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Potential for Sharing Nuclear Power Infrastructure between Countries

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FOREWORD

The introduction or expansion of a nuclear power programme in a country and its successful execution is largely dependent on the network of national infrastructure, covering a wide range of activities and capabilities. The infrastructure areas include legal framework, safety and environmental regulatory bodies, international agreements, physical facilities, finance, education, training, human resources and public information and acceptance. The wide extent of infrastructure needs require an investment that can be too large or onerous for the national economy.

The burden of infrastructure can be reduced significantly if a country forms a sharing partnership with other countries. The sharing can be at regional or at multinational level. It can include physical facilities, common programmes and knowledge, which will reflect in economic benefits. The sharing can also contribute in a significant manner to harmonization of codes and standards in general and regulatory framework in particular. The opportunities and potential of sharing nuclear power infrastructure is determined by the objectives, strategy and scenario of the national nuclear power programme.

A review of individual infrastructure items shows that there are several opportunities for sharing of nuclear power infrastructure between countries if they cooperate with each other. International cooperation and sharing of nuclear power infrastructure are not new. This publication provides criteria and guidance for analyzing and identifying the potential for sharing of nuclear power infrastructure during the stages of nuclear power project life cycle. The target users are decision makers, advisers and senior managers in utilities, industrial organizations, regulatory bodies and governmental organizations in countries adopting or extending nuclear power programmes.

This publication was produced within the IAEA programme directed to increase the capability of Member States to plan and implement nuclear power programmes and to establish and enhance national nuclear infrastructure.

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1. INTRODUCTION

1.1. Background

The introduction or expansion of a nuclear power programme in a country and its successful execution on short term and long term basis is largely dependent on a local infrastructure capable of covering a wide range of activities including:

— To plan, administer and regulate the execution of a nuclear power programme;
— To operate a reliable and adequate electric power generation, transmission and distribution system and to implement necessary expansion in a timely manner;
— To equip both public and private organizations such as the nuclear regulatory body (NRB) and industries with qualified personnel at all levels;
— To support required research and development (R&D) programmes for technological development;
— To foster adequate support by the national industry so that the targeted level of participation in the execution of power projects is attained; and
— To procure adequate financing for the necessary investments.

These capabilities within the country address a variety of infrastructure areas, namely:

(1) National legal framework and international agreements;

(2) NRB and environmental regulatory authority;

(3) Physical facilities;

(4) Finance/economics;

(5) Human resources, education and training;

(6) Public information and acceptance.

The development of the infrastructure areas could be in a progressive manner and evolve concurrent with the introduction and development of nuclear power programme as it passes through phases of planning to feasibility to acquisition and construction. Heavy investments in time and cost are demanded. Some countries may be denied the benefits of nuclear energy because of the infrastructure needs being too large or onerous for the national economy.

Lack of infrastructure like finance, fuel, manpower, legal and public information and acceptance is coming in the way of introducing nuclear power in many countries that have been at the threshold for adopting or extending this technology. Sharing of information and infrastructure can help in overcoming most of the foregoing problems. Of particular relevance is the high cost of additional infrastructure, which may deter and deny the Member States from benefits of a reliable source of nuclear power. However if cooperation could be achieved, the infrastructure burden could be shared and economic benefits gained by several countries acting jointly at regional or multinational level.

The major issues affecting near term nuclear power expansion include economics, safety and security, waste and proliferation resistance. Their effect on introduction of nuclear power and sharing potential is briefly discussed in the following.

Nuclear power plants (NPPs) are capital intensive and are often more expensive than alternatives. This has been deterring the developing countries from entering into nuclear business. But economic attractiveness of NPPs differs for different countries, investors and markets. New NPPs are most attractive where energy demand growth is rapid, alternative resources are scarce, energy supply security is a priority or nuclear power is important for reducing air pollution and global heating gas emissions.

Economics is also affected by usually long schedule for implementation of a NPP. This schedule can be compressed by sharing of infrastructure, which would considerably reduce efforts, resources and time.

The nuclear power grow has to ensure that nuclear facilities worldwide are operated according to the required levels of safety. This raises the need to ensure that lessons learned in some countries are effectively and thoroughly communicated to all countries, and that these lessons are incorporated into the operational practices of all relevant nuclear facilities. Therefore, sharing of feed back on operating experience is needed.

Technical solutions for spent fuel and waste are available for optimal implementation at the appropriate time. The present focus remains on establishing national repositories. However, there is renewed interest in the possibility of regional or international repositories. One reason is the interest noted in increasing international control of nuclear material as one effort to strengthen the global non-proliferation regime. The other is the reality that for countries with no appropriate waste sites, or with small research and power programmes, individual national disposal sites makes no economic sense. Therefore sharing of repository may remove one of the hurdles felt by some countries for introduction of NPPs.

Proliferation resistance is that characteristic of a nuclear energy system that impedes the diversion or undeclared production of nuclear material, or misuse of technology, in order to acquire nuclear weapons or other nuclear explosive devices. The ongoing work on new reactor types and fuel cycles includes in all cases considerations about such proliferation resistance features and measures that help ensure that future nuclear energy systems will continue to be an unattractive means to acquire materials for a nuclear weapons programme. The on going initiative of IAEA for multilateral fuel cycle activities from mining to waste disposal on sharing basis is of special interest in not only enhancing security of fuel supply and proliferation resistance but also significantly reducing infrastructure cost.

There could be several reasons for sharing of facilities, programmes, standards, etc between countries. The aim could be to reduce the hurdles to initiation of nuclear programmes (public information and acceptance, international support etc.) or to facilitate the construction and operation of the programmes in terms of economics, long term support, local and regional industrial participation etc.

The degree to which sharing can be achieved is a function of:

- Timing of the programmes;
- Technology alignment; and
- Contract type.

Clearly the maximum potential would exist if the countries entered into parallel supply contract for the same reactor design with the same vendor group using similar contract type and common regulatory requirements. The least options would exist if the countries had different technology choices for reactor types using different vendors and different regulation standards.

1.2. Objective

To provide guidance on the potential for sharing of nuclear power infrastructure among countries adopting or extending nuclear a power programme.

1.3. Scope

Areas where sharing of infrastructure could be possible during all stages of nuclear power project life cycle.

1.4. Users

Decision makers, advisers and senior managers in utilities, industrial organizations, regulatory bodies and governmental organizations in countries adopting or extending nuclear power programmes.

1.5. Structure

Section 2 covers characterization of sharing and highlights possible types and opportunities; prerequisites and limitations of sharing.

The major infrastructure items have been grouped into government, utility, and industry and vendors. These are briefly described in Sections 3, 4 and 5 and potential of sharing nuclear power infrastructure indicated.

The implementation methodology and strategies of sharing of infrastructure for nuclear power programme are described in Section 6.

Some case studies on sharing of services, physical facilities and programmes are provided in Annexes I to IV. Typical infrastructure needs of the government, regulatory bodies and utility are shown in Annex V.

1.6. How to use

It is assumed that the reader of this publication is familiar with the different reactor systems, various infrastructure needs and stages of nuclear power programme. For detailed description of infrastructure items the IAEA related publications listed in the references [1] to [9] can be consulted. In particular the reader should be aware of the basic infrastructure needs for a nuclear power project described in [1].

This publication should be used in conjunction with the IAEA Safety Standards Series and other appropriate safety related and safeguards publications.

This publication should be considered as a living document that will be further revised to reflect feedback experience from its use and future developments.

2. CHARACTERIZATION OF SHARING NUCLEAR POWER INFRASTRUCTURE

2.1. Introduction

This section briefly describes:

- Characterization of sharing;
- Types of sharing;
- Opportunities of sharing;
- Implication of sharing;
- Pre-requisites and limitations of sharing; and
- Grouping of infrastructure items.

2.2. Characterization of sharing

A country embarking on a nuclear power programme may find the cost of infrastructure too high to make the programme feasible. But sharing of infrastructure cost between two or more countries may bring the benefits of nuclear power to them. The sharing of nuclear power infrastructure can be at:

- Regional level, between neighbouring countries or
- Multinational level.

Sharing may lead to joint implementation and ownership, and to utilization of facilities owned by other partner(s). This may be implemented through cooperation agreements.

The alignment of interests will further ease the process of sharing.

Proposed multinational repositories (see [10]) are examples of multinational sharing.

2.3. Types of sharing

2.3.1. Sharing of similar technology

Two or more countries may decide to pursue a NPP based on same reactor technology and sharing infrastructure activities and cost. They may decide to share R&D programme, training programmes, etc.

Strong political will and intergovernmental relationships are needed.

2.3.2. Sharing of physical facilities

Physical facilities for sharing could include:

- Manufacturing facilities, for pumps, valves and other components;
- Nuclear fuel cycle activities from cradle to grave by one of the partner countries involved in mining and processing; second one fabricating the fuel; and third one carrying out reprocessing and radioactive waste disposal;
- Centralised industries for fabrication of key equipments like steam generators;
- Major erection equipment like heavy duty crawler cranes for erection of heavy equipment such as reactor vessel, steam generators, alternators using open top construction;

— R&D facilities;
— Incore testing facilities for fuel and materials;
— Mobile units for radioactive waste conditioning and immobilisation; and
— Transportation vehicles for heavy equipment and special casks for spent fuel.

2.3.3. Sharing of common programmes

Common programmes for sharing could include:

— Environment impact assessment;
— Transboundary movement of spent fuel;
— Emergency preparedness; and
— R&D programmes.

2.3.4. Sharing of knowledge

Knowledge management sharing could include:

— Education and training;
— Codes and standards;
— Legal framework;
— Regulatory standards; and
— Operating experience.

2.4. Opportunities and strategies of sharing nuclear power infrastructure

A country may embark on a nuclear power programme with a single NPP or long term nuclear power programme adopting regional or multinational sharing of infrastructure needs. It could be seen in the following sections that there is a large potential of sharing nuclear power infrastructure. Opportunities of sharing are enhanced if the countries choose to install identical type of reactors. This is further enhanced by adoption and sharing of project management strategy of similar contract types. Basically there are three different types of contractual approach or model hat have been applied for nuclear power plant projects:

- *Turnkey contract*: a single contractor or a consortium of contractors takes the overall responsibility for the whole nuclear power plant project

In this type of contract the contractor has total responsibility from site preparation to commissioning of nuclear power plant and handing over to the utility after satisfactory demonstration of its operation at rated capacity. Turnkey model is often used for the first project and also on subsequent projects when the country and utility have no long term plans for a comprehensive localization of the nuclear technology.

The turnkey supplier is contracted to initiate, manage and complete all activities from site preparation and site infrastructure all the way to commissioning and putting the plant in commercial service. The role of the utility in this model includes approval of invoices and supply of funds, contract administration and supervision, periodic technical and financial audits, obtaining of permits and licenses from the local and national authorities, and assumption of risks not accepted by the contractors. The utility also assumes the nuclear liability and the responsibility for decommissioning and final spent fuel disposal. A variation to the turnkey model is when part of the scope, which often does not require high technology capability, is carried out by the utility. The utility's scope may include:

- Site preparation and clearing;
- Bulk excavation;
- Water and power supply;
- Roads and harbors;
- Construction and operation townsite;
- Civil structures for cooling water system; and
- Supply of commissioning and operation staff for training.

- *Split-package*: the overall responsibility is divided between a relatively small number of contractors, each building a large section of the work.

The scope of the nuclear power plant consists of distinct parts, which can be supplied through separate contracts. The breakdown can be done into two main contracts: for a nuclear island and a turbine generator island (two-package approach) or into more packages (i.e. three to five-split-package approach).

- *Multi-contract*: the utility or its architect-engineer assumes overall responsibility for engineering the station, issuing a large number of contracts

Based on the nuclear steam supply system and turbine generator contracted for supply, the architect-engineer designs the balance of plant around this equipment. For this model to be successful, the utility should have extensive experience in contracting and management of large projects. The utility can adopt this model and progressively increase the national scope of supply and services in the successive projects. In this model the packages and island each have their own contracts with clear interface definition. The nuclear island supplier will warrant the steam quality and fuel burn up and the turbine generator supplier will warrant the electrical output based on the interface parameter specified in the respective contracts.

The infrastructure needs and opportunities for sharing of infrastructure for nuclear power in various fields will be determined by the strategy of development of nuclear power. It will depend upon the reasons why the country wishes to adopt nuclear power, the objectives that the country wishes to achieve ultimately, the arrangements with the supplier, and the short term and long term perspective of nuclear power programme and the national involvement.

A country with a long term nuclear power programme for generation of electricity may do so in number of stages. In the first stage the NPP is introduced without much emphasis on local participation or fuel cycle activities. In the second stage the country may enhance the national participation of industry and look for greater indigenisation towards self-reliance. Fuel cycle activities may also be initiated which is fully developed in the third stage.

Finally opportunities and potential of sharing will depend on the scenario of introduction of nuclear power programme. These scenarios could be:

(a) A country embarking on a nuclear power programme in a region where essential infrastructure and nuclear facilities are well established.

(b) Several countries in a region join hands for introduction of nuclear power programme. Assessment of infrastructure can be done on region basis and necessary augmentation can be achieved by setting up centralized facilities.

(c) Several countries in a region join hands for introduction of nuclear power programme based on similar if not identical nuclear reactor technology. Maximum sharing potential exists for the latter scenario.

Irrespective of the foregoing the sharing will help in reducing the cost burden of infrastructure development.

2.5. Implications of sharing nuclear power infrastructure

While there is large potential of sharing nuclear power infrastructure, it requires alignment of interests, determination to fulfil commitments, cooperation between nations and public support. Benefits of sharing are manifold. But there are some threats as well.

2.5.1. Benefits

The major direct benefits of infrastructure sharing are:

- Savings in infrastructure cost thus reducing the capital cost by sharing of
  - Expertise and optimal utilization of human resources
  - Knowledge
  - Erection and transportation resources;
- Reduction in O & M cost by sharing of
  - O & M spares
  - Maintenance crews for planned maintenance outage
  - Mobile radioactive waste management units for treatment, conditioning and disposal
  - Simulator and training programmes;
- Harmonization of safety standards and regulatory framework; and
- Avoiding repetition of mistakes through regular sharing of experience.

2.5.2. Weaknesses and threats

Potential weaknesses and threats can be:

- Impact on environment of transportation of spent nuclear fuel and high-level radioactive waste of other countries;
- Public resistance;
- Political strings;
- Multinational repositories can be; a public issue;
- Cooperation may become endangered if a participating country decides to pull out of the arrangement;
- Political or economic instability in the region can adversely effect the sharing potential;
- Possible disputes between sharing partners may delay the project implementation; and
- Collision of requirements of common resources or services may cause delays.

2.6. Prerequisites and limitations of sharing nuclear power infrastructure

2.6.1. Prerequisites

A country embarking on a NPP should have a basic infrastructure [1] including:

(1) R&D facilities in operation for several years.

(2) Experience in working in a nuclear facility with radiation background.

(3) Industrial experience in manufacturing basic construction materials.

(4) Construction, operation and project management experience of large sized chemical plants and/ or refineries / or thermal power plants.

(5) Participation in international agreements and treaties related to nuclear power.

(6) Known sources of finance.

(7) Political willingness to go for a NPP.

(8) Public information and acceptance.

(9) Experience in energy and electric system analysis.

