OPPORTUNITIES AND CHALLENGES FOR SMRS IN THE ECOWAS REGION

Building the required infrastructure for SMRs in West-Africa

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**Abstract**

Energy continues to be a central constraint to the socio-economic development prospects of the ECOWAS region. The current level of development of the energy system is a bottleneck for the social, economic, and industrial development throughout the region. Countries face challenges to energy access and energy security which are characterized by power shortages in urban areas and very limited access to modern, affordable, and reliable energy services in rural areas. Solutions to these challenges are closely related to a set of economic, social, environmental, and political problems. This paradoxical energy circumstance in the ECOWAS region has sparked interest in several Heads of States in the region who are keen to develop a common regional vision and plan on how to harness the different energy resources in the region to support their socio-economic development plans, through investigating economically viable and reliable base load electricity generation. This interest of nuclear is being increased with the latest 28th United Nations Climate Change Conference (COP28) that was a historic event for nuclear energy when it was formally specified as one of the solutions to climate change in the first global stocktake of progress toward meeting the goal of the Paris Agreement.

The paper is to take into consideration the electricity demand for the study that was developed and analysed based on the expected/projected development of several influencing factors, showing the importance of nuclear power in the countries’ energy mix. For the countries of the ECOWAS region with very limited grid, undertakings to build the infrastructure for a nuclear power programme will need to consider the implications and opportunities of sharing infrastructure building efforts that is very challenging. Remains therefore for countries that wish to build their own first nuclear power plant, the opportunity for building a SMR.

The effort required to build a nuclear power infrastructure may vary significantly among countries, depending on the nuclear facilities being operated and regulated in each country*.* Therefore, the paper aims to prepare a reference framework for a number of studies that the ECOWAS States will need to have prepared, providing the technical framework for studies and associated actions related to the following seven principal infrastructure areas of consideration for the development of a nuclear power programme including (1) Comprehensive studies for developing a strategy for sustainable supplies of electricity, and the possible contribution of nuclear energy : Energy planning; (2) Nuclear and radiation safety infrastructure; (3) Legal framework; (4) Technological and industrial infrastructure; (5) Workforce planning for SMRs; (6) Fuel cycle back end and waste management policies and (7) Nuclear power plant siting.

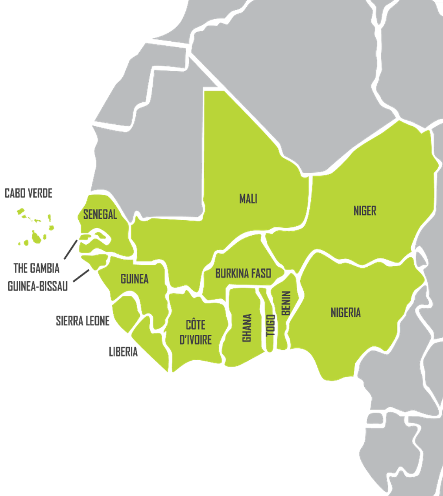
The outcome and deliverables are specified so that the results of the studies will support a detailed work plan specific to the ECOWAS region, including actions to be undertaken at the national and regional levels, identification of responsible organizations, practical arrangements and allocation of resources with a milestones schedule for implementation of all actions that will lead for the introduction of SMRs in this region.

## INTRODUCTION

The energy challenges the region faces manifest themselves in very low rates of access to modern energy services; abundant fossil fuel resources especially oil and gas that are not being exploited and in countries where they are being exploited, they are predominantly for export, high dependence on oil products and exposure to volatile market prices that drain foreign currency reserves. For the majority rural based population, high dependence on traditional biomass energy for cooking exposes the population segment to indoor air pollution and the associated adverse health impacts.

This is however so despite of the region being endowed with vast energy resources that could be used to support increased energy access and security that will provide a dynamo to the industrial development and the broader socio-economic transformation of the ECOWAS region. ECOWAS region has abundant oil and gas resources that have been exploited over the years. Recently countries like Ghana and Senegal have discovered huge oil and gas reserves. Hydropower potential on the region’s major rivers systems has largely gone underutilized. The situation is like other energy resources that include solar, wind, coal, uranium, etc. that are abundant.

The further development of the mining sector infrastructure, now limited to the mineral resources (i.e. bauxite, uranium, etc.) deposits and export, is accustomed to sufficient energy resources and historically low electricity prices. The development of mining and industrial activities might require competitiveness of energy prices and security of generating electricity. In addition, the region is facing stiff energy demand pressures due to demographic pressures and the need to increase access to modern energy services. While renewables and efficiency energies are essential elements of future national and regional energy strategies, there is also a need for reliable base load electricity in the context of progressive industrialization, accelerated economic growth, changing demographics, in short growing energy demand.

