology associated with design simplification, improved operability and automation. This gives the opportunity to optimize staffing regardless of any chosen SMR design.

In chapter 3.6 the report summarises the operational organisation for the Full-Time Equivalent FTE for 1-4 SMR units build at the same site.

1 Unit - 222	2 Units - 283	3 Units - 344	4 Units - 404

These numbers do not include contractors or security guards, the number of which will depend on a number of site-specific, technological and regulatory factors.

The current situation is that the SMR plants are still under development, this means that the training methods, training programs and the training environments is not optimised in the same way as staffing.

The duration for training is approx. 18 months for the longest program for control room operators and other programs varies between 6-12 months.

Our assessment regarding competence supply chain is based on a continued engagement with schools and education providers.

To develop a new nuclear power program in Norway requires that adequate knowledge and competences are in place along with the necessary regulatory and operative organisations.

2. INTRODUCTION

There is a growing interest in the development and deployment of small and medium sized reactors (SMRs), which can be seen through the numerous concepts that are under design certification according to the IAEA Advanced Reactors Information System (ARIS).

Norsk Kjernekraft has formed the company Halden Kjernekraft AS along with the regional energy company Østfold Energi and Halden kommune. The purpose of Halden Kjernekraft is to assess the potential for new nuclear power plant in Halden, find a site and plan for implementation.

Kärnkraftsäkerhet och Utbildning AB (KSU) have offered in letter No: 363777 dated 2024-01-22 a report to answer Halden Kjernekraft AS, according a plan for personnel, recruitment and training.

This report assumes that the new nuclear power plant is a light water-cooled Small Modular Reactor SMR in the size of 300-400 MWe.

A high level of competency is needed for safe and efficient use of nuclear energy. It applies to all phases of the nuclear power and fuel life cycle and to both the development and sustained use of nuclear technology. Operating organisations and countries that are experiencing a change in the industry, with prospects for new nuclear power plants or plans to phase out existing programmes, need to realign their organisational competencies to meet future demands. For newcomers to nuclear power, organisational competencies need to be built according to the demands of nuclear technology.

Mapping organisational competencies is a process that enables an organisation to identify its needs, develop an action plan and achieve its objectives. Mapping can identify missing resources and assess the risk of competency and knowledge loss.

SMR design organisations are pursuing new approaches, trying to take advantage of certain benefits of the innovative technology associated with design simplification and improved operability.

More than 45 innovative concepts and designs of SMRs for electricity generation and process heat production, desalination, hydrogen generation and other applications are under development in more than fifteen countries. Even though SMR designs and concepts are numerous and ambitious, their deployment is not necessarily an easy task, as there are many challenges; one such challenge is their economic competitiveness.

Most SMR designs share a common set of design objectives which, in part, aim to enhance plant safety and overall robustness while improving economic performance in order to remain competitive with other sources of power generation. For example, these new designs aim, where possible, to eliminate vulnerabilities, incorporate lessons learned from almost 60 years of reactor operations, significantly reduce the likelihood of an accident, greatly increase the time during which operators can act to cope with an unlikely event, and mitigate the consequences in the event of an accident

IAEA have the following definition on SMR:
Small modular reactors (SMRs) are advanced nuclear reactors that have a power capacity of up to 300 MW(e) per unit, which is about one-third of the generating capacity of traditional nuclear power reactors.
SMRs, which can produce a large amount of low-carbon electricity, are:

Small – physically a fraction of the size of a conventional nuclear power reactor.

Modular – making it possible for systems and components to be factory-assembled and transported as a unit to a location for installation.

Reactors – harnessing nuclear fission to generate heat to produce energy.

Several SMR concepts are based on multi-module designs which would allow a utility to perform maintenance and refuelling on one module while other modules continue to operate and produce power.

The capacity factor of a power plant is defined as the ratio of its actual output over a period of time to its potential output if it were possible for it to operate at full nameplate capacity continuously over the same period of time. Therefore, the ability to have several modules continuing operation during outage periods should ensure increased overall capacity factors, assuming the outage time for each SMR module is reduced with respect to large reactor units.

Increased capacity factors lead to a reduced levelized cost of electricity, and the ability to perform rotational outages will improve the use of staff resources and skill retention. Another key advantage of the multi-module design is that additional modules can be added to a power plant as the demand for more electricity increases at only marginal additional cost (i.e. the cost of more modules). This ability to add incremental generating capacity while at the same time producing power and collecting revenue improves long term financing costs by reducing the cost of debt.

3. THE PERSONNEL REQUIRED FOR THE NPP

The method used to schedule and planning personnel for new Nuclear Power Plants is based on current operational organisation and optimized according to staffing key factors.

IAEA has in [1] outlined the development of 19 national infrastructure elements, referred to in documentation as issues. Each of these infrastructure issues are essential to the support of a new nuclear program and its associated nuclear plant projects.

The 19 issues are depicted as follows:

IAEA Infrastructure Issues

Norsk Kjernekraft has produced a report that reviews the status of these 19 topics in Norway.

Link to report: https://usercontent.one/wp/www.norskkjernekraft.com/wp-content/uploads/2023/10/Fra-ord-til-handling Innledendemulighetsstudie.pdf?fbclid=IwAR11rxF7usZK1T63E4U0XniFI3lqocUrcoJS75ACXQT-63I66mnP35F5_rk

These 19 infrastructure issues are described in three phases,

Phase 1: Considerations before a decision to launch a nuclear power program,
Phase 2: Preparatory work for the contracting and construction of a nuclear power plant after a policy decision has been taken, and
Phase 3: Activities to implement the first nuclear power plant.

Staffing needs of the three different actors - Government, Regulator and Owner - will vary over the time of the nuclear power programme, both in terms of competence and number. Government and Regulator needs are more frontloaded since the Government have to initiate the implementation of a Regulator, which must be staffed and competent to create a regulatory framework and handle licensing applications.

This report refers only to the staff in the Owners operational organisation in Phase 3 and focuses on the infrastructure issues “human resource development”.

The workforce changes from a project organization to an operating organisation during the three phases. The owner staffing, the operational organisation increases and will require a large workforce. Unlike traditional numbers on workforce, this report can show that workforce can be optimized and lower than those of a traditional plant due to staffing key factors and a larger degree of standardisation and services provided by the vendor.

To remain a competitive source of energy, nuclear power must be produced as efficiently as possible while maintaining high safety standards. Because a large portion of the expense of nuclear power is related to staff size, efficient production means optimizing the staffing levels at nuclear plants.

The specific number of staff needed to achieve this goal of safe and efficient operations depends upon many factors including plant design, size, and material condition, regulatory requirements, work processes used, organisational structure, and management decisions. However, comparing staffing to levels at other power plants can provide management with information needed to optimize staffing.

If staffing is greater than at other plants, it may indicate that efficiency gains are possible that could reduce costs. If staffing is below that of other plants, it may indicate that efficiency is very good and further gains will be difficult. Lower staffing may also indicate the need for continued management oversight to ensure work is being properly performed.

The impact of losing critical knowledge was recognized by many nuclear energy organisations in the late 1990s and early 2000s when a significant number of first-generation nuclear professionals left the industry or retired, and consequently the industry lost significant years of knowledge and experience. This issue became more significant as there was stagnation in the growth of the nuclear energy industry coupled with declining interest in pursuing nuclear education. This prompted some of the nuclear energy organisations to start focusing on people-centric knowledge management programmes with activities aimed at mitigating the risk of critical knowledge loss.

3.1 Historical and present experienced based staffing

This part of the report focusses on historical and present experienced based staffing and the subsequent parts (chapter 3.3-3.6) focus more on new nuclear power plants.

The required number of staff for every organisation will be different. Benchmarks across the industry vary. A single unit will typically have a higher per unit head count than a site with multiple units. Units with small generational output (800 MW) will have higher head count per megawatt than a unit with large megawatt output (1800 MW). Different technologies require some unique technical capability and capacities (e.g., heavy water handling and processing at CANDU facilities).

The organisational staffing model is based on a small operating nuclear corporation with one site hosting two reactor units. The model describes an organisation as it might exist near the end of its first cycle of operation.

To begin with, IAEA provides in reference [4] from 2022 median staffing levels from 67 operating North American and western European nuclear power plants. They include several 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 organisation runs more than one nuclear site, while others are the only NPP operated by a particular utility or operating company.

The data does not reflect significantly different approaches to staffing levels that are driven by regulatory, cultural and operating organisation preferences/requirements. This means that the median value shown may be significantly different from the minimum or maximum level at a particular NPP.

The history of staffing approaches varies across a significant spectrum. Some NPPs had significantly lower staffing levels at start-up that grew over time with operational experience and regulatory development. Other NPPs began commercial operations with very high levels because they retained many of the architect/engineering/construction staff after start-up and then slowly reduced staff over long periods of time.

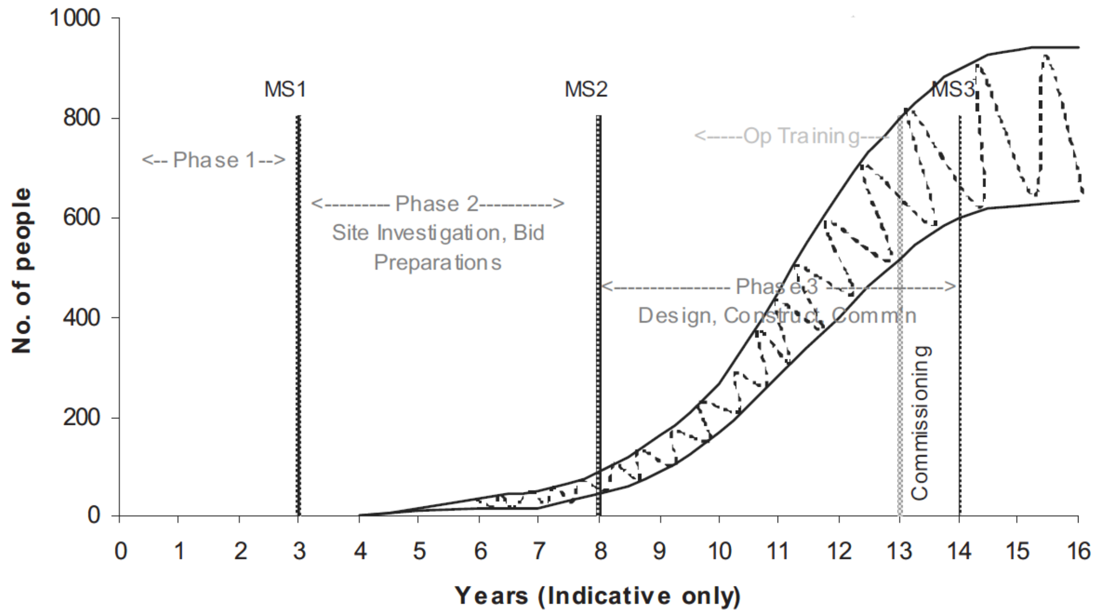


FIG. 7. Buildup of plant staff prior to commissioning.

The number of people (historical and present experienced based staffing) that is needed in such a organisations is 732 persons (median value) for a one unit plant and 1012 persons (median value) for two unit plant.

Thus, the staffing data shown should only be used as a general guide for new organisations 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 organisations and should not be considered as near-term targets for first NPPs, which may be higher.

This amount is with contractors and partners such as security guards, clercs, maintenance workers, radiological protection, and the whole training organisation is included. This report has assumed by experience, that approximately 15% to 35% is hired as contractors and partners.

There are two key aspects [4] 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 organisations. 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 organisation's workforce plans;
- Consideration has to be given to establishing formal training and knowledge transfer requirements as part of the contract.

When searching websites for the Nordic Nuclear Power plants the current figures that presented abowe, is reasonable and comparable even for the Nordic companies.

NPP	Operating Units	Employed	Comments
OKG AB, Oskarshamn Sweden	1	572	The number include the operating organisation for Unit O3 and the staff for two units under decommissioning. https://www.okg.se
RAB AB, Ringhals Sweden	2	1050	The number include the operating organisation for Units R3, R4 and the staff for two units under decommissioning. https://karnkraft.vattenfall.se/ringhals
FKA AB, Forsmark Sweden	3	1150	The number include the operating organisation for Units F1, F2, F3 https://karnkraft.vattenfall.se/forsmark

TVO Teollisuuden Voima Oyj, Finland	3	1029	The number include the operating organisation for Units TVO1, TVO2, TVO3 https://www.tvo.fi/en
Loviisa, Finland	2	600	The number include the operating organisation for Units 1, 2 https://www.Fortum.com/energy-production/nuclear-power/plants/loviisa

Nordic Nuclear Power Plants

The figures in the table above are based on figures from the companies websites and gives an aproximate figure how many emploees the Nordic companies have. However it shows that the figures are comparable and relevant with the IAEA data even that the data is over 25 years old.

To get an broader perspective his can be compared with the Spanish NPP GAROÑA and TRILLO [18]

Plant	Design	Own staff	Contractors
Garoña NPP	BWR-3, 460 MW(e) supplied by General Electric in operation since 1971	380	182
Trillo NPP	PWR, 1066 MW(e) supplied by Siemens-KWU in operation since 1988	383	175

Examples on two Spanish Nuclear Power Plants

Example from Russia; VVER-640 is the first Russian Unit of evolutionary class with completely passive safety under design status. It’s a PWR with 645 MW(e) supplied by Gidropress. The main staffing is 529 persons and 92 contractors.

Another example on historical staffing is Wesinghouse AP 600 reactor compared with Conventional Operating 2-Loop Plants in USA [18]. The AP600 is a model of relatively small, 600 MWe NPP with passive safety features characteristic of the Generation III reactor concept. None AP-600 has been build.