2.6.2. Limitations

(1) Government should be willing to enter into agreements for sharing of infrastructure facilities or create centralized ones with sharing partner/partners.

(2) The question of sovereignty sometimes can create hurdle. This should be settled well in advance.

(3) Nuclear technology is of sensitive and strategic nature and sharing of information may be prevented.

(4) In some countries right to information on matters related to nuclear energy is denied by law.

(5) Law against unfair competition/ anti trust law.

2.7. Grouping of infrastructure items

Various infrastructure items necessary for setting up a NPP are discussed in the following sectionss with respect to possibilities and potential of sharing. No attempt has been made in describing in detail the infrastructure items, for which reference is made to related IAEA publication listed in the Appendix.

The opportunities of sharing are presented in three groups addressing the infrastructures of:

— Government;
— Utility; and
— Industry and vendors.

The role of the government -including the regulatory bodies- and the utility is wide spread during the NPP project phases covering: 1) planning, construction and commissioning phase; 2) operation phase, and 3) decommissioning phase. An example of their typical infrastructure needs during the project phases is given in Annex V.

The role of industry and vendors is to provide engineering, supply, and services during all NPP project phases as per chosen contractual approach.

There may be overlapping of groups for an infrastructure item. For example, both government and utility deal with emergency planning and preparedness. The infrastructure items have been grouped based on the major share of responsibility for implementation.

Each infrastructure item requires human resources, physical facilities and finance and has sharing potential. The potential of sharing infrastructure could be discerned regarding *m*an, *m*aterial, *m*oney and *m*onitoring — 4 Ms — of any industrial activity including nuclear power programme.

3. OPPORTUNITIES OF SHARING GOVERNMENT INFRASTRUCTURE

Government infrastructure includes:

(i) National legal framework
(ii) International treaties and international cooperation
(iii) Regulatory framework
(iv) R&D
(v) Human resources
(vi) Education and training
(vii) Finance
(viii) Economics
(ix) Grid system
(x) Public information and acceptance
(xi) Transportation

These are briefly described from 3.1 to 3.11 with observations regarding opportunities of infrastructure sharing for nuclear power.

3.1. National legal framework

International treaties

The national legal framework of a State encompasses special legal norms of that State regulating the conduct of legal or natural persons engaged in activities related to fissionable materials, ionizing radiation and exposure to natural sources of radiation known as nuclear law. Being part of a State's general legal system, nuclear law must take its place within the normal legal hierarchy applicable in most States. This hierarchy consists of several levels. The first, usually referred to as the constitutional level, establishes the basic institutional and legal structure governing all relationships in the State. Immediately below the constitutional level is the statutory level, at which specific laws are enacted by a parliament in order to establish other necessary bodies and to adopt measures relating to the broad range of activities affecting national interests. The third level comprises regulations; that is, detailed and often highly technical rules to control or regulate activities specified by statutory instruments. Owing to their special character, such rules are typically developed by expert bodies (including bodies designated as regulatory authorities) empowered to oversee specific areas of national interest, and promulgated in accordance with the national legal framework. A fourth level consists of non-mandatory guidance instruments, which contain recommendations designed to assist persons and organizations in meeting the legal requirements.

Depending on which nuclear activities a State decides to sanction, the exploitation of nuclear technology can involve the application of a wide variety of laws primarily relating to other subjects (such as environmental protection, industrial safety, land use planning, administrative procedure, mining, transport, government ethics and electricity rate regulation). In general, deviations from the general framework of national legislation should be accepted only where the special character of an activity warrants special treatment. Therefore, to the extent that a nuclear related activity is adequately covered in other laws, it should not be necessary to promulgate new legislation. However, from the earliest days of its development, nuclear energy has been considered to require special legal arrangements in order to ensure that it is properly managed.

In the nuclear law area, harmonization of national legal frameworks would facilitate the implementation of States' decisions for sharing of nuclear power infrastructures.

The IAEA Handbook on Nuclear Law [11] provides concise and practical guide explaining the overall character of nuclear law and the process by which it is developed and applied.

The IAEA Safety Standards [12] provides basic requirements for legal and governmental infrastructures for nuclear, radiation, radioactive waste and transport safety.

Sharing potential: Legal framework

The legal framework should include a nuclear law establishing the mechanisms by which nuclear power regulation is performed. A country may have a radiation regulatory body, but this body may need to be enhanced to include aspects related to the regulation of nuclear power facilities, rather than only handling of medical and other sources of ionising radiation.

There are about 10 conventions/protocols and agreements that need to be entered into before it would be expected that a country should develop nuclear power. Some examples are listed in Section 3.2.

Among other issues (see [1]) the legislation should address the following:

- Law establishing powers of regulatory bodies;
- National law on nuclear security;
- Law on radioactive materials and radiation;
- Law on nuclear liability;
- Nuclear waste, spent fuel and decommissioning law;
- Non proliferation treaty and additional protocol obligations;
- Legislation to implement international conventions and agreements;
- Environmental protection law;
- Law on emergency notification of nuclear accidents;
- Law on foreign investment; and
- Law on safety of nuclear installations.

The major components of nuclear legislation can be identified as dealing with the following topical areas:

(i) Constitution of a NRB by enactment of nuclear law.

(ii) Radiological protection, nuclear safety and connected matters such as environmental protection, transport of radioactive materials, radioactive waste management.

(iii) Liability to third parties for nuclear damage and financial security.

(iv) Physical protection of nuclear materials and facilities.

(v) State system of accounting and control of nuclear materials.

Countries can join together for arriving at a legal framework after understanding the implications of international agreements. Alternatively the existing legal framework of a country could be utilized and shared as a model when complementing the legislation.

The partner countries may analyze the existing applicable laws and regulations for further additions and deletions. Necessary implementation of legal framework may need the following reviews:

(i) The possible organizational structures for nuclear activities, including ownership of NPPs, radiation protection, nuclear safety, R&D, waste management, disposal and safeguards.

(ii) The possible alternatives of nuclear safety policies (acceptance of supplier's country regulations or adoption of other alternatives).

 (a) IAEA safety standards or other regulations; and
 (b) Prescriptive or commitment based regulation methodology, etc.

(iii) Legislation requirements for ownership of nuclear plants and nuclear material radiation protection (ICRP recommendations, IAEA safety standards).

(iv) Possible options for waste management and disposal, including the back end of the fuel cycle.

While the drafting of bills, acts containing legal requirements and rules may be carried out jointly, their introduction in the legal system is the responsibility of legislature respective state.

Sharing of legal infrastructure may pose problems because of strategic nature of nuclear business.

Nuclear liability insurance can be taken jointly thus reducing the burden considerably.

3.2. International treaties and international cooperation

International treaties

Nuclear law of a State should implement the international obligations of that State as provided for in the respective treaties to which that State is a party. To cover specific nuclear related subjects a large number of international instruments have been adopted. Adherence to these instruments has both an external and an internal aspect. As a matter of international law, States that take the necessary steps under their national laws to approve (or ratify) such an instrument are then bound by the obligations arising out of that instrument in their relations with other States Parties (assuming that the instrument has entered into force).

In addition, such States need to establish legal arrangements for implementing those obligations internally. There are two basic approaches to internal implementation. Most States require that the provisions of international instruments be adopted as separate national law. In other States, the respective constitutional arrangements make international agreements concluded in a manner consistent with national law a part of those States' legal frameworks, without further legislative action; the international instruments are deemed to be 'self-executing'. Even in such cases, however, it is important to translate the agreement into the national language and to publish the resulting text in the relevant compilation of national legal instruments, so as to give all affected Parties adequate notice of the requirements of the international instrument.

The following multilateral treaties (conventions and agreements) have been adopted under the auspices of the IAEA:

— Convention on Early Notification of a Nuclear Accident;
— Convention on Assistance in the Case of a Nuclear Accident or Radiological;
— Convention on Nuclear Safety;
— Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management;
— Convention on Physical Protection of Nuclear Material and the Amendment thereto;
— Vienna Convention on Civil Liability for Nuclear Damage;
— Protocol to Amend the 1963 Vienna Convention on Civil Liability for Nuclear Damage;
— Convention on Supplementary Compensation for Nuclear Damage; and
— Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention.

In addition, the IAEA concludes safeguards agreements. Since the majority of States are Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, most safeguards agreements are based on the document "The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons", approved by the IAEA Board of Governors in 1972, and provide for comprehensive safeguards. The IAEA also concludes the additional protocols to safeguards agreements based on the Model Protocol Additional to the Agreement(s) between States(s) and the International Atomic Energy Agency for the Application of Safeguards as approved by the IAEA Boards of Governors in 1997.

International cooperation

Following two examples illustrate the potential of sharing in the nuclear field.

(1) Multinational radioactive waste repositories for cost savings in infrastructure.

A country that enjoys the benefit of nuclear energy, or the utilization of nuclear technology, should also take full responsibility for managing the generated radioactive waste. However, there are countries whose radioactive waste volumes do not justify a national repository, and/or countries that do not have the resources or favourable natural conditions for waste disposal to dedicate to a national repository project or would prefer to collaborate in shared initiatives because of their economic advantages. In such cases it may be appropriate for these countries to engage in a multinational collaborative effort to ensure that they have access to a common multinational repository, in order that they can fulfill their responsibilities for their managing wastes safely.

The concepts involved in the creation of multinational repositories, the likely scenarios, the conditions for successful implementation, and the benefits and challenges inherent to multinational repositories are dealt in [10]. In essence, it attempts to define a framework dealing with institutional aspects of repository development that could be employed for the establishment of multinational repositories.

(2) Multilateral arrangements for fuel cycle activities

Multilateral arrangements for fuel cycle activities in a comprehensive manner including front and back-end would considerably reduce the infrastructure burden by sharing. However, these are likely to be extremely complex, involving purchase of uranium from one country, enrichment in second, fabrication in third and possibly reprocessing in fourth. These have been under consideration for many years. Direct commercial negotiations between the countries and organizations are considered quite suitable on bilateral basis. But multilateral arrangements are said to enhance non-proliferation aspects and reduce potential of misuse.

IAEA and international cooperation

The IAEA has developed a body of safety standards and guides, and offers to organize safety evaluation missions in its Member States upon their request.

The IAEA safety standards cover five safety areas:

— nuclear safety: safety of nuclear installations;
— radiation safety: radiation protection and safety of radiation sources;
— transport safety: safety of transport of radioactive materials;
— waste safety: safety of radioactive waste management; and
— general safety: of relevance in two or more of the above four areas.

Drafters of national legislation in nuclear area may find it useful to reflect the recommendations found in the IAEA safety standards and guidelines.

There are a number of methods for dealing with requirements derived from such international sources. A common method is the adoption of legislation creating the basis for rules and regulations in the relevant area and authorizing the regulatory authority to adopt external requirements as binding rules or regulations. A second method (often used for requirements relating to quantities or activity levels of radioactive material) is to spell out the requirements in technical appendices or annexes to the law. If this is authorized in the legislation, these technical appendices or annexes can then be revised through an administrative procedure that does not require amendment of the law. A third method would be for the national law to authorize the regulatory authority to apply external requirements directly as licence conditions binding on a licensee.

3.3. Regulatory framework

National regulatory body (NRB)

A fundamental element of an acceptable national framework for the development of nuclear energy is the creation or maintenance of a regulatory body (or regulatory bodies) with the legal powers and technical competence necessary in order to ensure that operators of nuclear facilities and users of nuclear material and ionizing radiation operate and use them safely and securely. The central consideration in structuring a regulatory body is that it should possess the attributes necessary for correctly applying the national laws and regulations designed to protect public health, safety and the environment.

The regulatory body should be structured in such a way as to ensure that it is capable of discharging its responsibilities and carrying out its functions effectively, efficiently and independently. Several options exist: no single option is the most suitable for all States. Determining the best structure for a particular State requires a careful evaluation of many factors, including: the nature of the national legal infrastructure; the State's cultural attitudes and traditions; the existing governmental organization and procedures; and the technical, financial and human resources available in that State. In addition, the regulatory body needs a structure and size commensurate with the extent and nature of the facilities and activities it must regulate. Furthermore, it is important that the nuclear law contains provisions that ensure that the regulatory body is provided with adequate personnel, financing, office quarters, information technology, support services and other resources. If the regulatory body consists of more than one authority, the law should prescribe arrangements that ensure that regulatory responsibilities and functions are clearly defined and coordinated, so as to avoid any omissions or unnecessary duplication and to prevent conflicting requirements being placed on the operator or licensee.

If the regulatory body is not entirely self-sufficient in the technical or the functional area and consequently cannot discharge its review and assessment, licensing, inspection or enforcement responsibilities, the law should enable it to seek advice or assistance from outside sources. When such external advice or assistance is provided (e.g. by a dedicated support organization, by universities, by scientific institutes or by consultants), arrangements should be made to ensure that those providing it are effectively independent of the operator or licensee. It must be emphasized that receiving external advice or assistance does not relieve the regulatory body of its responsibility for decision making.

One of the most important attributes of a regulatory body is its freedom from unwarranted interference in its regulatory functions; this concept has been developed in a number of IAEA documents and in relevant international conventions (e.g. the Convention on Nuclear Safety and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management).

The fact that the regulatory body is located within the administrative structure of another organization, or is supervised by it, does not necessarily mean that the regulatory body lacks independence. The question is whether the necessary effective separation or effective independence of key regulatory functions and decision making exists. That question can be answered only after an evaluation of the detailed provisions determining how the practical work of the two organizations is conducted. If the parent organization has responsibilities regarding the conduct or promotion of nuclear related activities, the fact that it is supervising the regulatory body, will raise issues of "independence" or "separation of regulatory functions". If it is responsible for nuclear energy development, situations could arise in which the parent organization is called upon to take decisions, for example, about the establishment of facilities using nuclear techniques. In such situations, administrative measures would have to be taken in order to ensure that safety related decisions of the regulatory body are effectively independent of or separate from developmental or promotional decision making.

The IAEA Safety Requirements [12] sets out the requirements regarding the establishment of an independent NRB and the responsibilities and functions to be assigned to it. Four interrelated Safety Guides provide recommendations on satisfying the requirements addressing the organization and staffing of the NRB. [13], regulatory review and assessment

[14], regulatory inspection and enforcement [15] and documentation relating to the regulatory process [16].

Sharing potential: Regulatory framework

The establishment of the regulatory framework is country specific. However, the organizational structure could be shared. The supporting experts may be from partner countries.

A peer review between partner countries would significantly improve the safety implementation and safety culture. The IAEA contributes to the global nuclear safety culture through the introduction of binding conventions and recommended standards, the advisory services and the exchange of experience and information.

Safety reviews can be carried out with the availability of expertise from other country. Several working groups are needed in the safety review process and the manpower may be shared. The safety analysis report can be prepared jointly using experts from other countries.

The NRB prepares safety assessment reports that describe and explain the results of the NRB's review and assessment process, the basis for its findings and its conclusions or recommendations. Preparation of the safety assessment report can be done jointly and experience shared periodically.

Safety is a prime management function considered as an integral part at each stage of a NPP project namely siting, design, construction, commissioning, operation and decommissioning. Safety implementation is project specific and only information and experience can be shared.