This paradoxical energy circumstance in the ECOWAS region has sparked interest in several Heads of States in the region who are keen to develop a common regional vision and plan on how to harness the different energy resources in the region to support their socio-economic development plans, through investigating economically viable and reliable base load electricity generation. This interest is being highlighted with the latest 28th United Nations Climate Change Conference (COP28) that was a historic event for nuclear energy when it was formally specified as one of the solutions to climate change in the first global stocktake of progress toward meeting the goal of the Paris Agreement. In fact, the World leaders and innovators in climate change solutions came together in Dubai to keep the world on track to keep global warming below 1.5°C. In this connection, the final COP28 Decision Test which was adopted at the end of the two-week conference, recognises the need for “deep, rapid and sustained reductions in greenhouse gas emissions in line with 1.5 °C pathways” and calls for global efforts to accelerate zero- and low-emission technologies, including nuclear, renewables, and abatement and removal technologies such as carbon capture and utilisation and storage, thus urging further African countries to adopt further nuclear power.

## ECOWAS AND ENERGY WITHIN THE REGION

The ECOWAS comprises 15 countries with a land area of 5 million m2. The Climate from is a semi-arid to humid tropical with a population of over 300 million people under which 60% of population live in rural areas. 11 of the 15 countries are LDCS and HIPIC with almost 176 million people without access to electricity (52% of the population).

In 2030, the expected population is about 490,9 million peoples and the expected GDP reaching 870 US$.

### Demography and Economy

The current level of development of the energy system is a bottleneck for the social, economic and industrial development throughout the region. Countries in the region face challenges to energy access and energy security which are characterized by power shortages in urban areas and very limited access to modern, affordable and reliable energy services in rural areas. Solutions to these challenges are closely related to a set of economic, social, environmental and political problems.

Energy poverty is reflected in the electricity sector by national power systems in crisis and stalemate. These electrical systems are characterized by the following major findings:

* Low electricity access.
* High electricity supply cost.
* Shortage of supply relative to demand; and
* Difficult financial situation for most of the national utility operators.

In this connection, a study was developed in 2010 within the framework of the IAEA and supported by UNIDO. Electricity demand for the above study was developed based on the expected/projected development of several influencing factors. The main factors influencing future energy/electricity demand were economic activities in the country (overall GDP level and its structure, development of certain energy intensive sectors, etc.), expected changes in population and lifestyle (urbanization, electrification, number of dwellings, fuel switching, changes in mobility etc.) and technological development and choices (equipment and appliances improvements, new solutions, decrease in investment costs, etc.). There are also many interrelations between above mentioned factors.

According to the UN Population division data and forecasts[[1]](#footnote-2), the total population in the Western Africa in 2022 stood at 300.8 million, representing lest than under 30% of the total African population. By 2030 total population is expected to increase to 490.9 million or at average annual rate of 2.48%. Nigeria will still dominate with 52.5% of total region population living there.

### Electricity Demand Analysis

Several electricity demand projections were analysed under which, we will select two: Reference demand and Universal access scenarios. Under the Reference demand scenario, sub‑regional electricity access by 2030 should reach 67%, but large disparity between and inside countries will remain.

|  |  |
| --- | --- |
| Final electricity demand  Scenario Reference | Final electricity demand  Scenario Universal Access |

***Decreasing disparity under Universal Access demand scenario***

Universal Access scenario assumes additional policy efforts and field actions to speed-up the electrification programs, both in urban and rural areas, so that by 2030/2035 all population in the Western Africa enjoys affordable, reliable and sustainable electricity supply. It was clearly visible that reaching universal electricity access will require substantial policy and field actions as all the countries will at least double their need in electricity.

### Electricity Supply Strategies and scenario analysis

The energy planning study used two main criteria to define electricity supply scenarios including:

* Expected development of electricity demand and
* Level of sub-regional cooperation.

In all scenarios, all technological options were considered in line with the availability of resources in each country. The existing efforts of each country concerning the supply options were also considered to define the earliest possible year of operation for some technologies (e.g. availability of gas, development of nuclear infrastructure, etc.). The Scenario SE4ALL that is presented here assumes that additional efforts will be put in place to increase electricity access so that most of the population in the Western Africa enjoys universal electricity access by 2030/2035. In was noted that the planned installed capacity might require nuclear from 2030, thus opportunity for SMRs that could be installed in such a short notice as we are already in 2024.