AP600 Plant

	Conventional Operating 2-Loop Plants in USA				
	Plant 1	Plant 2	Plant 3	Plant 4	AP-600
Units	1	1	2	2	1
Capacity (MW(e))	535	517	1,048	1,186	600-650
Staff *(1)	359	204	479	567	282(2)
Staff/MW(e)	0.67	0.39	0.46	0.48	0.31

(1) Reference: 1997 DOE FERC Form 1.

(2) Staffing analysis compared to current reference, including standard work processes for station operations, configuration control, equipment reliability, materials & services, work control, waste services, training, security, and administrative services. Analysis result of 32% reduction relative to reference plants used with existing plant date to calculate value.

To summarise historical and present experienced based staffing

	1 unit	2 units	3 units
Employees	380-732	600-1050	1029-1150

The list is approximately figures on employees summarised

The amount of personnel needed might vary due to service agreements, with contractors or Service Providers, and there is no transparency if those persons are included or not in the basic data.

3.2 When and who sets the operating organisation

Building new nuclear power plants includes construction of the reactor, but also building the organisation needed to operate it. This includes setting up a management system, but also working towards a healthy nuclear safety culture.

A Nuclear Power Plant (NPP) is operated by people, and thus the achievement of safety requires qualified managerial and operating personnel working professionally, to the highest standards, within an appropriate integrated management system. Commitment to nuclear safety is required by all elements of the government, regulatory, vendor and operating organisations, and it is important that these organisations establish the appropriate safety culture and standards from the outset of the programme.

The body of scheduling and planning personnel are sometimes collectively referred to as a Project Management Office, or PMO.

Organisational discipline is born of three things: leadership effectiveness, personal accountability, and organisational teamwork. Several things must occur to achieve a high level of organisational discipline. First, executives must formally endorse and constantly reinforce the schedule and supporting PMO activities as the organisation’s path to success. Second, the leadership team must be aligned to full engagement with the PMO during schedule development, and accountable to and supportive of day-to-day execution of scheduled tasks. Employees and contractors must complete the assigned daily tasks. Finally, the organisation must demonstrate teamwork.

The organisation is growing and change over the project time. The figure below [22] shows a standardised sequence:

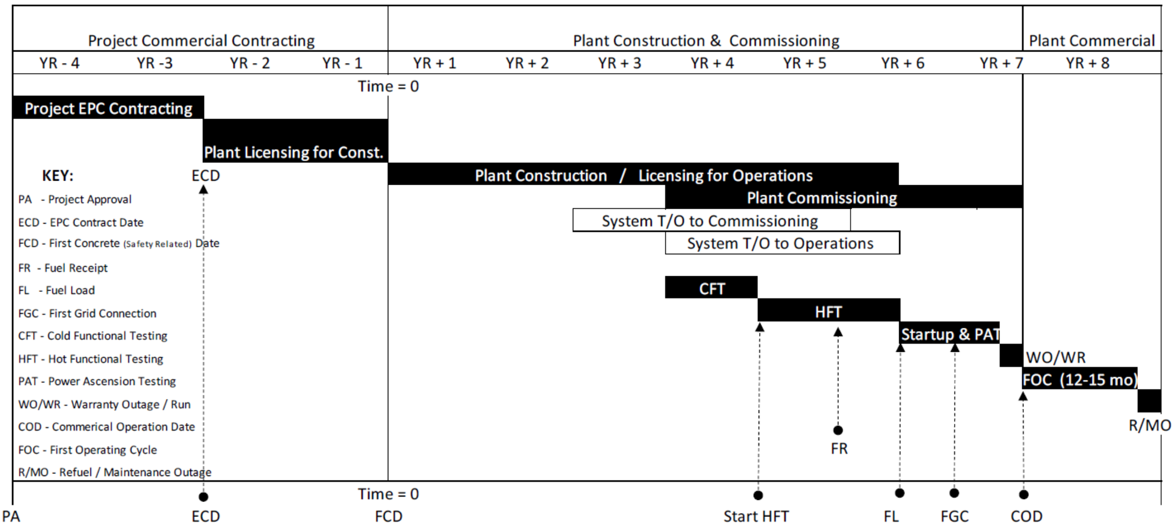


Figure D.2 Standardised Sequence of Project Activities to Plant Operation

Source: New Unit Assistance Industry Working Group

The operating organisation should be ready when fuel is loaded and final preparations for plant operation are being executed. The reality is that the operating organisation will look different at various points in the project and the basics is at three points in time, namely:

A. During the period of ECD to FCD
B. The period prior to the start of HFT
C. Prior to Fuel Load FL

Obviously, there will be a need to transition the organisation at Point A to Point B, and then again to Point C.

To create the organisation and the recruitment of the staff is mainly done in the period during the construction First Concrete safety related Date (FCD) and the cold functional test (CFT). The start is depending on the availability of educated trainers, training premises, training material and the full-scope simulator for the control room operators.

In FCD T=0, the operation organisation will approximately be staffed to around 30% of the final organisation (se chapter 3.6) and includes:

- Key leaders for all disciplines
- Key hires defined and process owners for each core process
- Program owner for each defined program
- Operations training staff in support of license training
- Initial class of operations license trainees
- On boarding training and personnel in processing protocols established

The milestone to start the hot functional testing (HFT) is:

- The staffing of operations main control room and plant operator staff personnel to targeted levels

- The training and qualification of the requisite number of personnel for each organisational function
- The documentation and retention of all relevant personnel training and qualification records

The milestone to start the fuel load (FL) is:

- The assignment of an adequately experienced leadership team
- The staffing of personnel to defined organisational target levels for each functional area
- The training and qualification of the requisite number of personnel for each organisational function
- The documentation and proper retention of all personnel training and qualification records

There are benefits to the operating organisation being ready early and the main reasons for this can be mean:

- Greater operational participation in testing and commissioning activities. Plant knowledge and experience gained by plant operating personnel engaged throughout these activities will be significant and result in safer, more efficient operations later.
- Earlier transition to plant processes, programs, and use of operating procedures. Organisational process, program and procedural proficiency will grow as documents are used, assessed, and upgraded and personnel become more comfortable with their use.
- Earlier focus on changing plant personnel and contractor behaviours. Behaviour change is hard. Establishing desired behaviours early will improve safety and accelerate organisational efficiency gains.
- The use of operating organisation personnel as contingency in the event of contractual and commercial challenges.

Workforce planning is an essential [4], ongoing human resources management process. Each organisation involved in the nuclear energy programme should develop and maintain its own workforce plan.

During Phase 1, the nuclear energy programme implementing organisation NEPIO will be responsible for most of the activities being undertaken. The number of staff involved will be relatively small and individuals may be drawn from various government departments, with much of the actual specialist work being done by external experts/expert groups.

At the beginning of Phase 2, the NEPIO will still be driving the programme, but the other key responsible organisations, including the regulatory body and the owner/operating organisation, should be fully established and taking an increasingly active role. The core project team for the construction of the plant should be in place, as even at this early stage there will be a wide variety of activities to be managed, and early recruitment of those operations staff with long training lead times should be under way.

By the beginning of Phase 3, although the NEPIO may still have an oversight/coordination role, especially if the first NPP is part of a bigger programme, primary responsibility for management of NPP construction and commissioning should be with the operating organisation. The regulatory body will be actively engaged in the licensing of the site and plant design as well as overseeing manufacturing and construction, as appropriate.
The operating organisation will be actively recruiting and managing the training of its permanent plant staff.

The organisation should be flexible and able to meet changing demands. During commissioning and the first years of operation the work load at the site may be high due to the many activities taking place; for example, establishing procedures, establishing work processes, completing inaugural inspections, and the training of staff.

This roadmap is based on historical data and will be challenged and optimized with the new nuclear power plants.

3.3 Caution before building a future organisation

To remain a competitive source of energy, nuclear power must be produced as efficiently as possible while maintaining high safety standards. Because a large portion of the expense of nuclear power is related to staff size, efficient production means optimizing the staffing levels at nuclear plants.

The specific number of staff needed to achieve this goal of safe and efficient operations depends upon many factors including plant design, size, and material condition, regulatory requirements, work processes used, organisational structure, and management decisions.

The word capacity, is referred to the amount or number of staff. In other words, do we have enough people? The answer to this is straight forward in some cases e.g., do we have enough licensed operators to fill the targeted number of positions within the intended number of operating crews. Other “enough” questions are more challenging, a newcomer nation with little to no operating experience will need to staff greater numbers of personnel to be equivalent to an experienced operating staff.

The word capability, is referred to competencies. Simply put, does the person assigned have the needed knowledge, skills, and abilities to perform their duties; and likewise, does the totality of the organisation have the collective set of knowledge, skills, and abilities to safely and efficiently operate the plants. Total capability will grow as individual, team, and organisational experience evolves and operational proficiency builds.

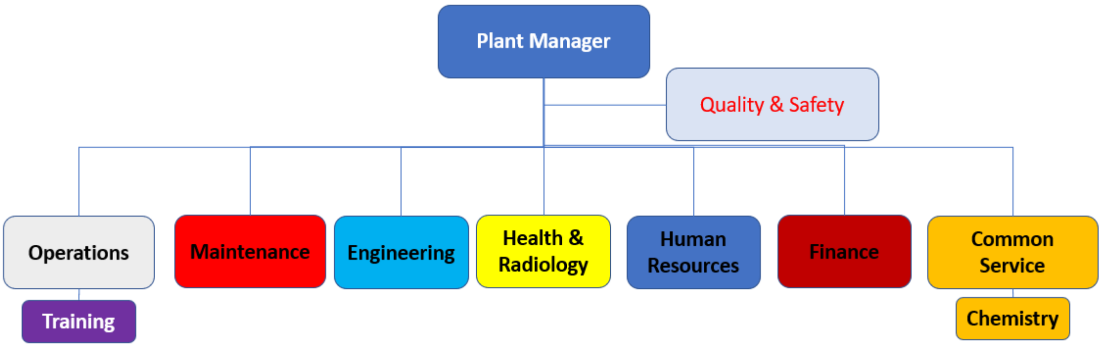
One caution before building a future organisation is to carefully consider the question, what organisation will be the licensed operator? The answer may be simple: A single, separate legal entity focused on the operation of a unit or site with all needed functional support either hired or contracted in support of plant operation. The answer can be very complex, especially when the licensed operating entity is envisioned as part of broader corporate enterprise and/or government agency. A vision for all company legal, financial, and commercial aspects must align to create a nuclear operating entity upon which the regulator can bestow clear responsibility for safe nuclear plant operation. Failure to have an early, clear vision of the licensed operator entity can and has resulted in significant project delays, costs, and organisational frustration.

3.4 Which roles are required for the operating organisation

The operating organisation will look different at various points through the project and will be fulfilled when fuel is loaded and final preparations for plant operation are being executed.

This information is provided as a help to understand the roles in an operating organisation that are required, based upon senior experiences and references. It is NOT intended to endorse this particular identification of workforce functions, as there is considerable variability in NPP workforce functions and organisation worldwide based upon factors such as technology, national norms and culture, labour rules and laws, and industry practices.

A typical operating organisation for a NPP consist of a management team lead by the plant manager and the senior department managers.



Typical Organisation Chart

The staffing can be listed in the following categories managers, technical-, and service personnel. The roles in each category are described below:

3.4.1 Managers:

The most senior member of the operating organisation on the site is the plant manager. The plant manager is the representative of the operating organisation on the site and has the overall responsibility for the safe and reliable day-to-day operation of the plant.

Management support administrate the senior management

Department managers should understand and support the need to develop the leadership, management and technical skills of all personnel involved in plant operations to the extent necessary to perform their assigned tasks. This support should be demonstrated through their own actions and behaviours, and by providing resources, including adequate funds, for programmes for the development of leadership, management and technical skills.

Middle managers or Line managers is a part of the workforce within each expert functions to be a part of the teams and to facilitate and demonstrate good teamwork.

3.4.2 Quality & Safety

- Emergency Preparedness develops, implements and maintains the emergency preparedness programme. Trains and qualifies emergency exercise participants. Responsible for emergency preparedness facilities, including the emergency operations facility (EOF) and tactical support centre (TSC). Focal point for local, state and federal legislation on emergency preparedness issues.
- Nuclear Safety Review is responsible for off-site and on-site safety review activities, including Independent Safety review. Reviews operating abnormalities and advises management on overall quality and safety of operations. Reviews operational and regulatory related documents such as LER, and technical specification changes. Reviews plant and industry event reports for applicability and lessons learned.
- Quality assurance (QA), ensures the implementation of the approved QA programme through periodic audits and surveillances. Provides follow-up in areas of concern from audits. Analyses the status and adequacy of operational QA programme and established QA policy for management approval.
  Primary contact for licensing and other regulatory issues with national regulatory body (regulatory body). Coordinates annual FSAR update process.

3.4.3 The Line organisation

Operations

- Shift personnel (Operators), supervisors and shift managers responsible for operating the plant. Control room operators and Field operators.
- Operating Support is non-shift personnel supporting the operations staff, including dedicated procedure writers, scheduling coordinators, technical specialists and training coordinators.
- Outage and work management coordinating all outage activities and work Permits. Central contact point for refuelling and maintenance outage planning and management, and forced outage management.
- Scheduling/Planning. Includes persons who schedule work activities for operations, maintenance and surveillance activities. Also includes persons coordinating with maintenance, construction management and engineering for daily schedule review and update. Persons preparing system outages and forced outage schedules are included with this function.

Maintenance

- Includes persons whose primary function is to perform maintenance and construction work within the power block. This includes routine preventive maintenance, corrective maintenance and predictive maintenance activities on plant components. It also includes the installation of minor and major modifications and metrology work.
- Includes mechanical, I&C and electrical maintenance staff and their supervisors.

- Persons who directly supervise these activities are also included in the function.
- Performs post-maintenance and post-modification testing and surveillance testing.
- Maintenance/Construction Support. This function includes people who support the work of maintenance/construction.
- Materials and tool room attendants are included in this function.
- Warehouse personnel's is directly associated with physical inventories, including persons performing materials inspection, tracking and maintenance.

