IAEA Nuclear Energy Series

No. NG-T-3.4

Basic Principles

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INDUSTRIAL INVOLVEMENT TO SUPPORT A NATIONAL NUCLEAR POWER PROGRAMME

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

IAEA NUCLEAR ENERGY SERIES No. NG-T-3.4

INDUSTRIAL INVOLVEMENT TO SUPPORT A NATIONAL NUCLEAR POWER PROGRAMME

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FOREWORD

One of the IAEA's statutory objectives is to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world." One way this objective is achieved is through the publication of a range of technical series. Two of these are the IAEA Nuclear Energy Series and the IAEA Safety Standards Series.

According to Article III.A.6 of the IAEA Statute, the safety standards establish "standards of safety for protection of health and minimization of danger to life and property". The safety standards include the Safety Fundamentals, Safety Requirements and Safety Guides. These standards are written primarily in a regulatory style and are binding on the IAEA for its own programmes. The principal users are the regulatory bodies in Member States and other national authorities.

The IAEA Nuclear Energy Series comprises reports designed to encourage and assist R&D on, and application of, nuclear energy for peaceful uses. This includes practical examples to be used by owners and operators of utilities in Member States, implementing organizations, academia, and government officials, among others. This information is presented in guides, reports on technology status and advances, and best practices for peaceful uses of nuclear energy based on inputs from international experts. The IAEA Nuclear Energy Series complements the IAEA Safety Standards Series.

There is growing interest in developing nuclear power owing to increasing energy needs, limitations in natural resources and concerns about climate change. However, the introduction and development of nuclear power is a major undertaking that requires building the necessary national infrastructure to construct and operate nuclear power in a safe, secure and technically sound manner. Many IAEA Member States that do not yet have nuclear power programmes have expressed their interest to the IAEA about the possibility of introducing nuclear power to help to meet their energy needs. To assist Member States, in 2015 the IAEA published IAEA Nuclear Energy Series No. NG-G-3.1 (Rev. 1), Milestones in the Development of a National Infrastructure for Nuclear Power, which describes 19 infrastructure issues that should be addressed in the three phases of development. The IAEA is also preparing a number of guides to address these issues.

Once a government makes a firm decision to proceed with the development of a nuclear power programme, national industries, such as the civil construction, electrical and mechanical industries, need to be developed. A key interested party in the successful construction and operation of the first nuclear power plant is the owner/operator. The IAEA has prepared a number of publications that provide guidance and advice with regard to the establishment of owner/operator organizations. This publication is intended to provide assistance in exploring the many considerations and decisions involved in preparing other national industries for participation in a nuclear power programme, including those that will participate in the construction and commissioning of the first nuclear power plant units in a Member State, as well as provide support to the owner/operator during operation.

The IAEA officer responsible for this publication was M. Yagi of the Division of Nuclear Power.

EDITORIAL NOTE

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1. INTRODUCTION

1.1. BACKGROUND

Nuclear power can play an important role in providing improved access to affordable energy on a sustainable basis. Developing a nuclear power programme is a major undertaking and involves many complex and interrelated activities of long duration — usually about 10–15 years. These activities involve, among others, planning, preparation and investment in a sustainable infrastructure that provides the legal, regulatory, technological, human resources and industrial support to ensure that nuclear power is used exclusively for peaceful purposes and in a safe and secure manner. Careful planning in the early stages of a programme across a wide range of national infrastructure issues can help to instil confidence in the States's ability to legislate, regulate, construct, and safely and securely operate a nuclear power plant.

The approach given in IAEA Nuclear Energy Series No. NG-G-3.1 (Rev. 1), Milestones in the Development of a National Infrastructure for Nuclear Power [1], hereinafter referred to as the Milestones approach, describes 19 infrastructure issues to be addressed during infrastructure development for a nuclear power programme. Early attention to all of these issues will facilitate the efficient development of a successful national nuclear power programme. Equally, a lack of appropriate attention to any of them may result in future difficulties that may significantly delay or otherwise affect the successful introduction of nuclear power.

National industrial involvement in emerging nuclear power States is one of the major areas of concern when developing a nuclear power programme. Many goods and services are required to construct a nuclear power plant and to support its operation. Industries are needed that can comply with strict codes and standards and rigorous quality programmes associated with these goods and services. Most States have an objective to increase national and local participation or to 'localize' those parts of industrial involvement where national industries can cost effectively achieve these high standards. This also requires States to fully formulate and establish:

— Policies for industrial capacity for participation in the nuclear power programme;
— Capacity building to learn the available and proven nuclear technologies for power production and non-power applications;
— Capabilities of the national industries to permit viable development of the nuclear power project, and subsequently to ensure the plant adheres to appropriate international standards;
— Partnerships to extend local involvement.

Countries embarking on the use of nuclear power therefore need to plan for the development of appropriate local industrial involvement that is able to support the national nuclear power programme and related projects.

In 1988, the IAEA published Technical Reports Series No. 281, Developing Industrial Infrastructures to Support a Programme of Nuclear Power: A Guidebook [2]. The present publication is intended to update the good practices provided in Ref. [2] in the context of the Milestones approach. Roles and responsibilities of governments, industries, utilities and other stakeholders are also explained.

In this publication, the term 'industrial involvement' is defined as the sum of the entire industrial capability required to support a safe and reliable nuclear power programme, of which a subset is 'local industrial involvement', provided by local or national organizations. Both concepts are important for a State considering a nuclear power programme. Industrial involvement is needed to meet the depth, breadth and quality of industrial capacity necessary for a nuclear power programme. Local industrial involvement is required to make well informed decisions about which parts of industrial involvement need to be developed locally. In this publication, the terms local and national are both used to indicate those organizations that operate solely within the Member State.

In most cases, local industrial involvement increases over the lifetime of a nuclear power programme. It is unlikely, for a variety of reasons, that the entire industrial involvement needed for a nuclear power programme will be supplied by local or national organizations. Of the 30 IAEA Member States that currently operate nuclear power plants, none has implemented industrial involvement solely through local or national organizations. One of the most compelling reasons to maintain a portion of the supply of goods and services from outside the country is cost effectiveness. In many cases, it is less costly to acquire a product or service from a specialized supplier outside the country than it is to develop the capability locally. Another reason may be the inability of local suppliers to meet the quality requirements for nuclear components. Similarly, the acceptance of intellectual property agreements as a condition of supply could be imposed by technology vendors and by hardware and software suppliers. Finally, the State's adherence to non-proliferation agreements may limit the involvement of national industries in fuel supply and reprocessing.

In a number of Member States, increasing national industrial involvement in the nuclear power programme developed over time has had spin-off benefits for other industrial sectors. These are attributable to the acquired technological capability and the high quality levels developed for the nuclear power programme.

This publication provides lessons learned from Member States on issues related to local industrial involvement for a nuclear power programme, including the use of national industry surveys, localization plans and technology transfer.

In support of a country's industrial involvement, there needs to be a general infrastructural framework within which industries can operate. These supporting infrastructures have a direct influence on the response of national industries to the requirements of nuclear technology. The industrial sector cannot develop if there are not any qualified personnel to staff the necessary functions. Thus, a human resource development infrastructure needs to be established to provide the relevant education, training and development support. Similarly, industry cannot operate without a legal framework that establishes regulations, directives, codes and standards, licensing, quality assurance and enforcement. In addition, communications and transport are vital to industry, as well as R&D infrastructures and a legal framework to regulate the whole sector.

Figure 1 shows the relationships between the total industrial involvement needed for a nuclear power programme and local industrial involvement. The solid lines show the relationship when the first nuclear power plant units are constructed and commissioned. As the nuclear power programme matures, local industrial involvement expands to take on a greater percentage of the total industrial involvement (dotted line). This expansion will depend on a number of factors, including government policies in support of the nuclear power programme, the number of nuclear power plant units being constructed and technology transfer agreements. Figure 1 also shows that there are normally spin-offs for local industry as a result of participation in the nuclear power programme.

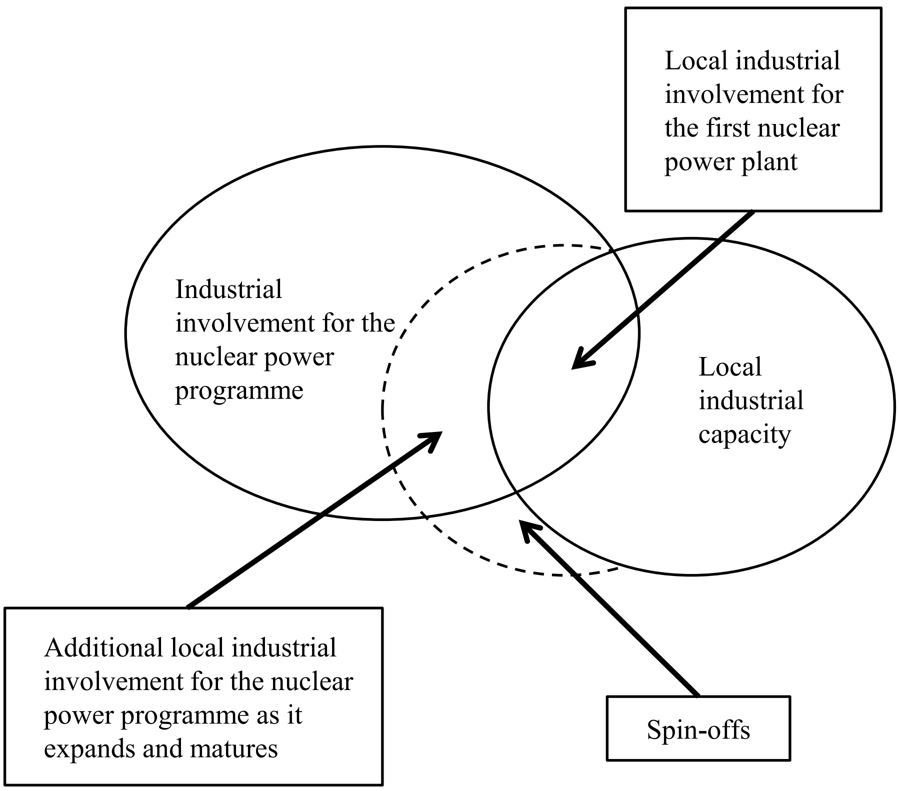

FIG. 1. Local industrial involvement for a nuclear power programme.

According to Ref. [3], the following nuclear technologies have been applied to areas outside the nuclear power programme:

— Seismic response technology, which is used in base isolated foundations for buildings;
— Remote controlled safety inspection technology used in the maintenance of ships;
— Non-destructive inspection technology, such as X ray and neutron radiography, gamma ray spectrometry, and ultrasonic, acoustic and associated imaging technologies;
— Hot laboratory equipment, such as remotely manipulated robotics and devices for harsh environments;
— Waste management technology used in the solidification of sludge and ashes from incinerators, and high efficiency filters for desalination;
— Laser techniques, such as isotope separation, laser cutting and improving residual stress, can be used in modelling and simulation techniques (fluid dynamics, thermohydraulics, and material and component behaviour).

In accordance with its mandate to ensure that Member States use nuclear energy efficiently, safely, securely and with minimal proliferation risks, the IAEA developed the Milestones approach to provide a method to plan appropriately, build adequate human resources and infrastructure, establish an effectively independent regulatory body and establish a sound legal framework including adherence to relevant international legal instruments. The Milestones approach for the development of the national infrastructure for a nuclear power programme can be divided into three phases [1]:

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

The completion of each phase is marked by a specific milestone at which the progress of the development effort can be assessed and a decision can be made to move on to the next phase. These milestones are [1]:

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

Figure 2 shows the milestones for developing a nuclear power infrastructure. Representatives of countries using an intergovernmental agreement, strategic partner and/or sole supplier, in lieu of a competitive process, are to interpret “ready to invite bids” as “ready to negotiate a contract for the first nuclear power plant” and references to “bid invitation specifications (BISs)” are to be interpreted as “nuclear power plant specifications for negotiating with a sole supplier”.

The Milestones approach also identifies, for each milestone, 19 infrastructure issues that need to be considered [1]:

— National position;
— Nuclear safety;
— Management;
— Funding and financing;
— Legal framework;
— Safeguards;
— Regulatory framework;
— Radiation protection;
— Electrical grid;
— Human resource development;
— Stakeholder involvement;
— Site and supporting facilities;

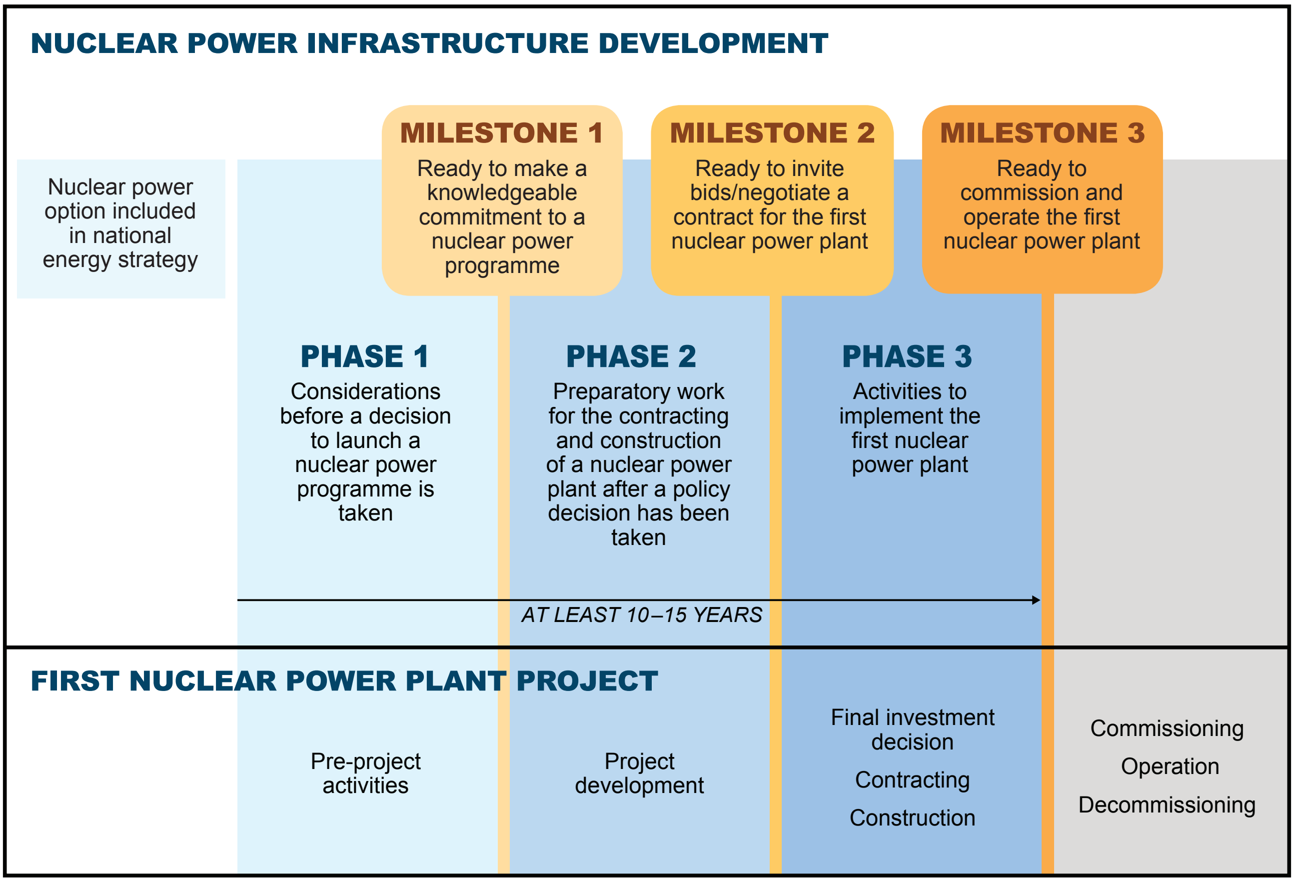

FIG. 2. Nuclear infrastructure development programme [1].

- — Environmental protection;
- — Emergency planning;
- — Nuclear security;
- — Nuclear fuel cycle;
- — Radioactive waste management;
- — Industrial involvement;
- — Procurement.

Industrial involvement relates directly to the milestones listed above, as well as to human resource development, programme management and national policies (for further information on these individual milestones, refer to the bibliography in Ref. [1]).

To systematically reach the objective of establishing a growing industrial involvement programme that is able to properly support the first and any additional nuclear power plants after it, an integrated method in line with the Milestones approach is suggested:

(a) By Milestone 1, be ready to make a knowledgeable commitment to a nuclear power programme, which includes the following actions:
- — To establish a strategy for optimizing local industrial involvement;
- — To conduct an initial survey of local industrial organizations;
- — To initiate dialogue — owner/operator (if determined) with suppliers, and government to government;
- — To develop a localization plan as part of the prefeasibility study of the nuclear power programme.

(b) By Milestone 2, be ready to invite bids/negotiate a contract for the first nuclear power plant, which includes the following actions:
   - To expand the survey of local industries, including audits of their capabilities;
   - To continue dialogue — owner/operator (if determined) with suppliers, and government to government;
   - To determine localization provisions to be included in turnkey contracts.

(c) By Milestone 3, be ready to commission and operate the first nuclear power plant, which includes the following actions:
   - To implement localization plans including technology transfer;
   - To establish the supply chain;
   - To conduct vocational and other training of the local workforce.

Section 6 provides further information on building local industrial involvement in each of the phases of the Milestones approach.

1.2. OBJECTIVE

The purpose of this publication is to assist Member States in:

(a) Establishing national policies and strategies for local industrial involvement that supports nuclear power programmes:
   - To identify, assign and promote the roles and responsibilities of the government and potential national suppliers;
   - To identify and evaluate key issues and risks that affect decisions on the suitability of local industrial capacity;
   - To formulate the long term vision and strategic plans for developing appropriate industrial involvement.

(b) Assessing their available industrial supply options and capabilities, including the national supply chain:
   - To identify processes and human resource management programmes associated with industrial involvement;
   - To establish a management framework for the planning, control, implementation, verification and coordination of activities.

This publication describes the methodology and framework necessary to enable Member States to plan, develop and assess a detailed and specific national process to meet the needs in all aspects of local industrial involvement within the three phases of the nuclear power development outlined in the Milestones approach. This approach also emphasizes the role of the government in creating incentives for the involvement of potential national suppliers, including its role in creating a climate of confidence with regard to programme continuity.

1.3. SCOPE

The publication applies to the planning and implementation of industrial involvement activities related to the introduction or re-establishment of a national nuclear power programme. Guidance provided here, describing good practice, represents expert opinion but does not constitute recommendations made on the basis of a consensus of Member States.

1.4. STRUCTURE

Section 2 describes typical facilities required to support a nuclear power programme. Section 3 provides information on industrial involvement for a nuclear power programme, with an emphasis on those aspects unique to nuclear power. Section 4 explores factors which affect local industrial involvement, while Section 5 discusses technology transfer and intellectual property issues associated with industrial involvement. Section 6 provides a summary of the steps required when the government and industrial organizations in Member States reach decisions appropriate to local industrial involvement in support of nuclear power programmes. Appendix I provides a checklist of the actions during Phases 1–3 associated with industrial localization and indicates which organizations are responsible. Appendix II provides data on the physical structures, systems and components (SSCs) of a nuclear power plant and the typical human resources involved.

1.5. USERS

This publication is intended for decision makers, senior managers and advisors, and technical specialists from:

— Governmental organizations, operating organizations and industries of Member States interested in developing their first nuclear power programme;
— Organizations involved in strategic planning and contractors providing services to the prospective nuclear industry;
— Regulatory bodies, governmental authorities and agencies;
— Other relevant stakeholders.

It primarily addresses newcomer countries, but may also be useful to countries that are expanding their nuclear power programmes.