The utility (operating organization) has the full responsibility for the safe operation of the NPP. Operation of the plant is to be in accordance with constraints to limit operation only to plant conditions shown to be safe. These constraints are embodied in the operational limits and conditions (OLCS) set down in the technical specification for operation. The preparation and review of this document can be shared.

The licensing of plant and personnel can be done on the basis of a common written test and interviews by a joint senior level committee comprising of members from safety group, NRB and operating unit.

Through regulatory inspection the NRB satisfies itself that the licensee is fulfilling the conditions set out in the license and regulations. Common and joint teams for regulatory inspection can be employed.

Technical specification includes regular surveillance requirements to ensure that safety systems comprising of reactor shutdown and protection systems, reactor containment and long term core cooling perform their safety functions as per reliability requirement. The surveillance is carried out on daily, weekly, monthly, quarterly, half yearly, yearly basis. Activities with a periodicity of half year or more may be entrusted to a joint team. Calibration facilities for surveillance and control instrumentation can be shared.

The NRBs of two or more countries could cooperate in the development of safety codes, regulations, guides and standards which play key roles in ensuring the safety of NPPs and:

- Serve as the foundation of safety and environmental protection;
- Define performance requirements that establish acceptable levels of risk;
- Codify good practice proven by experience;
- Provide the foundation for equipment standardization;
- Provide the basis for inspection and enforcement; and
- Encourage public acceptability.

The preparation of safety codes and standards poses a difficult problem for a country starting its nuclear programme and which most probably has no safety codes and regulations of its own. However, in most cases of countries importing nuclear plants this problem is overcome to a certain extent by adopting a policy that any nuclear project licensable in its country of origin would in principle be satisfactory to the buyer's NRB, subject to specific requirements that are stated or that might be developed.

There are no universal safety requirements accepted by all supplier countries, so that a reactor that is licensable in a given supplier country would not necessary be so according to another supplier country's regulations. Regulating safety in NPP is a national responsibility, and many Member States have decided to adopt the IAEA's safety standards for use in their national regulations. The IAEA comprehensive body of safety standards reflects best practices in Member States. The IAEA is working to promote the global acceptance and use of its safety standards. Safety standards are only effective, however, if they are properly applied in practice. The IAEA's services assist Member States in applying the standards and appraise their effectiveness. These services enable valuable insights to be shared.

3.4. Research and development

The status of existing R&D in the country may be reviewed in terms of how it can support a new and major development, such as a nuclear programme. Countries, which develop research strength in even a few fields, can have entry to many sectors, which provide an opportunity to enlarge the knowledge base and methodologies available to many parts of the economy.

Scientific and technological infrastructure

It is widely recognized that national development in general and nuclear power in particular demands a scientific and technological infrastructure mainly contained in:

- R&D institutes;
- Standardization and calibration laboratories;
- Institutions for higher education;
- Special training centres;
- Scientific and professional associations; and
- R&D centres set up by industry.

Past experience of countries that embarked on a nuclear power programme has indicated that the establishment of a nuclear research institute, though not prerequisite to a NPP, has proved to produce a catalytic effect upon the country's nuclear programme development.

An important role for the establishment of a nuclear R&D infrastructure is to stimulate the activities in the various fields of nuclear science and technology, which will keep the experts active in their respective specializations. It also provides a good source of manpower in some important areas needed for NPPs such as reactor engineering, reactor operation, radiation protection, nuclear safety and waste disposal.

Sharing potential: Research and development

Existing R&D infrastructures in each country need to be evaluated highlighting well-developed areas, which can supply services to other country.

Joint development on new but relevant areas will also allow considerable sharing. Institutions of nuclear research, including radioisotope research and applications, health physics, radiochemistry and metallurgy will be suitable supporting organizations.

The following list shows some basic science research areas with relevance to a nuclear power programme as well as a few of the many applied technology topics which could be supported by each research activity. Research activities in these areas could be reviewed jointly and R&D programmes framed to complement each other.

BASIC SCIENCE	***APPLIED TECHNOLOGY***
Geology, Hydrology, Soil Science, Seismology	Stability of soil, foundations Fluid dispersion in soils
Thermal hydraulics	Atmospheric dispersion Flow and temperature in plant system under normal and abnormal conditions
Structural analysis	Plant and component design Behaviour under stress and temperature
Statistical theory, Mathematics	System reliability and safety consequences of operating defects Probability of accidents
System analysis and control theory	I & C system design Computer programs
Electronics	Instrument design, measuring techniques
Interaction of radiation with matter	Irradiation of human tissue Shielding materials Radiography Nuclear fuel performance
Materials science	Nuclear fuel design Power plant water chemistry Welding, non-destructive testing Bulk and surface treatments, e.g. heat treatment, surface hardening
Psychology	Human behavior, safety culture, human-machine interface, and ergonomic

There could be common R&D programmes between two or more countries (this approach was successfully applied in Nordic countries in 70's and 80's). FP-6 programme on R&D in

European Union is a current example of sharing R&D programmes. IAEA conducts R&D related international programmes on safety research in areas like thermal hydraulics.

Also the use of research facilities could be shared.

An R&D programme is beneficial to many sectors. Engineering, construction, manufacturing and plant operating groups, QA/QM agencies and regulatory bodies are examples of organizations that will have vital interests in the results of both basic science and applied technology research. The pooling of the R&D infrastructure at regional level significantly promotes industrial development in the partner countries.

Presence of R&D infrastructure is considered desirable for national participation for giving strength to the nuclear power programme and gain international opportunities for technical advancement by sharing of R&D experience. It should however be understood that the development of a viable science and technology infrastructure is a long term process, which can take several years or even decades, depending on the level of the country's overall scientific and technological infrastructure at the beginning of this process. It is in general the government's role to take the lead in establishing a scientific and technological infrastructure for nuclear power.

3.5. Human resources

A country embarking on a nuclear power programme should make a critical and realistic assessment of its organizational, educational and industrial capabilities and determine the requirements for developing the quality and quantity of manpower needed. The manpower development programme for each country has its own unique characteristics that should be identified and taken into account. This is only possible when national planners primarily develop the programme. General guidance, or outside expertise can and should be used wherever needed, but it should never supplant the country's own effort to define its manpower requirements from a thorough understanding of the nature of each activity and task in its own nuclear power programme.

Since nuclear technology has special features that are not encountered in other areas of industrial development, special requirements are imposed on manpower for NPP operation, fuel cycle activities, radioactive waste management and radiological protection.

Sharing potential: Human resources

The management of a nuclear power project requires extensive planning and exhaustive studies for the initiation, establishment and development of a long-range programme. Nuclear projects need to comply with strict regulatory, safety and quality requirements. There are both supporting and regulatory activities, and special organizational structures are needed to carry these out.

Various models of organization structures are available. These could be developed jointly and shared for meeting specific country needs. Services of experts can be engaged for preparing organizational structures. Cost can be shared.

There is no universally applicable organizational framework that is equally applicable to every country and in each situation. It should also be recognized that the formation of the organizational structures is a continuous and gradual process. As the nuclear programme develops appropriate changes are gradually introduced according to the needs and available resources.

One of the first tasks to be performed when the introduction of nuclear power in a country is considered is the setting up of a national organization to be in charge of the planning and coordination of the nuclear power programme The manpower for this has to be local hence not possible to be shared during execution of this stage. The same manpower with some supplements is utilized for pre-project activities up to and including feasibility studies.

The manpower requirements for the management of the activities during implementation phase depend to a large extent on the contractual approach adopted for project implementation. Depending on the approach adopted, the lead responsibilities and task to be performed will be distributed between the owner/ utility, national and foreign suppliers of goods and services, and the NRB. Each of the partners will have to set up its own organizational structure. Only sharing of experience is feasible.

Each NPP needs its own control room crew and O & M staff. The sharing of maintenance and technical support staff is possible to some extent between several plants, especially if the plant designs are similar. It is preferred to have common language when staff is shared.

For sharing countries it is also possible to share experts from their NRBs.

Role of IAEA in human resource development

The availability of qualified manpower may constitute one of the principal constraints of the initiation, scope and schedule of a nuclear power programme. The IAEA has long since recognized the importance of manpower development and has consequently dedicated major efforts to promote it. Included in the IAEA's activities in this field are training fellowships, expert services, specialized courses, experts' meetings, and in particular the preparation of comprehensive guidance publications.

3.6. Education and training

A nuclear programme will recruit scientists and technologists from the educational system. The technical education system of a country produces the engineers, scientists, technicians and craftsmen to work in industry. Clearly, there is an interaction between what the industry needs and what the system, which is usually directed by the Government, produces. Industry itself may therefore have to supplement the technical education system by providing specific training in nuclear science and technology and operating industrial apprenticeship programmes.

Sharing potential: Education and training

This is an area that perhaps has maximum potential of sharing not only at regional level but also at multinational level. However, the development of an adequate national educational and training system is the only real way to develop qualified local manpower. Any country for which nuclear power is a viable option should have an education system of appropriate size. This will have to be expanded and adjusted in every case to the requirements of the nuclear power programme. It is possible and may be necessary to obtain some highly specialized experts and training from abroad, in particular in the early phases of a nuclear power programme.

The universities (especially nuclear faculties) can be shared in the basic education. Common training programmes can be arranged. The use of training facilities (training centers, simulators etc.) can be shared.

Operation staff and relevant positions of the organization need to be trained at the designer/vendor offices, followed by on-the-job training during final construction stage, commissioning stage and start up. Simulators for training can be shared.

The training at designer/vendor facilities and hands-on training in similar plants could be attended jointly and cost shared.

Training programmes for post-experience enhancement of skills and knowledge can be jointly arranged. Refresher programmes for training of trainers can be held on exchange basis.

Training centers may be jointly developed. Trainers may be also exchanged. Short term staff visits to facilities and job sites may be arranged.

Main training programmes are also advisable to be jointly developed by the operating organizations, which requires theoretical, on-the-job and simulator training.

The IAEA Technical Cooperation Programme can support education and training programmes in nuclear power.

3.7. Finance

Nuclear power represents a large capital investment in the range of US$1500-2000/kW.

The financing plan for the procurement of the plant will probably involve a number of sources, the sum of which needs careful management since long term commitments, in some cases extending up to 20–25 years, are involved.

Financing of the NPPs can be obtained and financial arrangements established through a variety of sources and according to different modalities.

Sharing potential: Finance

The potential owner of the plant has to arrange the financing of the project by itself. The financing of the project could be from local and/or international sources.

Whichever financial infrastructure and plans are adopted, they have to be realistic and inspire confidence in the lenders and participants. Thus, it would be reassuring if the country embarking on a nuclear programme itself provided some finance as a sign both of governmental determination and confidence in the success of its own programme. Equally, when international financing sources are necessary, it is always reassuring to the foreign lenders to be shown that the nuclear programme does satisfy a realistic forecast energy need, that the infrastructures and the nuclear programme have been well thought out and that a maximum of the relevant experience of other nuclear programmes has been injected into the overall plan. In addition, the use of well experienced nuclear contractors and vendors for the execution phase is a further comfort to the lenders.

There could be some possibilities to get better conditions from the international financing market if there are similar projects in other countries. The supplier country could also finance the project under intergovernmental agreement or through export credit agencies. When two or more countries as sharing partners approach the financial institutions for funding of their NPPs, they are likely to get better terms because of large quantum.

The key participants in the nuclear programme and the future owner of the nuclear plants should evaluate as best as possible the likely costs of the various components of the nuclear programme, not forgetting to include provisions for contingencies. Then, the various options for raising the finances required and establishing the modes for repayment of the loans are designed and assessed for their merits. These options will require developing future scenarios on such factors as: cash flow, revenues, interest rates, inflation and exchange rates.

This whole exercise is best carried out under the leadership of a single authority. In view of the high costs involved, it is common practice to have an adequately experienced outside organization carry out a similar exercise or at least check thoroughly the basic data, the method and the results of the initial exercise. The cost of experts can be shared.

The computer software to analyze and assess operating cost may be shared and continued later on, as a benchmarking tool. The financial management techniques including resource, budget and commercial management can be shared. Partner countries can support each other on government-to-government basis in situation of financial crisis. Procedures for financial scrutiny, concurrence and approval can be shared. Senior financial managers can be appointed to each other’s board for sharing of information.

3.8. Economics of nuclear power

The infrastructure aspects of economics and financing nuclear power are described in [1].

Sharing potential: Economics

While the sharing potential of economics of nuclear power may be limited, the methodologies and procedures for economic evaluation may be compared. Limited sharing potential is because of large dependence on local factors.

In a general analysis of the economics of nuclear power generation, a range of values for the main economic parameters such as interest rate, plant load factor, economic plant life, depreciation rate is usually adopted as a set of reference data, to provide some general guidance regarding the order of magnitude of the costs involved. It should be emphasized that general analyses have only very limited applicability and validity. The economy of scale is particularly important for NPP capital investment costs and O&M costs. Fuel costs on the other hand are practically independent of plant size. Such sensitivity analysis studies could be carried out jointly for the region.

Economic competition between available alternative energy sources is a powerful force, which acts on each of these sources. Biggest gain of sharing nuclear power infrastructure may be the significant reduction in capital cost if the partner countries decide to use same reactor technology and supplier. This would greatly enhance the competitiveness of nuclear power. Consequently, the cost trends of nuclear power cannot be considered in isolation.

A major factor, which may tilt economics in favour of nuclear power, is the sharing of cost for development of infrastructure between the partner countries. This would also have spin-off in the form of industrial development in high-tech areas.

3.9. Grid system

Safe and economic operation of NPPs requires an off-site electric power supply system with a capacity adequate to provide the necessary support for safe start-up, running and shutdown of the plant. Large power systems have successfully accepted NPPs within their electric grids, but smaller power systems will face problems unique to NPPs because these have special features and safety systems, which are necessary for safe reactor shut-down and require a high level of off-site power support.

For introduction of NPP the grid reliability, defined by its ability to maintain an uninterruptible power supply, should be high.

Sharing potential: Grid system

The size selection of the reactor is a key factor in all implications associated with making NPP operation viable in a low-performance grid system. Therefore, the following points should be carefully considered:

- Cost of extensive NPP engineering, such as load-following capabilities, additional equipment, adequate instrumentation and control system, and effective protection system to withstand transient conditions from the grid, to ensure adequate performance and to guarantee the designed plant life;
- Cost of meeting the increased reliability requirements for the on-site emergency power supply to ensure the performance of the essential safety functions of the NPP; and
- Cost of maintaining grid stability when the NPP is not available. This is comprised of costs for providing additional spinning reserve, establishing effective system generation control, enhancing the performance of the grid protection system, and reinforcing the transmission system.

To overcome the problems related to low-performance grid and grid stability for introduction of a NPP the interconnection of national grids may be considered. This will generate reserve capacity for sharing. The NORDEL grid system in Nordic countries is an example (Annex I).

It is necessary to jointly analyze the type of sharing that is possible (local regulation, other utility’s country regulations).

Sharing of power may be economically convenient, especially when peak hours are phased.

Sharing of grids amongst neighboring countries could ease and accelerate the introduction of nuclear energy in a country. It would not only enhance the grid capacity but also develop capabilities to provide reserve margins and spinning reserves. It would perform the necessary responses to load and generation trends and perturbations.