Engineering

- Computer engineers are responsible for hardware and software engineering associated with plant process computers, radiation monitoring system and other operational and support computers and systems. Provide software related system design, revision and user information services. Provide operations and system administration resources for hosts and servers. Also provide system hardware design, revision and user information services. Respond to technical and information requests from internal and external sources.
  If training not outsourced, includes personnel who provided similar services for the training simulators.
- Modifications Engineering. Provides modification engineering services and ensures design integrity for Civil/structural engineering, Electrical/I&C engineering and Mechanical engineering.
- Nuclear Fuels. Performs and/or reviews reload safety evaluation, reload design analyses, and thermal, hydraulic and transient analyses. Provides support to operations for core analysis. Supports fuel licensing and fuel management activities.
- Plant Engineering includes persons evaluating system and component performance, and monitoring system operating performance parameters (system health). These persons provide engineering assistance to maintenance 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.
  Plant Engineering is responsible for coordination and review of post-maintenance and post-modification testing and surveillance testing programmes.
- Procurement engineering is responsible for materials qualification process, including parts substitution. Identifies and resolves supplier non-conformance. Manages and performs commercial parts dedication testing and supports like-for-like replacement analyses.
- Project management, directs, controls and monitors contractor and in-house design packages and other work in support of engineering functions. Reviews products to ensure high quality work. Participates in developing work packages.
  Project management, establishes and monitors milestone schedules for assigned work. Assists in reviewing contractor proposals and recommending contract awards. Coordinates resolution of technical questions directed to or originated by contractors.
- Quality control/non-destructive examination. Implements inspection hold point programme and performs associated inspections of ongoing activities. Reviews work activities to ensure compliance with QA programme requirements. Performs receipt

inspections for QA programme materials. Includes personnel who perform non-destructive examinations, including radiography/sonography of welds and fittings.

- Reactor engineering. Includes personnel analysing fuel performance, performing core performance monitoring and trending, and providing support and technical direction to operations during, normal operation, refuelling, start-up and shutdown.
- Researches and analyses technical engineering issues but does not perform modification design package development. Provides support to modification engineers and plant/system engineers. Dispositions, nonconformances and other assigned items. Responds to design basis and configuration control issues and questions. Serves as technical consultant on engineering issues. Responds to technical inquiries and information requests from internal and external sources. 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. Ensures design integrity for assigned specialized areas.

Safety/Health

- ALARA. Radiological protection, includes persons planning and controlling the as low as reasonably achievable (ALARA) programme, and performing and evaluating radiation dose and shielding calculations. It also includes staff reviewing complex radiation work permits.
- Decontamination (Decon) and clean-up performing this inside the power block, and those responsible for dry radwaste systems, and for packaging and transport of contaminated materials.
- Environmental. Includes persons responsible for the non-radiological environmental monitoring programme and related requirements such as environmental licences and permits, audits and thermal monitoring.
- Fire Protection. Administers the fire protection programme, including surveillance. Responsible for fire protection programme inspections. Includes personnel who serve on full-time fire brigades.
- Radiation protection technicians DOSE Personnel responsible for technical oversight of health physics programme. Includes persons involved with respiratory protection, radiological environmental and dosimetry programmes, including clerical staff maintaining dosimetry records.
- Radiation protection technicians RAD are involved with activities such as routine and special surveys, and data reading and analysis. Also includes persons collecting and analysing radiation system samples.
- Safety/Health. Focal point for Occupational Safety and Health Administration (OSHA) requirements and contacts. Manages and maintains the industrial safety programme. Also includes personnel responsible for medical exams and emergency medical assistance.

Human Resources

- Communications is 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.
- Human Resources is responsible for implementation and operation of human resources, and personnel programmes and systems such as appraisal, benefits, compensation, vacancy selection and promotion. Coordinates employment and equal employment opportunity activities, as well as management development training. Typically includes the central point of contact for union relations.
  Coordinates placing of bids, and awarding and monitoring of performance on contracts for labour and services. Controls contract changes and associated claims. Coordinates administration and enforcement of contract terms and conditions such as bonus/penalty clauses and cost-plus provisions.

Finance

- Budgeting/Accounting. Responsible for operation of budget and accounting systems. Disseminates accounting and budget information and organizes budget input.
- Oversees preparation of budgets and provides ongoing accountability reports to managers.
- Contracts prepares business plans and interfaces with joint owners.
- Purchasing. Includes buyers, expediters and other procurement personnel responsible for obtaining contracted materials and services by evaluating and processing purchase requisitions and proposals. Persons are responsible for managing the return of damaged goods and are primary vendor liaisons.

Common Service

- Administration/Clerical. 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.
- Document control/Records receives, prepares, microfilms and indexes nuclear records and drawings. Controls and distributes station documents. Coordinates other aspects of document processing, records management, and central files and libraries.
- Facilities includes persons directing and performing routine preventive maintenance, corrective maintenance and predictive maintenance activities on non-power block buildings, systems and components other than substations.
  Also includes persons responsible for general yard work, telephone systems and vehicle maintenance.
- Security. Provides physical site security. Responsible for development of security plans and procedures. Addresses technical issues pertaining to security regulations and

requirements. Also includes staff responsible for site access control and fitness for duty programmes.

Chemistry (can be included in other departments according to policies and reactor type BWR/PWR)

- Chemistry includes chemistry technicians for normal and emergency shift functions such as chemical additions and chemical/radiochemical analyses. Also includes persons coordinating all aspects of the chemistry programme and providing guidance on chemistry standards; conducting evaluations of plant chemistry programmes; and addressing and resolving chemistry operating problems. Also includes staff responsible for radioactive effluents programme.

Training (Training can be outscored or can be included (whole or partly) in the plant organisation, typically under Operations and/or in Human Resources).

- Provides or coordinates all formal training for nuclear staff programmes.
- Coordinates training schedules and produces training reports. Provides instructor training and development as well as instructional system design and implementation.
- Operates plant simulators.

3.5 Staffing key factors for new Nuclear Power Plants

The staffing roles are based on the experience of existing large-scale light water reactors at present, as an example that operator monitoring rely on and active safety system control for normal and abnormal operation and accident mitigation. The new nuclear power plants (SMR), that are developed with advanced reactor design, advanced automation technology, less systems and the elimination or significant reduction of the use of active safety systems may change the role, responsibility, composition and scale of staff.

In the design of small reactor, measures of accident prevention and human factors engineering are used to reduce the task burden of control room operators, and the active safety system is not relied on excessively for normal, abnormal or accident operation. In addition, the number of small reactor’s total system is far less than that of large light water reactors. It can significantly extend the response time of personnel after the accident, thus reducing the necessary actions of staff.

To determine the number of personnel for new nuclear facilities there is necessary to set up key factors [17] that impact the size of staff and to be able to optimize.

A. **Experience-based data**
   For a new entrant it is always good to learn from experience and to compare staffing against levels at other NPPs. Chapter 3.1 “Historical and experienced based staffing” will give the approximate figures on staffing with historical data that will be influenced when counting staffing on a new NPP.

B. Degree of automation and use of modern computer-based information technology

The design of a new NPP today uses a higher number of digital systems than historical designs. However, defence lines for control of design basis accidents still use hard wired, diverse analogue systems.

The use of automated control, monitoring and protection systems that bring the plant back to normal conditions or to a safe shutdown state without the immediate need for operator action. Consequently, higher levels of automation and first of a kind system (FOAK) may influence the number of staff and the knowledge, skills and abilities required for control and mitigation actions.

Higher levels of automation and FOAK systems may influence the number of staff and the knowledge, skills and abilities necessary for control and mitigation actions. The use of FOAK systems does not, in itself, provide justification for less staff, and any claims will need to be supported by a comprehensive staffing analysis.

In new nuclear reactors have significant use of (digital) automation in the MCR and very little equipment is operated manually. The MCR is designed to give panel operators time to focus on big-picture situational awareness to always understand where they are inside the operating envelope. This will reduce the workload and stress levels imposed on the operators. Operators are notified when automatic actions occur or do not occur within prescribed operating limits. Any manual operation or actions are driven by procedures based on diagnostic information such as alarm manuals and abnormal incident manuals (AIM). Operator responses to changing conditions are rehearsed and inter-unit communication is addressed in procedures and training.

Modern computer-based information technology (IT) systems [18] can make major contributions to efficient plant operation. These systems are of greatest advantage when incorporated into the SMR design, and utilized throughout the design, construction, commissioning, and operation of the plant. The following are examples of computer-based support systems:

- Configuration management system
- Information management
- Maintenance and in-service inspection records system
- Spare parts and consumables records system
- Maintenance procedures and support systems
- Procedure guidance system
- Plant monitoring system
- Surveillance test system
- Inherent radiation protection
- Training systems

C. Design, size and layout of plant

Design, size and layout of new plants also influence the number of staff. The new design often optimizes material and manufacturing techniques while incorporating breakthrough passive and simple concepts that results in less systems.

The SMR design strive to achieve simplicity in every aspect of the plant design, including operations and maintenance procedures [18]. The plant employs the minimum number of components and systems, and each system is made as simple as is feasible.

Standardisation is utilised to the greatest extent feasible (for example, use of identical pumps, valves, motors and electrical and control devices in multiple systems should be used wherever feasible). This serves to simplify maintenance and inspection by reducing the number of procedures, reducing the number of spare parts, and in some cases, reducing the number of skills required. Effort is made to assure that all operations, maintenance and inspection procedures are as simple, logical and straight forward as possible.

Reductions in the number of systems and components can result in a direct reduction in the number of inspections, testing, and maintenance activities required.

Passive and inherent safety features that rely on natural forces can be considered in new SMR plant designs. Such systems can contribute to the simplification of the SMR design, and to a reduction in the number of systems and components, particularly safety grade systems and components. Taking advantage of inherent and passive safety features generally results in significant reductions in the quantity of valves, pumps, safety class piping, seismic building volume, and in both electrical and control cables.

Passive and inherent safety system designs can also substantially reduce requirements for operator action following plant transients and design basis events. This provides operators additional time to effectively evaluate and diagnose plant conditions, and reduces the potential for operator errors. The additional response time allowances can be an important consideration for SMR plants located in remote regions with longer lead times before external support can be available.

D. The policy for shift personnel

To optimise the shift personnel it is the assumption that the control room operators can fulfil all functions and that all are senior reactor operator (SRO) qualified.

The shift schedule, rules about working hours, the composition of the shift teams and the use of shift personnel to perform minor maintenance, radiation protection and chemistry tasks influence the number of staff. To rotate and conduct a wide range of duties during shift time contributes to plant knowledge and the ability to prevent disturbances, however, there is always a tipping point when the focus on control and preventing events decrease relative the work load to the shift personnel.

E. High degree of flexibility in work roles

Know-How Management consists of three fundamental components: people, processes and technology. Knowledge management focuses on people and organisational culture to stimulate and nurture the sharing and use of knowledge; on processes or methods to find, create, capture and share knowledge; and on technology to store and make knowledge accessible and to allow people to work together without being together. People are the most important component, because managing knowledge depends upon people's willingness to share and reuse knowledge.

High level of competences across all functions such as:

- Some non-operations staff are SRO qualified to allow rotation in for sick/vacation days of control room operators
- Maintenance and Operations teams are radiation protection technician qualified
- Personnel and/or operator staff rotate to maintain fire protection requirements
- On-site maintenance staff only perform routine preventive, fix-it-now and predictive maintenance during non-outage time
- The staffing plan leverages a Fleet Services model to share some functions between operating units

However, country-specific codes and regulations may impact staffing levels

F. **Amount and quality of training. And the implementing degree of a learning organisation.**
Well trained personnel and a high degree of a learning organisation creates an expected corporate culture and an input to an optimised staffing. Know-how Management is a term for practical knowledge on how to accomplish something – in this case, to develop the human capital for nuclear power plant new build projects. As such, Training and Education is clearly a central component of know-how management. One model is to implement organized and controlled training during normal work or Just in Time Training.

G. **Attrition (turnover),**
Low staff turnover rate is essential for establishing an effective organisation. This may be achieved by making the working conditions at the site attractive to the employees. Attrition is the departure of employees from the organisation for any reason (voluntary or involuntary), including resignation, termination, death or retirement.

H. **Number of auxiliaries, part-time duties, contractors, and partners**
Number of hired staff as auxiliaries, part-time duties, contractors, and partners varied between different company organisational strategies. This report has assumed by experience, that approximately 15% to 35% over the number of own staff is hired.

3.6 Staffing for new Nuclear Power Plants

Optimised staffing is necessary [18] to ensure high performance with regards to safety and economics of all NPPs. Optimising does not necessarily mean having a very low number of employees, nor does it mean maintaining a fixed number over time. The number of staff should be adequate to perform all the required tasks at the site in an efficient, competent and safe manner. This permanent staff number should refer to fully qualified employees (and contractors) assuming a zero staff turnover rate.

Planning for the anticipated staff turnover should provide for staff undergoing training and should be shown in addition to the permanent staff complement.

Optimising staff level should include optimising the workload and schedules for both routine and non-routine activities, the proper human engineering of work areas and work processes, comprehensive planning, the provision of well-defined work packages, and the provision of all tools and equipment necessary to efficiently accomplish the tasks.

Strategies to assure optimum staff levels include those listed below:

- Management layers should be minimised where possible.
- The organisation should be formed according to local rules prevailing at the time. These rules could include requirements from the regulators, organisation working rules, union agreements, and salary policies.
- The use of contractors may vary due to many factors, including the size of the utility, the number of nuclear units operated, the expertise of the utility, and local conditions.
- Assistance from the vendor and other qualified contractors and Service Providers should be considered.
- Contractors involved in outages and refuelling are not included in the list below.