1.6. DEFINITIONS

Industrial involvement — and the subset local industrial involvement, which is provided by local or national organizations — covers a very broad range of engineering, construction, commissioning, operation and maintenance activities that are typical of high capital value infrastructure development programmes, including:

— All essential support services in the design, delivery, construction, operation, maintenance and upgrade of equipment throughout the lifetime of a facility, and its eventual decommissioning;
— A comprehensive range of engineering skills, such as mechanical, electrical, instrumentation and control, information technology, civil engineering, applied sciences, management and project management, in which all levels are represented from craftspeople to technicians, to graduates or professionals;
— Special attention to the application of codes and standards, quality management and cost and schedule control in order to reach the required quality and performance levels of the nuclear industry;
— A control system to correctly integrate design and construction that includes performance assessment, event feedback and root cause analysis, and that is capable of recommending effective and timely corrective actions.

2. FACILITIES TO SUPPORT A NUCLEAR POWER PROGRAMME

2.1. INTRODUCTION

A necessary prerequisite for industrial involvement that is able to support a nuclear power programme is an awareness of the facilities required. Figure 3 shows the nuclear fuel cycle and associated nuclear fuel cycle facilities.

It should be noted that the only facility shown in Fig. 3 that needs to be physically located in the country is the nuclear power plant. International suppliers, using their existing facilities, can provide the remainder of the fuel cycle products. A brief description of some of the necessary facilities and processes follows.

2.2. NUCLEAR POWER PLANTS

2.2.1. Nuclear island

The nuclear island includes the nuclear reactor, with safety and protection systems and radiation monitoring.

2.2.1.1. Instrumentation and control

Essentially, the purpose of the instrumentation and control system architecture is to enable and ensure safe and reliable power generation. Therefore, much attention needs to be given to projects involving the design, testing, operation, maintenance, licensing and modernization of instrumentation and control systems.

2.2.1.2. Balance of plant

The turbine generator and the balance of plant (BOP) components are basically the same as those in conventional fossil fuelled power plants operating at saturated steam conditions.

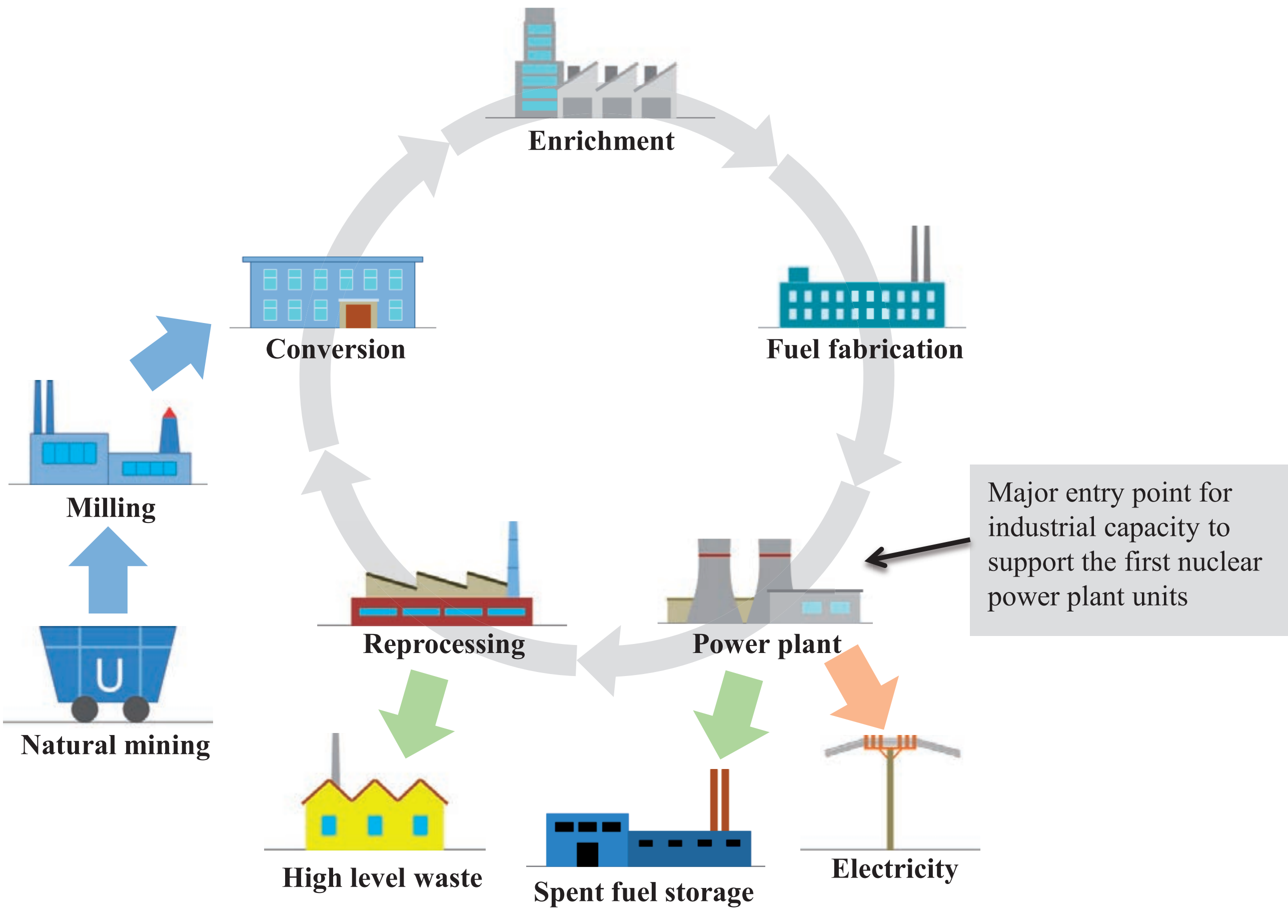

FIG. 3. Nuclear fuel cycle and associated facilities (courtesy of T. Bessex).

2.2.2. Temporary storage of spent fuel and radioactive waste

On the site, provisions are made for temporary storage of spent fuel and other radioactive waste and materials. The fuel is typically stored in water filled pools that are located near the reactor.

2.2.3. Structures, systems and components

Appendix II provides a summary of the SSCs needed for the nuclear island, the BOP, the temporary spent fuel storage and the radioactive waste facilities for a typical 1000 MW unit, as well as an estimate of the associated human resources required to operate them.

2.3. OTHER FUEL CYCLE FACILITIES[1]

Nuclear fuel is the most important reactor consumable throughout the lifetime of a plant. The nuclear fuel cycle starts with initial exploration, mining and refining of the uranium ore; it continues through to fuel fabrication; and after the fuel has been used during reactor operation, it moves to the spent fuel pool. There are currently two different approaches to managing spent nuclear fuel. The first approach is the once through cycle, where spent fuel is considered to be high level waste and is directly disposed of after cooling in the spent fuel pool and extended interim storage. The second approach is the reprocessing or recycling option, where the spent fuel is considered to be valuable material because more than 96% of its content could be used to fuel the reactor again. Most new nuclear power programmes rely upon established vendors to supply fuel under special licences. Fuel cycle facilities may include the following.

2.3.1. Uranium mining facilities

Excavation and in situ leach mining are used to recover uranium ore. Excavation can be either underground or above ground in an open pit mine. An increasing proportion of the world’s uranium now comes from in situ leach mining, where oxygenated groundwater is circulated through a very porous ore body to dissolve the uranium oxide and bring it to the surface. In situ leach mining may be conducted with a solution of a weak acid or alkaline to keep the uranium dissolved. The uranium oxide is then recovered from the solution as in a conventional mill.

2.3.2. Uranium milling facilities

The natural uranium ore may contain as little as 0.1% uranium, or even less. In a mill, usually located near the mine, uranium is extracted from the crushed and ground-up ore by leaching, in which either a solution of a strong acid or alkaline is used to dissolve the uranium oxide. The uranium oxide is then precipitated and removed from the solution. Uranium milling produces a uranium oxide concentrate, which is transported from the mill to the processing plant. It is sometimes referred to as yellow cake, and generally contains more than 80% uranium.

The rejects of the milling, containing most of the radioactive material and nearly all the rock material, become tailings, which are placed in engineered facilities near the mine (often in mined out pits). Tailings need to be isolated from the environment because they contain toxic materials and long lived radioactive materials in low concentrations. However, the total quantity of radioactive elements is less than in the original ore, and most of their collective radioactivity will be much shorter lived.

2.3.3. Conversion facilities

At a conversion facility, the uranium oxide is first refined to uranium dioxide, which can be used as the fuel for reactors that do not require enriched uranium. Most of the uranium dioxide is converted into gaseous uranium hexafluoride, which is then drained into strong metal cylinders, where it solidifies. The main hazard at this stage

[1] This section is based on http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/introduction/nuclear-fuel-cycle-overview.aspx

of the fuel cycle is the use of hydrogen fluoride in the conversion process. The cylinders are then transported to the enrichment plant.

2.3.4. Enrichment facilities

The most common process used to enrich uranium is the centrifuge method. Uranium hexafluoride gas is used as a feed in this process. The 1% mass difference between fissile ^{235}U and the more naturally abundant, non-fissile uranium ^{238}U is used to extract the fissile material in centrifuges. The process separates the gaseous uranium hexafluoride into two streams: one stream is enriched to the required level of ^{235}U, known as low enriched uranium; and the other stream is progressively depleted into material with a lower content of fissile uranium, called 'tails' or simply depleted uranium. The product obtained at this stage of the nuclear fuel cycle is enriched uranium hexafluoride, which is then converted into low enriched uranium oxide to produce nuclear fuel.

2.3.5. Fuel fabrication facilities

Reactor fuel is generally in the form of ceramic pellets. These are formed from pressed uranium oxide, which is sintered (baked) at a high temperature (>1400°C). The pellets are then encased in metal tubes to form fuel rods, which are arranged into a fuel assembly ready for introduction into a reactor. The dimensions of the fuel pellets and other components of the fuel assembly are precisely controlled to ensure consistency in the characteristics of the fuel. In a fuel fabrication plant, great care is taken with the size and shape of processing vessels to avoid criticality (a limited chain reaction releasing radiation).

2.3.6. Fuel reprocessing facilities

For a light water reactor employing enriched uranium fuel, used fuel is about 94% ^{238}U, but it also contains almost 1% ^{235}U that has not fissioned, almost 1% plutonium and 4% fission products, which are highly radioactive, along with other transuranic elements formed in the reactor. In a reprocessing facility, used fuel is separated into its three components: uranium, plutonium and waste, which contains fission products. Reprocessing enables recycling of the uranium and plutonium into fresh fuel, and produces a significantly reduced amount of waste (compared with treating all used fuel as waste). Reprocessing is currently an internationally available service, and, initially for emerging nuclear power States, it is a cost effective method of dealing with this aspect. Member States are not obliged to build reprocessing capacity, and it can be subcontracted. This is also the case for enrichment capacity, where such services exist in some countries that are supplying Member States.

2.4. RADIOACTIVE WASTE MANAGEMENT FACILITIES[2]

Waste from the nuclear fuel cycle is categorized as high, medium or low level waste, depending on the amount of radiation they emit. Treatment and conditioning processes are used to convert radioactive waste material into a form that is suitable for its subsequent management, such as transport, storage and final disposal. Conditioning processes such as cementation and vitrification are used to convert waste into a stable, solid form which is insoluble and which will prevent dispersion to the surrounding environment. The selection of processes used depends on the level of activity and type (classification) of waste. Each State has its own nuclear waste management policy, and its national regulations also influence the approach taken. Waste disposal facilities are designed and constructed in a manner that is consistent with their risks. Low level waste is typically disposed of in surface or near surface facilities that are engineered and constructed to keep the waste isolated from the environment, including prevention from entering groundwater. High level waste requires more sophisticated disposal methods. The high level waste facilities that have so far been designed and constructed use deep geological storage in facilities that provide multiple engineered barriers between the waste and the environment.

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[2] This section is based on http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/introduction/nuclear-fuel-cycle-overview.aspx

2.5. GRID, ELECTRICAL AND DISPATCHING FACILITIES

The interaction between the grid and the nuclear power plant is affected by several factors:

(a) The size of the plant output compared to the grid size;
(b) The location of the plant on the grid;
(c) The reliability of the grid interconnections.

Most commercially available reactors are large, and may have economic impacts as a result of the need for additional spinning reserve, transmission lines and interconnecting equipment that may be required to strengthen the grid for accepting the large output of a single nuclear power plant unit. The grid also needs to be able to provide the plant with an external power supply that is independent of the plant output (for further information on this topic, see Ref. [4]).

2.6. SECURITY AND PHYSICAL PROTECTION OF NUCLEAR FACILITIES

Plant security is ensured primarily through features that are built into structures, the configuration of the systems and layout of the buildings, and the barriers and security systems restricting access to the plant. Even though physical protection design requirements are influenced by site location, the final security measure is through the regional and national security agencies that monitor the potential sources of threats against the critical facilities (e.g. nuclear power plants) and that devise and implement plans and procedures to counter threats (for further information on this topic, see Ref. [5]).

2.7. STANDARD CALIBRATION LABORATORY FACILITIES

The safe construction and operation of nuclear power plants require devices for reliable nuclear, thermal, hydraulic and mechanical measurements. These devices are calibrated and used during the construction, erection and commissioning steps, and are tested and recalibrated periodically thereafter. The supplier typically provides such calibration laboratory services during these steps as part of the contract. However, provisions need to be established — primarily by the operating organization — to provide such facilities and services during the operational phase.

2.8. NUCLEAR POWER TECHNOLOGY

Awareness of the differences and similarities between nuclear power plants and conventional power plants is helpful when considering how to optimize local industrial involvement in the nuclear power programme.

2.8.1. Similarities in energy production

A nuclear power plant is mainly used for electricity production and therefore possesses common attributes with conventional electrical power plants. The similarities between a nuclear power plant and a conventional power plant include:

— Heat is produced in both processes.
— The heat produced generates steam, which passes through a turbogenerator unit, which produces electricity.
— Both types of plant are connected to, and interact with, the national electric power generation and distribution system in a similar manner.
— Both types of plant require similar heavy equipment (e.g. steam generators, turbines and generators).
— Both types of plant have interrelated supply chains and industrial involvements.

2.8.2. Unique characteristics of the application of nuclear power

The unique characteristics of nuclear power plants include:

- Nuclear energy generation based on the controlled fission of reactor fuel;
- The production of intense radiation (direct radiation) from the nuclear chain reaction in the reactor core;
- The production of radioactive material in the reactor core;
- The continuation of heat generation after the shutdown of the nuclear chain reaction (decay heat).

To ensure the highest standards of safety and security, measures are to be taken:

- To control the radiation exposure of people and the release of radioactive material into the environment;
- To restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation;
- To mitigate the consequences of such events if they were to occur, by adhering to the highest level of quality assurance in design, manufacture, construction and operation of nuclear systems.

In order to minimize the likelihood and consequences of accidents, absolute safety and reliability requirements are necessary for:

- Safety related SSCs;
- The technologies used, which need to be proven or qualified by testing, analysis and experience, and which need to meet regulations or criteria with appropriate safety margins;
- Designs, which need to possess inherent safety features;
- Emergency power supplies;
- The design of the nuclear island to limit personnel exposure and to protect the public from ionizing radiation;
- Radioactive waste management, including adequate storage, treatment and disposal.

In addition, it is essential to establish and maintain a safety culture that considers nuclear safety as an overriding need, and to make effective use of international sharing of operating experiences and lessons learned from events related to the safety of nuclear power plants and other nuclear facilities.

3. INDUSTRIAL INVOLVEMENT

3.1. INTRODUCTION

This section addresses industrial involvement during the planning stages of a nuclear power programme (Phases 1 and 2 of the Milestones approach), during the construction and commissioning of the first nuclear power plant (Phase 3) and during the plant operation phase (typically 40–60 years after the initial commercial operation). Specific development steps of the national share of industrial involvement during these phases are discussed in Section 4.

Local suppliers may be either invited to expand their capabilities to include nuclear or to build up their nuclear capability from scratch. Opposition and reluctance from potential local suppliers are to be expected owing to likely equipment upgrades and training required to meet the high quality standards for manufacturing nuclear power plant equipment, and the prospect of participating in an industrial project of large economic significance, especially if the nuclear development programme in the country is limited to only one or two plants. Local suppliers may not be able to obtain a return on their investments if the scope of supply is limited and the intervals between orders are unsustainable.

The technology involved in the construction of a nuclear power plant is similar in many respects to that required for building fossil fuelled plants and chemical process plants, although there are areas where specialized technology is utilized. This includes the manufacture of reactor components, the use of specialized in-core materials based on zirconium, and the use of fuel assemblies, reactor control devices and computerized control systems. There are greater differences in the industrial involvement between nuclear and conventional power plants in support of plant operation. This is largely due to the need to protect the owner/operator and the public from ionizing radiation resulting from nuclear fission and partly due to the specific technology required to harness the heat released in the reactor, which is used to generate electricity. The specific features of nuclear power plants require the use of many advanced technologies to achieve a high degree of safety and reliability:

(a) The high quality standards for the design, manufacture and construction of SSCs associated with nuclear safety;
(b) The use of special materials such as zirconium and nickel alloys with very low limits for cobalt impurities;
(c) The unique design of nuclear safety systems, which need to instantly shut down the nuclear reactor in an emergency, to cool it and to contain the associated ionizing radiation;
(d) The unusually large size and weight of some equipment;
(e) The long construction schedules and long lead manufacturing times of the main components, which may control the critical path in many areas;
(f) The use of advanced manufacturing techniques and construction methods to control upfront capital and financing costs and to remain competitive;
(g) The particularly high level of discipline required at all levels to implement a safety culture and to apply it to the operating organization and the entire supply chain.

Groups that typically become involved in a nuclear power programme include the following:

- Engineering companies;
- Manufacturing companies;
- Civil construction and system assembly companies;
- Services;
- Operation and maintenance companies;
- Technical support organizations (TSOs).

3.2. CONTRACTUAL ARRANGEMENTS

There are several types of business, contractual and industrial arrangement for building a nuclear power plant. One common option is a turnkey engineering, procurement and construction (EPC) contract, where the main contractor oversees the construction of the nuclear power plant, has complete responsibility for construction — from site preparation to commissioning of the nuclear power plant — and finally hands the plant over to the owner/operator after satisfactory demonstration of its operation at its rated capacity.

However, several nuclear power plants have been constructed under another type of arrangement called an engineering, procurement and construction management (EPCM) contract, in which the owner/operator manages the whole project. In comparison with an EPC contract, an EPCM contract gives the owner/operator more involvement in, or control over, the design and construction of the nuclear power plant and procurement of equipment and suppliers. The owner/operator can be assisted by partnering with an experienced firm as the EPCM contractor (this is usually a consulting firm or international utility).

There are several differences between EPC and EPCM contracts, but the primary difference is that in an EPCM contract, the owner/operator bears the risk of completion of the project. As EPC contracts are more common, this publication will focus primarily on them.

The owner/operator holds the ultimate responsibility for the safety aspects of the project and for ensuring that the construction of the plant meets the necessary quality and safety standards. The owner/operator will need to ensure that the national safety requirements are understood throughout the supply chain.

Therefore, the owner/operator oversees the project and needs to be knowledgeable and capable to ensure that the suppliers meet the established quality standards and regulatory requirements for the manufacturing of SSCs associated with reactor safety. In addition, once the plant is operational, the owner/operator will have responsibility for the sustainability of the supply chains for long term operation. This applies to goods and services provided by national and local suppliers, as well as those procured from foreign suppliers.

3.3. COMPANIES AND ORGANIZATIONS

This section provides an overview of the role that each type of company listed in Section 3.1 plays in the first nuclear power plant project. Figure 4 shows the sequence of this involvement.

3.3.1. Engineering companies

Engineering companies design and engineer nuclear power plant SSCs to deliver defined functions and performance targets that meet all the system requirements and individual component specifications. System designers meet design requirements through the integration of equipment, energy sources and adequate controls. For conventional equipment and systems in the BOP of a nuclear power plant, national companies with experience in the design and engineering of conventional thermal power plant systems should be capable of participating in the design function. They could also engage in the detailed design of certain safety related systems in the nuclear island.

In the design phase of a nuclear power project, the term ‘engineering’ usually covers the activities of both the basic and the detailed design (performed in part, or entirely, by the primary technology vendor).