Private companies or state owned companies operating grid systems (of similar characteristics) may share:

- Line surveillance equipment (such as helicopters) reducing the areas to be surveyed by each grid operator could be shared; and
- Inventory of line components may also be shared, reducing stock investments (typical are: cables, wires, poles and towers, insulators, transformers, breakers, arresters, etc.).

Another area of sharing could be exchange of expertise in electric system analysis studies.

3.10. Public information and acceptance

A nuclear power programme is a national undertaking and hence its introduction and implementation within the country, including the acceptance by the population in general, is a matter to be handled primarily by national (and regional) governmental organizations and authorities. It will be beneficial to both the social and technological development if, at the very early stage of starting a nuclear programme, complete and objective information is provided to the public on the benefits and the risks of this technology. This also enhances credibility, which is very difficult to regain once it has been lost. A public information programme aimed at both the general public and the population around the site of the nuclear power project should be carefully planned and implemented and started as early as possible.

Sharing potential: Public information and acceptance

Public information and acceptance programmes including information material can be developed in cooperation. Experiences can be shared.

For countries going nuclear for the first time it may be convenient to share experience of other countries (interface government/utility with public and media.)

Material used in other countries should be analyzed and when adequate used as starting point of a local programme.

3.11. Transportation

When a major project, such as a petrochemical plant, a mine or a NPP, is implemented, improvements or extensions in the transportation sector may be essential. New roads or ports with heavier load capability may be necessary for delivery of equipment and material.. For each method of transportation, there should be an assessment of whether the routes are suitable for delivery from foreign suppliers and from domestic manufacturers to the project site. For example, the suitability of a method of transportation should consider the weight and dimensions of the large components involved. In most cases, even with a well-developed transportation sector, a new project site for a NPP may require some extension of the existing facilities. This may be a major project in itself with its own impact on aspects like foreign exchange and long term debt.

Sharing potential: Transportation

Planning and assessment in the transportation sector are necessary elements in the implementation of a major national project. Appropriate planning can bring benefits, which extend to many other sectors of the economy. The planning of transportation infrastructure can be shared.

The choices to be made in terms of which existing forms of transportation can be used, or what new developments should be implemented, have implications on schedules and domestic participation. A mode of transportation too slow or subject to disruption from weather conditions can result in extended delivery times and schedule delays. Such experiences can be shared.

Transportation of heavy and over-dimensional consignment is a specialized field involving evaluation of route survey; load carrying capacity of bridges and culverts; headroom between road and bridges, road and overhead transmission lines. All these are essentially local matters but experience can be shared. Special transport vehicles can be shared. Survey teams for assessing the roadworthiness of vehicles can be centralized and shared.

During construction special transportation devices are necessary for heavy components. Some of these devices provide one or two services during the plant life. Sometimes the device is a unique type device (tailor made). The cost is considerable and may be shared by two or three utilities (device transportation to other countries should be evaluated) developing similar type projects. The same is valid for “over bridges” and special cranes.

4. OPPORTUNITIES OF SHARING UTILITY INFRASTRUCTURE

Functions performed by the utility include:

(i) Site survey and evaluation
(ii) Plant O & M
(iii) Operational experience feed back
(iv) Spare part management
(v) Fuel management
(vi) Management and disposal of radioactive waste
(vii) Transportation
(viii) Decommissioning
(ix) Environmental effects of nuclear power
(x) Emergency planning and preparedness

In a NPP the utility is the key player around whom many activities that contribute to project success revolve. The utility bears full responsibility for all aspects from project inception to power generation.
The world's power industry offers a wide variety and type of utility organizations, ranging from small power companies that combine their resources to purchase and operate even a single power plant to giant utilities that undertake these functions for a large number of plants.

Regardless of the utility's size, for any given power project the utility is usually the operator. And if the utility is acting as a prime contractor, he may either assume this latter responsibility directly or delegate it totally or partially to engineers, contractors or vendors, depending on his capabilities.

Role of the utility ranges from pre-project phase (defining a nuclear power project, integration of NPPs into an existing electric energy network) to defining an implementation policy and project implementation; plant start-up and operation.

In line with the sharing theme the countries in a region can form a joint venture utility with overall responsibility for introducing nuclear power programme.

4.1. Site survey and evaluation

An important stage in the development of a nuclear power project is the selection of a suitable site and the study of site characteristics to establish the site-related design input for the plant. Briefly, the activities related to siting of a nuclear power project consist of the following two main stages, which take into account site characteristics:

— Site survey; and
— Site evaluation.

The site evaluation report produced by the organization responsible for siting is usually submitted to the NRB for review. The NRB may issue a formal consent to site and the government gives site approval.

The infrastructure features of the site are briefly described in [1].

Sharing potential: Site survey and evaluation

The selection of a suitable site is the result of a process in which the cost, the impact to the environment and the risk to the population are minimized.

Siting of NPP is a highly specialised but localised affair. National participation in site survey and evaluation is essential activity. Manpower with skills in local language and customs having professional knowledge in geology, seismology, soil-mechanics, meteorology, civil engineering, nuclear engineering, hydrology etc. are needed for site survey. The fields of specific competence for site evaluation are in general similar to those that are required for the site survey stage.

The knowledge and experience of the experts who have to carry out site evaluation are extensive, because their work consists of developing sophisticated physical models to evaluate design bases and dispersions among other aspects.

A team consisting of 15–20 experts is typically needed to carry out the work, possibly half of them full-time, the others part-time. A certain amount of fieldwork has to be performed on the site such as drilling, seismic prospecting, meteorological measurements and collecting of soil samples for analysis. For many of the measurement programmes, a full year's data are necessary. Manpower, planning, procedure and methodology can be shared.

Special teams can be made with participation from individual partners. The teams can be equipped with instruments and tools needed for site survey. They can share the computer software for data compilation and evaluation. The cost of training programme can be shared.

If trained staff is not available for site evaluation work, the approach of assigning all site evaluation work to a specialized company is sometimes adopted for the first NPP. It does not necessarily mean that a foreign specialized company does all the site evaluation work. It should be established in the contract that local subcontractors would perform a substantial amount of work. Cost can be shared and benefits shared because of savings from business volume.

The other possible approaches of the utility organization for the site evaluation are:

— Performing the work directly, with some assistance if needed, from specialized consultants who have experience in site evaluation; and
— Performing part of the work directly (with the assistance of consultants) and part of the work with one or more specialized companies.

The feasibility of the first option, i.e. the evaluation of a site performed directly by the utility, depends mainly on the availability of qualified expert staff. This approach is rarely adopted for the first nuclear power project, but it might be adopted for the second or third plant in the country if the utility has used every earlier opportunity for training its staff. Site evaluation may cost around a couple of million dollars, while its impact on the plant may be twenty to fifty times this amount. It is thus prudent not to try to save expense in this very critical area.

When the evaluation of the site is performed partly by the utility and partly with specialized companies, among the parts of the work that are usually carried out directly by the utility are those that do not require very specialized methods, such as population distribution or man-induced events.

The extent of work necessary for site preparation is usually evaluated through the analysis of topographic maps. Site cleaning or levelling, foundation works, and water intake and outlet structures are the main aspects to be analysed in a preliminary way. During the site evaluation phase these as well as other relevant aspects such as site infrastructure, local labour market etc. needs an in-depth study. Most of these aspects and factors are similar for all power plants-nuclear or fossil-fired. These aspects could be evaluated jointly.

Regulatory review of site evaluation report and approval of a site however has to be a local effort. The staff of the NRB to perform the review should be trained in siting and site evaluation. The task of NRB for the first NPP may be particularly difficult. What is required from the NRB staff is to review critically the work that might have been performed by recognized international experts with many years of experience in the field of siting. Under these conditions, a possibility that remains is that the NRB employs consultants to assist in performing the review work.

The socio-economic aspects include effects on the availability of local services (e.g. housing, schools) due to the construction and operating personnel. The cultural impact can include effects resulting from the construction of the plant on the archaeological or aesthetic condition of the area around the site. These have to be evaluated locally.

IAEA activities in site survey and site evaluation

The IAEA has developed a set of standards for the site evaluation of NPPs. Training courses are also organized by the IAEA regularly on general aspects of siting.

Site related safety missions are also carried out by the IAEA on request. The missions and its experts should not be considered a substitute for the review by the NRB (conducted by its own staff and consultants). Nevertheless, the mission could be helpful in clarifying issues between the organization responsible for performing the siting work and the NRB.

4.2. Plant operation and maintenance

The O&M of a NPP is the full responsibility of the utility.

The NPP has to be operated within the permissible limits of radiation doses to the plant personnel and to the public, and the responsibility to reduce such releases to levels as low as practical lies with the plant owner.

The maintenance could be in mechanical, electrical, instrumentation, civil engineering and general services. A technical unit provides on-site technical support related to surveillance testing, plant performance, monitoring, core management, nuclear safety, and plant modification.

Advance procurement action for spares, in coordination with the purchase and stores units is a necessity, since downtime of the plant is very expensive.

Sharing potential: Operation and maintenance

O&M of a NPP are carried out with written procedures and technical specifications for operation. The development of the O&M procedures is an onerous task and takes couple of years for writing. These procedures can be developed in cooperation and shared.

Sharing is possible on testing and inspection equipment, special measuring and calibration devices, etc. which are used infrequently and not on continuous basis during the year.

Regarding personnel, radioprotection teams may be offered to the other utility during planned maintenance shutdowns. Sometimes sharing may be necessary because the local team may be insufficient or has received its authorized dose.

Quality assurance (QA) activities are usually performed in an organizational structure, which includes both the on-site plant operations personnel as well as off-site operations support personnel. Sharing of off-site QA teams is possible.

Training facilities and simulator can be shared. Because of the extensive training and retraining requirements, a special training division may be established jointly. It would be responsible for:

- Writing training documents;
- Preparing training programmes and plans for diverse personnel group;
- Training and retraining of operations staff;
- Training of maintenance staff;
- Training of new plant personnel;
- Training of all the station staff in radiation protection, emergency procedures etc;
- Training of personnel for activities other than plant O & M; and
- Manpower studies.

The great advantages offered by the possibility of practical in-plant training (if available) should be utilized and shared (Annex II).

Physical security sharing is not feasible in general. There are many confidential aspects, which make it difficult (type of detectors, clearing procedures, coding, encryptions, etc).

Maintenance must be in accordance with a written programme prepared before loading the reactor with fuel for the first time. Maintenance programmes can be planned jointly to maximize sharing of off-site manpower, tools and tackles.

Sister plants, especially those presenting close locations and perhaps same language, may arrange supply of shared maintenance teams (planned maintenance shut downs). Maintenance in radiological controlled areas may require some personal radiation dose policies to be observed by the team members.

Staff from the technical services departments can meet periodically to share performance data and planned improvements.

Chemical services department of a plant performs chemistry control of various water systems including reactor coolant system so as to provide optimal environment for the material of construction to give long life of clean operation. It would be useful for the partner countries to regularly share experience in this area to create a disciplined water chemistry regime.

4.3. Operational experience feedback

Experience with first NPPs in a country has shown that there are problems and difficulties, which can be overcome through experience feed back.

Sharing potential: Operational experience feedback

This is a typical sharing activity, especially among sister plants. There are several channels for sharing of operational feedback both for safety and productivity. The safe operation of nuclear power is of paramount importance for the acceptance of nuclear power by the public. Sharing of operational feedback helps in avoiding or repeating failures. International bodies like IAEA and WANO are providing its members with broad based operational feedback and history for trends and benchmarking. On-line sharing of operating data, outage information and corrective actions can be shared.

Owner's group interaction provides operational experience for same design plants. There are several owners groups for operation feed back on NPPs. Detailed analysis of specific events may be shared (root causes, strengths and weaknesses, lessons learned, etc).

The provision of peer review and advisory services by international experts enables national operators and regulators to draw on the nuclear safety experience available worldwide. WANO conducts peer reviews at NPPs in the world. Among the services of the IAEA are missions by Operational Safety Review Teams (OSART), providing plant operators with recommendations and suggestions for strengthening safety performance. The Peer Review of the effectiveness of the Operational Safety Performance Experience Review process (PROSPER), an IAEA service, provides a mechanism and platform for comprehensive investigations of incidents in the operation of NPPs, share good practices and operational feedback. Safety Culture Assessment Review Team (SCART) missions are peer reviews conducted by teams of international experts to identify strengths and opportunities for improvement of the safety culture. All these services are cost effective way to share expertise of international experts on safe operation of NPPs.

4.4. Spare part management

Spare parts are the lifeline for the safe and reliable operation of NPPs. There is an important question mark about the availability of spare parts for the lifetime of the reactor because of rapid developments, which may make the equipments obsolete. This may force the supplier to discontinue this line of product. Setting up of centralized common spare parts facility on sharing basis for identical equipments would be financially beneficial to the partner countries.

Sharing potential: Spare part management

Spare part pools could be established, especially if the equipment designs are similar.

Procurement of spare parts and consumables pools may be established as follows:

— Appointing (by utilities) a procurement office at the designer/vendor's country. Such office may represent several utilities. Quotations will be most competitive in terms of prices and supply conditions because procurement of large quantities for all partner countries is involved. Establishment and running cost of the office will be also shared.

— Adequate arrangements can be established among utilities to exchange spare parts and consumables in case of urgency or emergency (no question if the part is expensive or not).
— Expensive spare parts and components with low probability of failure may have special arrangements, particularly when plants have the same designer. Example: One utility buys, as spare part, one main pump rotor or the electric motor, because the large delivery time in case of a failure. The second utility does not need to have another spare in stock, because the probability of failure of the same component at the same time is very low. Then, the utility which had the failure, requests the spare to the other utility. Immediately the requesting utility releases a purchase order to procure a new spare for the "donor" utility. This type of sharing allows that only one spare part remains immovable (immovable capital cost) at the warehouse. An adequate spare plan may dictate that this type of spare components be shared also in cost.
— A common spare turbine rotor and generator may be possible if designs are same.

In case of urgency or emergency it is also important to have some mechanism between utilities for mutual supply of non-available components in the market, even low price components. Safety situations or shut downs due a small component lacking can result in big losses.

Procuring small devices, even low price may be a problematic situation when the normal manufacturer disappears or discontinued the item. A new manufacturer may need: reasonable order quantity, qualification, prototypes, testing, etc. It takes time and money. Exchange of spare arrangements make possible to locate the discontinued spare in the other utility's warehouse, avoiding a shut down. The arrangement may allow the utilities to act jointly to find or develop a new manufacturer.

Coordination of an owner's group may establish a "virtual warehouse" at his office. The owner's group will manage some "stock" in the virtual warehouse, having information of availability of spares in different utilities, and performing arrangements with suppliers or manufacturers. The owner's group will also search the market looking for better prices (it will manage large quantities resulting from needs of several utilities).

4.5. Fuel management

Nuclear fuel is an item with an ongoing requirement throughout the life of the plant. Long term fuel supplies have to be arranged, usually by entering into international agreements. This would also involve application of safeguards through IAEA.

The utility is primarily concerned with the reliability of the supply of the fuel assemblies and the handling of the spent fuel. To cater efficiently to these two items, fuel management has been developed as an expertise in itself, in both keeping the power plant in operation and holding the costs down. This includes following processes:

(1) Planning for and procurement of an adequate supply of nuclear fuel while taking into account the necessary lead times which amount to many months;
(2) Planning refueling campaigns to achieve maximum fuel use as well as optimum power from the reactor core. This involves a detailed knowledge of the physics of the core

design and requires the availability of fuel management codes for the particular reactor design;

(3) Management of spent fuel from the reactor.