The numbers in the list uses full-time equivalent (FTE) that is a unit of measurement used to figure out the number of full-time hours worked by all employees in a business.

Full-time equivalent (FTE) for nuclear work functions

		accumulated		
Nuclear work function	**1 SMR**	**2 SMR**	**3 SMR**	**4 SMR**
Management[1]	10	11	12	13
Management support	2	3	4	5
Emergency preparedness	3	4	5	6
Nuclear safety review	4	5	6	7
QA	5	6	7	8
Operations	28	56	84	112
Operations support	6	8	10	12
Outage management	3	5	7	9
Scheduling/Planning	6	7	8	9
Maintenance/construction[2]	36	40	44	48
Maintenance/construction support[2]	7	7	7	7
Materials management[2]	1	1	1	1

Warehouse[2]	2	2	2	2
Computer engineering[3]	3	4	5	6
Mods engineering[3]	1	1	1	1
Nuclear fuels[3]	1	1	1	1
Plant engineering[3]	6	7	8	9
Procurement engineering[3]	3	3	3	3
Project management[3]	4	5	6	7
QC/NDE[3]	4	6	8	10
Reactor engineering[3]	3	4	5	6
Technical engineering[3]	10	11	12	13
ALARA	3	3	3	3
Decon/radwaste	2	3	4	5
Environmental	3	3	3	3
Fire protection	2	2	2	2
Radiation protection Dose/RAD[4]	10	12	14	16
Safety/health	2	3	4	5
Communications	2	2	2	2
Human resources	2	3	4	5
Budget/accting	3	3	3	3
Contracts	2	2	2	2
Purchasing	4	4	4	4
Admin/clerical	9	10	11	12
Document control/records	6	6	6	6
Facilities	10	12	14	16
Security[7]	5	5	5	5
Chemistry[5]	4	6	8	9
Training[6]	5	7	9	11
Summary	222	283	344	404

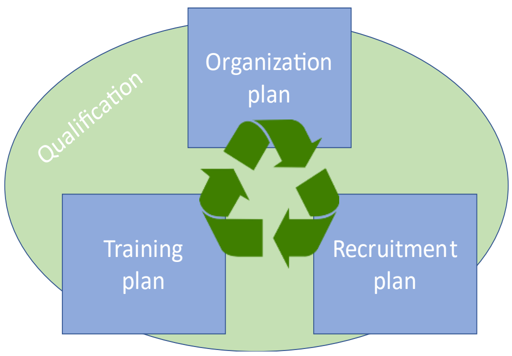
1. The senior management team is the same for the site and one operation manager for each unit.
2. Maintenance group is optimized according to better IT systems, fewer systems and contracted support providers.
3. Engineering orders expertise from the supplier/vendor.
4. Radiation protection technicians is optimized according to better IT systems and smaller stations to monitor.
5. Chemistry is optimized according to enhanced On-Line measuring, better lab and fewer systems.
6. Training for 1 SMR is counted as; 2 persons from the operation department and 3 from the HR department to administrate training. The conduct of training is outsourced to a training company.
7. Own personnel without security guards. Supervise and order security contractors.

4. A HIGH-LEVEL PLAN FOR RECRUITMENT

According to historical experience and advices from IAEA [13] as well as WANO [21] it’s important to start the recruitment process early and make a long-term plan for it. When designing the Organisation plan, Training plan and Recruitment plan they all have impact on each other. Qualification of personnel is needed for all three plans and should be included in the design. Staff motivation and career development should be considered in the recruitment and selection processes to provide the right balance between internal promotion and external recruitment in the future.

When building a new NPP it’s hard to recruit experienced staff so being a part of the building and organisation process to gain experience of the design, construction and commissioning stages by working alongside contractors and commissioning personnel is one way to compensate for lack of experience.

By participating in these stages, personnel will acquire a better understanding of the design intents, the assumptions which the safety criteria are based and the technical characteristics of the plant. Therefor recruitment is preferred in early stages, likely before the start of plant construction.

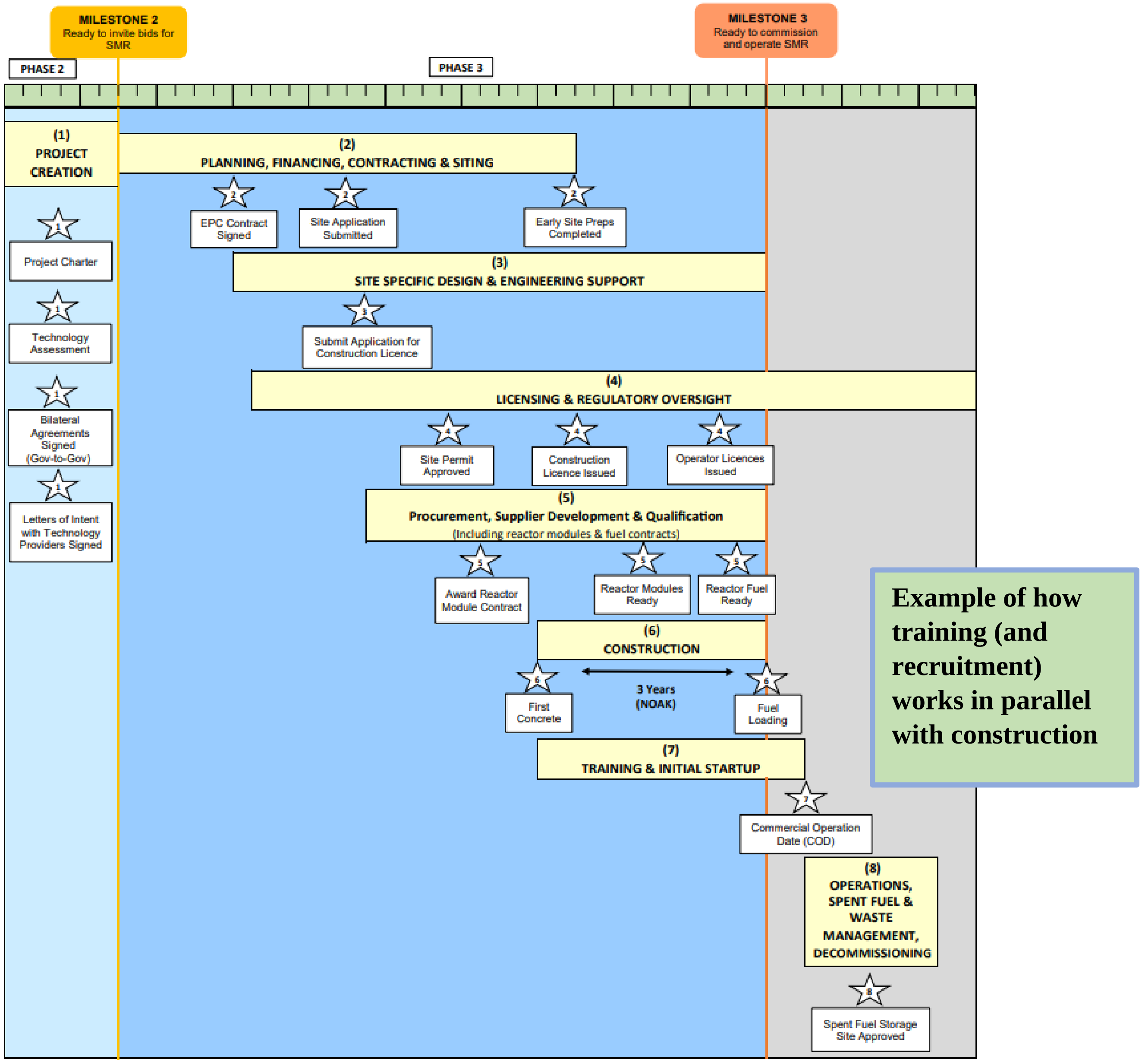


There are a number of institutional factors that influence staffing requirements at SMRs; the most important of these are company policies, regulatory requirements, trends within the Nuclear Industry, and country specific factors. Examples of factors that influence staffing requirements are:

- Corporate policies and functions
- Utility organisation
- Level of staff training and qualification
- Regulatory and licensing requirements
- Level of vendor support (including spare parts)
- Physical and procedure modification processes
- Availability of contractors (local technical base)

- Country and utility specific cultural and social factors
- Country and utility labour policies
- Medical and psychological requirements
- Emergency planning requirements
- Plant physical security requirements
- Government policies (for example staff and materials import restrictions)
- Country status (technology level, facilities)
- Degree of local participation/self-reliance
- Country and utility environmental policies
- Utility operating philosophies
- Plant life management philosophies (long term health of plant)
- National nuclear program status (for example, the number of nuclear units) [18].

Medical fitness for duty expectations should be clearly defined for each position as well as initial and periodic medical examinations for those who might be occupationally exposed to radiation at the plant. The operating organisation should ensure that all operating personnel whose duties have a bearing on safety are medically examined at the time of recruitment. For certain positions, the operating organisation may also conduct psychological tests. Low staff turnover rate is essential for establishing an effective organisation and has to be taken into account when plans for recruiting staff is made. This may be achieved by making the working conditions at the site attractive to the employees.



Technology Roadmap for Small Modular Reactor Deployment [10]

4.1 Education and work experience, relevant for different roles (entry levels)

An effective training and staff development programme is required to assure the availability of suitably trained and qualified staff; the staff development programme should provide for the maintenance and upgrading of the skills of the plant staff, and for the qualification of new staff. It is important to clearly define responsibilities and interfaces between departments. Good communication should be established;

The functions and the related duties and responsibilities of qualified personnel should be clearly indicated in the structure of the operating organisation and in the job description for each position. For each category of personnel, the necessary competence may be defined by means of the following:

(a) Educational level (academic qualification);
(b) Previous experience (including direct and related experience);
(c) Initial training and continuing training

The need for specific skills and knowledge will be different for different positions. The balance between managerial competences and technical competences should be evaluated by the operating organisation in establishing qualification criteria.

The selection of candidates should be based on a candidate’s potential to develop the necessary competence, through additional training, gained experience and building networks. A candidate’s potential for occupying higher positions may also be taken into account. The recruit must have entry level standard education such that he can secure the highest level of station qualification in his category. For example, an engineer trainee needs to reach up senior engineer /senior management positions and must therefore, have a bachelor of engineering university degree.

Training provides the general knowledge and develops the attitudes, behaviours and intellectual skills that are the foundations of competence. Appropriate criteria for educational background should be established for all positions at the plant. These criteria should be taken into consideration in the preparation of training programmes for plant personnel. In turn, training programmes should be used to complement formal education with practical and job-related knowledge and skills. The operating organisation should conduct an analysis of the knowledge and skills developed through the national education system, to help decide which educational qualifications are necessary for each particular position at its plant.

The scope of knowledge, and therefore the criteria for educational background, should be commensurate with the position to be occupied. Managers and technical specialists should possess a wide knowledge of general science and technology (physics, mathematics, chemistry, thermodynamics). Managers, shift supervisors and operators should have knowledge of nuclear science and nuclear engineering. Managers and technical specialists should also have in depth knowledge of the specific areas relating to their work (e.g. of mechanical, electrical, electronic, chemical or civil engineering). Individuals recruited for managerial positions should additionally have an educational background in administration and human resources management. In common for most employees at the NPPs are a high grade in Mathematics, Science and language (Native language + English). At least at High School (Videregående skole/Gymnasium) level, College/ University preferred for many positions.

4.1.1 Senior Managers

Senior managers, particularly the plant manager and department manager, should be recruited at the very beginning of the recruitment period, since their first duties include supporting preoperational activities and planning and conducting further recruitment and training. Particular attention should be given to the early recruitment of shift supervisors and senior reactor operators. Building up the training department and recruitment of managers and instructors are included in the very beginning.

Education background
Managers and technical specialists should have a university degree or equivalent certification in management, engineering or science, or some other educational background appropriate to the national education system and the specific job assigned. They might also have attained the necessary competence through appropriate experience and training, where this is permitted by the national regulations. Many positions, however, should be filled by individuals with formal educational qualifications. For example, the title of electrical engineer is established by the awarding of a formal degree and cannot be obtained through experience or training.

Managerial positions (e.g. plant manager, department manager, operations manager, safety manager, maintenance manager, quality assurance manager, technical support manager, training manager) are usually occupied by university graduates in engineering or physical sciences.

Experience
Plant managers should have experience in several key areas of the operation of the plant, such as operations, maintenance and technical support. This experience is usually gained over a period of at least 10–15 years, but of not less than five years. Plant managers should also have appropriate management experience.

4.1.2 Operators, Engineers and Technicians

Operators, engineers and technicians for a new plant should be recruited early. Time should be allocated for performing duties for which no additional training is necessary, or that can be accomplished under supervision before commissioning. Time should also be allocated to operators, engineers and technicians for training before they assume the full responsibilities of their positions. Some of these personnel could be assigned to the plant supplier or construction organisation to obtain experience with new and/or complex equipment. The training of technicians for Maintenance, Engineering and the Quality & Safety department should include working with the construction organisation and commissioning personnel in the checking and initial calibration of instruments and controls, and in the initial operation of such equipment before fuel loading. This also provides a valuable opportunity for personnel to familiarize themselves with parts of the plant that will subsequently have limited or no access. Some individuals might therefore be recruited and employed at the site well before the commencement of operation.

Educational background
The following practices in relation to the educational background of nuclear power plant personnel are commonly applied:

(a) The other positions (than managers) for which a university degree is normally expected are those of operating support and safety engineer. Reactor physicists, radiation protection, plant chemists and maintenance engineers will also generally have university degrees, and some of the more junior personnel might also have completed university level education.

(c) Supervisors (e.g. for the plant, unit, shift and control room) will often have a degree from a university or engineering college. Control room operators are typically expected to have a diploma from a technical school, although they might instead have a degree from a university or engineering college.