During the project implementation phase, engineering activities are often assigned to a reputable architect–engineering firm, acting as the main contractor. Sometimes, the architect–engineer or main contractor is part of, or associated with, the technology vendor organization. More often, the architect–engineer or main contractor is a different organization specializing in the construction and commissioning of nuclear power plants. This does not mean acting in isolation. The technology vendor and the architect–engineer need to cooperate and even to integrate their engineering deliverables and milestones and those of the main equipment manufacturers if the project is to be successful.

The technology vendor typically performs basic engineering, but, depending on the contract, the architect–engineering firm or the technology vendor and its associates perform the detailed engineering (either entirely or partially). Detailed engineering, or site specific engineering, is the engineering required for adaptation of the standard or reference design to meet the specific site conditions, all local laws and regulations and the customer’s special design requirements. For example, work specific to site conditions involves specialized areas such as the study of the seismic ground motion at the specific nuclear power plant site and the seismic response spectra calculations for the various floor elevations in the plant. Detailed engineering work is also needed for standard reactor designs with generic licensing certifications.

From the SSC design viewpoint, structural and system stress analysis, system thermohydraulic analysis and the study of emergency and abnormal behaviours, in what is usually referred to as safety analysis, are performed.

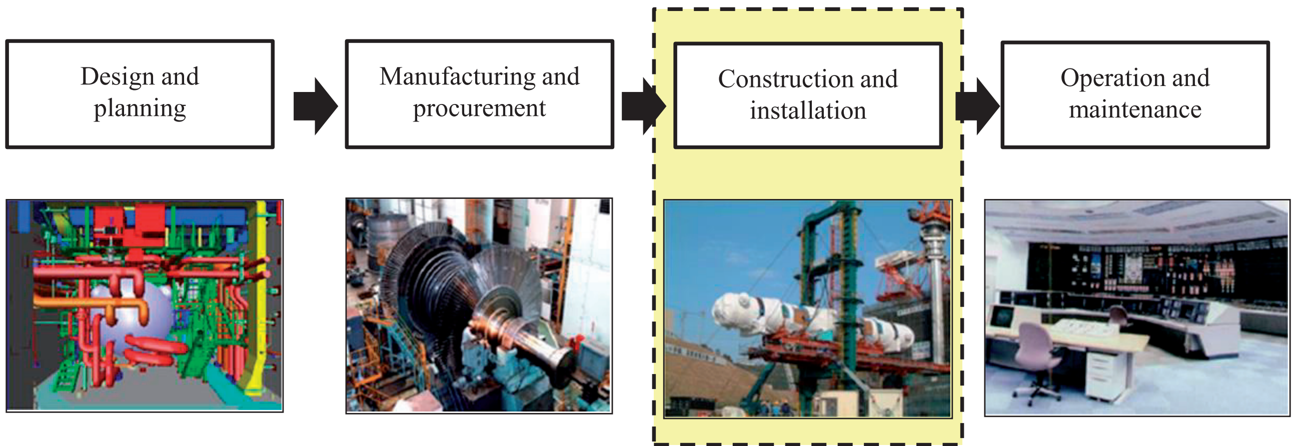

FIG. 4. Steps in nuclear power plant development.

Recently, the trend has been, particularly for turnkey contracts that are more frequent for first nuclear power plant projects in a country, for the owner/operator to award an EPC contract to one supplier, or consortium, that combines the technology vendor and architect–engineer tasks described above. The resources required to develop a basic engineering design include:

- Civil designers of nuclear power plants for the design of the site, buildings and structures;
- Mechanical designers of nuclear power plant systems for the design of piping and pipe support systems;
- Equipment engineers to create equipment specifications and data sheets to be used in procurement and in contract negotiations;
- Electrical designers for the design of electrical equipment, wiring and lighting;
- Computer aided design and drafting technicians;
- Technical reference material (including the reference design documentation, methodologies and criteria if the new design is based on the design of a similar plant or existing technology);
- Computational software and hardware.

Basic construction and project management resources include:

- Planners and schedulers;
- Quality assurance, quality management and quality surveillance technicians;
- Technicians for material management system software;
- Documentation control and approval software technicians;
- Construction supervisors, welders, pipe fitters, instrument calibrators, crane operators and non-destructive examination technicians.

Typical end products of the engineering design functions are a three dimensional model, general arrangement drawings, tendering drawings and equipment specifications to complement the requisition packages against which the equipment and materials are purchased. In addition, in the detailed engineering phase, all of the special nuclear, safety engineering and analysis documentation required to obtain a construction licence is prepared.

During construction, the term engineering is used to indicate technical and design support to construction contractors. It is also used to indicate field engineering, which supports installation, initiates all field changes and also involves engineering assistance to commissioning activities.

The coordination role of all these engineering functions is the responsibility of project engineering and project management. These terms are often used to describe general engineering management tasks such as coordinating and expediting the various engineering disciplines, planners, installers and material management professionals, so that they may all be integrated efficiently and coherently.

After the systems and areas are turned over from construction to operation, engineering takes the form of technical support for plant operation and plant life management. The functions in support of operation are usually carried out by engineering companies or by specialized groups within engineering companies, often referred to as TSOs.

3.3.2. Manufacturing companies

The equipment and materials used in the construction of a nuclear power plant cover a wide range of complexity and required quality. They range from conventional rebar steel to specialized steels, and from high nickel content alloys to zirconium alloys. Although much is conventional power plant equipment, in many cases the standard of quality exceeds conventional power plant requirements. This is particularly true of the components for the reactor core. The costs of the equipment, components and materials in a nuclear power plant represent approximately 30–40% of the overall cost of the plant.

For construction companies and component manufacturers of BOP equipment, local manufacturers with experience in manufacturing thermal power plant equipment can be qualified to manufacture equipment for the nuclear power plant if they can meet reliability targets and other conventional manufacturing requirements. For components in the nuclear island, manufacturers with nuclear qualification stamps and specific experience in manufacturing to nuclear codes and standards are preferred. However, local manufacturers would need to acquire the necessary experience, for example through partnerships with experienced suppliers, in order to produce components that are compliant with nuclear codes and standards.

A qualification programme for local suppliers would entail the development of proper management system documentation, facility modifications or upgrades to comply with International Organization for Standardization (ISO) standard 9001:2015 [6] and the establishment of a nuclear culture mindful of nuclear specific quality management requirements (e.g. IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [7], and comprehensive safeguards agreements). The organizations which establish such technical guidelines, codes and standards include:

— AFSEN;
— American Society of Mechanical Engineers (ASME);
— Japan Society of Mechanical Engineers (JSME);
— Nuclear Safety Standards Commission (Kerntechnischer Ausschuss, KTA).

Among these, ASME Section III [8] is the code most commonly used for the design, verification, fabrication and testing of a nuclear safety system. The staff involved in design and manufacture would have to be formally trained in the applicable codes and standards.

3.3.3. Civil construction and system assembly companies

About 30% of the total nuclear power plant investment cost is typically civil construction and erection on-site, including:

— Site excavation;
— Construction utilities and support infrastructure;
— Construction itself, which encompasses civil work and system installation comprising mechanical, electrical and instrumentation and control components;
— Commissioning and startup of the plant.

Similar to engineering, the company with overall responsibility (the primary or main construction contractor) for the construction of a nuclear power plant needs to have previous experience with nuclear power plant projects, since it will have the necessary skills and be familiar with the more stringent nuclear standards. However, local companies with experience in the construction of ports, complex buildings and hydro projects should not be excluded. They may be considered as subcontractors or partners in a joint venture for BOP structures and other auxiliary or supporting facilities, such as administrative buildings, training centres and switchyards. If the nuclear power programme foresees a number of nuclear power plant units, local companies may have a chance to develop sufficient capability to qualify for an increasing scope in construction and commissioning as the programme proceeds beyond the first unit (for further information on the management of nuclear power plant construction, see Ref. [9]).

Construction workers hired without previous nuclear construction experience will need additional training and oversight by supervisors to learn how to comply with nuclear specific standards. Construction equipment and methods used for much of the nuclear power plant structures are quite similar to those used for other large industrial projects, such as conventional power plants. However, more stringent standards are applied to areas such as welding, concrete mixing and pouring, non-destructive examination quality hold points and surveillance.

It is not uncommon in nuclear power construction projects that new roads, harbours or docking facilities become necessary to facilitate the delivery of heavy equipment and material from foreign suppliers and from domestic manufacturers to the project site. The designers of such infrastructure have to take into account both the weight and dimensions of the components involved. A turbine generator rotor can weigh several hundred tonnes; a reactor vessel or a steam generator may be as long as 20 m. Bridges and culverts have to be checked for load carrying capacity. Road designs need to be checked for obstructions such as tunnels, projecting rocks and the presence of transmission lines. In most cases, even with well developed access facilities, access routes to the new site may need to be upgraded. This could be a major project in itself, outside the scope of the EPC contract for the nuclear power plant, and it is the responsibility of the owner/operator and local or national authorities. The overall principles to follow in the design or upgrade of such infrastructure include the following:

- During construction, reliable access to the nuclear power plant site is necessary in all phases of the project for large and heavy equipment, either by water or land.
- Sea routes require adequate docking facilities and access roads for the successful delivery of heavy equipment to lay down areas or storage spaces.

Accessibility resources may include:

- Land and railway routes with sufficient bridge and tunnel clearance for large loads;
- Deep harbour access for large ships, and adequate heavy lift cranes and platforms to unload equipment from ships;
- Special and customized transport equipment for the delivery of extra heavy and extra large modules and components;
- In some cases, very heavy lift cranes for the handling of modules and large components at the site.

3.3.3.1. Commissioning phase

Conceptually, the commissioning of a nuclear power plant is similar to the commissioning of conventional power plants and other industrial facilities. Commissioning requires demonstration in the field that the SSCs are fit for the purpose and function indicated in their design documents. After core loading, the nuclear testing that takes place is unique. However, the means for commissioning a nuclear power plant are similar to those used in conventional plants and other industrial facilities, only more rigorous. Test procedures and results need to be thoroughly and precisely documented and reported to the nuclear regulatory body (NRB) in order to obtain a licence to operate the facility.

The following four basic phases typically cover the commissioning stage of a nuclear power plant [10]:

- Phase A: Pre-operational tests, including cold performance tests and hot performance tests.
- Phase B: Initial fuel loading and subcritical tests.
- Phase C: Initial criticality and low power testing.
- Phase D: Power ascension tests.

The acceptance of a nuclear power plant, or of parts of it, by the owner/operator indicates the transfer of responsibility from the contractor or vendor to the utility. Another type of acceptance concept is the transfer of responsibility of the whole plant at a suitable moment.

Commissioning is usually the responsibility of the owner/operator and of the technology vendor (precise arrangements will depend on the contract). Commissioning of the mechanical, electrical and instrumentation systems is conducted in parallel with the assembly and installation of other systems. As some systems are assembled, others are completed, and as soon as they are turned over, their commissioning can start.

Non-nuclear tests are conducted first. However, prior to non-nuclear plant testing (phase A), commissioning needs to be completed. Similarly, low power tests are conducted first, and the permission to conduct higher power tests is only given if the results of the preceding tests and examinations are acceptable.

As components are manufactured to drawings and specifications, checking that the components conform to the intention of the designer requires the measurement of characteristics such as dimension, weight, temperature and chemical composition. Checking that the components have been correctly manufactured involves both destructive and non-destructive tests, using techniques such as radiography, ultrasound, eddy current, dye penetrant inspection, toughness and impact testing, tensile strength testing and microscopic examination of metallurgical sections.

Once the nuclear fuel has been delivered to the site, the NRB will consider the plant to be a live nuclear facility. After the fuel is loaded into the core, the plant is considered to be an operating nuclear power plant, and the operating organization will be held completely responsible for nuclear safety by the NRB.

3.3.4. Services

There are a variety of services that will be needed during the planning, construction and commissioning phases of a nuclear power plant project (Phases 2 and 3 of the Milestones approach) by the engineering, construction and system installation organizations. During the plant operation phase, the operating organization will continue to need many of these services and the radiological aspects of nuclear power plant operation will require other services. The companies providing these services are described in the following subsections.

3.3.4.1. Environmental and siting companies

The Member State's environmental protection agency will review the environmental impact assessment and grant licences or permits to the owner/operator based on local and national laws and regulations. The NRB is generally involved in this process, as it relates to the radiological aspects of the nuclear power plant. If the owner/operator does not have suitable staff to collect data and to prepare the environmental impact assessment, a specialized services organization with such experience is utilized. This organization needs:

— To establish the framework, criteria and processes for the environmental impact assessment of the nuclear power plant project;
— To review the country's environmental laws, establish a process for technical assessments, and be adequately prepared to justify the environmental impact assessment in the public consultation and formal review if required by law and following the process established by the environmental and nuclear laws of the country;
— To advise the owner/operator in the resolution of arguments with nuclear and environmental protection agencies. In the area of communications with the regulator and the various authorities, depending on the legal framework, the environmental agencies and the NRBs usually establish communication protocols with the owner/operator. If the owner/operator hires a consulting firm to conduct the environmental impact assessment, in case of disputes, the consultants can only advise the owner/operator. However, it is the owner/operator and its lawyers who ultimately communicate with the regulators, judiciary, local authorities and national government (for further information, see Ref. [11]).

3.3.4.2. Calibration laboratories

All measuring instruments will need to be calibrated against accurately known quantities by using gauges or other devices that are stable and calibrated against quantities that can be traced to international standards. Test laboratories and services are therefore an essential component of the infrastructure, whether established as national facilities or within individual instrument manufacturing organizations.

3.3.4.3. Site utilities

Among the most important utilities for the nuclear power plant site are electrical power (including both temporary power during construction and a reliable connection to the grid to support commissioning and operation), water, waste treatment and communications. However, in the case of a turnkey EPC contract for the first nuclear power plant of a country, the aspects of these utilities that are located off the nuclear power plant site would generally not be part of the EPC contract. Thus, the prospective owner/operator of the nuclear power plant needs to establish interrelated projects for the supply of these utilities that will support the schedule and quality provisions of the EPC contract. The interfaces between these projects and the EPC contract need to be well defined and clear to all parties.

The main water demands for the nuclear power plant site will be similar to those of a conventional fossil fuelled plant. However, the nuclear island will also need a large source of high purity water.

Radioactive waste storage and treatment are addressed in Sections 3.3.5.3, 4.7.6 and 4.8.3. Any waste streams that could potentially be contaminated with radiation need to be considered for inclusion in the EPC contract. However, sewage and other waste streams from administrative buildings, dormitories and other similar facilities would be candidates for contracts with local qualified suppliers.

Modern, high speed and reliable equipment and systems will be needed to transmit data and information to connect the nuclear power plant site with its support network during both construction and operation. For the construction phase, the main drivers are schedule and cost. Once the plant is operating, reliable communications become paramount because the main drivers are nuclear safety and security. Developing and maintaining the communication network is not just needed within the nuclear power plant but also with the outside world. Hence, this network needs to connect to the national system, particularly the national emergency management system. In particular, the owner/operator needs to establish:

— Wide networks of public and interorganizational information exchange;
— Strong communication links between the plant, head office, the NRB, security forces and government public information services;
— Strong communication links with neighbouring countries and the IAEA.

Basic resources may include:

— Telephone, email and direct satellite links between various locations of information exchange;
— A comprehensive plan for dissemination of information to all relevant parties;
— Experienced staff for information management and exchange.

The communications requirements for a nuclear power plant project need to be reviewed in relation to the facilities available within the existing infrastructure. New development and investment in the communications sector may be required both to ensure that delays do not jeopardize the value of the project and to help to increase domestic participation.

3.3.4.4. Physical protection and security services

As described in Section 2.6, the security of nuclear facilities is an important criterion for site selection and for establishing plant configuration and plant operational procedures, as well as for safeguarding nuclear material. Each State carries full responsibility for nuclear security, including the following:

— Providing for the security of nuclear and other radioactive material and associated facilities and activities;
— Ensuring the security of such material in use, storage or transport;
— Combating illicit trafficking and the inadvertent movement of such material;
— Being prepared to respond to a nuclear security event.

Physical protection against unauthorized removal of nuclear material and against the sabotage of nuclear facilities or transport has long been a matter of national and international concern and cooperation. The international community has agreed to strengthen guidance based on the Convention on the Physical Protection of Nuclear Material [12] and its amendment [13], and it has cooperated with the IAEA in establishing nuclear security guidance.

Three types of risk need to be taken into consideration for the protection of nuclear material and nuclear facilities:

— Risk of unauthorized removal with the intent to construct a nuclear explosive device;
— Risk of unauthorized removal that could lead to subsequent dispersal;
— Risk of sabotage.

The possibility that nuclear or other radioactive material could be used for malicious purposes cannot be ruled out. States have responded to this risk by engaging in a collective commitment to strengthen the protection and control of such material and to respond effectively to nuclear security events. States have agreed to strengthen existing instruments and have established new international legal instruments to enhance nuclear security worldwide.

With regard to local industrial involvement, security forces, whether military, governmental or private, will be provided locally. As indicated earlier, physical protection features are integrated into the structures and systems of nuclear power plants.

3.3.5. Operation and maintenance companies

The industrial involvement of operation and maintenance companies is primarily a consideration for the operation phase of a nuclear power plant project. It is extremely important for nuclear power industrial involvement that the operating organization take the lead, or at least play a key role, in the country from the beginning of a project. There needs to be a management and control organization to lead the industrial involvement and its growth in the country. This publication does not address the details of how the operating organizations carry out these responsibilities.

An important aspect of ensuring the safety of nuclear facilities is for the regulator to require that the operating organization be completely responsible for the safe operation of its facilities. It may subcontract safety related functions for the supply chain or activities to other industrial organizations and delegate to them the purchase of goods and services from its supply chain. However, the operating organization needs to remain legally responsible to ensure that such goods and services function as intended to ensure the safe and reliable operation of its facilities.

During operation, the owner/operator will continue to need qualified services to manage and maintain the nuclear power plant. Among the many functions, there need to be groups responsible for maintenance, testing, calibration, in-service inspection (ISI), equipment replacement and upgrade, engineering and safety reviews and assessments, consumables, education and training. These can cover a range of skills and levels from craft through to professional. The following subsections discuss these aspects in more detail.

3.3.5.1. Core management and safety analysis

The operating organization is responsible for ensuring that the reactor is maintained within its licensed safety envelope at all times. Examples of this responsibility include the analysis of reactor core fuel loads to ensure that power levels are within allowable limits for all parts of the core, and the safety analysis and review of all planned modifications and changes to plant equipment. While these activities may be contracted out to a nuclear steam supply system (NSSS) supplier or other specialized contractors, the operating organization needs, as a minimum, to maintain the expertise to oversee the contractors.

3.3.5.2. Planning and conducting outages

In some Member States, the operating organizations maintain the staff and competencies to plan for, and conduct, refuelling and maintenance outages on their own. In most Member States, the operating organizations augment their staff with contractors, both to take on tasks such as radiation monitors, for which a much greater number are needed during an outage than for normal plant operation, and also to conduct specialized maintenance work on particular equipment, such as the turbine generator. In other Member States, some operating organizations have long term contracts with suppliers to plan and manage outages. In all cases, the operating organizations remain responsible to the NRB for the safety of the plant.

3.3.5.3. Spent fuel and waste handling

The most important wastes from a nuclear power plant are radioactive waste and spent fuel. The design of nuclear power plants includes spent fuel pools typically inside the reactor building in the vicinity of the reactor vessel (for some reactors, such as pressurized heavy water reactors, spent fuel pools are located outside the reactor building in a safety structure in the service building). These pools are generally designed with sufficient capacity to store several years’ worth of spent fuel. While plant operators typically monitor these pools, other on-site facilities for temporary storage of other radioactive waste are generally operated by dedicated personnel, who may either be employees of the operating organization or of a contractor that specializes in this field.