**Table 01: Installed capacity for scenario SE4ALL**

|  |  |  |  |
| --- | --- | --- | --- |
| **Installed capacity, MW, scenario SE4ALL** | **2020** | **2030** | **2035** |
| **Coal** | 447 | 1737 | 4823 |
| **Oil** | 2407 | 1947 | 2569 |
| **Gas** | 20507 | 30780 | 37373 |
| **Nuclear** | 0 | 229 | 2000 |
| **Hydro** | 11454 | 22221 | 22464 |
| **Biomass** | 293 | 1073 | 2293 |
| **Solar PV** | 584 | 2666 | 5115 |
| **Solar Thermal** | 1016 | 4039 | 7540 |
| **Wind** | 799 | 2103 | 3472 |
| **Oil Distributed** | 3839 | 4399 | 8007 |
| **Biomass Distributed** | 0 | 0 | 0 |
| **Mini Hydro Distributed** | 944 | 4130 | 5041 |
| **Solar PV Distributed** | 19 | 350 | 1738 |
| **Total Generation Capacity** | **42309** | **75674** | **102437** |
| **Peak Load Centralized System** | 19096 | 48314 | 78129 |
| **Interconnection Capacity** | 14824 | 20828 | 22178 |

Findings of the sub‑regional analyses scenarios will facilitate development of the strategic plans for building the required electricity infrastructures in the Western Africa, with the following views:

* Electricity growth in the region is an important part of sustainable development to ensure fast, efficient and sustainable growth while making a significant contribution to the implementation of national and regional climate change strategies.
* Electricity growth will lead to increased investments in conservation, development and efficient use of natural capital and resources, improvement of environmental quality, and thereby stimulating regional economic growth.
* Electricity growth will contribute to more employment and improving the life of all the population within the region for emergence of these countries in 2035.
* Electricity growth will be based on science and modern technologies which are suitable to regional’s conditions with the aim to own and localize the above foreign technologies, and
* Nuclear power proves to be a competitive option from 2030, reaching 2 GW by 2035 (equivalent to 1.000 MW per country.

## Opprtunities and challenges for introducing SMR

**West-Africa is facing a crucial challenge with limited access to reliable electricity. However, there is promising potential in nuclear power as per the energy plans of the region.** Large-scale nuclear reactors offer significant electricity generation capacity; however**, the utilization of Small Modular Reactors (SMRs) could be an exciting opportunity. In fact,** large-scale nuclear reactors come with high upfront costs. Over time, these costs decrease, making them more affordable in the long run. On the other hand, small reactors have lower upfront costs, making them an ideal choice for remote locations and areas with limited resources as the case here. They also have simpler designs, potentially enhancing safety, particularly in unstable regions. Moreover, small reactors can potentially navigate stringent regulatory environments more effectively, even though they offer a handicap that is the fact that they are still under development and might be First-of-A-Kind (FOAK).

SMRs presents an attractive investment option compared with large LWRs, especially in liberalised electricity markets. Their affordability with a lower, overall capital outlay implies that private investors will face lower capital at risk, which make SMRs an opportunity for the region. In turn, this lower capital risk is attractive with its new sources of financing (e.g. private equity, pension funds), that lower the cost of capital and ultimately the levelized cost of electricity (LCOE) generated by SMRs. For multi-unit SMRs, the ability to add modules and start generating electricity incrementally reduces both upfront investment and capital risk, which translates into lower financial costs. And its shorter payback period and the shorter construction duration promoted by SMR developers would further reduce the cost of financing, rendering SMRs an opportunity for ECOWAS countries.

### Constraints and barriers for nuclear power

Nuclear power is still facing some barriers in West-Africa and this paper is to prepare for the studies that might ease the introduction of nuclear power within the region, with emphasis on SMRs. Some of the key bottlenecks, among others, are the following:

* **Policy and Institutional Issues:**
  + Absence of political targets for renewable energy in general and solar/wind in particular, in many countries.
  + Non-existent or weak nuclear policy measures for level playing field in many countries.
  + Weak national agencies with unclear responsibility for nuclear in many countries.
* **Financial/Economics:**
  + High upfront costs of nuclear compared with smaller scale conventional systems even where competitive.
  + Lack of large-scale projects at regional level to take advantage of higher solar or wind resource endowments and economies of scale.
  + Lack of innovative financing mechanisms.
* **Capacity Building & Technology Transfer**
  + Inadequate skilled technical manpower in many countries.
  + Limited or no local manufacturing due to small national markets.
  + Limited R&D with little or no linkages to entrepreneurial/ manufacturing sector.