Sharing potential: Fuel

Perhaps one of the most critical steps is to devise effective strategies, which are commercially competitive and free of monopolies, for assuring a reliable supply of material and services. Effective strategies should consider back-up sources of supply in the event that a supplier is unable to provide the required material or services.

Fuel supplies can either be outsourced or a fuel fabrication plant can be set up.

In-reactor testing of first production fuel in a power reactor is not advisable since the consequences of fuel failures can be costly or even dangerous. A means of testing fuel assemblies in small test reactors or in in-reactor loops is needed together with post-irradiation examination facilities. The provision of such facilities can be a significant burden for a nuclear developing country. It is advisable that the domestic fuel fabricator, at least initially, develop arrangements offshore for performance testing of the fuel assemblies by sharing the multiple testing facilities.

For similar reactor design, common spare fuel assemblies may be stored in a centralized place.

Fuel sipping facility for detecting failed fuel may also be shared.

Fuel management code for fuel loading and shuffling can be shared.

Procurement of uranium, conversion, fuel manufacturing and spent fuel disposal and storage could be shared under multilateral agreement where each country is responsible for one of the activities from uranium, conversion and fuel manufacturing. This type of sharing is under consideration for many years from safeguard angle. Enrichment could also be treated in a similar fashion, although any infrastructure sharing proposals related to enrichment should take into account the status and prospects of possible international initiatives for tighter controls on enrichment facilities.

4.6. Radioactive waste management

Radioactive waste is generated during the operation of NPP. The principal waste classes include exempt waste, low and intermediate level waste, which may be subdivided into short lived and long lived waste, and high-level waste.

The objectives of waste management are:

(a) To perform safely and efficiently a series of operations leading from the collection of wastes arising from nuclear operations through waste conditioning and transport to storage and disposal; and

(a) To ensure that no unacceptable detriment to humans will occur at any time as a result of these waste management and disposal operations.

Management and disposal of radioactive wastes are always a national responsibility.

Sharing Potential: Radioactive waste management

R&D concerning disposal of high-level waste/spent fuel can be done in cooperation and shared. The cooperation between SKB (Sweden) and Posiva (Finland) is an example (Annex IV). A multinational repository is also an option [2] as many countries may not have large nuclear power programme to justify high investment in deep geological formations for safe disposal of waste. Multinational repositories for spent fuel may ease the pressure on countries with limited nuclear power programme and/or lacking suitable geological formation for disposal of high-level waste. This requires strong political will and public support as there is resistance for storing someone else's waste.

For the time being, waste disposal facilities are not shared by utilities of different countries. Easier to share are the design and engineering costs by two or more utilities with same plant technology.

It is also possible to employ mobile units on sharing basis for treatment and conditioning of low-level waste short lived.

4.7. Transportation of heavy components and radioactive material

In the transport of radioactive material the actual quantities involved are very small in comparison with the transportation requirements for coal-fired stations. It is only the radioactivity that requires special care. Radioactive materials arising in the nuclear fuel cycle are generally transported by truck and to a lesser extent by rail or sea. Regarding protective measures, extensive experience is available.

Sharing potential: Transportation

The transport facilities and experience can be shared on a regional basis. It would be more beneficial if the countries in a region jointly create centralized heavy-duty transport and material handling infrastructure. But this would assume that the programmes run in parallel with a phase difference of about 6 months. Agreements for usage of this centralized facility and sharing of idle time should be carefully drafted to prevent disputes.

Special vehicles needed for the transportation of heavy components can be shared. Casks, railway vans and ships for spent fuel transportation can also be shared.

Shielding casks for spent fuel (route transport or railroad) complying with safety regulations may be shared. Qualification of such casks is an involved procedure and requires demonstrating the integrity of cask under severe road accidents, fire, and fall from a height. The facilities for qualification of casks may be shared.

Route surveys for identification of routes for transportation of heavy/over dimensioned consignment; assessment of load carrying capacity of culverts and bridges; ensuring clear head room between loaded consignment and bridge/ transmission line may be carried out jointly.

4.8. Decommissioning

Decommissioning of a nuclear facility includes the measures taken at the end of the facility's lifetime to ensure the continued protection of the public from the residual radioactivity and other potential hazards in the retired facility. Two basic approaches are generally considered in this regard, one being immediate dismantling and the other, safe storage with or without deferred dismantling. In the second option fuel is discharged to a storage facility and non-radioactive parts of the plant are dismantled but radioactive parts are mothballed for 30 or more years before dismantling. The selection of approaches depends on the investment needs, the value of land at the plant location and regulatory requirements.

Methods for decommissioning nuclear facilities range from minimal removal and fixation of residual radioactivity with maintenance and surveillance, to extensive cleanup, decontamination and entombment. Each of these methods of safe storage requires surveillance and care during the holding period, which may vary in length from a few years to decades.

Sharing potential: Decommissioning

Decommissioning plans can be made in cooperation. Equipment needed in decommissioning can be shared.

Sharing possibilities on this subject are:

- Policies regarding decommissioning;
- Regulatory requirements;
- Decommissioning options;
- Decommissioning plans and procedures;
- Skilled manpower; and
- Special devices for dismantling.

4.9. Environmental aspects

The generation of electricity by nuclear power has some environmental effects even when all performance standards are met. One of the objectives in the design of NPPs and other nuclear facilities is to minimize the impact of various possible effects of releases from the plant to the surrounding environment. Potential sources of releases to the environment from the operation of NPPs include mainly radioactive gaseous or liquid effluents, heat discharges from waste steam, and chemical discharges from different systems of the plant. Various releases from the plant are subject to strict control both by batch processing of effluents or by continuous monitoring before discharge to the environment to ensure that the established permissible levels are not exceeded.

Sharing potential: Environmental aspects

For public safety it is essential that terrestrial, air and water routes be monitored for radio nuclides on regular basis and information shared. Radiation and health facilities can be shared. Environmental impact studies may be shared and carried out jointly for cross border impact on neighboring states.

International safety standards for environment protection can be studied jointly and implemented particularly with respect to release of radioactivity to marine environment, water body and air. IAEA safety standards for environment protection can be used. Transboundary consultations for liability and compensation should be encouraged.

4.10. Emergency planning and preparedness

Absolute safety cannot be achieved for NPPs any more than for any other type of power plant or industrial facility. There always remains a residual risk of extremely improbable but conceivable events beyond the range of accidents considered in safety analysis. These extreme events require preparation of emergency plans and procedures.

Management of emergency requires quick response from the people entrusted with this responsibility. Any delay or wrong step can lead to panic in the public and to law and order situation. Therefore the district authority and plant personnel should carry out regular mock drills.

The IAEA Safety Standards [17] provides the requirements for an adequate level of preparedness and response for a nuclear or radiological emergency in any country.

Sharing potential: Emergency planning and preparedness

Today the world has shrunk into a global village because of network of fast communication and transport. Still emergencies resulting from acts of nature — Tsunami in Asia, floods in USA — have exemplified the urgent need of sharing expertise. Such a need is also felt in NPP emergencies arising from accidents.

Procedures can be developed in cooperation and shared. Drills arranged by one plant can be participated/followed by other plants.

District emergency planning may be shared for methodologies and procedures. However district population, prevailing meteorological conditions, terrain characteristics and routes require particular emergency plans. Also, radiological conditions established for indoor protection, iodine pills ingestion and evacuation call for specific instructions.

Special medical units for acute irradiated persons may be shared if distances and transportation media imply time and economic convenience.

Should an emergency situation develop, the NRB should be prepared to render immediate assistance. NRBs of partner countries can support each other during such emergencies.

For the emergency situations expert help in the form of safety engineering team should be made available on short notice. This team should consist of professionals with thorough knowledge of systems, operations and accident analysis. Safety engineering teams may be shared.

5. OPPORTUNITIES OF SHARING INDUSTRIES AND VENDORS INFRASTRUCTURE

Industrial infrastructure plays a key role in the introduction and development of nuclear power in a country. In this section following industrial infrastructure areas are discussed:

(i) Engineering and safety asessment;
(ii) Manufacturing;
(iii) Construction and erection;

(iv) Commissioning;
(v) Management system (including QA/QM);
(vi) In-service inspection;
(vii) Procurement;
(viii) Vendor qualification.

The industries likely to be involved in setting up a NPP are shown in the following list.

Raw materials

— Civil - aggregate, sand, timber, cement, etc.
— Metals - iron and steel plates/ingots, rods, wires, etc.
— Chemicals - petroleum and coal products, rubber, plastic, etc.
— Special material - zirconium, titanium, special alloy steel.

Material products

— Piping (CS and SS), supports, joints anchors,
— Rebars, structural steel, plates, ducting,
— Nuts, bolts, screws, fencing, gates, etc.

Machinery and equipment

— Pumps, blowers, filters, valves, strainers,
— Low pressure vessel/tank, heat exchangers, condensers,
— Heating and ventilation equipment,
— Water treatment plants,
— Lifting equipment, elevators.

Electrical and electronics

— Cables, insulators, conduits, earthing, trays,
— Switchgears, transformers, electrical drives,
— Activators, recorders, indicators, controllers, control panels, etc.

Scientific/industrial instruments

— Laboratory and field testing instruments,
— Fault detectors, measuring and calibration instruments,
— Meteorological instruments,
— Water and soil quality testing.

Transportation

— Trucks, railcars, heavy and long load carrying equipment,
— Marine handling and transportation, barge roll on-off, etc.

Construction

— Earth moving machines,
— Batching plants, concrete pumps,

- Cranes, rebar workshops,
- Testing,
- Trucks, graders, trenchers, forklift trucks, scaffolding, etc.

Erection

- Piping, heavy lifts, field welding, prefabrication,
- Heating and ventilation, scaffolding,
- Testing equipment.

Services

- Warehousing - Buildings, shelves, forklift truck, lifting, bins, etc.,
- Offices - Office equipment and materials,
- Others - Canteen, cleaning, security,
- Industrial safety, fire fighting.

Engineering and management

- Engineering design, procurement, site management,
- Project management.

Utilities

- Water, electricity, drainage, transportation,
- Communications.

To determine the degree of participation at local and regional level, industrial surveys should be carried out which highlight the project's positive and negative aspects, the latter usually expressed as deficiencies. The industrial strength in each participating country can be pooled for arriving at the extent of local participation (local means partner countries).

5.1. Engineering and safety assessment

The term engineering usually covers the activities of basic and detail design, project engineering, support at the home office as well as at site. The activities at site normally include field engineering and assistance in commissioning and startup activities.

Plant supplier and utility carry out major engineering activities either on their own or through consultants in a turnkey and package contractual approach.

Typically a core group carries out work in specialized areas like stress analysis, seismic analysis, thermal hydraulic and safety analysis. This group needs highly qualified people as it shoulders onerous responsibilities for safety of reactor. While core competence may be built over a few years, the services of consultants may be engaged for the first project.

Transfer of technology and localization of any of the manufacturing activities may be part of engineering and can take place in the home office and other locations.

Project engineering is a term often used to describe general engineering work, such as layouts and general specifications. It includes, in particular, coordinating and expediting the various engineering disciplines so that these integrate efficiently and coherently.

Typical end products of the engineering design functions are the drawings and specifications to which the project is to be built and the requisitions against which the equipment and materials are purchased.

Sharing potential: Engineering and safety assessment

Sharing of expertise and experience during pre-project activities namely feasibility studies and preoperational fingerprints is possible. The evaluation of site survey data and site evaluation can be shared. The preparation of national standards can also be carried out jointly. Quality assurance plans and procedures can be exchanged. Independent review of safety analysis reports and engineering documents for safety components/ systems can be carried out on reciprocal basis.

Typical engineering end products for procurement are the technical specification for bid requests. Construction support activities at the home office usually produce drawings and specifications to define how construction will be carried out and what site support and temporary facilities are needed. Other end products within the construction support activities are the construction plans and the outline draft of the various construction contracts. These can be prepared jointly.

The design includes vast number of activities from system studies to process design, from selection of components and equipment to the design calculations and analysis of structures and equipment to preparation of equipment and piping drawings for manufacturing and construction. It is a multidisciplinary activity and covers civil, mechanical, electrical, control-instrumentation and analysis, which finally produces several types of documents and reports. Design documents normally require review by an independent body. This review process can be shared.

Formatting of documents, procedures for writing and authorization for approvals can be done jointly.

The expertise needed for analysis can be shared. It could also be agreed that one country specialize to certain areas and the other countries take care of other areas.

5.2. Manufacturing

The equipment, components and special materials that are needed in the construction of a NPP represent approximately 40-50% of the overall cost of the plant. 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 infrastructure within that country. While it is possible for a country to establish a 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 needed suggests that this capability can only be achieved over a long period of time encompassing several NPP projects.

Sharing Potential: Manufacturing

Looking at the manpower qualification requirements and intensive investment in setting up manufacturing facilities, for the first NPP it might be advisable to make use of the manufacturing facilities, particularly for critical components, of the plant supplier. Examples of such equipment include reactor vessels; steam generators; reactor coolant pumps; turbine generators; special purpose nuclear valves; and diesel generator sets for reliable on-site power for supporting safety systems. In other areas manufacturing capacity can be shared extensively.

The electrical systems serving safety related systems of the plant must be of high quality. The cabling and electrical components for these systems have to be manufactured to stringent and unique standards, which may demand significant capital investment and which can cause difficulties in production. Nevertheless, over half of the electrical equipment is used in systems where conventional industrial standards are adequate. Thus there is a wide variety of electrical equipment, which could almost certainly be supplied by domestic manufacturers in a country with a sufficient electrical load to justify a nuclear power programme.

Sharing may be made according to the type of manufacturing facilities. If there is alignment in the type of NPP type and rating, centralized manufacturing facilities may be set up on sharing basis.

Special purpose nuclear valves and instruments will not generate enough volumes for setting up separate facilities but may be considered for centralized development on a joint venture basis.

Special alloy tubing requirements will vary with the specific design of the plant, but common demands are for Inconel 600 or Incoloy 800 high nickel alloy tubing and for the steam generators and Zircaloy tubing for the fuel cladding. A facility for producing either high nickel alloy tubing or Zircaloy tubing would demand an investment of several million dollars. However, since Zircaloy tubing is an ongoing requirement, a plant producing this material may warrant more serious consideration. Centralized manufacturing facilities is considered possible if countries join hands for nuclear power programme and agree to share infrastructure.

Heavy water production facility can be shared. The technology of heavy water production is a special variant of basic chemical engineering technology. The main concern is process optimization to minimize energy use, to reduce leaks from enriched heavy water streams and, whenever needed, to minimize toxic hazards. Overall, the technology is not much more difficult than that of a modern oil refinery and, in principle, is commercially available.

5.3. Construction and erection

About 30% of the total NPP investment cost is spent on the site for excavation and construction that encompasses the civil work, the erection of the systems with the mechanical and electrical components and the commissioning and start up of the plant.

The total construction of a single unit NPP covers a period of five to six years involving integration of many activities including designs; material and equipment supplies; the assembly of thousands of individual pieces.