3.3.6. Technical support organizations

It is now quite common for both the operating organization and the NRB to have specialized support through TSOs. This TSO support is a cost effective method to fill the knowledge gap in both the operating organization and the NRB, as it is neither cost effective nor feasible to retain experts on staff for all possible situations that could arise. A TSO for the owner/operator means an organization established to provide support in various areas, including:

— Specific research;
— Engineering services and the development of technical improvements wherever required;
— Legal advice;
— Analysis and testing to support management decisions;
— The conduct of quality surveillance on procured items;
— Safety inspections;
— Seismic assessment and qualification walk downs;
— Design changes and design reviews;
— Targeted maintenance;
— Emission monitoring;
— Testing;
— Licence renewal;
— Plant life extension.

TSOs are expected to provide expertise, independent technical or scientific advice, competent judgement, services and assistance to a nuclear power plant operating organization (for further information, see Ref. [14]). A TSO is also an independent, specialized support organization that supports the work of NRBs. TSO areas with direct relevance to a nuclear power programme include the following:

(a) Applied technology:
 — Materials science;
 — Stability of soils and foundations;
 — Fluid dispersion in soils;
 — Atmospheric dispersion;
 — Flow and temperature in the plant system under normal and abnormal conditions;
 — Plant and component design;
 — Behaviour under stress and temperature;
 — System reliability and safety consequences of operating defects;
 — Probability of accidents;
 — Instrumentation and control system design computer programs;
 — Instrument design and measuring techniques;
 — Irradiation of human tissue;
 — Shielding materials;
 — Radiography;
 — Nuclear fuel performance;
 — Nuclear fuel design;
 — Power plant water chemistry;
 — Welding;
 — Non-destructive testing;
 — Bulk and surface treatments (e.g. heat treatment and surface hardening).
(b) Basic sciences:
 — Geology, hydrology and soil science;
 — Thermohydraulics;
 — Structural analysis;
 — Statistical theory and mathematics;

— System analysis and control theory;
— Electronics;
— Interaction of radiation with matter.

3.4. SHARING INDUSTRIAL INVOLVEMENT

Sharing industrial involvement with other States that are initiating a nuclear power programme, or that have an existing nuclear power programme, has significant potential benefits. Sharing can be at regional or multinational levels and can include physical facilities, or common programmes and knowledge, which can result in economic benefits. Sharing can also contribute in a significant manner to the harmonization of codes and standards, in general, and to the regulatory framework, in particular. The opportunities for, and potential of, sharing nuclear power infrastructure are determined by the objectives, strategy and scenario of the national nuclear power programme.

Sharing industrial involvement is not directly addressed in this publication. For a comprehensive review, see Ref. [15], which should ideally be reviewed in parallel with this publication when considering effective ways to develop the necessary industrial involvement for a nuclear power programme.

4. FACTORS AFFECTING THE DEVELOPMENT OF LOCAL INDUSTRIAL INVOLVEMENT

4.1. INTRODUCTION

This section provides information on the local industrial involvement that can, or needs to, be established as part of the overall industrial involvement for a nuclear power programme. Figure 5 shows the industrial and governmental organizations that will need to work together in an integrated manner in order to introduce a nuclear power programme. Appendix I contains more information about the specific actions to be taken by these organizations.

For the first nuclear power plant in a Member State, the most common scheme is a turnkey EPC contract for both the nuclear island and the BOP. EPC contractors for such schemes come from countries with established nuclear power programmes, and have experience in managing the design and EPC of nuclear power plants. The EPC contractor will engage subcontractors and suppliers to engineer, design, construct and commission the nuclear power plant units. Typically, this is a mix of local industrial organizations and international suppliers. The owner/operator will usually take on projects that are related to the turnkey project with the EPC contractor (e.g. grid upgrades, roads, training centres and administrative facilities) and will enter into contracts with local industrial organizations to support these projects.

Developing local or national industrial involvement for a nuclear power programme involves the arrangement or rearrangement of a number of industries in the country for services, materials supply, fabrication and construction, as part of the integrated supply chain established for the programme. In this way, the best industrial support available is provided to the nuclear power programme, and local or national industries obtain an optimum, positive spin-off.

A key part of Phase 1 of the Milestones approach is a prefeasibility study of the nuclear power programme for the country. It is important that this study include the determination of realistic goals concerning local and national industrial involvement based upon the risks and benefits of the alternatives. The following key questions need to be addressed through this study:

— Does the government want to build a single nuclear power plant or a number of them (i.e. what is the extent of the envisaged programme)?
— To what degree does the State wish to be independent in the execution of the programme, the operation of the plants and their maintenance?

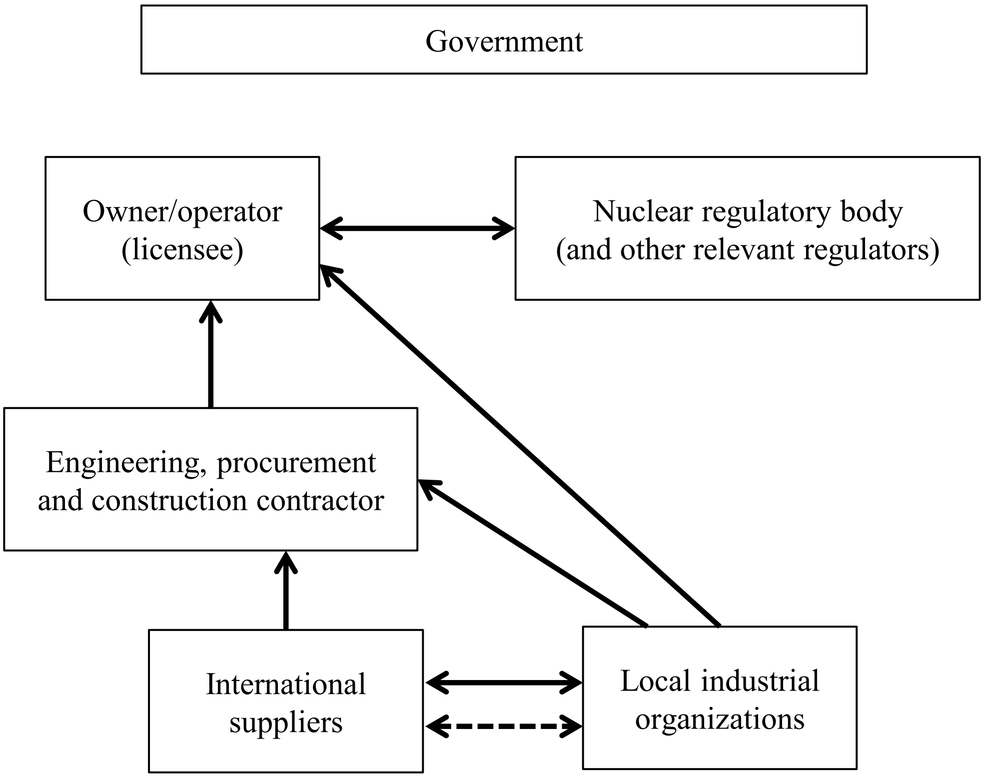

FIG. 5. Organizations typically involved in the introduction of nuclear power.

- To what degree is it feasible for existing industries to meet the objectives and participate with their existing know-how, and what new technology and facilities are needed?
- What investment is required in establishing the planned industrial involvement and is that investment economically viable? What is the comparative cost advantage for the State?
- Will the new infrastructure open up to new non-nuclear work, and will it help to make existing industries more competitive?
- Will the local human resources available be able to meet the additional load as a result of participation in the nuclear power programme?
- How established is the nuclear power programme and is it likely to change?

In other words, to what degree should the country's industrial resources take part in the programme so that participation is economically sound and yet is able to meet certain strategic national needs? In all cases, if local or national industrial involvement is to be a success, it needs to be economically viable so that it may provide a maximum of motivation to the participating industries.

Given the potentially sensitive nature of some nuclear power technology, there are special considerations with regard to technology transfer from suppliers to newcomers' domestic manufacturers or engineering companies, including, but not limited to, compliance with international treaties and instruments. These considerations are addressed in Section 5.

4.2. AVAILABLE NATIONAL INDUSTRY AND EXTENT OF NATIONAL PARTICIPATION

There is a minimum level of nuclear know-how and experienced personnel that a country needs to have available if plant operation and maintenance are to be conducted efficiently and safely. This know-how and experience will evolve over time with the development of the nuclear infrastructure. Industrial involvement plays an important role in this process as it contributes to the enhancement of the infrastructure and resources of the country. One useful group that is effective in building relationships among national industrial organizations associated with nuclear power is the nuclear industry coordination organization. Typically, this organization has a small number of dedicated staff members who provide networking and training to its members (local and national companies that can potentially serve the nuclear industry).

A Member State can find itself unable to take advantage of all the economic, industrial and technological opportunities a nuclear power plant programme can offer. This can occur by being overambitious in the objectives of participation or by not giving the participation plan the importance and attention that it needs.

The technical limitations that may result include the ability of local and national suppliers to meet the delivery schedule and stringent quality requirements, and the availability of a qualified workforce and the relevant technology and know-how.

The financial and economic limitations include the following:

- The availability of funds for expanding the factory facilities and machinery that would permit acquisition of new technologies;
- The adequacy of the market size to justify the investments required for the items to be produced domestically;
- The actual total cost of the items to be produced domestically compared with the cost on the international market.

An important consideration governing the extent of national participation is also the size of the domestic nuclear power programme. It has to be sufficiently large to be attractive to local participants. They can then make the necessary investments of effort and money to obtain special equipment and to create a pool of skilled labour. All the participating industries, if new to nuclear related work, most probably will have to modify their facilities or methods of work in order to satisfy the nuclear requirements. These modifications may also involve seeking some technology transfer. In all cases, retraining some of the personnel and management will be necessary. These modifications will depend upon the industries in question and their respective involvement. Relevant considerations include whether:

- The prospective operating organization is involved in all phases of planning and implementation of the programme;
- Engineering companies (civil, mechanical and electrical engineering contractors) are involved in the construction and installation phase and can supply services associated with maintenance and backfitting during the operating phase;
- Manufacturing companies are involved in the construction phase for the provision of components and equipment and similarly in the operating phase for the supply of replacement parts and components;
- Suppliers of metals, chemicals and plastics are involved in all phases;
- Construction companies covering civil, mechanical, electrical and instrumentation work are involved during the construction and erection phase;
- Professional services are required throughout the phases to provide specialized experts whom other participating organizations may not normally provide;
- Companies in the chemical industry are involved in the operating phase depending on the nature of the fuel cycle activities that the State decides to undertake.

When setting targets for national participation, planners should consider evolutionary aspects of local involvement. The following is a series of progressive levels of local participation that a State could achieve after experience is acquired and involvement increases:

(a) Level 1: As a minimum, local labour and some construction materials are used for on-site, non-specialized purposes, especially for the civil engineering work.
(b) Level 2: Local contracting firms take full or partial responsibility for the civil work, possibly including some design work.
(c) Level 3: Locally manufactured components from existing factories are used for non-critical parts of the BOP.
(d) Level 4: Local manufacturers extend their normal product line to incorporate nuclear designs and standards.
(e) Level 5: Special factories are established locally to manufacture heavy and specialized nuclear components.

The potential for national participation in a nuclear power plant project varies between pessimistically too low and optimistically too high. Too frequently, there is a call for maximum participation, when rather the objective should be optimum participation. Excessive local participation not backed by proven experience may involve appreciable risks in terms of schedule delays, cost overruns and poor performance. Therefore, partnerships between experienced suppliers and local and national suppliers need to be strongly encouraged. Sections 4.3–4.9 address considerations with regard to local industrial involvement, focusing particularly on aspects that are unique to the nuclear power sector.

4.3. ENGINEERING AND PROJECT MANAGEMENT COMPANIES

A turnkey EPC contract with EPC contractors experienced in managing design and EPC of a nuclear power plant is a common way to build both the nuclear island and the BOP, even for the first nuclear power plant in a Member State.

The owner/operator (the customer for the turnkey EPC contract) needs to have a project management team that mirrors that of the EPC contractor. The owner/operator project team oversees the work of the EPC contractor, and is the recipient of systems and structures as they are turned over during commissioning by the EPC contractor. This project team is typically established in Phase 2. The team plays the lead role for the future owner/operator in planning for the project, including activities such as site selection and preparation of the BIS for the EPC procurement. During Phase 2, individual experts or a consulting company with experience in nuclear power plant projects often support this team. In some cases, this support is carried over into Phase 3, the construction phase. This support is often referred to as the ‘owner’s engineer’.

The owner/operator (or other local industrial organizations) may be the design, engineering and management organization for projects that support, or are linked to, the EPC contract for the first nuclear power plant units. Examples of such projects include grid expansions and upgrades, transport system upgrades, sewage and water treatment facilities, environmental monitoring systems, training centres and administrative buildings. The interfaces between these projects and the EPC contract for the nuclear power plant units need to be defined starting in Phase 2.

Technology transfer and localization of manufacturing activities may be a part of the EPC contract; however, it is more likely that such technology transfer will be through a separate contract. Section 5 explores a phased approach towards decisions on the localization of engineering services and equipment manufacturing.

In some Member States, local industrial involvement has developed to the point where the engineering, design and management of nuclear power plant projects have been fully localized. However, this has been a long term, step wise process over a period of about 20 years after the first nuclear power plant units were put into service. Another characteristic of such full localization is that the scale of the nuclear power plant programme was large enough to justify the investment required.

4.3.1. Industrial codes and standards

The industrial codes and standards for many of the SSCs for a nuclear power plant project will also apply to other power plant projects. However, for SSCs associated with nuclear safety, nuclear specific industrial codes and standards need to be agreed upon and put into place. The project team that prepares the BIS and takes on other preparatory activities during Phase 2 initial needs to make decisions regarding these codes and standards. There also needs to be an effective link between national nuclear safety regulations and industrial codes and standards. The timing of the development is also important. The framework for nuclear safety regulation needs to be in place by the end of Phase 2 to enable suppliers to propose a nuclear power plant project. However, the technical details of these nuclear safety regulations need to be consistent with the codes and standards under which the nuclear technology is designed. Thus, once a decision has been made regarding the EPC contractor for the nuclear power plant project, there need to be discussions between the NRB, the operating organization and the EPC contractor on how the nuclear regulations will be achieved for a given design.

In general, the supplier will propose a combination of national and international standards in designing and specifying the nuclear power plant. The use of different sets of standards in the same technical area is a potential source of confusion and error. It is therefore important to manage the standards selected for a project. Such a reduction can be achieved by adopting standards identical to those of the supplier or by using existing national standards. However, what is chosen may have major schedule and cost implications.

The formation of a national standards organization should be given high priority. Suppliers of other technologies may use different standards; and as the country's industry develops, both the manufacturers and the major buyers of industrial goods will tend to establish their own standards. In the absence of a national body to impose uniformity, the country may find itself with multiple standards. It can then become increasingly difficult to rationalize this situation because the buyers, and to a lesser extent the manufacturers, will find it takes considerable effort and expense to change from the particular standard with which they have been working.

4.3.2. Management systems

Requirement 6 of GSR Part 2 [7] states that:

> "The management system shall integrate its elements, including safety, health, environmental, security, quality, human-and-organizational-factor, societal and economic elements, so that safety is not compromised."

Requirement 11 and para. 4.35 of GSR Part 2 [7] state that:

> "The organization shall put in place arrangements with vendors, contractors and suppliers for specifying, monitoring and managing the supply to it of items, products and services that may influence safety.
>
> "4.35. The management system shall include arrangements for qualification, selection, evaluation, procurement, and oversight of the supply chain."

Nuclear power plants require a far more rigorous management system than other types of power plant, which is commensurate to the potential consequences of an accident. During the construction and commissioning phase (Phase 3 of the Milestones approach), the EPC contractor will be responsible for implementing the management system for the nuclear power plant. The owner/operator needs to have its own organization in place to oversee the EPC contractor's implementation. During commissioning, the EPC contractor will hand over equipment and systems to the owner/operator in accordance with the provisions of the management system. Once fuel is brought on-site, the owner/operator needs to take responsibility for ensuring the quality of all activities related to nuclear safety. During the plant operation phase, the owner/operator, which is licensed to operate the facility, has full responsibility for the quality of all activities.

The establishment of the management system for the industrial supply chain is dependent upon the applied standards and requirements (specifications) generated by the regulatory authorities, the licensed owner/operator and the EPC contractor's root design standards.

4.3.2.1. Qualification of suppliers

The qualification of the suppliers in the new build supply chain is directed and supported by the following three main components:

- Regulatory requirements under licensed design requirements, which are often shaped by the country of origin of the first build;
- Standards for owner/operators that are applicable to the licence granted by the regulator;
- Vendor design criteria and applied codes of practice that are often derived from the country of origin of the reactor designer.

Suppliers therefore have little choice other than to adhere to the established regulatory system of codes of practice and to submit their company organizations, products and services to the prescribed entry level quality management systems. Suppliers to the nuclear industry are in a chain relationship, and the qualification of all suppliers in the supply chain has to be sequentially determined to ensure control at every level. Qualified suppliers are also required to maintain surveillance of, and to audit regularly, their own supply chain.

4.4. MANUFACTURING COMPANIES

Owing to the high barriers to entry of the unique and comprehensive industrial standards associated with nuclear safety related equipment, local companies will probably not be successful in manufacturing this type of equipment for the first nuclear power plant units unless a partnership or joint venture is established with an experienced supplier. The manufacture of large, specialized components such as reactor vessels and steam generators is a global undertaking, and not a near term national opportunity for a new nuclear power programme.

The EPC contractor will utilize manufacturers with experience in manufacturing to nuclear codes and standards in order to control financial and project risks. However, much of the manufactured goods for a nuclear power plant project that are not nuclear safety related will be built to the same standards as a conventional power plant or other large industrial facility. In addition to BOP equipment, there is also equipment to be purchased for use in auxiliary and administrative facilities, such as administrative buildings, training centres, security facilities and dormitories. Local companies that manufacture equipment for such facilities should have no significant barriers to entry into the nuclear power plant project supply chain, as long as the EPC contractor and its subcontractors are aware of the extent of their capabilities.

The proportion of these items that can be manufactured economically by a country embarking on a nuclear power programme will depend, to a large extent, on the facilities and abilities of the existing manufacturing industry and supportive industrial involvement within that country. While it is possible for a country to establish the capability to manufacture a large fraction of the nuclear related equipment through appropriate technology transfer, the considerable investment in the facilities, skilled personnel and capital required suggests that this capability can only be achieved over a long period of time that will encompass several nuclear power plant projects (see Section 5 for information on technology transfer).

4.4.1. Safety related system components

Safety related system components include the reactor core, its control systems, and the reactor coolant system and its support systems. Codes and standards define the requirements for the materials, design, fabrication, examination, testing, inspection, installation, certification, stamping and overpressure protection of nuclear power plant components and their support systems. The pumps, valves, metal vessels, systems, piping and core support structures are intended to function within the overall safety requirements of the nuclear power system.

Codes include design considerations such as mechanical and thermal stresses due to cyclic operation. They also provide requirements for reactor vessels and concrete containments. In addition, they provide requirements for the transport and containment of high level radioactive waste. It is not realistic for local companies to produce safety related system components for a first nuclear power plant

4.4.2. Components important to safety systems

The components in the turbine building, such as the feedwater heaters, reheaters, condensers, pumps, storage tanks and cooling systems for the condensers and generator, can be produced by local or national suppliers, but the emergency core cooling system pumps and piping (if located in turbine building) would be excluded like other safety components because the emergency core cooling system is classified as a safety system. Codes and standards applicable to high pressure systems in ASME Section III Class 3 [8] require individual registration numbers and a quality assurance certificate.

4.4.3. Non-nuclear systems

Non-nuclear systems do not directly affect the operation of the plant: any failures can be repaired while the plant is in operation. The requirements of non-nuclear systems are similar to good engineering practices and to codes and standards used in conventional power plants and industry (e.g. building codes, fire codes and electrical codes). A quality assurance standard, ISO standard or other applicable standards will be required. Small and low pressure vessels, piping and systems do not normally require a registration certificate from the boiler and pressure vessel safety authority.