(d) Field operators commonly have, at a minimum, High school graduation.

(e) Other technical positions might be filled by graduates of vocational or technical schools.

(f) Training instructors should have an appropriate background in an education related subject, in addition to a degree in an appropriate discipline in their area(s) of responsibility. Experience from the trained area is in some countries necessary but not in all. Higher level of examinations could be an alternative.

Experience
Shift supervisors should have experience in reactor operations at a nuclear power plant, in terms of both leading and working with a shift team. This experience is usually gained over a period of at least four to six years, with a minimum of two to three years at an operating plant, of which at least one year should be at the site concerned (or at a similar site).
Control room operators should have experience of working on shifts at nuclear power plants or at conventional power plants. Sufficient experience is gained over a period of at least three to four years, of which a minimum of two years should be at a nuclear power plant, with at least six months at the site concerned (or at a similar site).
All other operators should have acquired experience appropriate to their duties and responsibilities. In general, one year of experience should be considered a minimum for field operators.

Senior technicians and *personnel with specific manual skills* should have at least two to three years of practical experience. Other technicians and personnel with specific manual skills should have the appropriate experience to demonstrate the skills necessary to perform their duties and meet their responsibilities

4.1.3 Radiological Protection, Chemists, Decontamination

The initial recruitment of experienced personnel with specific manual skills for Radiological Protection, Chemistry, Decontamination and Common Service departments should start in such a way that these people can discharge their duties according to the specified safety and quality requirements. Such persons might receive specialized training from suppliers during the assembly and pre-shipment testing of special equipment such as diesel or gas turbine sets, large pumps or fuel handling equipment. Some of them might need lengthy training programmes if particular skills asked of them are as yet unavailable to the operating organisation, such as those of a certified nuclear welder. Recruitment should continue in accordance with operational needs

4.2 Retraining of oil and gas rig operating personnel (re-schooling)

The following chapter is a plan for how personnel that have operated oil and gas rigs can be re-trained to operate SMRs (re-schooling).

It isn't realistic to expect that a country or organisation initiating a nuclear power programme will, at the beginning, have personnel with all the competencies needed for the programme. There will, most certainly, be a need for assistance in this regard. Turnkey projects provide one effective mechanism for developing competencies in these organisations. However, at some point in the project it is necessary that the operating organisation take over responsibility for the safe and reliable operation of the plant.

Knowledge, skills and experience from working in process industry will definitely be a good ground for the work at NPPs. In modern training programs the principles of Adult learning is applied and the participants previous experience is a very important starting point. Norway along with Estonia, Poland and several other countries today are exploring the possibilities of reschooling personnel from other industries. Norwegian oil and gas rig workers have today very applicable knowledge. Like Stig Stellberg describes in his book "Det er folk som gjør jobben" [23] the challenge and balance between production and safety is the same in oil/gas production as in nuclear business. Staff that's been working as Higher management, Managers and Supervisors, Control room Operators, Mechanical-, Electrical- and I&C-Maintenance, Station Engineering have all a good basic training level.

A historical experience is for example Sweden when building the first NPP´s in the early 70s. Staff from shipping and other process industries were attracted to a new and expanding business. In USA a large number of operators at the NPPs have been working at nuclear ships and submarines. When United Arab Emirates commissioned their first NPP at Barakah they attracted experienced NPP workers from USA and Sweden along with staff from other industries.

Radiation safety needs to be trained. Invisible pollution like radiation is a challenge for us as humans. Organisations in the nuclear business strive to adapt the ALARA (As Low As Reasonably Achievable) principle to radiation and good examples of how to train can be adopted from IAEA and WANO. Human Performance/Human Factors (HUP/HF) training and Safety Culture will be essential!

To train behaviours and have focus on Foreign Material Exclusion (FME) from the beginning is a lesson learned from many NPPs all over the world. Problems with damages to the fuel that comes from carelessness during construction and commission affects for a long time with expenses for both new fuel and loss of incomes during unplanned outages.

The design and specifications of the actual plant will still be a large part of the training. Even though the trainees have good competence from pumps and valves the systems and their function together with other equipment is important to understand. Experience of working as a contractor is great to look after as well as experience of shift work. All for having staff who knows what the work entails and can contribute to a good working environment.

The cascaded training strategy is one of the recommended training methods to be used in the early stage of developing the staff especially for technicians, maintenance and tradesmen. Both recruitment and training should start from the top and be connected to a clear responsibility.

Example of a “Nuclearization program” can be described as:

Considering location, timeframe, available competences etc a tailormade transformation programme can serve both as a re-education for craftsmen and managers in other industries and also as a complement to other trainee and talent programmes that aims to reassure a steady flow of competence to the industry.

- **Analyse**: Create a curriculum covering all necessary knowledge and skills for working in nuclear technology. This may include nuclear physics, radiation protection, nuclear engineering, reactor design, and safety procedures. This information is normally available in the standard training programmes provided by the training organisation or a TSP.

- **Design**: Tailor the training to fit the existing knowledge and experience of workers from the oil industry. For example, some technical and engineering skills may be transferable and require less retraining. This may also introduce an opportunity to assess the applicants. (GAP training)

- **Training Implementation**:
    1. **Theoretical training:** Provide theoretical instruction through lectures, workshops, and online courses. This will give participants a fundamental understanding of nuclear technology and its principles.
    2. **Hands-on training**: Provide hands-on training through simulations, lab work, and internships at nuclear power plants or research facilities. This allows participants to apply their theoretical knowledge in practice and gain experience in real-world work environments.
    3. **Safety training**: Prioritize safety training to ensure that participants understand and can adhere to strict safety protocols necessary in nuclear technology, radiation protection, FME etc.

- **Examination**: Prepare participants for any certification exams required. This may also involve meeting specific education and experience requirements set by regulatory authorities.

- **Mentorship**: Provide mentorship from experienced nuclear engineers and technicians to assist participants during their training process. This can be invaluable in facilitating the transition and providing ongoing support and guidance.

- **Evaluation**: Regularly evaluate the program to identify any challenges or areas for improvement. Conducting follow-up surveys with former participants can also assess the effectiveness of the program and any needs for adjustments.

5. A HIGH-LEVEL PLAN FOR TRAINING

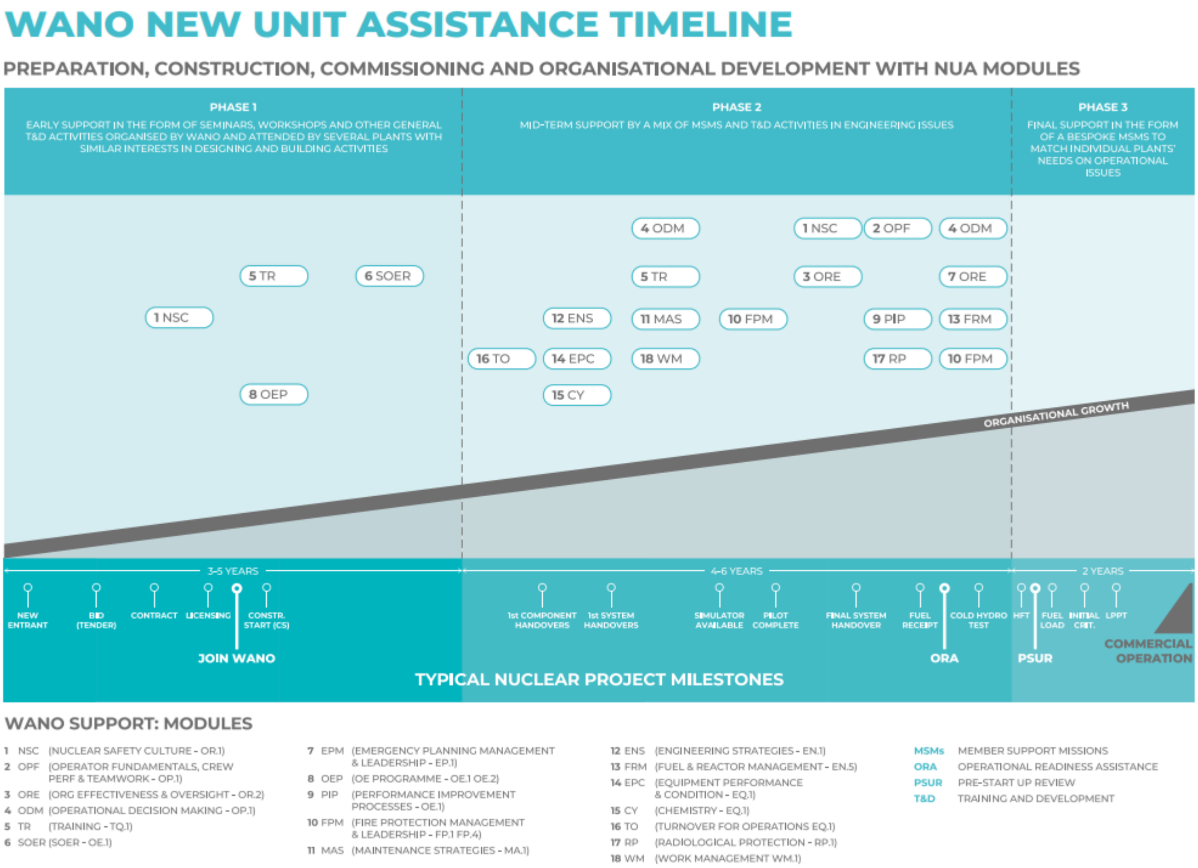
The time from recruiting an individual with suitable education for a position to when that individual is fully qualified to work independently in the nuclear sector is longer than for many other fields. This lead-time for certain positions in the owner/operator can be five to ten years (e.g. engineer, 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.

The training policy should be known, understood and supported by all relevant personnel. Managers, including the training manager, should be involved in developing the training policy. A training plan should be prepared on the basis of the long term needs and goals of the plant. This plan should be reviewed periodically in order to ensure that it is consistent with current (and future) needs and goals. Training should be used to foster and sustain a strong safety culture.

The type of project for NPP construction has a significant effect on the responsibilities and organisation of training for commissioning. For a turnkey contract, the organisation responsible for the turnkey project generally has the lead responsibility for developing and conducting this training. For a split package contract, or a project managed by the plant owner/operator, it is more likely the case that the project organisation/operating organisation will have the lead role.

A systematic approach to training should be used when designing training programs. IAEAs Systematic approach to Training, SAT (IAEA Nuclear Energy Series No. NG-T-2.8), is standard for nuclear industry worldwide. The SAT provides a logical progression, from identification of the competences necessary for performing a job, to the development and implementation of training towards achieving these competences, and to the subsequent evaluation of this training. In many cases the commissioning and operating organisations have separate training programmes (particularly for turnkey projects). However, personnel from both organisations often participate in common training activities.

Initial training, on the job training and retraining are planned so as not to overload training centres in the start-up phase. Training resources of simulators, mock ups, manuals and trainer development are planned in advance.



WANO, The New Unit Assistance (NUA) Modules [22]

For each position that performs safety related activities, the initial training needs and the continuing training needs should be established. These needs will vary depending on the individual position, the level of responsibility and the level of competence, and should be determined by persons with specific competence in plant operation and experience in developing training activities. These training needs should relate to the tasks and activities to be performed and include a clear focus on safety.

Completion of any NPP basic training included in training plans should be considered as a prerequisite for beginning job-specific commissioning training. Completion of required commissioning training should be an obligatory qualification requirement for commissioning personnel, as should the required level of education and experience. The duration of commissioning training programmes for key positions is typically from 12 to 36 months (with a median of 18 months). For other positions, such as for technical support organisation (TSO) and maintenance personnel, the duration is less. In some countries, the commissioning training plan is required to be approved by the nuclear safety regulatory body, while in others not.

All new personnel starting work at a plant should be inducted into the organisation and their working environment in a systematic and consistent manner. General personnel training programmes should give new personnel a basic understanding of their responsibilities and of safe and secure work practices, the importance of quality management and of following procedures, and the practical means of protecting themselves from the hazards associated with their work. The amount of training to be provided on specific topics should be commensurate with the assigned duties of personnel. The basic principles of safety culture should be taught to all personnel, and refresher training on general topics should also be provided periodically.