Sharing potential: Construction and erection

Construction and erection capacity can be shared extensively.

Plant schedules in the partner countries can be phased in time period of 6–12 months for enhancing the potential of sharing of construction equipment. Subcontractors may participate in the other plant construction and erection. Costs, language, etc. should be evaluated.

Some prefabricated parts may be supplied from one country to the other. Special formworks for containment building can be made once and shared thereby saving duplication of effort, material and time. However a balance should be struck between jobsite savings and transport expenditures.

Modern construction technology adopts open top construction for erection of heavy components such as the reactor pressure vessel, steam generator, generator stator and main transformer is possible. This requires special transportation vehicles, large capacity and expensive lifting and material handling equipment. Sharing of construction equipment will bring a big relief and cost savings.

Construction technology is making greater strides and is moving towards modular construction to achieve required quality in a controlled shop environment and compression of time schedule. For prefabrication of modules, centralized facilities can be financed jointly.

Selection of contractors through tendering and evaluation process is a long duration activity. The time period can be reduced if contractors are pre-qualified. Pre-qualification of contractors can be done jointly.

Project directors can meet regularly for sharing of experience particularly with respect to interface management between design, supply of material and equipment, and construction.

Industrial safety documents including job hazard analysis documents can be shared. Industrial safety staff can meet regularly and share experience. Job hazard analysis and fire hazard analysis studies can be carried out jointly.

For performing specific quality verification functions during plant construction, an organization participating in a nuclear power project should be equipped with necessary measuring and testing equipment corresponding to the scope of its activity and the methods to be used in verification. The first line inspections and after-installation testing are normally performed by inspection groups of the organization performing the work. These groups should be equipped with basic inspection tools specific for the type of activity (mechanical, electrical, civil) and adequate for field use. With proper planning it may be possible to share these facilities.

5.4. Commissioning

The following four basic phases typically cover the commissioning stage of a NPP:

Phase A: pre-operational tests

Phase B: hot trial run No. 1 (without nuclear core)

Phase C: first core loading and hot trial run No. 2

Phase D: first criticality and power tests

The mechanical and the electrical/instrumentation commissioning start simultaneously with the erection of the plant and as soon as parts of the plant or part of the systems are completed. Prior to the non-nuclear total plant tests, phase A must be completed. The release to the higher power test can only be given if the results of the preceding tests and examinations permit.

The acceptance of a NPP or of parts of a NPP by the utility indicates the transfer of operating responsibility from contractor or supplier to the utility. Another type of acceptance concept consists in transferring the operation responsibility of the whole plant at a suitable moment.

Sharing potential: Commissioning

Procedures for construction completion certificates and system transfer documents from construction team to commissioning team can be standardized and shared. Teams for pre-service inspection of safety equipment and systems may carry out the specialized job with specialized equipment on sharing basis. The commissioning crew (or some part of that) can move from one plant to another plant. Also same procedures could be utilized.

Some expensive necessary devices (testing) during this stage may be shared, in terms of costs and usage. Examples:

- Containment pressure test transducers and measuring equipment. containment leak test procedures and measuring devices may be shared; and
- Data acquisition means and evaluation software and services can be shared.

5.5. Management system

An integrated management system (MS) focused on satisfying the totality of requirements is essential to compete and survive in the global environment, while maintaining and enhancing safety. The organizations involved in a NPP project should evaluate their needs and existing management systems including QA systems against the requirements and guidance provided in [18] and [19].

An integrated MS should provide a single framework for the arrangements and processes to address all the goals of the organization. These goals include safety, health, environmental, security, quality and economics and other considerations such as social responsibility. A MS comprising organizational models, concepts and tools should also include human factor issues and other integrated management approaches that complement the traditional approach to achieving results that was based only on inspections and verification checks.

Technological innovations have radically altered the interactions between systems and humans and, therefore, the management of the whole organization. Complex activities and multiple objectives involve individuals operating at different levels in the organization, while operating processes are modified by the introduction of new management practices and new requirements. Daily practices and the results achieved by the organization, the organization culture and the management process are deeply interrelated. The MS should be able to evolve accordingly to accommodate such changes and to ensure that the employees understand what has to be done to meet all the requirements applicable or relevant to them.

Sharing Potential: Management system

Sharing the resources and processes is an effective way to help establishing MS. However, the organization retains overall responsibility for the MS when others are involved in the work of developing all or part of the MS.

The following can be shared:

(a) Human resource management

- Assessment including audit personal;
- Inspection and testing staff; and
- Training, qualification and certification of key personal, where appropriate.

(b) Tools & equipment

- Non-destructive examination equipment along with its operators;
- Regional QA unit can be set-up keeping in mind the type of QA functions dominating in the region;
- Testing and calibration laboratories; and
- Inspection, testing and examination.

(c) Processes

- Classification of systems as per safety;
- Joint preparation of quality plans, procedures;
- Process mapping with shared expertise; and
- Development of the procedures such as:
  - plans and work schedules
  - review and approval of documents and specifications
  - assessment of suppliers, constructors and installers
  - design control.

(d) Assessments

- Surveillance and assessments of construction activities and review and approval of construction and installation procedures, as well as the witnessing of all important inspections and tests and initiation of corrective actions can be shared; and
- Team from other country and vice-versa can perform the evaluation of the MS for a country.

5.6. In-service-inspection

In-service inspection (ISI) is a part of the activities for monitoring healthiness of critical piping weld joints, thinning of reactor pressure vessel, thinning of steam generator tubes etc. ISI is also carried out on the containment and the turbo generator. Techniques used for in-service inspection are mostly non-destructive in nature and include:

- Visual examination;
- Surface examination by liquid penetrate examination;
- Ultrasonic examination;

- Eddy current examination; and
- Radiography.

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

Sharing potential: In-Service-Inspection

Eddy current testing equipment is required for examination of steam generators tubes, heat exchangers tubes, condensers tubes, etc. It is expensive equipment, which mainly necessary during maintenance and inspection shutdowns. Two or more utilities may share development or purchase costs. Adequate arrangements may be made for the use of such equipment. Later on, if the utilities consider economically convenient, another set may be bought.

Containment testing equipment can be shared.

Since ISI has to be conducted on yearly or longer intervals, joint ISI teams can be formed and testing equipment shared.

5.7. Procurement

With a turnkey arrangement the main contractor has the responsibility for procurement of every item of equipment and of materials within his 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:

- Establishment of procurement criteria;
- Procurement planning;
- Supplier qualification and selection;
- Bidding and bid evaluation;
- Contracting;
- Contract monitoring and enforcement;
- Expediting; and
- Handling of warranty claim.

If a centralized independent unit performs procurement, this would require working with and for project management and engineering within the framework of a matrix organization. Centralized independent procurement unit could do the procurement of practically all plant items by this unit.

Sharing potential: Procurement

Under ideal situation procurement services may be possible to be shared. But on practical grounds it appears less feasible. However, expertise can be shared in developing procurement organization and procedures.

5.8. Vendor qualification

More the number of vendors for particular equipment or material more would be the competitiveness in procurement activities.

Sharing potential: Vendor qualification

Vendor qualification system can be shared. A vendor qualification given to one plant can be valid for other plants.

The vendor qualifications may be required during initial project procurement stage and when the original qualified vendor discontinues a component or consumable spare part supply. In the latter case, utilities under operation may find that the original supplier is no more in the market or discontinued a certain product. Qualification of a new product or a new vendor may imply a considerable effort (searching time, testing and approval). Such effort can be shared by several utilities looking for the same component. The advantages are:

- Purchase volume would be more attractive for the new potential supplier; and
- Qualification, testing and approval costs will be shared among utilities.

6. IMPLEMENTATION OF INFRASTRUCTURE SHARING

The previous sections described the potential of sharing in several nuclear power infrastructure items. The implementation of sharing demands special skills, ability to adjust, transparency and above all mutual trust.

This section describes the implementation of sharing nuclear power infrastructure items.

6.1. Factors influencing the potential of sharing

Alignment in the individual country interests in following areas would facilitate implementation of sharing of nuclear power infrastructure.

Selection of reactor type and size

The most cost effective scenario of infrastructure sharing is that two or more countries join hands and enter into agreement for constructing a NPP of identical reactor type and size. The selection of a reactor with proven design may be desirable. However, even though reactor type and size are similar there may be certain differences in the design of balance of plant due to specific site parameters of civil foundation, earthquake, tsunami, cyclones, cooling water supply and temperature, etc.

Project implementation strategy

Implementation of the NPP project will depend on a contractual arrangement. For sharing of nuclear power infrastructure it would be beneficial if the participating countries adopt similar contractual approach.

6.2. Sharing arrangements

Sharing of nuclear power infrastructure can be implemented in many ways as described here.

— ***Bilateral Cooperation Agreement***

When two countries join hands for sharing of infrastructure, a bilateral agreement could be entered into. It is understood that such agreements would include reference to all the international agreements including IAEA safeguards.

— ***Multilateral Cooperation Agreement***

Such agreement could be entered into when more than two countries join hands for introduction of nuclear power. Management of fuel cycle activities is an example of multilateral agreement. Activities related to fuel from mining to disposal of radioactive waste can be distributed in different countries thereby ensuring the safeguard requirements also.

— ***Memorandum of Understanding***

Here an agreement is reached in the form of bipartite or tripartite understanding for sharing of nuclear power infrastructure. This type of understanding is suitable for sharing R&D programme, services, computer software, non-destructive examination (NDE) tools etc. A Memorandum of Understanding does not involve any financial implications.

— ***Protocols***

A working arrangement based on set of rules for exchange of information can be agreed upon through protocol. Protocol cannot be enforced legally and are therefore considered draft rules of convention. Kyoto protocol on climate control is an example.

— ***Conventions***

A working arrangement based on a formal agreement can be established through convention for sharing infrastructure items.

— ***Contracts***

A contract is a binding agreement between two or more parties (say utilities). It is written and enforceable by law. Such contracts are usually on payment basis for services like consultancies.

— ***Jointly owning physical facilities***

Centralized manufacturing facility is an example of arrangement that could be formalised through a cooperation agreement.

— ***Sharing facility owned by partner country***

Use of simulator for training of operators; sharing of grid; sharing of R&D facilities like in-core testing of materials and fuel; are some of the examples of this mode of implementing sharing of nuclear power infrastructure.

— ***Exchange of services***

Sharing of services such as simulator training, QA personnel, maintenance crews, mobile waste treatment units can be done through protocols or conventions.

6.3. Role of IAEA in implementation of infrastructure sharing

Following are some examples of IAEA support regarding infrastructure activities:

- Development of safety standards;
- Safeguards;
- Guidance related to manpower development;
- Education and training;
- Guidance related to electrical systems;

— Site evaluation; and
— Studies related to economics of nuclear power;
— Operating experience feed back; and
— Conducting advisory missions in the field of nuclear power.

IAEA also conducts regional technical cooperation projects for sharing of experience in nuclear power management. An example for the Latin American countries namely Argentina, Brazil, Cuba and Mexico, is described in Annex III. Lessons learned indicated potential for sharing nuclear power infrastructure at regional level for enhancing the safety and reliability of the nuclear power programmes.

6.4. Role of national government in infrastructure sharing

The governments of countries participating in the sharing of nuclear power infrastructure have a key role to play. As part of their nuclear power programme planning, they need to convince the public to support their programme. There has to be alignment of interests not only at national level but also at international level between the partner countries. The introduction of nuclear power programme is a long term commitment and the countries have to honor their agreements sometimes for 20 to 25 years or even more, particularly when fuel supply is also a part of the sharing infrastructure.

For introduction of nuclear power, each of the participating countries may have to carry out nuclear power programme planning studies themselves because of involvement of large number of local factors. However, the partner countries can provide support by sharing experience of carrying out this evaluation by holding regular coordination meetings.

6.5. Basic infrastructure

The introduction of nuclear power in a country cannot be conceived as an isolated project. There are certain basic infrastructure activities within the scope of a nuclear power programme, for which full responsibility has to be borne by national organizations and which should be primarily executed by national manpower whatever the contracting arrangements. Expert help from abroad could be obtained and used up to a point, but only for technical assistance and not as a complete replacement of the national effort.

Guidance on the issues that need to be addressed within a basic infrastructure for a nuclear power project is provided in [1].

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ABBREVIATIONS

ICRP	International Commission on Radiological Protection
ISI	in-Service-inspection
MS	management system
MW	megawat
NORDEL	Norway, Denmark, Finland, Iceland, Sweden
NPP	nuclear power plant
NPPs	nuclear power plant projects
NRB	Nuclear Regulatory Body
O & M	operation and maintenance
OECD	Organisation for Economic Cooperation and Development
QA	quality assurance
R&D	research and development
WANO	World Association of Nuclear Operators

ANNEX I. CASE STUDY: NORDEL GRID SYSTEM — SHARING OF A PHYSICAL FACILITY AND TRADING OF ELECTRICITY

I-1. Introduction

Nordic countries comprise of Denmark, Finland, Iceland, Norway and Sweden. Nordel grid system was conceived to provide trading of electricity and grid stability.

This grid is now expanding and has links with France, Germany and Poland to trade electricity during dry years when countries like Norway largely dependent on hydropower face shortages.

This case study is related to the grid stability, reliability and trading aspects.

I-2. Maintenance of operational reliability

Maintaining the operational reliability of the power system means that the power system is dimensioned and operated so that the impacts of disturbance situations are minimized, that there are provisions for restoring the power system to the normal state, and that the disturbance incidents are cleared as quickly as possible.

I-3. Grid dimensioning

The power system in Finland has been dimensioned in accordance with principles agreed upon jointly between the Nordic countries. The main dimensioning principle is that the power system has to withstand any single fault at all times in such a way that the influence area of the fault does not expand and lead, in a worst case scenario, to a major disturbance in Finland. Such faults include a permanent disconnection of any generator, transmission line or power transformer. The worst possible fault in the power system is referred to as a dimensioning fault. A dimensioning fault varies on the basis of the operational situation of the grid, but is often the tripping of the largest production unit or an extensive bus bar fault.

I-4. Transmission limits

Electricity transmissions are kept within the limits of the prevailing operational situation by means of the control of electricity transmissions in the main grid. These limits are determined by operational reliability calculations, which take into account potential faults in the power system. The transmission limits vary in different operational situations, and issues such as planned service outages in the grid may have a great impact on the transmission limits.

The transmission limits are calculated individually for each case. The principle is that a dimensioning fault must not lead to loss of synchronized operation, voltage collapse, disconnection of loads, too large voltage or frequency deviations, overloading of grid segments, or self-sustained electromechanical fluctuations.

A point, which limits electricity transmission in the grid, is called a bottleneck or congestion. Short-term bottleneck problems in the main grid are managed commercially through counter trade, and long term bottlenecks are managed by applying price areas or by strengthening the grid.

The maintenance and modifications of the various parts of the grid require planned outages, during which parts of the grid have to be temporarily taken out of operation. Careful planning and timing of the outages optimizes and assures disturbance-free and commercially purposeful operation of the grid. This benefits all parties of electricity trade.

I-5. Disturbance management

The purpose of disturbance management is to prevent disturbance situations in the power system from cascading and to restore the normal state of the power system as quickly as possible. For disturbance management purposes, both power and transmission reserves are maintained in the power system. Fin grid is responsible for the maintenance of reserves that are needed in the Finnish power system.