Local suppliers are usually part of a general agreement between the local government, the owner/operator and the nuclear power plant vendor. Their participation tends to be expressed in terms of the percentage of the total cost. The owner/operator normally awards contracts and subcontracts to local suppliers according to their capabilities, taking into account whether their facilities are upgradeable to meet nuclear standards or whether their staff have the necessary experience and to what extent they can be trained. The selection is generally based on:

— The capability of local suppliers of material and services to achieve the required specifications;
— The quality consciousness of local suppliers;
— The determination that the involvement of local suppliers is essential and the owner/operator may need to support them technically as part of a strategy.

4.4.4. Bulk material management

The shortage of bulk material availability can become critical during the course of the project, and its standardization can help in cases of unavailability. During the construction phase, the construction organizations will have to use many bulk materials, including:

— Metal sections;
— Welding electrodes;
— Bolts, screws, nuts and washers;
— Standard pipes;
— Fittings and supports;
— Conduits;
— Lubricants, sealants and paints;
— Non-destructive examination materials;
— Chemicals (for leak detection, cleaning and markings);
— Consumables;
— Concrete anchors;
— Pull boxes and junction boxes;
— Terminals.

Since there is a very large range of products that can be purchased for the same purpose, the architect–engineer, or responsible contractors, needs to establish a procurement policy to prevent the use of products that do not meet the specified requirements. Whenever specific qualifications are necessary, or stringent quality requirements are applicable, the responsible contractors need to purchase the bulk material and to issue it freely to the construction organizations, to be used under strict control and according to clear instructions. An alternative option is to positively identify products that are prequalified (with specific catalogue data) and to allow the contractors to buy them. However, special care needs to be taken when using, for example, chemicals that come into contact with high alloy steels, because they are sensitive to halogens and sulphur.

Some materials are used throughout the construction period, therefore preservation is necessary to ensure the delivery schedule meets the site's needs (using the minimum–maximum approach), especially if the guaranteed shelf life of a material is short. The following precautions need to be adopted:

— Free issue of materials that have stringent quality specifications;
— Preservation of the materials received;
— Identification, cataloguing and numbering of materials.

4.5. CONSTRUCTION COMPANIES AND COMMISSIONING SUPPORT FUNCTIONS

The owner/operator should consider including provisions or incentives in the turnkey EPC contract that encourage the EPC contractor to use local subcontractors for construction and erection whenever these contractors can meet the supply chain qualification requirements and are cost effective compared with offshore suppliers. Even in the absence of such provisions, the EPC contractor will generally find it financially advantageous to use local industrial companies, where they are qualified, as local labour will almost always be less expensive than using experts.

Most of the construction workers are usually from the local workforce. Typically, local construction and erection subcontractors are cost effective choices. Therefore, the main hurdle to overcome is to qualify them to meet nuclear industry codes and standards. For turnkey EPC contracts, the qualification of companies to participate in construction and commissioning will be the responsibility of the EPC contractor. If the EPC contract has suitable incentives, it will likely be in the best interest of both the owner/operator and the supplier to make the relatively minor investment needed to qualify these local contractors. The upfront investment is in helping these local contractors to implement the quality controls needed for their work, while the ongoing investment by both the owner/operator and the supplier will be in providing additional oversight of these contractors until they have established the processes to make these high standards part of their normal routine.

The focus on finding suitable local contractors and workers needs to include those that support other large industrial projects, such as the construction of conventional power plants, as the equipment and methods used for most nuclear power plant SSCs are quite similar to those projects. EPC contractors need to be willing to provide practical training to the staff of such prospective subcontractors in areas such as welding, concrete mixing and pouring, non-destructive examination, and quality hold points and surveillances, as these are typical areas where higher standards are required for nuclear power plant projects.

Based upon their performance during construction, it needs to be clear to both the owner/operator and EPC contractor which subcontractors that participated in construction are candidates to support commissioning. Typically, these subcontractors will support commissioning and correct deficiencies that are identified in tests. At this point in the project, the number of construction workers involved in the project will be significantly lower than at the peak of construction.

An increasing number of systems and buildings will be under operational control of the owner/operator as commissioning progresses. In advance of fuel loading, which is one of the major project milestones, all nuclear safety related systems need to be turned over to the owner/operator (with selected systems or parts of systems returned to the EPC contractor test engineer control as needed).

4.6. IN-SERVICE INSPECTION

A team of nuclear design and engineering experts needs to be developed during the construction and commissioning of the nuclear power plant to become an effective part of the operating team in the service of the plant. The number of experts required will depend on the operating policy of the plant, but this team will constitute a permanent and ongoing ISI at all levels. Specialist service companies to provide analytical services will augment this facility, all of which need to be regulated by the national regulatory bodies.

ISI is part of the activity for monitoring the health of critical piping weld joints, and the thinning of reactor pressure vessels, steam generators and tubes. ISI is also carried out on the containment and the turbogenerator. Techniques used for ISI are mostly non-destructive in nature and include the following:

- Visual examination;
- Surface examination by liquid penetration examination;
- Ultrasound examination;
- Eddy current examination;
- Radiography techniques.

The periodicity of coverage and type of examination are a function of the safety class of the equipment.

4.7. SITE SERVICE PROVIDERS

Nuclear power plant sites need the typical services of an industrial facility such as a power plant or a chemical plant. In addition, specialized services associated with the ionizing radiation resulting from plant operation are required. During construction, the EPC contractor needs to have the lead role in managing services that are unique to nuclear power technology. For other services, however, the owner/operator will have either the lead role or a significant support role. The EPC contract needs to include provisions for localizing all the services that can be provided locally, as well as provisions for how specialized services will be provided to the owner/operator once the EPC contract is completed.

4.7.1. Environmental and siting services

Local service companies with experience in complying with national regulations governing environmental monitoring and the siting of industrial facilities need to be able to participate in similar activities for the nuclear power plant project. Because nuclear power plant projects involve unique aspects of environmental monitoring and site selection, the lead in such activities is often a contractor with previous experience in site selection for a nuclear facility. Another alternative is for a local company with experience in environmental monitoring and site selection within the Member State to augment its staff with individuals or a subcontractor with nuclear specific experience. It should be noted that most of the activities associated with siting are typically completed prior to, or in parallel with, awarding a turnkey EPC contract under the direction of the owner/operator project team (see Ref. [11] for further information).

4.7.2. Calibration laboratory services

The turnkey EPC contract needs to include a provision for providing calibration laboratory services for construction and commissioning, as well as consideration of a provision for the transfer of lead responsibility for these services to the owner/operator for the plant operation phase. Thus, there are incentives for the localization of as many of these services as feasible for local industrial organizations to take on during the construction of the first nuclear power plant units.

4.7.3. Communications services

New development and investment in the communications sector may be necessary to ensure that weaknesses in communication systems do not cause delays in the first nuclear power plant project and to help to increase domestic participation. This is the responsibility of the owner/operator and the government.

4.7.4. Electrical grid

Upgrades or expansion of the electrical grid, particularly off the nuclear power plant site, would most likely not be within the scope of the EPC contract. Such work needs to be done using established local or national resources. Grid reliability will be an important issue for the nuclear power plant project, but more importantly, once the plant is operational, it is also a nuclear safety issue (see Ref. [4] for further information).

4.7.5. Water supply

The main demands for water supply for the nuclear power plant site will be similar to those of a conventional power plant. However, the nuclear island will need a source of high purity water. This portion of the water supply should be considered for inclusion under the EPC contract owing to its importance to the nuclear power plant project.

4.7.6. Waste treatment

Any waste streams that could potentially be radioactively contaminated need to be considered for inclusion in the EPC contract. However, sewage and other waste streams from administrative buildings, dormitories and other similar facilities should be candidates for contracts with local qualified suppliers, as well as waste streams during plant construction phases and at locations where there is no possibility of radioactive contamination.

If there are existing activities in the country that generate radioactive waste, then local organizations that can manage radioactive waste generated by the nuclear power plant need to be utilized.

4.7.7. Transport

In general, local companies that participate in existing national projects for new roads or ports with heavy load capability can support the nuclear power plant project. These transport projects are often not included in the EPC contractor's scope, particularly if they are not on the nuclear power plant site. For each method of transport, the suitability of the delivery routes needs to be assessed. For example, the method of transport has to take into account the weight and dimension of any large components involved.

Materials for the nuclear island are not radioactive, with the exception of the nuclear fuel. However, new fuel does not pose the same serious hazard as used fuel, and thus the special provisions required for the transport of radioactive material will not need to be implemented during construction. However, once the plant begins to operate, there will periodically be a need for the transport of radioactive material, for which planning is required.

4.7.8. Physical protection, security and safeguards

Prior to nuclear fuel loading, physical protection provisions for the nuclear power plant site are similar to those for other industrial facilities. However, once nuclear fuel is brought on-site, the special aspects of nuclear security and safeguarding of nuclear material from inappropriate use come into effect. Provisions for physical protection, security and safeguards are the responsibility of local organizations, although the EPC contractor and other nuclear industrial organizations will provide support related to the specialized equipment and systems they provide. The provisions that are needed will involve multiple governmental and industrial organizations working in an integrated manner, such as the owner/operator, local police and emergency response organizations, a dedicated security force, and national military and defence organizations.

4.8. OPERATION AND MAINTENANCE ORGANIZATIONS

As indicated in Section 3, the organization licensed to operate a nuclear facility is legally responsible for its safe operation, which includes ensuring that it is designed in accordance with applicable regulations, that it is constructed in accordance with the approved design and that it continues to operate within this safety envelope throughout its lifetime. This responsibility means that owner/operator organizations are either government entities or companies incorporated within the Member State. One of the main challenges facing the operating organization for a new nuclear power programme is to become a knowledgeable customer and to develop the capabilities to carry out these responsibilities based largely upon local or national resources.

During Phase 1, it is highly desirable to have organizations that will potentially be the future owner/operators of nuclear power plants participate in the prefeasibility study in order to help them to better understand the risks and benefits of their participation in the nuclear power programme, as well as to bring their expertise in the generation and transmission of electricity within the country to the study.

During Phase 2, the prospective operating organization needs to establish continuing dialogue with potential suppliers in order to better understand the organization's role in the new nuclear power programme and the capabilities it needs to develop in order to carry out its responsibilities during Phase 3 and the plant operation phase. This dialogue needs to include the following:

(a) Inviting potential suppliers (in the bidding process) to periodic meetings to discuss topics such as the BIS, surveys of local industrial organizations that could potentially participate in the first nuclear power plant project, and industrial codes and standards for nuclear power plant SSCs;
(b) Providing opportunities for staff who are expected to have key roles during Phases 2 and 3 and plant operation to have work and observation opportunities at operating nuclear power plants and design and manufacturing facilities (suppliers need to be able to assist with identifying such opportunities).

The turnkey EPC contract needs to include provisions for the supplier to train and develop the staff of the operating organization during the construction and commissioning phases to prepare them for their responsibilities during the plant operation phase. In every new nuclear power programme, support from the supplier has continued into the plant operation phase. In some cases, this support has included providing mentors for control room operators and managers for a year or longer after commissioning.

Reference [16] develops in detail the necessary relationships that industry needs to understand and accept. Tables 1 and 2 of Ref. [16] provide typical owner/operator responsibilities during Phases 2 and 3 of the Milestones approach, including those associated with industrial involvement development.

During the plant operation phase, the operating organization will continue to need qualified services to manage and maintain the nuclear power plant, including maintenance, testing, calibration, ISI, equipment replacement and upgrade, engineering and safety reviews and assessments, consumables, education and training. These services can cover a range of skills and levels, and a new operating organization will need a plan for what mix of local and international services will be used. Some of these functions are discussed in Sections 4.8.1–4.8.4.

4.8.1. Core management and safety analysis

A new nuclear power plant operating organization generally needs specialized support from the NSSS supplier for core management and safety analysis, as it is neither feasible nor cost effective to develop the depth and breadth of plant design knowledge that the supplier has. This does not mean that there is a need to rely upon the supplier for every decision regarding the safety envelope, but only those that require expert level knowledge. As indicated in Section 3.3.5.1, the operating organization needs, as a minimum, to maintain the expertise to review the supplier's analysis. As the operating organization gains experience and knowledge, it normally expands the safety analysis that it undertakes.

4.8.2. Planning and conducting outages

The turnkey EPC contract for the first nuclear power plant generally includes provisions for the EPC contractor to have the lead role in planning and conducting the first scheduled outage. The operating organization needs to have a long term outage management strategy and implementing plans that indicate its expected role in managing and implementing subsequent outages.

4.8.3. Radioactive waste handling

The contract that the operating organization has with its fuel suppliers generally does not include the return of used fuel to the supplier (although this may change in the future). Thus, the operating organization will need, as a condition of its licence, to provide for the temporary storage of used fuel, as well as have plans for either disposal or reprocessing after the fuel has cooled sufficiently.

4.8.4. In-service inspection

In most Member States, there are companies that provide inspection services to other national industries, such as the construction, chemical, power generation and oil production industries. These companies are candidates for participation in the first nuclear power plant project. During Phase 2, these companies need to participate in discussions with prospective EPC contractors and the prospective owner/operator on supply chain qualification, as discussed in Section 4.3.2.1. Inspection services that are unique to nuclear power (e.g. steam generator tube inspections for pressurized water reactors) may not be cost effective to localize early on in a nuclear power programme or if a small number of units is planned. Such considerations need to be part of the localization plan.

4.9. APPLIED R&D AND TECHNICAL SUPPORT ORGANIZATIONS

For a new nuclear power programme, most applied R&D in nuclear power will initially come from organizations outside the country that have specific experience in nuclear power. When introducing a nuclear power programme, the status of existing R&D in the country may be viewed in terms of how it can support this new programme. An alternative view is that, quite separate from any major industrial or energy programme, conducting basic research in even a few key fields is comparable to retaining membership in a club; countries that do not pay their dues are excluded. Countries that strengthen and develop research in even a few fields can have access to many sectors, which provides an opportunity to enlarge their knowledge base and methodologies available to many parts of the economy.

Closely associated with applied R&D is the nuclear power industry's use of TSOs to provide specialized assistance to both operating organizations and NRBs. Most operating organizations and NRBs in countries with established nuclear power programmes use TSOs for specialized assistance. Depending on the size of the national nuclear power programme and national norms, these TSOs are often a combination of local and international organizations (see Ref. [14] for further information on TSOs for nuclear power plant operating organizations).

In the case of new nuclear power programmes, the TSO is often either the NRB in the country of origin of the nuclear supplier or the TSO that supports this NRB. The operating organization's TSO is often the EPC contractor for its turnkey project for the first nuclear power plant units. TSO support for the NRB would generally begin during the licensing of the first nuclear power plant; while for the operating organization, the TSO support would begin at the start of the plant operation phase (because the supplier generally provides technical support during Phase 3 as part of its EPC contract).

4.10. SUPPLY CHAIN AND PARTNERSHIPS

The supply chain covers facilities, construction equipment, services, operation and project management. Some organizations in the supply chain will be unique to the nuclear power market; however, most suppliers to this market are also in other business sectors. For many of these, the nuclear power sector is a minor part of their markets.

A nuclear power programme is a long term commitment of at least 100 years, from planning through to decommissioning of the first units. Thus, the supply chain needs to be considered from the long term perspective, with partnerships established among industrial organizations, such as between:

- NSSS vendors and operating organizations;
- TSOs and NRBs;
- TSOs and operating organizations;
- NSSS vendors and local manufacturers.

The list of component parts, products, materials and services to be used is very long and detailed, and each involves a supply chain. In terms of a new build nuclear power plant for emerging nuclear power States and the current trend for vendor driven designs from specific development orientated host countries, the supply chain matrix will be, for the foreseeable future, a mix of international and local (i.e. national) suppliers.

These combined supply chains create the means by which the nuclear power plant will be built and then operated. The supply chains have to meet the standards of the international nuclear community in general and those specific to the nuclear power technology and supplier selected. By definition, the end supplier is the end of the chain of supply, and all subsuppliers or lower level suppliers in the chain have to contribute to the integrity of supply by operating within the safety and quality management culture of the nuclear industry.

It should not be assumed that an established supply chain for another method of energy generation, such as conventional power plants, can be used for a new build nuclear power plant project. The differences in design requirements, operating environments and codes and standards need to be assessed. Therefore, the choice by industrial companies when considering the opportunities, however encouraged by governments and other organizations, has to be based upon a carefully developed assessment of risk and a deep understanding of the requirements.

Supply chains are multifaceted, international, regional and local, and are interlinked by many individual supply chains. The criterion that each participant of the supply chain is looking for is sustainability. Without this, the attractiveness of the business opportunity degrades and costs rise. If the supply chain does not have the conditions to make it stable and therefore to offer sustainable business opportunities, then the elements that differentiate the nuclear industry become too costly to maintain within acceptable market limits, and the industrial involvement created to support a nuclear power programme falters.

A supply chain will be created for the first nuclear power plant project primarily by the EPC contractor, but with inputs and support from the owner/operator. After construction, the owner/operator will take over some aspects of the supply chain from the EPC contractor. Thus, the EPC contract needs to address this point.

A widely used graduation of the suppliers in the new build process includes:

— Tier 1: Licensed owner/operator and architect–engineer.
— Tier 2: Vendor (design authority and design owner, programme and procurement management).
— Tier 3: Major equipment suppliers (reactors, steam generators and turbines).
— Tier 4: Secondary equipment suppliers and services and systems (e.g. valves and pumps).
— Tier 5: Component suppliers.
— Tier 6: Raw materials, primary components and primary services (e.g. steel, concrete, rebar, transport and cranes).

The layers can go further. As the tier becomes lower, the number of suppliers tends to increase and the number of enterprises that could choose to engage in nuclear work also increases. However, as the qualification of the product or service rises by nature of application or requirement, the cost of entry rises substantially.

Many members of current supply chains, mostly in the international supplier networks, have decades of experience, which masks the fact that they too started at some individual point and that the direction of nuclear power programmes indicates that supply chain development is certainly necessary to create capacity and capability. Partnership development as part of industrial involvement plays a key role in the introduction and development of nuclear power in a country.

When considering supply chain requirements, the availability of human resources is a significant requirement and opportunity. The provision of the correct quality and quantity of people for the project is one of the long term objectives of the nuclear power programme that includes the Member State's policy for the support of education, training and R&D.

4.10.1. Procurement

With a turnkey arrangement, the main contractor has responsibility for the procurement of every item of equipment and material within the scope of supply, which could be the entire project. With non-turnkey arrangements, the responsibility for procurement is either with the utility/owner, or can be shared among the utility, architect–engineer and system suppliers or contractors, each within its specific scope of supply. A specialized procurement unit consisting of both business and engineering talent is therefore usually entrusted with the following:

— Establishing procurement criteria;
— Procurement planning;
— Supplier qualification and selection;
— Bidding and bid evaluation;
— Contracting;
— Contract monitoring and enforcement;
— Expediting;
— Handling warranty claims.

4.11. HUMAN RESOURCES FOR INDUSTRIAL INVOLVEMENT AND STAKEHOLDER INVOLVEMENT

The problems of preparing the workforce required by a nuclear power programme are treated extensively in Ref. [17], which provides best practices on planning for, and developing, the workforce necessary to initiate and sustain a nuclear power programme.

A closely related topic is stakeholder involvement in the nuclear power programme. The principal stakeholders with regard to industrial involvement include the following:

- — Industrial organizations that have the capabilities needed for the construction, manufacture and operation of nuclear power plants;
- — Industrial trade organizations;
- — Labour unions;
- — Vocational education and training organizations.

All of these stakeholder organizations need to be involved from Phase 1 of the planning for a nuclear power programme so they can harness the potential benefits of the programme to the country and their roles in ensuring its success (for further information, see Ref. [18]).

4.12. PREREQUISITES FOR INDUSTRIAL INVOLVEMENT

While not considered a part of industrial involvement, the following framework needs to be in place in order for the nuclear power programme's industrial involvement to function effectively:

(a) A legal framework, including laws and supporting regulations such as, but not limited to, licensing and oversight of nuclear facilities, nuclear safety, nuclear liability, security, transport, safeguards, and import and export controls on nuclear material;
(b) A competent and independent NRB;
(c) Governmental ministries and agencies responsible for finance, transport, security and physical protection, environmental protection and education.