Presently, most NPP projects include the provision for a plant-specific, full-scope simulator (for a majority of recent NPP projects provided by the supplier) to be operational 1 year or more prior to fuel loading in order to provide sufficient time for both control room personnel training and verification and validation of plant procedures. For all NPP projects, control room simulator training is provided for control room personnel and their supervisors, as well as safety engineers if they are a part of the shift organisation. In addition, for some NPP projects, control room simulators are also used for other training purposes, including the following positions/groups:
— System engineers
— Instrumentation and control personnel
— Commissioning staff (e.g., leaders of selected tests)
— Regulatory body local inspectors.
The duration of initial simulator training for operator positions is generally from 4–40 weeks (median: 8 weeks). For other positions: the duration is 1–4 weeks (median: 2 weeks). The simulator training provided for commissioning is often conducted for shift crews as an integrated group. [9]

General induction training should be provided to each member of personnel or contractor working at the plant, to address the following:
(a) Introduction to the plant organisation and administration;
(b) Nuclear safety principles (e.g. defence in depth);
(c) The management system;
(d) Safety culture;
(e) Non-radiation-related safety (e.g. electrical safety, rigging and lifting, work in confined spaces, chemical hazards, use of protective equipment, first aid);
(f) Radiation protection, including techniques for the optimization of radiation protection;
(g) Foreign material exclusion;
(h) Fire protection, including fire prevention;
(i) Environmental protection;
(j) Use of human performance tools;
(k) Nuclear security and access control;
(l) Emergency alarms, escape routes and assembly points

Operation personnel must apply the essential knowledge, skills, behaviours and practices needed to operate the plant safely and reliably. The specific criteria for this objective are fully discussed in WANO Performance Objectives and Criteria (PO&C) Operations Fundamentals. (OP.1)

Operations possess job-related knowledge and skills in areas such as the following:
(a) Station policies and procedures regarding control rod manipulations and other actions that

affect core reactivity
(b) Plant technology, systems and procedures and bases
(c) Nuclear power fundamental concepts and applications
(d) General information and functions such as plant layout, reporting relationships, communication methods, document and procedure issue and revision, records management, material procurement and industrial safety practices
(e.) Operating practices, including administrative and watch-standing activities, diagnostics and transient response, conservative decision making, procedure use, supervisor roles, teamwork and communication skills, interaction with emergency response organisation and core damage mitigation
(f) Site-wide normal and emergency power supplies; normal, alternate and emergency distribution schemes; and the impact of electrical transients on the plant in operating, startup and shutdown modes
(g) Radiological protection theory and techniques, including as low as reasonably achievable applications
(h) Application of appropriate lessons learned from operating experience and risk analyses

Maintenance personnel possess job-related knowledge and skills in areas such as the following:
(a) general information and functions such as plant layout, reporting relationships, communications methods, document and procedure issue and revision, records management, material procurement and industrial safety practices
(b) nuclear power fundamental concepts and applications
(c) tool and test equipment selection, inspection, use and care
(d) plant equipment fundamentals and the effects of maintenance on plant systems
(e) component inspection, repair and adjustment techniques; procedure application and quality requirements
(f) application of appropriate lessons learned from operating experience
(g) radiological protection theory and techniques, including as low as reasonably achievable (ALARA) applications
(h) troubleshooting equipment problems

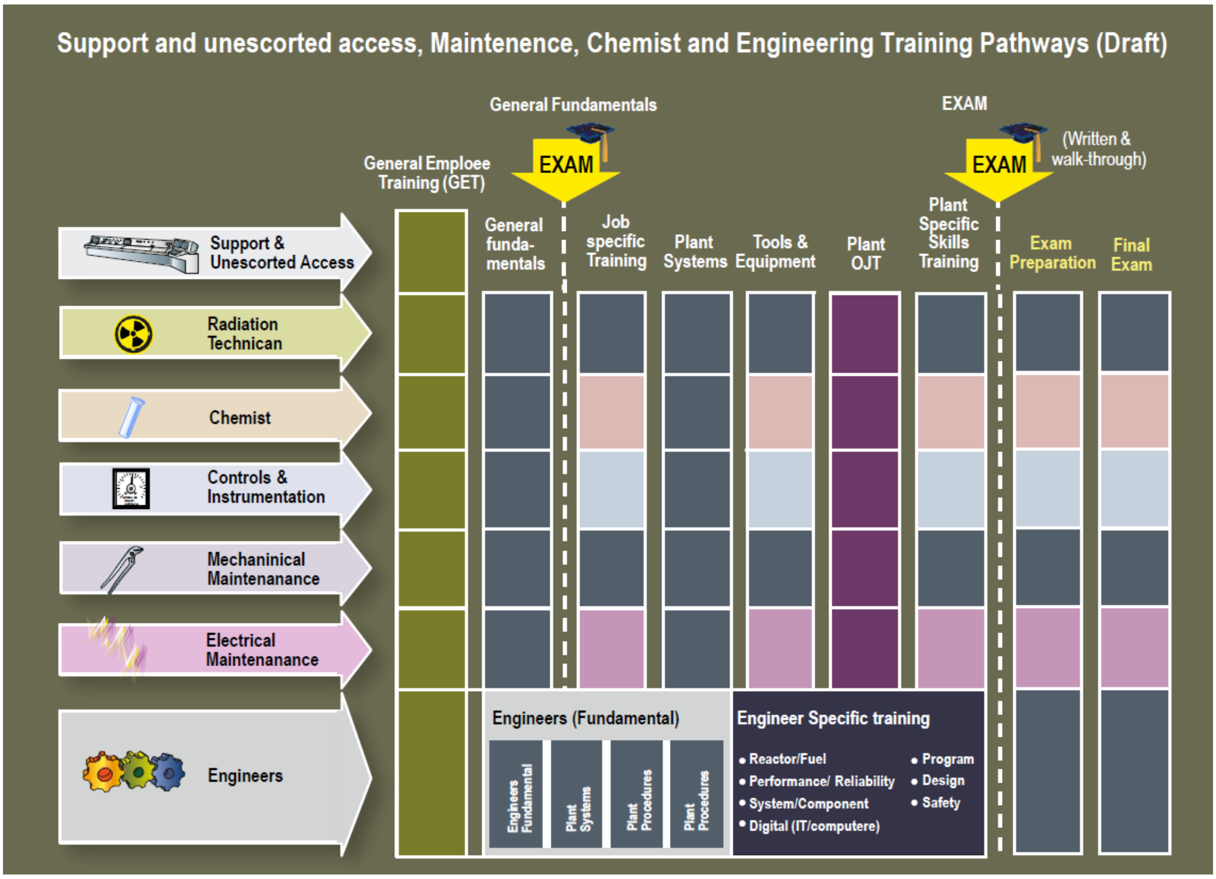
Engineering personnel are trained and qualified to possess and apply the knowledge and skills needed to perform engineering activities that support safe, reliable plant operation. Engineering personnel are provided system and equipment experience by performing pre-operational and start-up activities to gain relevant system operating experience. Engineering personnel are trained regarding beyond-design-basis programmes and continuing training is planned, as appropriate.

Radiological protection personnel possess job-related knowledge and skills in areas such as the following:
(a) general information and functions such as plant layout, system knowledge, reporting relationships, communications methods, document and procedure issue and revision, records management, material procurement and industrial safety practices
(b) radiological protection theory and techniques, including as low as reasonably achievable

(ALARA) applications
(c) plant component and system fundamentals
(d) radiological surveys, including data collection, analysis, documentation and selection, inspection and use and care of instrumentation
(e) application of appropriate lessons learned from operating experience
(f) response to off-normal conditions

Chemistry personnel possess job-related knowledge and skills in areas such as the following:
(a) general information and functions such as plant layout, reporting relationships, communication methods, document and procedure administrative controls, records management, material procurement and industrial safety practices
(b) plant component and system fundamentals and maintenance of system chemistry
(c) chemistry and radiological equipment selection, inspection, use, and care
(d) radiological control techniques, including as low as reasonably achievable applications
(e) chemistry theory and techniques, including water chemistry fundamentals, specifications and bases; laboratory practices and techniques; procedure application; quality requirements and other job responsibilities
(f) application of appropriate lessons learned from operating experience
(g) response to off-normal conditions

Training personnel have knowledge of job-related areas, including the following:
(a) general information and functions such as plant layout, reporting relationships, communication methods, document and procedure issue and revision, records management, material procurement and industrial safety practices
(b) radiological protection theory and techniques, including ALARA applications
(c) power plant technology, fundamental concepts and applications
(d) instructional fundamentals concepts and applications, instructional techniques, material development, learning techniques and other job responsibilities
(e) technical knowledge and skills in the subjects being taught
(f) plant-specific application of appropriate lessons learned from industry operating experience
(g) management expectations and standards associated with the proper use of human performance tools
(h) beyond-design-basis events and associated programmes to support personnel training



Suitable personnel should be trained in root cause analysis and the assessment of human and organisational factors, with the aim of creating a pool of staff who can evaluate events objectively and make recommendations on how to avoid their recurrence.

All training programmes for specific plant activities should make reference to the need to sustain a strong safety culture. These programmes should stress the need for an understanding of safety issues, should include consideration of the possible consequences of shortcomings in human performance and should deal specifically with ways in which such shortcomings can be avoided or corrected.

All personnel who are likely to be occupationally exposed to ionizing radiation should receive suitable training to understand radiation risks and the technical and administrative means of optimizing protection and safety in accordance with Requirement 11 of IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards

Few Hints for successful New Build Training:

→ Pay highest attention to **cultural differences** and **language barriers**. If the training will be delivered or received in a foreign language include sufficient margins in your training programs.

- → Collaborate, and **work close together as much as possible** with all training stakeholders involved, especially in early stages of the project.
- → Follow any kind of First Of A Kind, FOAK, solutions (not only technical) in the project and analyze their **impact on training**.
- → Carefully analyze different applications of the Full Scope Simulator, FSS, (and other simulators) during the project. Create a **simulator availability timeline**. Simulators will be used for many other time-consuming activities than training. Other examples to use FSS can be; plant modifications, testing new procedures, engineering issues, and emergency scenarios.
- → Establish a clear project-wide **training glossary** and definitions.
- → Be prepared for (but do not count on) significant delays and **continuous plant modifications** especially during commissioning.
- → **Roles and responsibilities** of the owner’s Operations & Maintenance staff **during commissioning** will have a significant impact on their **training planning and availability**.
- → **New build NPP projects desperately lack suitable training content in the early phases** (licensing, construction). If possible, do not wait with training development activities until a certain initiating milestone. Allow development of the training content in several stages, more or less corresponding to the plant design baselines. Plenty of training content can be easily and efficiently developed already during Conceptual and Basic Design of the plant. This content can be immediately used in many ways, such as technical training of newcomers as well as current employees, can be provided to important stakeholders like local schools and universities (for joint activities), etc. These training **“early deliverables”** will also spread the training development activities over a time and reduce later high peaks of workload.
- → In relation to previous, as soon as possible start developing training **pilots, proof of concept solutions, templates**, etc. as a framework for future activities.

Nuclear power plant organisation and staffing for improved performance lessons learned [17] describes how to create a learning organisation:

“CREATE A LEARNING ORGANISATION
Many utilities are finding that the pace of change due to external factors is faster than ever before. The challenge for these utilities is to organize their efforts so as to respond to change in a structured manner, rather than in a chaotic way. In addition to the changes resulting from the initiation of open energy markets, technological advancement has resulted in major changes in NPP activities. Information technology has been widely adopted within the nuclear industry in areas of work management, materials management, financial systems, human resource management, outage management, and document control. The pace of such technological changes is likely to continue at present levels or even increase. The challenge

created by information technology advances is to organize work to take full advantage of its potential. The following are considerations when responding to such changes:

1. Establish an environment where change is looked upon as a normal state of affairs, and continuous self-assessment is encouraged. Change is a natural part of life. It is unreasonable to expect that one way of organizing work will be the most effective for all circumstances-throughout the life cycle of an NPP.

2. Confirm the need for change and communicate the need to all affected persons. If item one is achieved, then change will be expected, and even embraced, if it has clear advantages over current practices. Those people who perceive that they have something to lose through reorganisation will need particular attention in this respect.

3. Make a realistic assessment of the situation, and identify the best integrated, overall approach. An assessment of the situation can either be made by professional organisations, through self-assessment, or both. Based on this assessment, various options are identified for further discussion. The strengths and weaknesses of these options should be investigated from different aspects, e.g., cost/benefit, influence on safety, number of people, number of layers of management, and conformance with functional processes. Also, an implementation strategy should be prepared with the optimal date, duration, and detailed time schedule of the structural change. An integrated, overall approach is needed.

4. Establish an experience feedback program and associated indicators to monitor progress. It is important to establish measures which can be monitored in order to determine whether the objectives of reorganisation are achieved.

5. Consider human related aspects. During preparations for an organisational change, communications with affected staff should be carried out. Strategies for looking after people who are leaving, remaining or considered for promotion should be identified. The role of trade unions should be identified. A viable process for selecting managers and other key personnel should be clearly communicated.

6. Manage the change process. There will be a transition period between the past and the future structure which needs very careful management. The main criterion is that safety must not be compromised.

7. Measure results. Continuous monitoring and evaluation of the change process is needed. The organisation must be candid enough to admit if a change has not been effective, and be willing, after a suitable time to acknowledge that a modified approach is needed. Managers have been found to develop more realistic and reliable proposals for change when they know that implementation will include evaluation of the achievement of their goals.”

5.1 Training programmes and sequences

A systematic approach to training is used to achieve a high level of personnel knowledge, skill and performance. The SAT by IAEA is standard for Nuclear Power Plants [5]. In Sweden the Swedish Radiation Authority demands the usage of SAT in the Regulations SSMFS 2021:6 [24]. Nuclear safety is foremost in training.

- Line managers – such as operations, maintenance and engineering managers – are responsible for the training and qualification of personnel assigned to their work groups.
- Training and evaluation methods and standards are sufficient to verify trainee competence for assigned functions.
- The schedule for Training department procedure preparation provides for timely availability of procedures to support plant operation.
- Facilities are appropriate to support training activities.
- Workers from off-site, such as contractors or workers from other utility facilities, are appropriately trained and task-qualified before they work independently.
- General employee training provides plant personnel, contractors and visitors with a basic
- Understanding of employee responsibilities, including the use of human performance tools and safe work practices.

Training activities are conducted in a manner that supports start-up and safe, reliable plant operation.

1. Classroom, simulator, laboratory, on-the-job training and individualised instruction are presented effectively.

2. Training personnel exhibit professionalism and competency in performing assigned training tasks.

3. Line management expectations and standards are reinforced during training.

4. The training facilities, equipment and materials support training activities effectively, as follows:

- Classroom, simulator and laboratory facilities are appropriate for effective group instruction.
- Reference material is appropriate and readily accessible.
- Equipment is available, as needed, to support training material development.
- Training aids are sufficient to support hands-on and practical demonstration training.
- Training materials are sufficient to support the training programmes.
- Areas are provided for individualised instruction.

5. Training is presented as outlined in approved training materials. Training materials are well organised and current.

6. Training activities encourage appropriate trainee interaction in the learning process.

7. Instructor preparation results in effective and consistent instruction.

8. Instructors use instructional techniques appropriate to the learning objectives and lesson content.

9. Conditions of task performance in the laboratory setting, including trainee and instructor actions, references, tools and equipment, reflect the actual job situation to the extent necessary to provide effective training and practical experience.