I-6. Frequency controlled and fast disturbance reserve, black start reserves

Disturbance reserves are used as a contingency measure for disturbance situations in the power system. Such disturbance situations include disconnection of a generator from the grid (consumption greater than production) and disconnection of load (production greater than consumption).

The frequency controlled disturbance reserve consists of active power reserves that are activated automatically as a result of frequency changes. The frequency controlled disturbance reserve begins to activate when frequency goes below 49.9 Hz, and the full reserve has been activated at a frequency of 49.5 Hz. The frequency controlled disturbance reserve includes both active power reserves of power plants and disconnect able loads. More information on the frequency controlled disturbance reserve is available under item Maintenance of frequency.

The fast disturbance reserve consists of active and reactive power reserves that can be activated manually within 15 minutes. After activating this reserve, the power system has been restored to such a state that it can withstand another potential disturbance. In the Nordel grid (the inter-Nordic grid), each country should have a volume of fast disturbance reserve that equals the country's /dimensioning/ expected fault. In Finland, this volume is normally 850 MW.

Machinery with a black start feature can be started to a dead grid without external power supply. This feature enables voltage to be restored to the grid in conjunction with a major disturbance. Some of Fin grid’s gas turbine plants have the black start feature, but if there is no voltage available in Finland, the goal is to obtain it primarily from a 400 kV substation in Sweden.

I-7. International Electric Power Trading

The region, where international electric power trading has become the most developed in the world, is probably the countries of Northern Europe, and in particular Scandinavia.

The electricity trading has undergone a dramatic change in recent years as the old model of cooperation between the leading utilities in each country within the NORDEL organisation has been replaced by competitive market rules. A common power market NORDPOOL for Norway and Sweden was in fact established in 1996. Finland and Denmark has joined it later.

There are a large number of HVDC interconnections in place involving all countries in the region, and several new ones are being planned.

- An interconnection between Sweden and the western grid in Denmark was established in 1965 with the 250 MW Konti-Skan HVDC link across the Kattegatt from Gothenburg to Aalborg. A second Konti-Skan cable rated 300 MW was added in 1988.
- In 1976/77 a more than 50 year old dream - to establish a power link between Norway's hydropower system and Denmark's thermal power system - was realised. The 500 MW Skagerrak HVDC link crossing the 600 m deep waters south of Norway was commissioned. The capacity of this link was doubled to 1000 MW in 1993 by adding a third cable to the two original ones.
- A direct connection between Sweden and Germany was established in 1994 when the 250 km 600 MW Baltic Cable HVDC link between Malmö and Lübeck was commissioned.
- An interconnection from Denmark's eastern grid to Germany was established in 1995 by the 600 MW Kontek HVDC link from Sjælland to Rostock in Germany.
- A 600 MW interconnection**, SwePol**, has been put in service in 1999 between southern Sweden and Poland. Poland is now interconnected with Germany and thereby with the whole UCTE network of Western Europe.
- A 700 MW interconnection**, NorNed** between Norway and The Netherlands will go into operation in late 2007. This will be the longest submarine cable in the world - 520 km.

I-7.1. The Traditional NORDEL Cooperation

As long as all the Nordic countries had vertically integrated power utilities, the NORDEL cooperation was based on the principle that each country would build enough generating capacity to be self-sufficient. The trading between the NORDEL countries was therefore a means to achieve an optimum dispatch of the larger interconnected system. The investments in the interconnections were therefore generally not based on a net export from one country to another, but on the expected savings by pooling the available generating resources. The large differences between the countries with respect to type of generation made such savings probable, but the necessary investments were also large in the cases where submarine cables had to be installed. The first Skagerrak link built in the 1970s between Norway and Denmark can serve as a good example of the benefits that can be achieved through an interconnection.

I-7.2. Recent Interconnections in a Market Oriented Environment

The interconnections that have been commissioned from 1994 and onwards, as well as the interconnections now being implemented and planned have been undertaken based on strategic business decisions in an increasingly competitive environment. It is very unlikely that they would have been built by vertically integrated utilities, because interconnection with others is always of secondary importance to an electric utility in a monopoly situation. But in the new environment, a competitive advantage may be gained by having a power exchange possibility (export and import) from a market with a different price structure.

Source: A. Rastas, Finland

ANNEX II. CASE STUDY: ARGENTINA AND BRAZIL SHARING OF OPERATION SERVICES IN THEIR NPPs

II-1. Introduction

The first Argentine NPP is Atucha I, a PHWR type (pressurized heavy water reactor, pressure vessel, KWU-Siemens design). Net power is 319 MW(e). Commercial Operation was declared on June 1974.
The second NPP is Embalse, a CANDU type (pressure tubes heavy water reactor, AECL-Italimpianti design). Net power is 600 MW(e). Declared in commercial operation on January 1984.
The third plant under construction is Atucha II, a PHWR type, similar to Atucha I with enhanced design. Net design power is 745 MW(e). The construction was delayed several years and resume of construction decided in 2005.

The first Brazilian NPP is Angra 1, a PWR type (Westinghouse pressurized light water reactor). Net power is 657 MW(e). Commercial operation was declared on January 1985.
The second NPP is Angra 2, a PWR type (pressurized light water reactor, KWU- Siemens design). Net power is 1350 MW(e). It is in commercial operation since February 2001.
A third NPP, Angra 3, same type, design and power rating as Angra 2, is under assessment (2006) to resume construction.

The scope of supply in the Brazilian–Germany nuclear agreement included a NPP simulator for operator training. The simulator was erected in Brazil, close to the NPPs site, and commissioned in 1985. Because Angra 2 NPP construction was delayed, it created an option for using simulator services for training other NPP teams (the simulator was not applicable to Angra 1 NPP). It was decided to offer simulator services to Argentine and European utilities.

II-2. Initial sharing

Argentina did not have a local simulator at the time when simulator training was required for Atucha I NPP. It was not found a substitute facility, because the German prototype MZFR (Mehrzweckforschungsreaktor –Multipurpose research reactor) started to be decommissioned. No other PHWR type NPP similar to Atucha I NPP was in operation.

The Brazilian simulator, in principle designed for Angra 2 and Angra 3 NPPs, was analyzed and considered basically compatible with Atucha I NPP needs. The training could be complemented through some additional procedures at the simulator training facility.

The Embalse NPP simulator training was performed at a Canadian simulator utility (sister plant: Gentilly 2 NPP– Hydroquebec).

II-3. Implementation and increase of sharing

A sharing activity was considered a pragmatic solution. From the Brazilian side, simulator hours were offered to the Argentine side. The Brazilian utility ELETRONU (Eletrobras Termonuclear SA – Eletronuclear) requested services to the Argentine utility NASA (Nucleoeléctrica Argentina S.A), initially regarding supply of teams in the area of radiation protection during plant shutdowns (planned and unplanned). The Argentine utility offered radiation protection teams, creating a credit account in terms of “simulator hours”.

Subsequently, additional teams were supplied in other disciplines: instrumentation and control, mechanical maintenance, electric maintenance, non-destructive testing, in service inspection, etc. It was differentiated when teams traveled to Brazil or Argentina for hands-on training and when for technical support services during NPP outages. The attached table presents the man-hours exchanged between the NASA and ELETRONU utilities, during the years 1999-2004. The difference in man-hours provided by NASA was accounted to the use of the simulator provided by ELETRONU.

The services are arranged under a Protocol and offered with reduced prices since certain cost components are not completely charged. The main purpose of the Protocol is to put at disposal the resources that are temporarily not fully used.

II-4. Current status

Revision of the Protocol is undergoing considering the following activities:

- Exchange of information;
- Training of personnel of NPPs (including use of simulator);
- Technical assistance in the areas of radiation protection and environmental preservation;
- Inspections and activities in different areas of engineering;
- Planning and organization of plant reviews;
- Review of operational incidents;
- Supply of material, spare parts, components, consumables, special tools, etc;
- Development of special tests or inspections and repair of components, including steam generators;
- Experts' technical visits; and
- Steam generators inspections using eddy current tests.

II-5. Conclusions

Already in the seventies the two neighboring countries, in spit of having different reactor types, decided to explore the possibility of sharing efforts to complement their respective programmes. Following differences were recognized and not allowed to become hindrances for the sharing arrangements:

- Different languages, however similar (Portuguese and Spanish);
- Different grids (50 Hz in Argentina, 60 Hz in Brazil);
- Different reactor types (heavy water in Argentina, light water in Brazil); and
- NPPs about 3000 km distant.

The good, open and transparent relationships between utilities and countries resulted in an effective and beneficial sharing. This experience can be used for other countries taking in consideration the reduction of available qualified manpower, one of a kind system in nuclear facilities, etc.

Man-hours worked under the sharing agreement during 1999–2004

Activities	**Man-Hours**	
	Provided by **NASA**	Provided by **ELETRONU**
Commissioning	6,720	
Steam Generators / EDDY Current Inspection	2,517	144
Maintenance	3,544	
Radiation Protection	11,546	
Simulator Training		1,200
Total Man-Hours worked for Eletronuclear	24,327	
Total Man-Hours worked for NASA		1,344

Source: E. Diaz, Argentina and J. Costa Mattos, Brazil

ANNEX III. CASE STUDY: IAEA REGIONAL PROJECT ON COOPERATION IN NUCLEAR POWER MANAGEMENT

III-1. Introduction

A regional project was implemented during the period 1995–1998 in the Latin American region under the IAEA Technical Cooperation Programme.

The project was directed to exchange management practices and to develop mechanisms of regional integration for improving safety and reliability of nuclear power programmes in Argentina, Brazil, Cuba and Mexico.

III-2. Training/capacity building

III-2.1. Main achievements

(a) Exchange of information and cooperation on management issues

Eight management executive meetings, 2 in each participant country, were accomplished. The main purposes of the meetings were:

— To identify common problem areas;
— To exchange proven practical measures which contribute to solving these problems; and
— To mutually help each other through the development of regional cooperation.

The meetings were held in each of the 5 nuclear sites in the region including:

— Atucha I and II NPP, Argentina;
— Embalse NPP, Argentina;
— Angra 1 and 2 NPP, Brazil;
— Laguna Verde 1 and 2 NPP, Mexico; and
— Juragua NPP, Cuba.

About 50 representatives from the upper management level, including general managers and NPP superintendents of the regional nuclear utilities, dedicated a total of about 800 man-days for participating at the meetings.

(b) Analysis of specific technical items and mutual learning

Sixteen technical visits, 4 in each participant country, were accomplished. This work required the displacement of about 100 supervisors/specialists who traveled to the different nuclear sites in the region in order to exchange know-how and information in-situ. At each technical visit about 22 specialists interacted directly: 6 from outside the host country, the rest locals. Practically no language problem existed, which facilitated and contributed to the effectiveness of the exchange.

More than 350 specialists took part at the different technical visits and expended all together about 4000 man-day of direct work on exchanging and discussing specialized topics of common interest.

(c) Technical assistance

An independent peer review, with a team of experts from the region assisted by one external expert provided by IAEA, was accomplished at Laguna Verde NPP, Mexico (September 1997).

(d) Documents produced

- 8 executive reports with the summary of the results and decisions resulting from each executive meeting;
- 16 technical reports describing the work accomplished, conclusions and recommendations resulting from each technical visit; and
- 1 technical document: "The nuclear power option in the Latin America and Caribbean region".

III-2.2. Innovations

- The capacity building was mostly implemented through direct interaction at the corresponding levels of management or supervisory/specialized staff with the aim of mutual learning. In pursuing this aim, information was exchanged not only regarding those areas were the corresponding organizations considered that they were strong or successful. Also weak or problem areas, where assistance was needed, were communicated each other. This resulted in a frank and open exchange of experience that facilitated the prompt establishment of mutually beneficial cooperation arrangements.

- While most of the activities involved managers and staff from the nuclear utilities, the work plan also occasionally included specific items where representatives from regulatory bodies, nuclear suppliers, and out-of-region nuclear utilities took part. Thus the project expanded the original scope by providing a forum for exchanging experience and discussions at the Executive Meetings with invited participants from:

  (a) Regulatory bodies: from Argentina and Cuba.

  (a) Nuclear suppliers: AECL (Canada), KWU (Germany), Union Fenosa Ingeniería (Spain), General Electric (USA) and Westinghouse (USA).

  (a) Utilities external to the region: Unidad Eléctrica S.A. (UNESA), Spain.

III-2.3. Constraints

Because the participants at the executive meetings or technical visits were actively engaged with direct responsibility at different levels in their organizations, unforeseen requirements arising from the operation, maintenance or contractual aspects sometimes prevented their participation in the planned project activities. Such situations, which appeared only occasionally, where kept to a minimum and when the originally appointed person could not be made available, an adequate substitute was nominated for replacement.

III-3. Role of targeted end-users in project development and planning

III-3.1. Main achievements

The whole work plan for the project was developed and accorded by the same management representatives directly involved with the implementation of the established actions, i.e. upper management personnel and plant superintendents from the regional nuclear utilities. The involved managers determined the priority areas and the specific project issues. The work plan for the project activities was then developed together with the IAEA in accordance with the project resources and estimated costs. The resulting tailor-made programme was fully supported by the involved managers and the IAEA and completely fulfilled.

III-3.2. Innovations

The preparation of the work plan by the end-users jointly with the IAEA ensured that the programme reflected real needs and enforced the commitment of the upper management personnel regarding the efforts for its implementation. This included the allocation of resources and provisions for the manager's personal involvement and for the assignment of their own staff as required for implementing the work plan.

III-3.3. Constraints

The high responsibilities normally assigned to the upper management of nuclear utilities limited sometimes the attendance at the executive meetings due to unforeseen requirements.

III-4. Quality of commitment and support of government counterpart officials

III-4.1. Main achievements

The government support and commitment is a pre-condition for approval of any Agency's technical cooperation project. The four participant countries in this project provided significant support through manpower resources and contributions in kind. These contributions complemented the financial assistance from the IAEA mainly by providing lodging, meals, transport and other facilities to the participants in executive meetings and technical visits.

III-4.2. Innovations

The contributions in kind were mainly provided through the use of installations and facilities normally available at the nuclear sites, including lodging, meals, and transportation for the participants, which could be used at the discretion of the responsible managers who were also involved with the implementation of the project activities. This procedure significantly facilitated the arrangements and made it possible to accomplish an extensive and flexible work plan, with a reasonable and limited financial assistance from the IAEA.

III-4.3. Constraints

In one case the country conditions could not make available lodging and meals, which then were covered under the IAEA budget.

III-5. Cooperation and coordination with other relevant national/external programmes and projects

III-5.1. Main achievements

— Information on the project activities was exchanged with the Latin American Energy Organization (OLADE). This contributed to disseminate the nuclear power issue and search for common areas of interest and cooperation directed to regional energy development projects in Latin America and the Caribbean.

- The attendance of regional experts at other IAEA's activities out-of-the-region was made possible under the project's budget, including participation at:

  (a) Advisory Group Meeting on Improving NPP Performance at Competitive Costs, Vienna, Austria (1997).

  (b) Regional Europe Workshop: Management of the Utility-Regulatory Interface, Cernovoda NPP, Romania (1997).

  (c) Regional Europe Workshop: Public Information regarding Delayed NPPs, Belene NPP, Bulgaria (1997).