Although important in their own right, the above topics are only addressed briefly here, since the main focus of this publication is on industrial involvement (for a more comprehensive overview, see Refs [1, 17]).

4.12.1. Legal framework

The legal system of a country needs to provide a framework within which various sectors of the industrial involvement can operate, while providing protection for individuals and companies. Such a system includes laws covering contracts between companies — both local and foreign — and regulations on employment, professional practices and liabilities. For the industrial involvement for a nuclear power programme, there are unique and demanding aspects of this legal framework. There are various legal arrangements associated with industrial involvement that need to be reviewed to ensure consistency between nuclear legislation and other laws which may have an impact on the nuclear power programme.

It is fundamental to have a clear understanding of the different pieces of legislation to ensure a smooth development of the nuclear power infrastructure. Laws associated with industrial involvement include areas such as:

- — Energy sectors;
- — Foreign investment;
- — Capital transfer and foreign currency control;
- — R&D;
- — Intellectual property;
- — Electricity rate making, incentives and taxation;
- — Information technology;
- — Small and medium enterprises;
- — Private sector;
- — Industrial quality assurance;
- — Industrial standards.

Liability for radiation related damage to people and the environment resulting from nuclear facilities is a unique area and is of particular interest to industrial organizations participating in a nuclear power programme (for further information on nuclear law, see Ref. [19]).

4.12.2. Regulatory framework

In all Member States, agencies are legally bound to carry out regulatory mandates such as ensuring conformance with building construction codes, pressure vessel design guides, construction practice requirements, licensing and environmental protection. When initiating a nuclear power programme, it is necessary to augment this regulatory framework to address the unique regulatory aspects of nuclear power. Of particular importance and relevance to this publication are the regulatory aspects associated with licensing, design, construction and operation of SSCs important to nuclear safety.

Regulations controlling the use of ionizing radiation and experience in regulating the use of X rays, gamma rays and radioactive material in medicine and research may already exist. While this provides a base of relevant experience, regulation of the activities of a nuclear power programme is more complex and calls for a very wide range of engineering and scientific expertise (for further information on the regulatory framework for a nuclear power programme, see Refs [19–25]).

The first decision is whether the State wants to develop its own nuclear regulations or to adopt regulations from other national NRBs and IAEA safety standards. In Phase 2 of developing the infrastructure for a new nuclear power programme, the regulatory framework will be put in place. During Phase 3, the details of the regulatory framework, such as particular codes and standards, need to be developed in a manner that is compatible with the codes and standards for the technology or supplier selected for the first nuclear power plant project. As a result, the codes and standards at the start of the nuclear power programme may be adopted and harmonized with those of the country of origin of the technology or those of the countries that already have a fully developed nuclear regulatory regime, while at the same time ensuring compliance with IAEA safety standards.

5. TECHNOLOGY TRANSFER AND INTELLECTUAL PROPERTY

5.1. INTRODUCTION

This section provides information on technology transfer and intellectual property associated with the introduction of a nuclear power programme. In this publication, technology transfer is defined as the process of moving technology from one entity to another. The transfer may be said to be successful if the receiving entity, the transferee, can effectively utilize the technology transferred. Technology transfer thus involves the transfer of both physical assets and the knowledge how to use them.

Technologies generally consist of a rather complex combination of physical assets and intangible assets, such as formulas, practical solutions, inventions, know-how and trade secrets. Some assets are recognized as the property of the creator (or of the person/entity to which the creator assigned the rights) and are called intellectual property. In order for intellectual property to become a legally recognized intellectual property right (IPR), it is necessary to be protected under specific intellectual property laws. There are two main categories of IPRs: industrial property rights (patents, industrial designs, trademarks, service marks, layout designs of integrated circuits, geographical indications and protection against unfair competition); and copyright (literary, scientific and artistic works, and software). Both of which can be registered rights (e.g. patents, industrial designs and trademarks) and non-registered rights (e.g. trade secrets) [26].

Similar methods are used for protecting intellectual property in various countries, where the laws provide for the registration of designs and trademarks, for the patenting of inventions and for the copyright of documents and recordings. The laws prevent or stop the unauthorized use of protected intellectual property.

Designs, patents and copyrights apply to distinct and relatively easily identifiable types of intellectual property and therefore can be described and registered. There is much intellectual property covered by the general term ‘know-how’ (i.e. expertise or understanding of how something works) that does not fall into any of these definitions, and for these the owner/operator has to rely on secrecy for protection. Most nuclear technology transfer agreements are on this type of intellectual property. A relatively small proportion of the information transferred will have been described in patents and other published documents. Technology transfer issues that are particularly important for, and unique to, a new nuclear power programme include:

(a) For the first nuclear power plant project of a country, the know-how transferred to the operating organization by the EPC contractor, typically as part of a turnkey contract, is not considered to be technology transfer.
(b) Technology transfer with regard to the design, manufacture and erection of nuclear power specific technology may be one of the long term objectives of the nuclear power programme, and such technology transfer may have a higher priority as the programme matures and additional units are constructed.
(c) Suppliers of nuclear technology in States party to the Treaty on the Non-Proliferation of Nuclear Weapons [27] are prohibited to transfer certain nuclear weapons technologies. These prohibitions also apply to NSSS vendors and particularly to parts of the fuel cycle associated with enrichment and reprocessing of spent fuel (for further information, see Ref. [28]).
(d) The volume and structure of national participation and technology transfer to be defined in BISs (as indicated in Ref. [29]) primarily depend on:
    — The size of the nuclear power programme in the country;
    — The technical and economic status of national industry;
    — The owner’s business plans;
    — Non-proliferation considerations.

For the owner or vendor of the technology, the intellectual property is an important economic asset in which the vendor invested knowledge, time and financial resources and thus will protect and, if necessary, enforce. The ability of the recipient country to provide efficient protection of intellectual property and IPR enforcement, in particular know-how and trade secrets, will be one of the risk assessment considerations for the vendor.

5.2. TRANSFERRING TECHNOLOGY

The complexity of nuclear technology requires a relatively high financial investment as well as a commitment of human resources. Since there are serious consequences if technology transfer is poorly executed, it is important to develop a comprehensive plan for the transfer. Various independent participants in the nuclear power programme will need to cooperate to ensure coherence.

Technology transfer is a learning process that is only successful when knowledge, skill and experience have been imparted to people in the receiver organization (hereafter referred to as ‘the receiver’). It is not enough to transfer documents and equipment. If the receiver does not practise the technology, knowledge will be forgotten, and the technology will not have been transferred. The receiver needs then to have sufficient prior knowledge to enable it to understand the new information to be learned, and sufficient experience and skills to enable it to practise the new techniques of the transferred technology. Like all learning processes, technology transfer takes time. If well managed, it can benefit both the supplier and the receiver of the technology.

From the point of view of the vendor of the technology, technology transfer achieves:

— The establishment of a long term relationship with the receiving country and its industries (such a relationship is usually commercially advantageous to both parties);
— The development of a new market in nuclear and other related industries;
— An improvement in the vendor’s international image and export capacity;
— The advancement in existing technology, which can benefit both the vendor and the receiver when technology transfer is used on specific R&D projects;
— The successful conclusion of contracts more attractive to the receiver because of the technology transfer package offered.

From the point of view of the receiving country, technology transfer allows:

- The acquisition of intellectual property and know-how developed by others more quickly and at a lower cost;
- The development of capabilities that can be transferred to other industries through spin-offs (depending on the extent to which the receiver is licensed to use the technology);
- Greater independence by better control within, and management of, the execution of the nuclear power programme, as well as through a buildup of increasing national participation in future projects;
- An increase in the standards of technological education and training.

Finally, a factor that can lead to a better definition of technology transfer is the realization by both the vendor and the receiver of what technology transfer is not. It is not a simple mechanical process but a complex teaching process which does not produce instantaneous results and which involves many stages: negotiation, education, facility development and training. This process requires commitment from both sides for a successful outcome. Technology transfer will not immediately provide all the benefits that technology will eventually produce.

5.2.1. Types of technology transferred

In a nuclear power programme, there are three basic technologies that can be transferred:

(a) Design technology: This can start at the R&D stage and continue right up to final process design of all the systems which comprise a nuclear power plant.
(b) Manufacturing and construction technology: This includes the design of nuclear equipment and extends through the special manufacturing techniques and quality assurance methods to the construction techniques of a nuclear power plant.
(c) Project engineering and project management: This deals with the work necessary for the successful execution of a nuclear power project. It includes both home office and activities on-site, and also partly covers the pre-project period.

Typical technological areas in which capabilities are transferred include the following:

- Nuclear island design, supply and construction;
- NSSS design and supply;
- Subsystem design and supply;
- Component supply;
- Fuel supply;
- Licensing support;
- Project engineering and project management;
- Site management;
- Quality control and quality assurance.

Each technology and area requires a different approach and method for successful technology transfer. Figure 6 shows the different areas of technology transfer and how they relate to the nuclear power plant programme.

5.2.2. Technology transfer stages

There are several stages of technology transfer:

(a) Initiating stage: Technical dependency (subcontractor). This is the first, which is the copying or initiating phase. At this stage, the plant and equipment are specified and provided by the supplier, while the receiver operates the process according to the supplier's specifications and instructions. The receiver's personnel are trained to undertake the necessary tasks, but they do not have the technical capacity to operate independently. The receiver can operate the process and maintain the equipment in normal conditions, but requires technical support from the supplier to deal with abnormal conditions.

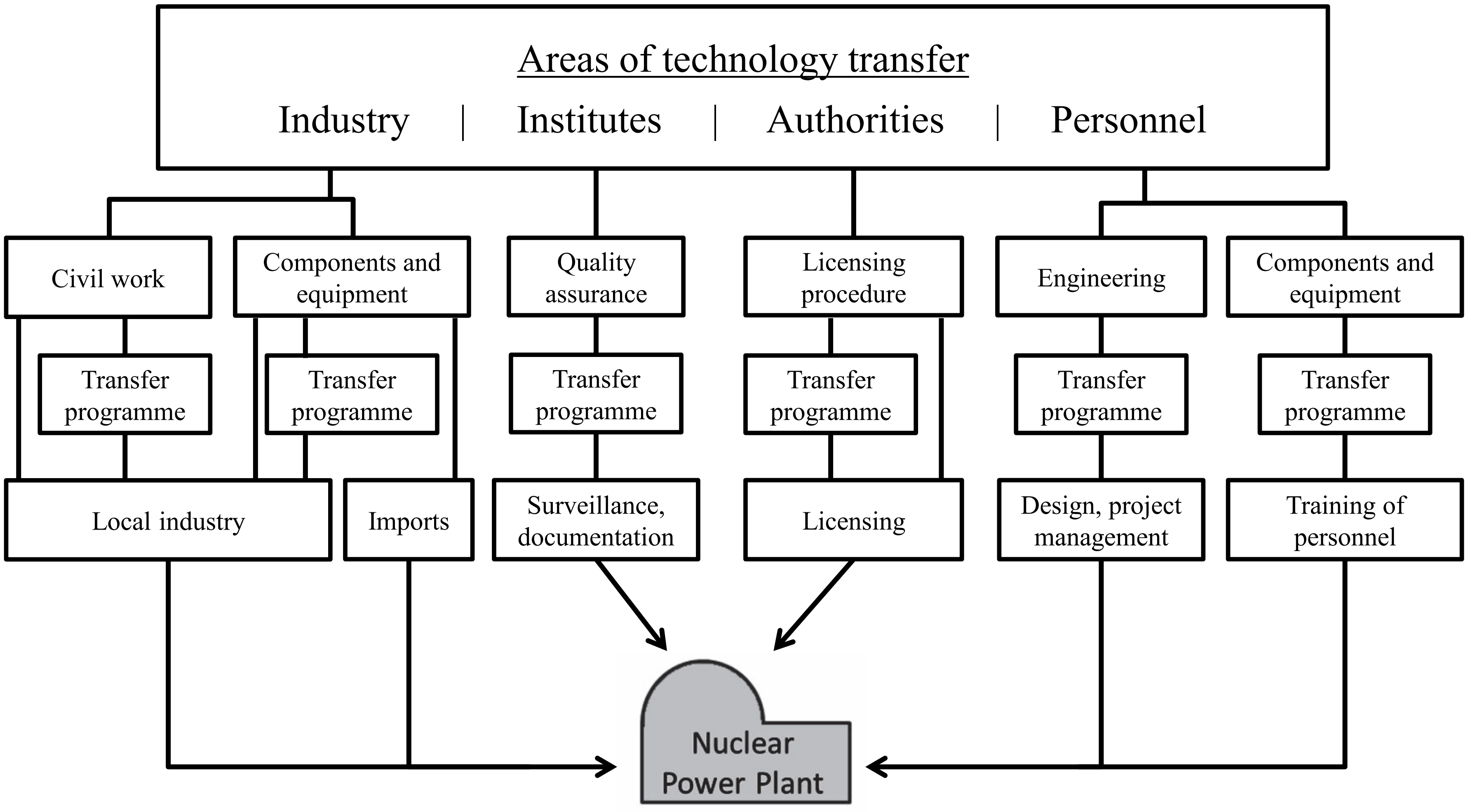

FIG. 6. Areas of technology transfer for nuclear power plants.

(b) Selective stage: Technical acquisition of the technology (subcontractor). The next stage is characterized by the receiver's increased technical understanding that enables it to be selective in its choice of processes, equipment and foreign suppliers. The receiver may also be selective in operational and maintenance methods and techniques, but remains dependent on the supplier for technical support in the more difficult situations.
(c) Adaptive stage: Joint design of indigenous product (subcontractor or primary contractor). The adaptive stage follows wherein the receiver is able to design an indigenous product with the help of the vendor. The receiver can remain the subcontractor of its foreign primary contractor (vendor) or could act as the primary contractor with the vendor as its subcontractor. The receiver starts modifying the vendor's technology to adapt to its specific markets. Adjusting to specific markets usually involves the introduction of site specific conditions into the engineering. It also requires modifying specifications and processes to accommodate the components of local manufacture if the materials are available locally and to accommodate the abilities of the local labour force.
(d) Mastery stage: Technical self-reliance (primary contractor). This stage is the highest that can be achieved. At this stage, the receiver has such a good command of the technology acquired that it can now modify the technology at will to suit its own objectives and policies. At this stage, the receiver acts as a primary contractor to sell its products, and the vendor could be its subcontractor. Modifying a technology is a creative activity based on a thorough knowledge of the processes and technology. The activity is creative because a solution has to be invented to satisfy a new need. A thorough understanding is also essential to ensure that the product is not affected adversely by the modification.

There is no clear division between each stage because all four are part of a continuum in which the growing experience of the receiver results in the acquisition of knowledge and increasing competence.

The move towards self-reliance is also a move towards responsibility and liability in contracts. Understanding the process of technology transfer requires that the receiver has personnel at a higher level of technical education than is needed for the first two stages of a nuclear power plant. The creative activity requires personnel that are capable of original thinking. Once the receiver has personnel of this quality contributing to the technology, it is only a matter of application and time for the receiver to master the technology. To make this significant step, the receiver also needs to have, or to develop, the more sophisticated management skills required to guide technological change to integrate technology, personnel, finance and the market into a successful corporate achievement.

The transfer of all aspects of a technology need not take place at the same speed. Indeed, they are unlikely to do so when a complex technology is transferred. For example, some civil engineering activities may be adapted to the use of local materials and labour practices at an early stage in nuclear technology transfer. However, the materials and the fabrication techniques used for the manufacture of key components are likely to remain unchanged for some time.

5.2.3. Methods and means of technology transfer

Any country starting a nuclear power programme is immediately involved in a technology transfer with a range of institutions. The utility requires the capability to manage, operate and maintain a nuclear power plant, while engineering companies require the capability to construct nuclear power plants, including undertaking the design, which is specific to the local plant. The manufacturing industry requires the capability to manufacture to nuclear standards, while the NRB needs to be able to devise regulations and supervise their implementation. There is also a need for technology transfer for activities that are not purely nuclear, such as standardization, testing and R&D. Methods of technology transfer can be one, or a combination, of the following:

— Off the job training or education in universities or educational institutions, industrial classroom training within receiver or vendor organizations, field observations and briefings;
— On the job training or education in home offices or site offices concerned with an ongoing nuclear power plant project, in manufacturing factories or construction facilities involved with an actual nuclear power plant project, or in technical assistance programmes either in the offices, sites or factories.

For both approaches, there will be customized and standard courses.

In the transfer approaches and methods employed, documentation will be important. At the end of an extensive technology transfer, there may be a large quantity of documents. The documentation needs to be managed considering the demand from receiving countries. The content, format, distribution and control of this documentation are therefore important. The cost of this seemingly minor item of technology transfer can be an important, non-negligible amount. In a typical example of technology transfer, a selection of more than 10 000 technical reports and engineering documents could be transmitted in the first year, and in 5 years this total could increase to 55 000, with 125 computer programs supplied.

The language employed for technology transfer can be a vital factor in the process. Ideally, the technology transfer would be conducted in the receiver's language, but this is not always practical for reasons such as:

— It can be difficult for the vendor's personnel to acquire the new language quickly.
— There is often the need to expand the receiver's language to include the new technology.
— Producing the documentation, videos and computer programs in the receiver's language is a long term project on its own.

5.3. STRUCTURES OF TECHNOLOGY TRANSFER

There are many types of agreement under which technology can be transferred. The form of agreement suitable in particular conditions is determined by the technical competence of the receiver and the way the supplier and the receiver intend to use the technology after the transfer. The characteristics of some distinct types of agreement and the conditions for which they are more appropriate are described in Sections 5.3.1 and 5.3.2.

The definition of the technology and the technical services is of fundamental importance to a successful agreement. This is not only a question of defining the scope of the technology transfer. It is also necessary to be specific about the scope and nature of technical services and technical assistance to be provided and especially to be clear about the end product and the know-how involved. In practice, differences in expectations are a common cause of difficulty in technology transfer: the perceptions of the receiver and the supplier may differ in the technology to be transferred, the capability to be achieved by the receiver, and the relative importance of documentation and training in achieving this capability. Misunderstandings of this sort can be avoided by a full discussion and careful documentation of the technology transfer process and its scope.

5.3.1. Intergovernmental agreements

For nuclear power plant projects, intergovernmental agreements are generally necessary for countries participating in technology transfer because of the sensitive nature of nuclear technology and the related treaties and conventions that govern its transfer. These intergovernmental agreements indicate the intent of each State to respond to the request of the other State in the area covered by the agreement.

Intergovernmental agreements are particularly desirable in the pre-project phase, when a country is exploring the technical and commercial aspects of a nuclear power programme. One result of an intergovernmental agreement is that it provides a framework. The individual working agreements for technology transfer and providing the plants, equipment and services can be drawn up and rapidly agreed to, since they conform to an already established and accepted method of working between the two countries. This is particularly important for nuclear power plant technology because vendors are prohibited by national laws and international agreements from transferring technology without specific government approval. These approvals can result from intergovernmental agreements.

The agreements between specific organizations under the general cover of intergovernmental agreements need not be limited to companies in the nuclear power industry. If both parties wish, the contract can be written to include detailed agreements among R&D organizations, standards institutes, government departments and educational institutions.

As a technology is only transferred when the receiver is able to practise the technology, the importance of training cannot be overemphasized. The agreement needs to specify the training to be given and the level of competence that the trainees are to achieve.

When entering into contractual agreements, suppliers will generally only accept contracts written in their own language or in a language common to both parties. Here there is the potential for misunderstandings that could cause serious problems and perhaps lead to litigation. The language used for technology transfer for all documentation, including drawings, specifications and official communications, is of great concern and can also have wider implications.

5.3.2. Company agreements

Of particular importance for company agreements is the definition of the technology to be transferred, and the level of competence that the receiver is to achieve. There also needs to be a clear definition of how the competence is to be established. The type and nature of documents that will be transferred, the formal training that will be given, the on the job training in the supplier's facilities and the secondment of supplier's personnel to the receiver's organization all need to be covered.