10. Simulator exercises are used effectively to develop, reinforce and evaluate job-related knowledge and skills in the following areas:

- application of theory to practical situations
- in-house and industry operating experience (including actual events)
- station procedures and technical specifications
- application of conservative control room operating philosophies and practices
- diagnosis of plant conditions during normal, off-normal and emergency conditions
- ability of the control room crew to work as a team
- ability of the control room crew to handle simulated emergencies

11. The planned frequency of simulator training cycles and the practice time on the simulator are sufficient to maintain operating crew competency.

12. The attitude and actions of trainees and instructors reflect a real-plant atmosphere to the extent practical.

13. Training is enhanced by the use of pre-exercise briefings and post-exercise critiques. Post-exercise critiques identify and correct important weaknesses.

14. A suitable simulator is used effectively for hands-on training to demonstrate plant operational characteristics and for recognition and control of normal, abnormal and emergency plant conditions. Differences between the simulator and the plant are considered during training sessions.

15. Procedures used during simulator training reflect those used in the plant.

16. Methods are established to ensure that procedure conflicts and errors identified during simulator training are fed back to the station for resolution in a timely manner.

17. Applicable simulator emergency exercises include event classification and the use of emergency plan implementing procedures.

18. On-the-job training and evaluation are conducted by designated individuals who have received instructions on how to provide effective training and evaluation.

19. On-the-job evaluation of trainee performance is conducted to verify that the trainee has attained the essential performance skills associated with his or her tasks. Remedial training and re-evaluation are provided when performance standards are not met.

20. Operations personnel assigned responsibility of start-up activities are provided appropriate simulator training prior to these activities.

21. Training programmes for operations personnel involved in start-up activities are developed with consideration of industry plant commissioning experience at similar plants.

WANO GL 2016-02 has been issued to align with WANO Performance Objectives and Criteria. Information has been updated to further strengthen the standards for fundamental operator behaviours when operating a nuclear power plant that were established in PO&C 2013-1, Performance Objectives and Criteria and PO&C 2013-2, WANO Pre-Start-up Performance Objectives and Criteria. These behaviours are broadly known as operator fundamentals and represent the essential knowledge, skills and practices that individuals and operating crews must apply to operate the plant safely, reliably and effectively. The use of operations fundamentals, along with the appropriate level of proficiency, increases the probability of success. This document provides a discussion of each fundamental and describes the attributes that exemplify excellence. The intent is to provide insight into the teaching and understanding of operator fundamentals. The examples cited are intended to illustrate a desired behaviour and do not necessarily represent an INPO or industry standard.

1. Monitor plant indications and conditions closely.

2. Control plant evolutions precisely.

3. Operate the plant with a conservative bias.

4. Work effectively as a team.

5. Have a solid understanding of plant design, engineering principles and sciences

5.2 Training Service Providers

The most common way of organising training service is as an in-house compartment at the plant. In some countries, like Sweden, the training department is organised in a separate company (KSU) that provides training for many sites. In both cases there is a combination of full time and part time instructors.

Training that goes on all the time like for operations is manly provided by full time instructors. Specialists from for example, chemistry, engineering and radiation protection can give some training as a part of their role. And more, training can also be provided by contractors and supply delivering companies.

Hereby it’s important to create a strong Training Culture (as a part of the Safety Culture) there everybody feels that they are a part of a Learning Organisation. Both as a trainer and a trainee.

A positive attitude to training is important when recruiting staff to NPPs and actively working for resilience in the organisation. The best way to create and maintain a high-quality professional training is to engage a training service provider.

For new countries or FOAK projects a training centre with simulators in another country can be used at the beginning. Like Finnish operators from Olkiluoto were trained in the simulators at KSU Studsvik in Sweden before they built their own training centre. It was ASEA Atom that built both the Swedish and Finnish reactors.

There is (see chapter 6) existing Norwegian educational institutions that can provide with key competences, and these resources could be integrated with the training programs and taken into consideration when planning. Nevertheless, additional resources are also required, including when it comes to practical training, train the trainer and evaluating competence and training programmes.

5.3 Duration of initial training for key personnel

Because there are no specific NPP/SMR to build a training program around here follows some examples collected from around the world. It looks like most SMR providers will also deliver training programs specific for their plant.

A high-level plan from IAEA as an example:

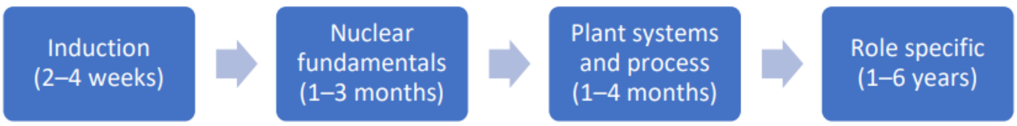


FIG. 4. Durations of typical training programmes.

IAEA Human Resource Management for New Nuclear Power Programmes [4]

With a few more details, also from IAEA:

TABLE 2. FOUNDATION TRAINING FOR FRESH RECRUITS

Entry Streams	Qualification at the time of recruitment	Classroom training	On-the-Job Training
Executive Level Induction Training	Graduate in Eng./Post graduate in basic science	Six months theoretical	Six months on the Job
Supervisor Level Induction Training	Diploma in Eng./Graduate in basic science	Six months theoretical	1 year on the job
Tradesmen Level Induction Training	Secondary School Certificate/Industrial training certificate	Six months theoretical	1½ years on the job

Foundation training for fresh recruits [9]

IAEA made a survey on nuclear power plant personnel training in 19 countries. Here you can see how it differs in both total time and how time is used:

TABLE 2.11. FIELD OPERATOR INITIAL TRAINING

Country	lassroom Hours	Laboratory/ Workshop Hours	Simulator Hours	Self-Study Hours	OJT Hours	Total Hours
Brazil	26%	0%	0%	21%	54%	1950
Canada	36%	18%	0%	44%	2%	2760
China	22%	2%	0%	0%	77%	1300
Czech Republic	44%	11%	0%	4%	40%	975
Finland	39%	0%	2%	0%	59%	1275
France	50%	0%	0%	0%	50%	1900
Germany	19%	6%	0%	13%	63%	4800
Hungary	25%	3%	0%	13%	60%	1600
Japan	25%	7%	8%	13%	47%	1512
Kazakhstan	23%	0%	0%	23%	55%	264
Korea, Republic of	48%	1%	0%	8%	43%	1220
Lithuania	14%	0%	0%	39%	47%	1160
Mexico	21%	0%	0%	0%	79%	1264
Romania	41%	0%	0%	18%	42%	1816
Russia	16%	1%	5%	6%	72%	953
Slovakia	38%	0%	0%	0%	63%	640
Slovenia	40%	0%	0%	20%	40%	808
Spain	95%	0%	0%	0%	5%	420
Sweden	18%	0%	0%	0%	81%	2144
Switzerland	34%	1%	1%	19%	45%	1150
Ukraine	14%	1%	0%	20%	65%	771
United Kingdom	17%	0%	7%	23%	52%	807
United States of America	38%	3%	2%	15%	42%	1651

TABLE 2.2. PLANT SHIFT SUPERVISOR INITIAL TRAINING

Country	Classroom Hours	Laboratory/ Workshop Hours	Simulator Hours	Self-Study Hours	OJT Hours	Total Hours
Brazil	39%	1%	1%	34%	24%	4370
Bulgaria	0%	0%	7%	84%	9%	1102
Canada	32%	0%	12%	35%	22%	3280
Czech Republic	33%	1%	7%	3%	56%	3654
France	48%	0%	14%	0%	38%	1560
Hungary	0%	0%	0%	33%	67%	1440
Japan	42%	0%	58%	0%	0%	82
Kazakhstan	0%	0%	0%	81%	19%	744
Korea, Republic of	61%	22%	17%	0%	0%	23
Lithuania	0%	0%	8%	39%	53%	2016
Mexico	59%	0%	18%	0%	24%	5100
Romania	49%	0%	5%	14%	32%	7040
Russia	28%	1%	16%	16%	39%	1439
Slovakia	25%	0%	18%	18%	37%	160
Slovenia	74%	0%	0%	0%	26%	400
Spain	28%	0%	9%	38%	25%	1220
Switzerland	32%	13%	13%	21%	21%	4600
Ukraine	17%	0%	4%	19%	60%	992
United Kingdom	22%	0%	12%	9%	57%	1292
United States of America	42%	15%	15%	9%	20%	967

TABLE 2.5. UNIT OR CONTROL ROOM SUPERVISOR INITIAL TRAINING

Country	Classroom Hours	Laboratory/ Workshop Hours	Simulator Hours	Self-Study Hours	OJT Hours	Total Hours
Brazil	39%	1%	1%	34%	24%	4370
Bulgaria	5%	0%	5%	83%	7%	1505
Canada	15%	0%	4%	7%	74%	272
China	14%	2%	8%	0%	77%	1305
Czech Republic	36%	1%	7%	3%	53%	3306
Finland	44%	0%	15%	0%	41%	2424
France**	-	-	-	-	-	-
Germany	56%	16%	6%	9%	13%	4800
Hungary	16%	0%	8%	38%	38%	2520
Japan	42%	0%	58%	0%	0%	83
Kazakhstan	0%	0%	0%	81%	19%	744
Korea, Republic of	70%	1%	16%	13%	0%	155
Lithuania	0%	0%	2%	36%	61%	3316
Romania*	49%	0%	5%	14%	32%	2200
Russia	15%	1%	18%	24%	42%	882
Slovakia	25%	0%	19%	0%	56%	215
Slovenia	0%	0%	0%	20%	80%	400
Spain	23%	0%	10%	41%	26%	1220
Sweden	26%	0%	7%	0%	67%	822
Switzerland	49%	10%	9%	16%	15%	6080
Ukraine	8%	0%	3%	16%	73%	1825
United Kingdom	21%	0%	14%	12%	53%	1548
United States of America	35%	15%	16%	8%	26%	1904

TABLE 2.8. CONTROL ROOM OPERATOR INITIAL TRAINING

Country	Classroom Hours	Laboratory/ Workshop Hours	Simulator Hours	Self-Study Hours	OJT Hours	Total Hours
Brazil	38%	1%	1%	35%	25%	4270
Bulgaria	6%	0%	3%	61%	29%	2454
Canada	30%	0%	13%	36%	21%	4480
China	33%	1%	10%	11%	44%	2400
Czech Republic	41%	1%	7%	3%	48%	2811
Finland	44%	0%	15%	0%	41%	2424
France	16%	6%	13%	0%	65%	3240
Germany	56%	16%	6%	9%	13%	4800
Hungary	24%	3%	8%	26%	39%	2480
Japan	22%	2%	13%	8%	55%	2376
Kazakhstan	0%	0%	0%	81%	19%	744
Korea, Republic of	37%	2%	48%	13%	0%	393
Lithuania	53%	0%	5%	15%	27%	1700
Mexico	63%	0%	10%	0%	27%	4000
Russia	25%	1%	20%	18%	36%	823
Slovakia	43%	0%	7%	7%	43%	2140
Slovenia	46%	2%	0%	28%	24%	1778
Spain	56%	0%	7%	16%	21%	2290
Sweden	23%	0%	22%	5%	51%	1588
Switzerland	59%	13%	6%	12%	10%	4700
Ukraine	10%	0%	2%	32%	55%	1191
United Kingdom	21%	0%	12%	12%	56%	1226
United States of America	43%	9%	16%	11%	21%	2087

TABLE 2.14. MECHANICAL MAINTAINER INITIAL TRAINING

Country	Classroom Hours	Laboratory/ Workshop Hours	Simulator Hours	Self-Study Hours	OJT Hours	Total Hours
Brazil	100%	0%	0%	0%	0%	1014
Canada	22%	77%	0%	0%	1%	1630
China	31%	4%	0%	15%	50%	1690
Czech Republic	50%	0%	0%	8%	42%	420
Finland	25%	0%	0%	8%	67%	1200
France	11%	0%	0%	0%	89%	3580
Hungary	56%	0%	0%	44%	0%	360
Japan	10%	15%	3%	0%	71%	712
Kazakhstan, Republic of	0%	0%	0%	29%	71%	204
Korea, Republic of	46%	3%	0%	10%	41%	1040
Lithuania	27%	13%	0%	35%	25%	300
Mexico	9%	0%	0%	0%	91%	1096
Romania	41%	0%	0%	18%	42%	1816
Russia	26%	1%	2%	7%	64%	478
Slovakia	38%	0%	0%	0%	63%	640
Spain	67%	0%	0%	0%	33%	360
Sweden	88%	13%	0%	0%	0%	80
Switzerland	6%	3%	0%	4%	86%	442
Ukraine	5%	10%	0%	13%	71%	277
United Kingdom	30%	0%	14%	25%	31%	1506
United States of America	26%	13%	6%	3%	51%	1465

TABLE 2.20. INSTRUMENTATION AND CONTROL TECHNICIAN INITIAL TRAINING

Country	Classroom Hours	Laboratory/ Workshop Hours	Simulator Hours	Self-Study Hours	OJT Hours	Total Hours
Brazil	100%	0%	0%	0%	0%	972
Canada	21%	68%	0%	11%	1%	1850
China	43%	3%	3%	0%	50%	2100
Czech Republic	45%	0%	0%	4%	51%	927
Finland	25%	2%	0%	8%	65%	1220
France	15%	3%	0%	6%	75%	5305
Hungary	100%	0%	0%	0%	0%	200
Japan	22%	13%	3%	0%	63%	832
Kazakhstan	0%	0%	0%	29%	71%	204
Korea, Republic of	48%	1%	0%	8%	43%	1220
Lithuania	11%	24%	0%	32%	33%	1323
Mexico	21%	0%	0%	0%	79%	1264
Romania	41%	0%	0%	18%	42%	1816
Russia	38%	9%	2%	9%	42%	706
Slovakia	41%	0%	0%	0%	59%	680
Spain	77%	0%	0%	0%	23%	520
Sweden	88%	13%	0%	0%	0%	80
Switzerland	8%	0%	0%	13%	79%	600
Ukraine	24%	1%	4%	32%	38%	647
United Kingdom	30%	0%	14%	25%	31%	373
United States of America	35%	11%	1%	3%	50%	1691