III-5.2. Innovations

- The information exchanged with OLADE regarding nuclear power in the region: it brought to attention a subject that OLADE was not considering specifically;
- The support provided for participation of regional experts in out-of-region activities covered by the IAEA regular programme: it augmented the technical assistance received from IAEA; and
- The participation of experts from the LA region in activities covered by another TC project in the Europe region: it contributed to extend and make more cost effective the promotion of technical cooperation among developing countries across different regions.

III-5.3. Constraints

The resources available for the implementation of the project work-plan limited the support provided to activities not specifically included within the initial project's scope.

III-6. Lessons learned

- The direct involvement of the upper management level personnel proved to be a key element contributing to the success in establishing a frank and open exchange of experience and cooperation on common NPP management problems. The direct participation and commitment of high level managers made it possible that:

  (a) The regional nuclear facilities were opened to each other;

  (b) Practical experience was effectively exchanged, and

  (c) Not only country strengths but also weaknesses and needs were identified, with the aim to seek for solutions and help through regional cooperation.

(1) Due to the commitment of regional resources by the counterparts, a more extensive work plan could be established and fully accomplished with optimum use of the IAEA's as well as regional resources.

(2) The working method, based upon the performance of management's Executive Meetings and specialist's Technical Visits, proved to be effective and with a trend toward continuous improvement in the achievement of the project objectives. The

method made it feasible to pursue the regional cooperation even under financial constrains that the participant countries were facing during some periods.

(3) The interactions developed throughout the project implementation were successful in developing mutual trust and enabled to explore and establish agreements for concrete bi- and multi-lateral cooperation regarding: provision of specialists, personnel training, spare parts and mutual assistance in common problems/activities.

(4) The management forums made available through the executive meetings enabled to discus and exchange views/measures at the appropriate level regarding a broad spectrum of relevant critical issues including the technical, economical and social changes affecting the nuclear activities in the region.

(5) The preparation of the technical document on "The Nuclear Power Option in the Latin America and the Caribbean region" served to focus the discussions and to produce concrete material useful for consideration of nuclear power as a valid option within the national energy supply systems of the region countries. It addressed sensitive issues of special relevance for different areas of society, including politicians, public media, university and scientific groups. The document represented the first collation and integration of views on the nuclear power subject from all the regional nuclear utilities.

(6) Material from the above mentioned document on "The Nuclear Power Option in the Latin America and the Caribbean region" was selected, summarized and presented at the International Meeting of the American Nuclear Society/Latin American Section, Acapulco, Mexico, 18 to 21 July 1999. The presentation, which highlighted the objective, scope, target users and conclusions, was well received and commended. Congratulations were expressed for the development of the document. Elaboration of similar type of documents in other regions in the world was suggested as a way to encourage nuclear power development.

(0) The self-evaluation of the project results, made by the counterpart managers, concluded that the project:

- Contributed to identify and share good practices applied at the different nuclear installations;
- Enabled to implement effective communication channels among the technical groups, facilitated by the fact that there were practically no language difficulties;
- Improved the information on the capabilities existing in the regional nuclear utilities; and
- Provided the basis for further developments on regional cooperation.

Source: N. Pieroni, IAEA

Excerpt from Project Review RLA/4/012 [1995-1998]

ANNEX IV. CASE STUDY: SKB – POSIVA COOPERATION FOR MANAGEMENT OF NUCLEAR WASTE

IV-1. Introduction

In Sweden and in Finland the geological disposal of nuclear wastes has been considered to be the most feasible method for their safe management. In both countries the power companies are responsible for the management of nuclear waste including the geological disposal. The long term management programmes were initiated in 1970s, and as a result the repositories for low and medium active nuclear wastes have been in regular operation since 1990s.

IV-2. Joint Development of the Concept

Swedish Nuclear Fuel Co. (SKB) and Posiva Oy in Finland have been developing the concept for the deep geological disposal of spent nuclear fuel. Studies into deep geological disposal were started already in 1970s. The common concept is called KBS-3, the main features of which were reported in 1983 by SKB. The concept is based on the multi-barrier principle in which the technical barriers and bedrock, as a natural barrier, act in concert with each other and provide isolation for sufficient time periods into the distant future. The isolation principle of the safety concept is primarily provided by long-lived canister in which the spent fuel bundles are sealed hermetically. The role of the other barriers is to provide favourable conditions in the vicinity of the canister and make possible for the canister to maintain in good isolation properties. The role of the bedrock as the natural barrier is to act as a cocoon for the canisters, and finally, retard and dilute possible releases from the canister.

IV-3. Site Selection for Repository

Typical to concept development has been a stepwise approach. In the beginning the emphasis was on the assessment of the long term safety of the concept to increase the understanding on safety critical issues and create design basis for the technical development. In parallel with technical development site selection research has been conducted in Sweden and in Finland. In Finland the siting process culminated in the selection of Olkiluoto site to host the future deep repository in 2001. In Sweden the site characterisation work is underway at two candidate locations. The objective is to select the site in connection to licensing process in 2008. An essential element of the stepwise approach is to apply licenses (e.g. construction license, operation license) needed in several phases.

IV-4. Areas of Cooperation in the R&D

During the years SKB and Posiva have moved gradually towards practical implementation of spent fuel disposal. Since the disposal concept is similar and the geological environment, Fennoscandian Shield, is common to both programmes, the companies decided to enhance the cooperation in the R&D work. An agreement was signed in 2001 in order to:

- Avoid conducting duplicate work and enhance the cost effectiveness;
- Enhance the usage of resources; and
- Contribute to the Public information and acceptance of the geological disposal.

In formulating the scope of the cooperation a few main areas were identified. These were: encapsulation technology, repository technology and site investigations. The cooperation within these areas aims at using the existing resources by most effective manner, the canister laboratory and Äspö Hard Rock laboratory of SKB being essential resources the work. In encapsulation technology the main emphasis has been put in the manufacturing tests of the canister components. The sealing and inspection methods of the canister belong also to target areas of the joint work. In repository technology the main focus has been in developing important sub-systems of KBS-3 like tunnel backfill and an alternative concept KBS-3H in which "in-tunnel emplacement" is being studied.

SKB and Posiva have established procedures for planning and coordinating the joint activities. The most important work is taken care in conjunction with the annual activity planning when proposals for joint work are dealt with. Based on the activity planning "joint projects" will be formed on selected and agreed topics. The costs of the projects are shared and the personnel of the both companies participate accordingly in the execution of the project. Since the signing of the agreement more than 50 joint projects have been launched. The turnover of these projects is more than 20 million euros.

During 2005 SKB and Posiva have evaluated the success of the cooperation and realisation of the objectives set for the work. The experiences gained from the review were positive and supported the continuation of the cooperation. SKB and Posiva have seen another five years period during which R&D work is sensible to conduct jointly following the principles of the past five years. In the long run, however, the cooperation may cover new areas like industrial purchasing of canister components and their assembly.

Source: A. Rastas, Finland

ANNEX V. TYPICAL INFRASTRUCTURE NEEDS OF GOVERNMENT, REGULATORY BODIES AND UTILITY

1.0	GOVERNMENT
1.1	**Planning, Construction and Commissioning Phase (~10–15 years)** • **Government Incentives** - Adequate knowledge for Government support - Public open information and acceptance (awareness of energy needs and options, awareness of sustainable development options) - Long term nuclear policy, - Long term public participation and involvement in benefits of operation. • **Government guaranties** (transparency, predictability) • **Electricity trading arrangement** • **Legal framework** (see [1]) - Law establishing powers of regulatory bodies - National law on nuclear security - Law on radioactive materials and radiation - Law on nuclear liability - Radioactive waste, spent fuel and decommissioning law - Non proliferation treaty and additional protocol obligations - Legislation to implement international conventions and agreements - Environmental protection law - Law on emergency notification of nuclear accidents - Law on foreign investment - Law on safety of nuclear installations
1.2	**Operation Phase (~ 40–60 years)** • **Government incentives** - Adequate knowledge for Government support - Public open information and acceptance, - Long term nuclear policy - Long term public participation and involvement in benefits of operation • **Government guaranties** (transparency, predictability) • **Electricity trading arrangement keeping or improvement** • **Legal framework keeping or improvement**
1.3	**Decommissioning Phase (~ more than 50 years)** • **Government incentives** - Adequate knowledge for Government support - Public open information and acceptance - Long term nuclear policy, - Long term public participation and involvement in benefits of operation • **Government guaranties** (transparency, predictability) • **Legal framework keeping or improvement**

2.0	**REGULATORY BODIES**
2.1	**Planning, Construction and Commissioning Phase (~10–15 years)** Adequate qualified human resources for regulatory bodies Regulatory Framework - Defined nuclear regulator - Defined technical inspection (regulator) - Defined environmental regulator - Regulatory codes and standards (for all areas) Review processes (inspection duties and capabilities) Emergency planning arrangements (local, national, international) - Communication - Safety conditions Standard calibration laboratory Support for regulators
2.2	**Operation Phase (~ 40–60 years)** Adequate qualified human resources for regulatory bodies - training Regulatory framework keeping or improvement Review processes (inspection duties and capabilities) Emergency planning arrangements (local, national, international) – training, improvement. Calibration laboratory support for operation Technical and scientific support for regulators: e.g. for evaluation of design, safety reports, welding evaluation, non-destructive tests, etc.
2.3	**Decommissioning (~ more than 50 years)** Design of decommissioning approved as a part of NPP's design. Decommissioning is under licensing and inspection of NRB. Specific licensing requirements are needed for the various phases of decommissioning: fuel transport, radioactive waste treatment, transport and disposal. The decommissioning license establishes minimum requirements to provide assurance that the radiological and non-radiological activities conducted at the facility will pose no threat to public health, safety or the environment. Pre-review and licensing of decommissioning activities during the transition period
3.0	**UTILITY (OPERATING ORGANIZATION)**
3.1	**Planning, Construction and Commissioning Phase (~10–15 years)** **Site selection and evaluation*** (including water supply, no geological disturbances, no active seismic or volcanic region, grid facilities + back up power supply, transport access infrastructure)

	Design evaluation* (including decommissioning)
	Selection and contract of supplier* (component manufacture and delivery)
	** In same cases, prior to the involvement of the utility a dedicated agency is assigned by the government to implement the initial development of the nuclear infrastructure. This agency is referred as the "Nuclear Power Implementation Agency" (NPIA) in [1]. The three activities marked with * above could be undertaken by the NPIA.*
	Construction and contract management
	Operation preparation:
	• Management, organisation, administration.
	• Personnel training and qualification for preparation of adequate knowledgeable first NPPs staff, training facilities including simulator.
	• Operation
	• Maintenance
	• Chemistry
	• Technical support (including fuel engineering):
	  o Material procurement, enrichment and fabrication (long term fuel supply guaranties),
	  o Spent fuel management,
	  o Relationship with IAEA SS and guides
	• Radiation protection (including Storage or disposal of low/intermediate waste)
	• Emergency preparedness (emergency response facilities, emergency response organization, safeguard plan and equipment)
	— **Commissioning:** organization charts for design, construction, commissioning and operating groups; interfacing arrangements between these groups, commissioning administrative procedures; committees concerned with commissioning; commissioning QA programme; manual or procedures describing commissioning organization; license requirements with respect to commissioning; commissioning documentation, qualified staff, Safety Analysis report.

3.2	**Operation Phase (~ 40–60 years)** — **Management, organization, administration**, i.e. managemnet system, corporate and plant organizational charts, including functional responsibilities; corporate and plant strategic/business plans, with long term planning of goals and objectives, which should provide appropriate emphasis on safety (nuclear, radiation and industrial); job descriptions for plant management positions, documentation reflecting the interface control between the plant and other organizations, including contractors, the documentation reflecting the staffing and requirement policy, QA. — **Personal training and qualification**, i.e. training policy, regulations, guides and administrative procedures applicable to training, training centre, simulator, training programmes, individual training plans for diverse personnel groups, qualification test sheets, training records. — **Operation,** i.e. responsibility for handling (by shift personnel) according to the operating licensing conditions (OLC) and operating procedures, operating standards, meeting goals and objectives with supporting indicators, interface for coordination of work groups during normal operation, anticipated operational occurrences, design basis accidents and beyond design basis conditions, surveillance testing.

	— **Maintenance,** i.e.; inspection, in-service testing and maintenance in accordance with approved procedures to ensure that components, structures and systems continue to be available and to operate as intended, material and spare parts storage and reparation, outage management including management of contractors, equipment and tools, procedures. — **Chemistry supervision,** i.e. activities of chemical treatment to maintain the integrity of the barriers retaining radioactivity, including fuel cladding and primary circuit, limiting all kinds of corrosion processes causing either direct breach of safety barriers or weakening of them so that failure could occur during a transient, the chemical treatment from perspective of all effects on the out-of-core radiation fields that in turn influence radiation doses to which the workers are exposed. Laboratories, analysis, evaluations recommendations, optimisation of chemical treatment from perspective of radioactive waste volume. — **Technical support,** i.e. on-site activities related to surveillance testing, plant performance monitoring, core management, nuclear safety, operational modes analysis, fuel handling, computer applications, operational experience feedback, plant modifications, technical archive, design basis knowledge. — **Radiation protection,** i.e. regime established and implemented by operating organization at NPP to ensure that in all operational states doses due to exposure to ionising radiation in the plant or due to any planned releases of radioactive material from the plant are kept below prescribed limits and as low as reasonably achievable (ALARA). Controls for radiation protection during operation of the plant, including the management of radioactive effluents and waste arising in the plant, should be directed not only to protecting workers and members of the public from radiation exposure, but also to preventing or reducing potential exposures and mitigating their potential consequences. — **Emergency preparedness,** i.e. the capability to take actions that will effectively mitigate the consequences of an emergency for human health and safety, quality of life, property and the environment. This refers to emergency planning and preparedness both on-site of the nuclear plant (operator responsibility) and off-site area (mostly local and state authorities responsibility). — **Management of contractors*** Usually following type of contractors are involved: o Architect engineer (AE) and designers of the NPP's systems (for plant modifications, licensing effort, lifetime extension, decommissioning plans) o Suppliers of main components (RPV, TG, SG, etc.) o Institution for material stresses calculation and evaluation + RPV samples testing o Institution for corrosion studies * *Note:* • Many suppliers during NPP lifetime disappear, or change delivery profile, deliver new technology (e.g. I&C) and have no specialists who are familiar with original technology. Therefore the early transfer of knowledge from supplier to operator (or its' long term service organisation) is needed. • Also AE organization will lose specialists who are familiar with design basis (DB). Therefore DB knowledge should be a NPPs "property" and people responsible for plant modifications should approve the modifications proposals with appropriate senior engineer, who know DB.

3.3	**Decommissioning (~ more than 50 years)** Preparation for decommissioning (preparation of plans, organization, administrative and technological procedures, assurance of qualified human resources for decommissioning including training and re-training of personnel should be a part of last year of operation). 7. Transition Period (~ 1 - 5 years): - Fuel removal - Drainage of circuits - Conditioning of operational waste - Cleaning and decontamination 7. Initial dismantling and preparation of safe enclosure 7. Final dismantling (~ after 50 years).

Source: F. Hezoucky, IAEA

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Consultants Meetings

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Technical Meeting

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