5.3.2.1. Licensing agreements

Licences can be categorized in three ways. They can be: for select IPRs to copy and distribute a technology; for all of the IPRs necessary to reproduce, make, use, market and sell products based on a type of technology; or for all the IPRs necessary to create and market a product that complies with a technical standard [30]. When looking to acquire a licence for a certain technology, it is important for the receiver to have determined how the technology will be used over the duration of the entire nuclear power programme, as this will affect the number of IPRs to be included in the licensing agreement. A receiver needs to be careful not to acquire more rights than are needed to meet the goals of the nuclear power programme, because this could lead to unnecessary increased costs.

Regardless of the extent of IPRs included in the agreement, the agreement needs to specify that the receiver has access to improvements in the technology. If it does not, the receiver will have bought a static technology and will only be able to keep a place in the market by improving the technology or by concluding a further agreement with a supplier, which could require additional cost. Another reason for defining the technology clearly is to ensure that there is no dispute about what constitutes a change in the technology, although it may still be difficult to distinguish between improvements and the development of new techniques. Guarantees by the licensor need to ensure that:

- The technology is suitable for the products covered by the agreement.
- The know-how transferred belongs to the licensor.
- The technology is capable of achieving the level of production that is specified.
- The content of the technology transferred is full and complete.
- The delivery of drawings, specifications and materials is completed within the specified time period.

Restrictions on the licensee depend on the relative bargaining strength of the supplier and receiver. In addition to restrictions on the territory of sales and the purchase of specified materials and items, suppliers may wish to impose restrictions on items such as pricing, production and obtaining know-how from others.

Inspection and reporting concern the rights of the supplier to have access to the plants, records and accounts of the receiving company. Inspection and reporting assume special importance when the receiver makes royalty payments to the supplier to use the technology.

5.3.2.2. Technical cooperation agreements

Technical cooperation agreements are usually based on a very limited scope of technology transfer in which the receiver performs the work with the technical assistance of the vendor. These agreements, which automatically involve on the job training, are particularly used in manufacturing and construction sectors. In this type of agreement, the vendor plays a fairly dominant and leading role, and, in principle, the receiver follows the instructions of the vendor.

The term technical cooperation agreement is used here to cover a wide spectrum of technology transfer agreements in which the supplier's efforts to transfer technology go beyond handing over documents. However, the intention of these agreements is the same as a licensing agreement; namely, that when technology transfer has been completed, each party will continue as before to pursue its business independently and competitively. The word cooperation is used in recognition of the close working relationship that is necessary for successful technology transfer.

The number of documents, such as drawings, specifications, codes of practice, materials lists, reports and computer codes, involved in the transfer of nuclear technology can be very large. The work required for identifying and cataloguing can be considerable, and the supplier needs to take steps to ensure that the material is understood and used correctly. These steps include training and consultancy work, which may involve formal training sessions in which the receiver's personnel work in the supplier's shops and offices. At the same time, the supplier's personnel may work with the receiver's staff during the execution of the project in both the supplier's and the receiver's countries.

The agreement may be prepared in several ways with regard to the following three distinct aspects of the transfer process:

(a) Establishing the agreement: The supplier provides information on what may be transferred, on defining the scope of the technology to be transferred, and on the methods and administration of the transfer. With this process, the supplier runs the risk that its proprietary knowledge may be disclosed without the protection of an agreement. These costs and risks are often covered by an initial fee or down payment.
(b) Implementing the transfer: The supplier prepares and transfers documents, provides consultancy services and trains receiver personnel. The receiver usually pays for these services on a normal cost plus basis.
(c) Licensing the technology transferred: When the technology has been transferred according to the terms of the agreement, the supplier and receiver are in the position of licensor and licensee. The technical cooperation agreement needs to make provisions for the continued use of the technology by both parties. The provisions will usually include royalties or similar payments from the receiver, based on the use of the technology.

The agreement will also normally contain provisions defining the way the receiver uses the technology, and the markets in which the supplier and receiver will operate after the technology has been transferred. Provisions of this nature will have to be discussed in due time. As there is no absolute way of calculating the value of technology, the amount of the initial down payment and of the royalties on subsequent use of the technology can only be determined by negotiation and bargaining between the supplier and receiver. The payment for services given by the supplier during the transfer are usually charged at cost plus, and are thus not subject to the same type of negotiation.

5.3.2.3. Joint ventures

A joint venture is distinguished from licensing and technical cooperation agreements by the arrangement existing after the technology has been transferred. In a joint venture, the supplier and receiver agree at the beginning that the association established for transferring the technology will be maintained in the future and that there will be a continuing relationship between the parties through the phase of transfer into the phase of exploitation.

The organization and administration of the transfer, and the payment by the receiver for services from the supplier, need not be any different from a technical cooperation agreement. However, the considerations affecting an initial fee and the commercial relationship after the technology is transferred need to be judged from a different perspective.

The joint venture implies an identical interest in the outcome of the transfer and in the continuing association. This in turn implies that both parties will continue to commit resources to the venture after the initial transfer is complete. The definition of these commitments in practical terms is usually a necessity. Thus, the vendor and receiver co-sign and co-produce the products resulting from the technology transfer. The agreement needs to include a provision that the receiver has access to improvements in the technology within a certain time frame and under specified conditions.

5.3.2.4. Consultancies

Agreements governing consultancies provide limited technology transfer, and the vendor plays a relatively passive role in contrast to that played in the other agreements. In principle, the vendor advises but does not instruct the receiver on how particular work needs to be done or how a particular situation needs to be handled. This can be a good means for transferring software technologies and skills.

5.3.3. Commercial considerations

Suppliers develop a mastery of the technology at high cost and great risk, and usually over a long period. In addition, considerable effort will likely be expended when transferring the technology. It is reasonable to expect the supplier to want compensation when it transfers its technology and to seek payment in some form, because the technology is being bought and sold like any commodity.

However, the receiver's usual lack of experience in, and appreciation of, the degree of complexity of the technology in question complicates the establishment of a fair price for the value of the technology transfer. Therefore, the receiver has difficulty appreciating or quantifying the investment in effort and money made by the supplier in developing the technology. In addition, there is also the difference in costs of resources used as perceived in the supplier's country and in the receiver's country.

Nevertheless, the technology market has one aspect in common with other markets: technology transfer will only be successful when both the supplier and the receiver perceive that they will benefit from the transaction.

5.4. PROTECTING THE TECHNOLOGY

The establishment of a technology transfer agreement will be facilitated if the legal system in the receiver country recognizes the ownership of intellectual property, as well as physical property, and also gives technology transfer contracts the same legal protection as any legal contract. For example, the undertakings of both parties need to be legally enforceable and both need to be protected against a third party having access to the information transferred when that party is not a participant in the transfer agreement.

Similarly, there needs to be special provisions for technology transfer that allow the supplier to receive fair and reasonable compensation and to be protected against unreasonable exploitation. The legislation needs to reflect a proper balance between the rights and interests of the supplier and those of the receiver. When this is achieved, the responsible organizations will be able to reach an agreement within the legal framework.

5.4.1. Legal framework for agreements

The function of a legal framework is to facilitate technology transfer by establishing conditions that afford protection of the legitimate rights of the supplier and receiver. Thus, the framework needs to enable technology transfer agreements to be made, including:

- The handover of specifications, drawings, designs, samples and models as appropriate to the agreed scope of transfer;
- A provision for training the receiver's personnel to enable the receiver to acquire the technology up to the desired level of transfer;
- Agreement on a sufficient duration to enable the receiver to practise the acquired technology;
- Fair and reasonable use and exploitation by the receiver of the technology transferred;
- Protection against abuse of the information transferred and its unauthorized exploitation by third parties;
- The establishment of licence fees, royalties and other forms of payment that give the supplier fair compensation.

Designs, patents and copyrights apply to distinct and relatively easily identifiable types of intellectual property and therefore can be described and registered. There is much intellectual property covered by know-how that does not fall into any of these definitions, and for these the owner needs to rely on secrecy for protection. Most nuclear technology transfer agreements are on this type of intellectual property. A relatively small proportion of the information transferred will have been described in patents and other published documents. In an area as complicated as technology transfer, it is often beneficial to review the experience of others as a means to learn what to implement and what to avoid.

6. BUILDING LOCAL INDUSTRIAL INVOLVEMENT FOR A NUCLEAR POWER PROGRAMME

6.1. INTRODUCTION

This section provides a summary of important actions that need to be taken by government and industrial organizations in Member States in order to make decisions appropriate to local industrial involvement in support of nuclear power programmes. The main organizations that need to be involved in the decision making process with regard to local industrial involvement are considered during each of the three phases of the Milestones approach. This section can be viewed as a starting point for the preparation of national strategies and plans to develop industrial involvement in support of a nuclear power programme. However, Member States need to develop their own, much more detailed and specific plans.

6.2. MAIN ORGANIZATIONS INVOLVED

6.2.1. Government

One component of the total infrastructure that is central to the implementation of a new and large endeavour is the government, as represented by all its departments and political structures. The government provides a focus and is a source for major movements towards new commitments. It also represents the formal link between domestic intentions and foreign countries and external agencies. The role of the government is:

— To establish national policy;
— To support industries through setting BIS conditions consistent with industrial involvement;
— To build capacity;
— To standardize the programme;
— To develop the necessary legal framework.

It is important to note that not all vendors are owned by governments. In cases of both private and State owned suppliers of nuclear technology, the government's role is also to provide bilateral assurances, export approvals, regulatory experience and insight into the designs licensed in the country of origin.

At the broad national level and in setting details in specific areas, a planning process is essential. To ensure the delegation of the governmental authority in the first two phases of the Milestones approach for a nuclear power programme, governments should organize a coordination mechanism, referred to as a nuclear energy programme implementing organization (NEPIO), within the Milestones approach [1]. The overall responsibility of the NEPIO is to lead the effort in establishing a nuclear power programme. During Phase 1, the NEPIO is responsible for compiling all the information necessary for the government to make an informed decision on whether or not to proceed with the nuclear power programme. If a positive decision to do so is taken, the NEPIO will be responsible during Phase 2 for coordinating and overseeing the development of the necessary infrastructure to bring the country to a point of issuing a bid for its first nuclear power plant project. The main roles for the government include planning for infrastructure and supporting national industrial involvement.

6.2.1.1. Planning for infrastructure

Long term national energy system planning led by the government is an essential element in exploring options available to the country and in assessing associated costs and benefits. The government can help to determine whether a major programme such as a nuclear power plant is a viable option, when it should ideally be implemented and what agencies need to be involved. It is also the role of the government to discuss the priorities with regard to job creation, foreign exchange demand, scheduling and other aspects of the nuclear power project. The planning process will recognize existing policies that influence or determine national activities and lead to recommendations for new policies. These policies may include taking positions on issues such as public versus private enterprises, resource allocation, trade and tariff barriers, and the degree of encouragement of foreign investment or other participation. Government policy identifies the jurisdictional control over education, health and safety measures, and is reflected in laws and regulations on matters such as technology transfer and foreign ownership.

6.2.1.2. Supporting national industrial involvement

Local industrial involvement is not only in plant operation and maintenance, but also in civil construction, mechanical and electrical installation, equipment manufacture and support services. While some areas of the programme, both nuclear and non-nuclear, have a high technological content and stringent quality requirements, other areas, such as the construction of buildings, minor civil works and fencing, will involve standard engineering practices. In addition, there may be local firms that are already capable of manufacturing much of the construction equipment and the less critical system components.

The support that can help local industrial suppliers is derived from a combination of political, technical and organizational factors within the infrastructure. Whether or not local suppliers are given protection will depend on the benefit to the country. Before making a decision, it is necessary to evaluate whether the investment — either directly through subsidies or indirectly through tariffs or import control — will lead to stronger companies that are able to compete later in nuclear, or other allied high technology, projects that are planned without subsidies. If the evaluation is positive, the implication is that the main contract for the nuclear power plant could require that bids include local companies as subcontractors where local involvement is feasible.

However, much more is involved. If local companies do not properly understand the technical and commercial conditions in the bid documents or commercial contracts, they may not price the bid appropriately, which can lead to prolonged renegotiation.

In most cases, technology transfer will be necessary if local participation is to increase as the nuclear power programme progresses (as discussed in Section 5). Once a local participant has been identified, adequate resources need to be provided for it to absorb and use the technology. Participants will have to invest resources to train personnel and to develop test facilities. The government can help by providing suitable incentives.

6.2.2. Industry

Once there is a commitment from the government to support the introduction of nuclear power (Milestone 1), the transition of the main responsibilities for the development of local industrial involvement begins to shift from the government to industry. The main local industrial organizations that are expected to have the lead roles in this effort include the following:

- The prospective owner/operator of the planned nuclear power plant units (often one of the main suppliers of electricity generation in the country);
- Local industrial organizations that provide goods and services to the existing electricity generation industry;
- Professional organizations that represent local engineering, construction and manufacturing industries;
- Trade unions whose members work in the above industries;
- Vocational education and training organizations that develop the skills of the local workforce;
- Organizations that provide technical support, including goods and services, to the existing local nuclear application organizations (e.g. non-destructive examination, radiation protection, dosimetry and quality management).

Sections 6.3–6.6 examine the specific actions that the governmental and industrial organizations need to take to plan for, and develop, the local industrial involvement to support the nuclear power programme.

6.3. ASSESSING POTENTIAL FOR LOCAL INDUSTRIAL INVOLVEMENT (PHASE 1)

During Phase 1, a NEPIO would consider the 19 issues identified in the Milestones approach and produce a comprehensive study clearly delineating the commitments and processes necessary to undertake a nuclear power programme. This comprehensive study should be backed up by a series of more detailed papers for individual or related groups of these issues [31].

One such study area is industrial involvement and the expected involvement of local and national industrial organizations. The results of these studies are generally reported in a prefeasibility study (PFS). Depending on how the NEPIO is organized, it will be either responsible for the conduct of the PFS or will be the customer who oversees the PFS, which is performed by a consultant. In either case, the NEPIO needs to be closely involved with the PFS and own the results.

During Phase 1, the organizations that need to contribute to the PFS with regard to local or national industrial involvement include:

- Government organizations involved in energy, industry and economics;
- National industrial organizations and their principal members;
- Utilities (owner/operators of the electrical generation industry).

The principal activities of the PFS associated with industrial involvement to be conducted during Phase 1 include:

- A survey of national industry capabilities that could support a nuclear power programme;
- The establishment of a strategy for national industrial participation;
- A localization plan;
- A technology transfer plan.

Those who participate in these activities collectively need to have competencies associated with establishing industrial involvement for a nuclear power programme and national or local laws, regulations and practices governing the industrial sector. Experience has shown that the competencies in establishing the industrial involvement for a nuclear power programme are generally not a part of the organizations listed above. Thus, consultants are often used to provide this expertise for the PFS.

Establishing ongoing dialogue with potential NSSS vendors and EPC contractors for nuclear power plant projects helps to develop an understanding of the steps needed to provide industrial involvement for a nuclear power programme. Such organizations are generally quite willing to organize joint meetings and workshops with the NEPIO on topics such as industrial codes and standards, regulatory and licensing approaches, technology transfer, and local industrial involvement in construction, erection and plant operation. The NEPIO needs to invite leading local industrial organizations, governmental officials and other affected stakeholders to these sessions. It is generally advisable to have government–government agreements in place to establish a framework within which this type of industry–industry dialogue can be implemented. This is particularly important for nuclear power programmes, given the sensitive technologies involved.

A realistic survey and assessment of the national and local capabilities to supply commodities, components and services for the construction of a nuclear facility is an essential input to further economic, financial and commercial studies. Consequently, the national industry survey needs to focus on several aspects, including the financial and economic aspects outlined in Section 4.2.

In particular, the strategy for localization and the localization plan will rely upon the results of this assessment. The strategy needs to include realistic estimates of the funding and financing mechanisms that will be provided by the government and industry to achieve the localization goals and to avoid project risks and any negative impacts on the project schedule. Appendix I provides a checklist of the actions during Phase 1 associated with industrial localization and indicates the organizations responsible for these actions.

6.4. PLANNING FOR LOCAL INDUSTRIAL INVOLVEMENT (PHASE 2)

Phase 2 will only be initiated if a decision has been made to proceed with the nuclear power programme. Thus, the emphasis in this phase will be on developing the capabilities of the future NRB and operating organization, as well as updating and implementing the plans for local industrial involvement as part of a larger overall plan for the programme. The NEPIO will continue to have a role in coordinating planning efforts and communications that cross organizational lines, as well as in ensuring that other governmental and industrial organizations with important roles to play are engaged in the programme. However, organizations that will have the lead roles in the nuclear power programme will increasingly take greater responsibility for implementing the plans developed during Phase 1. In particular, these will include the prospective owner/operator of the first nuclear power plant, governmental organizations that may finance developing the capabilities of local industrial organizations, and industrial organizations that expect to have roles in the construction, commissioning and operation of the first nuclear power plant units.

As Phase 2 commences, the prospective owner/operator will establish the team to manage the project for the first nuclear power plant units. Even though it is expected that the construction and commissioning of these projects will be turnkey contracts with the lead responsibility resting with an EPC contractor, this contract will not yet be in place (and much of Phase 2 will be devoted to developing the information needed to solicit bidders for this project). This team needs to include individuals with expertise in the industrial involvement required for the nuclear power programme. If this expertise is not available within the organization, the owner/operator needs to consider ways to supplement the team, such as through the use of consultants.

During Phase 2, one of the main activities of the owner/operator project team is to prepare the specifications for the contract for the first nuclear power plant units. The localization plan will have a direct impact on the scope of supply to be specified in the EPC contract, as well as provisions in this contract regarding incentives or requirements for the use of local suppliers. The expectation is that, during Phase 2, there will be continuing dialogue among potential EPC contractors and the owner/operator team, as well as local industrial organizations on all aspects of the planned project in order to build mutual understanding, including:

(a) Sharing draft plans on localization and technology transfer, as well as survey results of local industrial capacity with potential suppliers, and soliciting their feedback;
(b) Inviting potential suppliers to meetings, conferences and industrial fairs that provide opportunities to interact with local industrial organizations that can support the nuclear power plant project;
(c) Sharing draft specifications for the first nuclear power plant units with potential suppliers and soliciting their feedback, including incentives and requirements for local industrial participation;
(d) Updating and expanding the survey of local industrial organizations that can contribute to the nuclear power programme;
(e) Prequalifying local industrial organizations for the supply chain for the first nuclear power plant units (to include audits and assist visits related to quality management systems);
(f) Holding workshops and training courses to develop the competencies that are unique to the construction and commissioning of nuclear power plants.

As indicated in Section 5.1, the transfer of knowledge from the EPC contractor/NSSS vendor to the owner/operator on the operation and maintenance of the first nuclear power plant units is not considered technology transfer. Technology transfer pertains to the design and manufacture of SSCs for nuclear power plant units. Thus, if there are plans for technology transfer for the first units ordered, the contracts and agreements for this transfer will be generally separate from the turnkey contract between the owner/operator and the EPC contractor. These agreements will be between the design and manufacturing organizations that provide the SSCs for the first units and local design and manufacturing organizations (with government–government agreements providing the foundation for these commercial agreements). Thus, during Phase 2, the structure for these technology transfer agreements needs to be put in place, along with the financing that will be needed to implement these plans. The volume and structure of national participation and technology transfer to be defined in the BIS (as indicated in Ref. [29]) depend primarily on:

— The size of the nuclear power programme in the country;
— The technical and economic status of the national industry;
— The owner/operator's business plans;
— Non-proliferation considerations.

Appendix I provides a checklist of the actions during Phase 2 associated with industrial localization and indicates the organizations responsible for these actions.

6.5. IMPLEMENTING LOCAL INDUSTRIAL INVOLVEMENT PLANS (PHASE 3)

At the beginning of Phase 3, the prospective owner/operator is ready to invite bids for the first nuclear power plant units. If the prospective owner/operator has completed the activities described in Section 6.4 for planning the local industrial involvement, then these plans will be implemented during this phase and progress will be tracked based on the actions identified in these plans.