TABLE 2.31. INSTRUCTOR INITIAL TRAINING

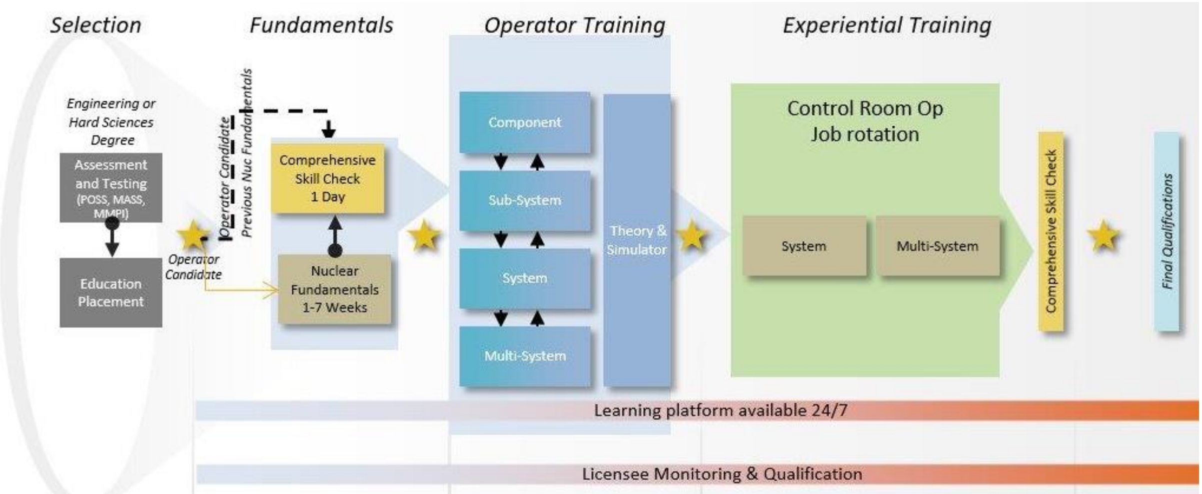
Country	Classroom Hours	Laboratory/ Workshop Hours	Simulator Hours	Self-Study Hours	OJT Hours	Total Hours
Brazil	13%	0%	0%	0%	87%	1210
Canada	40%	31%	0%	27%	3%	109
China	45%	0%	4%	0%	51%	1570
Czech Republic	67%	0%	0%	3%	30%	1015
Finland	25%	0%	0%	0%	75%	400
France	100%	0%	0%	0%	0%	150
Hungary	5%	19%	0%	19%	57%	840
Japan	18%	47%	18%	15%	2%	260
Korea, Republic of	5%	2%	0%	1%	92%	488
Lithuania	33%	0%	0%	29%	38%	420
Mexico	100%	0%	0%	0%	0%	900
Romania	58%	18%	0%	18%	5%	220
Russia	38%	1%	8%	28%	25%	347
Slovakia	86%				14%	116
Spain	86%	9%	0%	0%	6%	140
Sweden	100%	0%	0%	0%	0%	260
Ukraine	33%	9%	0%	26%	33%	363
United Kingdom	38%	0%	26%	0%	36%	488
United States of America	29%	10%	24%	18%	18%	111

TABLE 2.34. SIMULATOR INSTRUCTOR INITIAL TRAINING

Country	Classroom Hours	Laboratory/ Workshop Hours	Simulator Hours	Self-Study Hours	OJT Hours	Total Hours
Brazil	13%	0%	0%	0%	87%	1210
Canada	67%	0%	2%	16%	16%	322
China	32%	0%	14%	0%	54%	2800
Czech Republic	54%	2%	9%	4%	32%	1995
Finland	20%	0%	32%	0%	48%	620
France	100%	0%	0%	0%	0%	150
Germany	36%	6%	25%	13%	20%	5120
Hungary	4%	15%	19%	15%	46%	1040
Japan	7%	17%	55%	17%	3%	220
Korea, Republic of	5%	2%	0%	1%	92%	488
Lithuania	0%	0%	36%	43%	21%	336
Mexico	100%	0%	0%	0%	0%	1164
Romania	59%	0%	14%	14%	14%	296
Russia	37%	0%	48%	3%	12%	98
Slovakia	64%	0%	0%	0%	36%	220
Spain	27%	0%	13%	0%	60%	150
Sweden	33%	0%	29%	0%	38%	840
Switzerland	16%	0%	11%	36%	36%	550
Ukraine	14%	0%	13%	51%	22%	236
United Kingdom	30%	0%	24%	0%	47%	683
United States of America	23%	8%	24%	0%	45%	66

IAEA world survey on nuclear power plant personnel training [15]

A common operator training can be illustrated in the following picture:



The duration is approx. 18 months for the longest program for control room operators and other programs varies 6-12.

5.4 High-Level plan

Activity	Start	Start	Start
Contract date	2025-01-06		
First Concreate Date (Nuclear)	2027-07-01		
Fuel Loaded	2033-07-01		
Commercial Operation Date	2034-07-03		
Pre-Vendor selection			
Information to the public	2024-01-01		
Media strategy	2024-01-01		
Training/Information to Decisionmakers	2024-01-01		
Partnership with educational instiututions	2024-09-02		
Social engagement	2024-09-02		
EPC Contract in place	2025-01-06		
Management Training (Conceptual Design)	2025-01-06		
Basic Plant course	2025-01-06		
Basic Engineering Course	2025-01-06		
Technical Traning (Safety Analysis, Licensing, Codes&standards etc)	2025-01-06		
Construction phase			
Engaging key staff	2025-01-01		
Development of Training roadmap and training governance framework	2026-01-05		
Simulator Development	2026-08-03		
Analysis & Design of CR Operator training	2026-08-03		
Development of training material for CO Operator training	2027-08-02		
Development/Implementation of trainig platforms and tools	2027-08-02		
Training facility Design	2028-01-03		
Equipment installation phase	2028-10-02		
CR Operator reqruitment and On-boarding	2028-10-02		
General Employee Training (GET)	2028-10-02	Cadre 2, 3 and 4	
CR Operator initial Training	2029-09-03	2030-09-01	2031-09-01 2032-09-01
FSS installation	2029-02-05		
Commissioning phase	2030-01-01		
Field Operator Initial training (Detailed Design)	2030-01-01	Cadre 2, 3 and 4	
FO Training	2030-01-01	2031-01-01	2032-01-01 2033-01-01
Emergency Response Organisation Initial Training	2031-01-01		
Maintenence staff Initial training	2032-10-04		
Non operational Staff Initial training	2032-10-04	Re-Training annually	
Re-training (Detailed Design)	2031-10-01	2032-10-01	2033-10-01
CR Operators and Operational support	2031-10-01	2032-10-01	2033-10-01
Field Operators	2031-10-01	2032-10-01	2033-10-01
ERO	2031-10-01	2032-10-01	2033-10-01
Maintenence	2031-10-01	2032-10-01	2033-10-01
Fuel Loaded	2033-07-01		
Operational phase	2034-07-03		
Re-training (Actual Design)	2034-10-01		
CR Operators and Operational support	2034-10-01		
Field Operators	2034-10-01		
ERO	2034-10-01		
Maintenenece	2034-10-01		
Initial training (Actual Design)	2034-10-01		
CR Operators and Operational support	2034-10-01		
Field Operator Initial training	2034-10-01		
Maintenence staff Initial training	2034-10-01		
Emergency Response Organisation Initial Training	2034-10-01		
Non operational Staff Initial training	2034-10-01		

Generally speaking, a success factor is to take into account is to start a plan for building competence as early as possible in the process. In this rapport we have used some examples from IAEA and WANO that describes time tables for commissioning a new NPP. The result of this background materials, the high-level plan can be created.

6. AN ASSESSMENT OF AVAILABLE EDUCATION PROGRAMS

When it comes to recruitment of staff, educational background is important (see chap. 4.1). Norway has a long history of research and education in nuclear physics at universities and other institutes. This is both a prerequisite for recruitment and in the future potential as a partner/provider for training. For example, like shown in cap 5.3 Nuclear fundamentals should be a part of the initial training and a cooperation here could be useful.

In our assessment the available programs in Norway have good basis to supply nuclear professionals. They are international comparable to countries with developed nuclear industries. For example the Bachelor program in physics at University of Oslo, *Kjernefysikk og nukleærteknologi*, matches the Swedish programs at Uppsala Universitet, Kungliga Tekniska Högskolan, KTH and Chalmers University of Technology. The listed opportunities below are examples that are used and can also be used for future interest to look at.

- UiO Master in Nuclear physics: https://www.uio.no/studier/program/fysikk-master/studieretninger/kjerne-partikkelfysikk/
- UiO; BSc Kjernefysikk og nukleærteknologi: https://www.uio.no/studier/program/kjernefysikk-nukleartekno logi/
- UiO; MSc Nukleærteknologi: https://www.uio.no/studier/program/nukleartek nologi-master/
- NMBU; BSc Radioaktivitet og miljø: https://www.nmbu.no/studier/bachelor/radioaktivitet-og-miljo
- NMBU; BSc Miljøvitenskap (inkluderer studieretning Radioøkologi): https://www.nmbu.no/studier/bachelor/miljovitenskap
- NMBU; BSc Energi- og miljøfysikk (inkluderer kjernekraft): https://www.nmbu.no/studier/bachelor/energi-og-miljofysikk
- NMBU; MSc Nukleær og miljøvitenskap: https://www.nmbu.no/studier/master-2-aar/nukleaer-og-miljovitenskap
- NMBU; MSc Miljøfysikk og fornybar energi (inkluderer kjernekraft): https://www.nmbu.no/studier/master-5-aar/miljofysikk-og-fornybar-energi
- NMBU; MSc Miljøvitenskap (inkl radioøkologi): https://www.nmbu.no/studier/master-2-aar/miljovitenskap

7. AN ASSESSMENT OF THE FEASIBILITY OF RECRUITING EXPERTS FROM ABROAD

IAEA describes the following [4] "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 organisations to ensure that the right staff are attracted to, and retained in, the organisation."

Norway has a close connection to Sweden and the cultural gap between the countries is quite small. For a swede its common and easy to work and live in Norway. Staff that have been working in decommission of old NPPs in Sweden (R1, R2, O1 and O2) are absolutely a possible source to attract. We heard a lot of positive response to the news that you are looking at possibilities to build NPPs.

In Swedish nuclear business IFE in Halden is a well-known and honoured institution. At KSU along with other consultant and training providers like AFRY there is a lot of experience from cooperation with them.

Smart Innovation Norway works towards a green transition and new jobs through research, innovation, and scaling. The company is a non-profit research and innovation organisation that assists businesses and the public sector with networks, capital, and expertise in energy transition, applied artificial intelligence, and climate initiatives.

Germany has also been decommissioning NPPs during the last years and experts from them is another possible source to recruit from. The Barakah Nuclear Energy Plant in United Arab Emirates attracted staff from Europe and North America. There might be a possibility to recruit them or the ones who didn't jump on the train that time.

There are also possibilities to recruit expertise from the supplier of the technology chosen.

Following the analysis of the Knowledge, Skills and Abilities (KSAs) required by the organisation, it is possible to identify those industries and organisations whose workforce can already have some of the competences required for the nuclear industry. These sources include the following organisations:

- Organisations in the nuclear industry (e.g. research reactors, nuclear medicine)
- Organisations in other adjacent or relevant industries (e.g. energy, rail, petrochemicals, aviation or mega infrastructure)
- Military, especially navy personnel with nuclear propulsion experience.

8. ABBREVIATIONS

AIM	Abnormal Incident Manuals
CB	Configuration Baseline
CFT	Cold Functional Testing
CLG	Construction License Granted
COD	Commercial Operation Date
CR	Control Room
ECD	EPC Contract Date
EOF	Emergency Operations Facility
EPC	Engineering Procurement Construction contract
ERO	Emergency Response Organisation
FCD	First Concrete Date ("nuclear concrete")
FGC	First Grid Connection
FL	Fuel Loading
FME	Foreign Material Exclusion
FOAK	First Of A Kind
FOC	First Operation Cycle
FR	Fuel Receipt
FSAR	Final Safety Analysis Report
FSS	Full Scope Simulator
FTE	Full-Time Equivalent
GET	General Employee Training
HFE	Human Factors Engineering
HFT	Hot Functional Testing
HR	Human Resources
HR	Human Resources
I&C	Instrumentation and Control
IAEA	International Atomic Energy Agency

KSU	Kärnkraftsäkerhet och Utbildning AB
LER	License and Event Reports (to the regulator)
MCR	Main Control Room
NDE	Non-Destructive Examination
NEPIO	Nuclear Energy Programme Implementing Organisation
NMBU	Norges miljø- og biovitenskapelige universitet ()
NPP	Nuclear Power Plant
O&M	Operation and Maintenance
OHS	Occupational Health and Safety
OLG	Operating License Granted
PA	Project Approval
PAT	Power Accension Testing
PMO	Project Management Office
PR	Public Relations
QA	Quality assurance
QC	Quality control
R2OR	Roadmap to Operational Readiness (document by WANO)
SAT	Systematic Approach to Training
SMR	Small Modular Reactors
SRO	Senior Reactor Operator
T&Q	Training and Qualification
TSC	Tactical Support Centre
TSP	Training Support Partner
UiO	University of Oslo
WANO	World Association of Nuclear Operators

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