Once bids are received for the turnkey project, the bid evaluation team will assess all aspects of the proposals submitted, including those associated with local industrial involvement. Assuming that suitable weighting has been included in the bid evaluation process for the local industrial involvement, the bid evaluation team will evaluate all bids using these criteria, and will make technical recommendations that consider these and other factors in ranking the technical proposals. In addition, the financial proposals may have aspects related to budgets and financing for local industrial involvement.

There will be some scope of work for the first nuclear power plant project that the prospective owner/operator will be either responsible for, or will contract out to, other local industrial organizations. Examples of such projects include:

— Site preparation and development of local roads and waterways;
— Administrative buildings;
— Lodgings for site workers;
— Training centres;
— Switchyards and grid upgrades;
— Physical protection and security;
— Emergency response facilities.

Vocational training to support the technical areas that are unique to a nuclear power programme that was planned for during Phase 2 need to be implemented on a schedule that supports the first nuclear power plant project. This needs to be a cooperative effort among government ministries, educational and training organizations, the EPC contractor and local industrial organizations.

Once the turnkey contract has been awarded and the nuclear power plant project is under way, regular monitoring and reporting by the EPC contractor on local industrial involvement will be implemented in keeping with the provisions of the contract. If there is a separate technology transfer contract between the EPC contractor and local industrial organizations, regular reporting on technology transfer progress will be provided. Appendix I provides a checklist of the actions during Phase 3 associated with industrial localization and indicates the organizations responsible for these actions.

6.6. LOCAL INDUSTRIAL INVOLVEMENT DURING THE PLANT OPERATION PHASE

From Phase 1 onwards, localization plans need to have considered opportunities across the full spectrum of the nuclear cycle, from the front end (e.g. uranium conversion, uranium enrichment, fuel fabrication and, in particular, localization during the new build projects) through to the operation and maintenance phases. Opportunities for localization will also exist at the back end, such as in waste management facilities, in spent fuel reprocessing and even in the decommissioning phase. During the plant operation phase, such plans need to be regularly reviewed and updated, particularly when significant changes in the nuclear power programme are considered, such as adding additional nuclear power capacity.

At the beginning of the plant operation phase, there will be a transition from the EPC contractor having the lead role in the supply chain to the owner/operator being largely responsible. The EPC contractor/NSSS vendor will typically have a significant support role during the first years of the plant operation phase. However, the localization plan needs to include efforts for the owner/operator and other local industrial organizations to take on increasing responsibilities for maintenance, engineering, outage management and technical support. Economic and financial considerations will have a role to play in such plans. Both the government and industry need to consider the investments that they are willing to make to support industrial localization, given the medium and long term benefits and risks.

If the owner/operator or NRB plan to use TSOs to support their activities, localization plans need to include the identification of local industrial organizations that can take on some, or all, TSO functions. Partnerships between local industrial organizations and established TSOs that support similar nuclear technologies need to be considered. Existing local R&D and TSOs, particularly organizations for nuclear applications, are logical candidates to provide technical support for the nuclear power programme or to take on roles to operate other fuel cycle facilities or services involved in radioactive waste management, dosimetry, non-destructive examination and ISI.

Appendix I

CHECKLISTS FOR BUILDING LOCAL INDUSTRIAL INVOLVEMENT FOR A NUCLEAR POWER PROGRAMME

Tables 1–4 provide checklists to supplement the information provided in Section 6 on building local industrial involvement for a nuclear power programme. The checklists are organized chronologically based on the Milestones approach to infrastructure development. The checklists have also been developed in accordance with Ref. [32]. Table 4 is a checklist for the plant operation phase, but it is only a general framework. The owner/operator and other local organizations involved in the nuclear power programme will need to develop detailed plans for local industrial involvement during this phase as they proceed with the construction and commissioning of their country's first nuclear power plant (Phase 3).

TABLE 1. ACTIONS FOR PHASE 1

Action	Responsible organization	Completed	
		Yes	No
Ensure that the NEPIO is staffed or supported by individuals who have knowledge of both local industrial capabilities and the industrial involvement needed for a nuclear power programme	NEPIO		
Include industrial involvement as a topic area in the PFS of the nuclear power programme	NEPIO		
Initiate dialogue with potential NSSS vendors	NEPIO and prospective owner/operator (if determined)		
Initiate government–government dialogue with the countries of origin of potential suppliers	NEPIO and cognizant ministries and agencies		
Invite selected potential suppliers and leading local industrial organizations to a working session to discuss industrial involvement issues such as industrial codes and standards, regulatory and licensing approaches, and local industrial involvement in construction and erection	NEPIO and prospective owner/operator (if determined)		
Consider opportunities to provide key staff with knowledge of industrial involvement for a nuclear power programme by working alongside NSSS vendors or operating organization personnel for an established nuclear power programme	NEPIO and prospective owner/operator (if determined)		
Ensure that the PFS includes a determination of realistic goals concerning local industrial involvement based upon a study of associated risks and benefits of various alternatives as well as identification of technology transfer goals	NEPIO		
Establish mechanisms to build interest and support of local industry in the potential nuclear power programme	NEPIO and prospective owner/operator (if determined)		
Conduct surveys to identify local companies potentially capable of participating in a nuclear power programme	NEPIO and prospective owner/operator (if determined)		

TABLE 1. ACTIONS FOR PHASE 1 (cont.)

Action	Responsible organization	Completed	
		Yes	No
Develop a draft policy and approach for the management system (including quality control and quality assurance) to be used for the nuclear power programme	NEPIO and prospective owner/operator (if determined)		
Determine a suitable approach in drafting contracts for the first nuclear power plant project given the industrial involvement and other considerations	Government		
Propose a government policy with respect to national or local industrial involvement if the nuclear power programme proceeds	NEPIO		

Note: NEPIO — nuclear energy programme implementing organization; NSSS — nuclear steam supply system; PFS — prefeasibility study.

TABLE 2. ACTIONS FOR PHASE 2

Action	Responsible organization	Completed	
		Yes	No
Ensure that the project team for the first nuclear power plant has expertise in the industrial involvement needed for the nuclear power programme	Prospective owner/operator		
Decide upon the scope of supply of the EPC contract given the localization strategy and capabilities of local industrial organizations as well as technology transfer goals and objectives	Prospective owner/operator		
Continue dialogue with potential suppliers, including distributing draft BISs to qualified bidders for comment before they are officially issued to bidders Of particular interest to industrial involvement are provisions and incentives in the draft document with regard to the involvement of local suppliers in construction, erection and commissioning, including local manufacture of SSCs that can meet project quality standards and budget and schedule constraints	Prospective owner/operator		
Continue government–government dialogue with the countries of origin of potential suppliers, leading to formal memoranda of understanding on industrial and governmental support to be provided during Phases 2 and 3	NEPIO and cognizant ministries and agencies		
Work with qualified suppliers to survey local industry capabilities that can be proposed by bidders in the EPC contract	NEPIO and prospective owner/operator		

TABLE 2. ACTIONS FOR PHASE 2 (cont.)

Action	Responsible organization	Completed	
		Yes	No
Determine which incentives, if any, will be included in the EPC contract regarding preferences for local suppliers	NEPIO and prospective owner/operator		
Establish comprehensive legislation that covers safety, security, safeguards and nuclear liability, licensing and environmental impact assessment that need to be included in the bid package	Cognizant government ministries and agencies		
Establish that regulations for licensing the nuclear power plant are in place such that they can be included in the bid package for the EPC contract (detailed regulatory requirements to be developed once a supplier is selected)	NRB (with owner/operator and other affected parties to provide comments)		
Establish EPC contractor requirements for technology transfer, including intellectual property identified for inclusion in the bid package	Prospective owner/operator		
Identify a management system for construction and commissioning and plant operation (overall framework, not detailed codes and standards for nuclear specific SSCs)	Prospective owner/operator		
Ensure that the bid package includes (in the bidding process) requirements for suppliers to provide plans in their bids for transition to national and local suppliers during the plant operation phase and also for plants after the first nuclear power plant unit	Prospective owner/operator		
Conduct audits and assist visits to local industrial organizations to monitor their progress in preparing to be partners in the nuclear power programme	Prospective owner/operator		
Develop an approved local vendor/supplier list for inclusion in the BISs	Prospective owner/operator		
Include provisions in the bid package for suppliers to substitute foreign supplied items in case supply problems will have significant impacts on costs or schedule	Prospective owner/operator		

Note: BIS — bid invitation specification; EPC — engineering, procurement and construction; NEPIO — nuclear energy programme implementing organization; NRB — nuclear regulatory body; SSCs — structures, systems and components.

TABLE 3. ACTIONS FOR PHASE 3

Action	Responsible organization	Completed	
		Yes	No
Ensure that the bid evaluation team includes members who have competencies to evaluate effectively industrial involvement areas (in the bidding process)	Prospective owner/operator		
Ensure that the technical evaluation of bids appropriately considers industrial involvement in selecting the supplier to negotiate with (in the bidding process)	Prospective owner/operator		
Establish a supply chain for industrial involvement for the nuclear power plant project	Prospective owner/operator and EPC contractor/subcontractors		
Implement government–government support with country of origin of the EPC contractor	Cognizant government ministries and agencies		
Establish the qualification and selection of local industrial organizations for construction and erection contracts	EPC contractor with support from prospective owner/operator		
Provide vocational training to upgrade local labour force competencies, where needed, to meet nuclear standards	Vocational training organizations and EPC contractor		
Develop plans for the transfer of the lead role in the supply chain from the EPC contractor to the owner/operator	EPC contractor to submit proposed plan to the prospective owner/operator for review and approval		

Note: EPC — engineering, procurement and construction.

TABLE 4. ACTIONS FOR PLANT OPERATION PHASE

Action	Responsible organization	Completed	
		Yes	No
Transfer the supply chain lead role for maintenance and operation of the first nuclear power plant units to the owner/operator	Owner/operator and EPC contractor		
Implement outage planning with an emphasis on the first planned outage, including localization of suppliers	Owner/operator and EPC contractor		
Implement the plan for gradually increasing the localization of suppliers of goods and services for the operation phase, as well as subsequent units after the first nuclear power plant	Owner/operator		

Note: EPC — engineering, procurement and construction.

Appendix II

NUCLEAR POWER PLANT RELATED DATA

This appendix provides data on the physical SSCs of a nuclear power plant and the typical human resources involved. The source of the data is Ref. [2]. The data provide a general overview of the magnitude of the resources needed for a 1000 MW single unit nuclear power plant. The data are not to be used as the basis for budgeting or planning for a nuclear power programme.

The industries involved in the life cycle of a nuclear power plant are those directly implicated in the programme, such as the engineering companies, the suppliers of equipment and materials, and the construction contractors for site work. There are also the indirectly associated industries such as the test laboratories, subvendors and subcontractors, training centres, maintenance services and transport. Approximately 300–500 companies may participate for typical supplies of material and equipment, and provide typical semifinished products for mechanical, electrical and other components. Figure 7 depicts the typical supplies of material and equipment needed for the construction of a nuclear power plant. Table 5 reports some typical quantities of hardware involved in the construction of a nuclear power plant, and Table 6 shows the human resources required for the construction of a nuclear power plant.

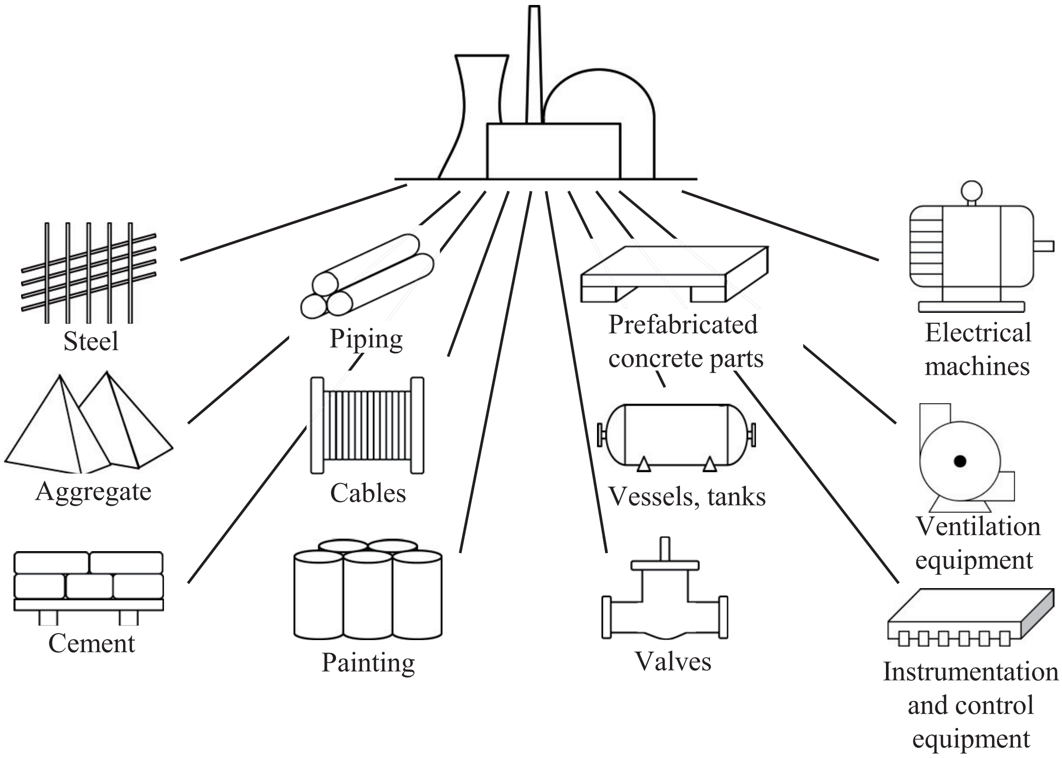

FIG. 7. Typical supplies of material and equipment [2].

TABLE 5. TYPICAL QUANTITIES OF HARDWARE IN A 1000 MW NUCLEAR POWER PLANT

Item	Typical value
Civil	
Cement	60 000 t
Aggregate	200 000 m^3
Concrete	200 000 m^3
Formwork	350 000 m^2
Reinforcement	20 000 t
Embedded parts	2 000 t
High tension steel	500 t
Decontamination paint	200 000 m^2
Mechanical	
Supports	400 t
Pipes	60 000 m
Welds	50 000 m
Pumps	280
Vessels/tanks	260
Heat exchangers	250
Valves	12 650
Hand operated (150 different types)	10 600
Motor operated (25 different types)	450
Valves for measuring circuits	1 600
Electrical	
Drives	900
Large transformers	21
Cables	430 000 m
High voltage	20 000 m
Low voltage	410 000 m
Control and instrumentation	
Video display units	8
Recorder	60
Indicators	500
Alarm windows	1 000
Cubicles	200
Modules	16 000
Instrumentation cables	1 500 000 m

Source: Kraftwerk Union, table V of Ref. [2].

TABLE 6. TYPICAL HUMAN RESOURCES INVOLVED IN A 1000 MW SINGLE UNIT

Area	Person-hours
Engineering and project management (utility)	2 500 000
Construction	
Engineering and project management (main contractor)	4 500 000
Civil	7 600 000
Mechanical/electrical	5 500 000
Quality assurance/quality control	500 000
Startup	300 000
Typical peaks	**No. of people**
Regulatory function	50
Engineering and management (main contractor)	500
Construction	2 500
Startup	200
Quality assurance/quality control	100
Operation and maintenance	220

Source: Table VI of Ref. [2].
Note: Equipment manufacturing is not included.

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ABBREVIATIONS

ASME	American Society of Mechanical Engineers
BIS	bid invitation specification
BOP	balance of plant
EPC	engineering, procurement and construction
EPCM	engineering, procurement and construction management
IPR	intellectual property right
ISI	in-service inspection
ISO	International Organization for Standardization
NEPIO	nuclear energy programme implementing organization
NRB	nuclear regulatory body
NSSS	nuclear steam supply system
PFS	prefeasibility study
SSCs	structures, systems and components
TSO	technical support organization

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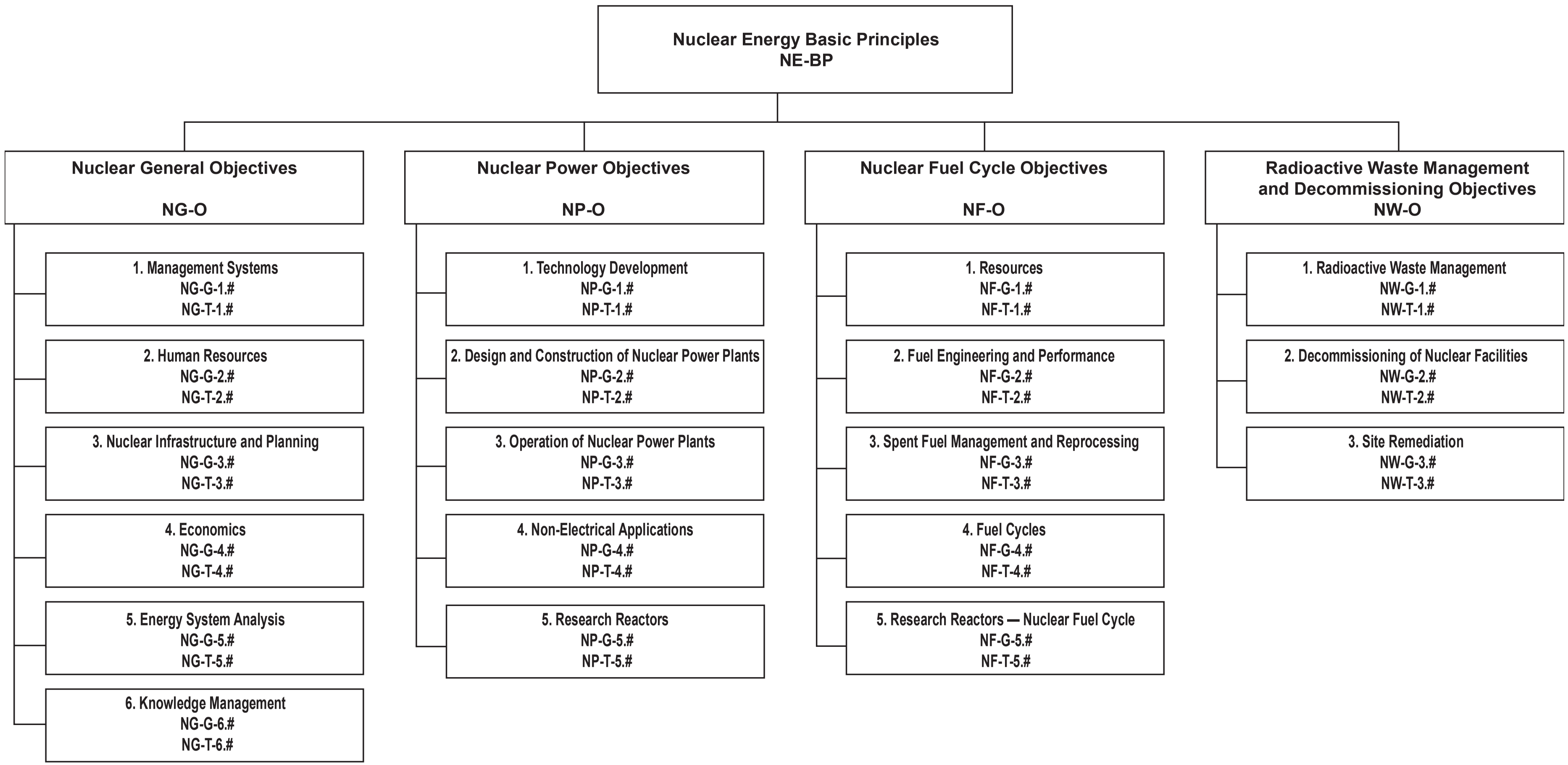

Key

BP: Basic Principles
O: Objectives
G: Guides
T: Technical Reports
Nos 1-6: Topic designations
#: Guide or Report number (1, 2, 3, 4, etc.)

Examples

NG-G-3.1: Nuclear General (**NG**), Guide, Nuclear Infrastructure and Planning (topic **3**), **#1**
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NF-T-3.6: Nuclear Fuel (**NF**), Report (**T**), Spent Fuel Management and Reprocessing (topic **3**), **#6**
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