### Requirements and Challenges for nuclear power

|  |  |
| --- | --- |
|  | **REQUIREMENTS AND CHALLENGES** |
| **Technological Issues** | * Competent Staff and OJT availability * Licensability (delays due to design innovation & FOAK) * Non-LWR technologies (worsen the challenges) * Impact of innovative design * Fuel cycle to proliferation resistance * Operability * Spent fuel management and waste handling policies * Transport and Safety |
| **Non-Technological Issues** | * Economic competitiveness (impact of economies of scale) * Regulation for fuel or NPP leasing * First of a kind cost estimates / O&M additional need * Availability of design for newcomers in a short term * Infrastructure requirements * Post Fukushima action items on Institutional Issues and Public Acceptance * Siting |

Key other challenges related to funding and financing of nuclear power in the region include the:

* Regional Development Banks (African Development Bank, Infrastructure Development Bank, etc.) that are not financing new NPPs
* New (Private) structures that are still needed
* Capital payback cost that are very sensitive to interest rates that is very HIGH in this region, especially in countries being in the CFA Franc area.
* Interest rates that reflect credit/sovereign rating / Currency issue
* Most West African Countries that are BB+ or less credit rating that is a slightly lower credit risk compared to BB rating. Countries with BB+ rating have a stronger ability to meet their financial commitment, but they are still vulnerable to adverse economic conditions or changes in circumstances.
* The Banking System that is still very weak in this region

### Key Requirements in SMR’s Descriptions

SMRs can provide safe, reliable and zero-emissions energy to these growing economies in ECOWAS region, while creating new opportunities to further develop new local knowledge and expertise. SMRs are opportune in for these countries, compared to other nuclear power plants with their:

* Lower upfront capital cost
* Capital cost confidence
* Readily available supply chain
* Off-the-shelf components
* Fewer large components
* Shorter construction schedule
* Factory constructed transportable modules
* Simpler to operate and maintain
* Long cycles / short outages
* Full accompaniment of the Supplier / Need of an Integrator
* FOAK / Short term operation and experience

A diagram of a group of people

Description automatically generatedHowever, even though SMRs could more easily be integrated in the relevant national and regional grids in ECOWAS, there is still several infrastructures that are missing and need to be fully established. This includes:

* Safety and licencing
* Operational and management
* Emergency planning and Quality assurance
* Plant safety and security
* Radiation safety and health physics
* Nuclear power including regulatory staffing
* Supervisors / Senior Operators / Operators / Technicians
* Engineering / Procurement / Administrative Support
* Radwaste processing and disposal
* Competent stakeholders in nuclear power

## STUDIES FOR Building the required nuclear power infrastructure for SMRs

For the countries of the ECOWAS region with very limited grid, undertakings to build the infrastructure for a nuclear power programme will need to consider the implications and opportunities of sharing infrastructure building efforts. It therefore why my paper aims at guiding the ECOWAS region for providing a technical framework for studies and associated actions related to the following seven principal areas of consideration for the introduction of SMRs in the ECOWAS region. These include:

* Legal framework for nuclear power programmes.
* Nuclear and radiation safety infrastructure for SMRs.
* Technological and Industrial Infrastructure
* Comprehensive studies for developing a regional strategy for sustainable supplies of electricity, and the possible contribution of nuclear energy with emphasis on SMRs.
* SMRs’ siting and site selection.
* Workforce planning and Manpower Development for SMRs.
* Fuel cycle back end and waste management policies.
* Technological and industrial infrastructure.

### Study No. 1: Legal Framework for SMRs

A sound legal framework governing the peaceful uses of nuclear energy is a central element of the infrastructure needed for establishing a nuclear power programme, whether at the national or regional level. Emphasis will be given to the scope of a SMR that will take into consideration, the level of magnitude of the infrastructure. The objectives of this study are:

* To develop a draft comprehensive nuclear law that incorporates the concepts of safety, security, safeguards and liability for nuclear damage.
* To allow all States within the ECOWAS region to have a clear understanding of their international obligations and to promote adherence to the relevant international legal instruments concluded under the IAEA’s auspices.
* To provide for a mechanism for harmonizing national legal frameworks in the sub- region.

A comprehensive framework of national legislation should cover the following areas:

1. The regulatory authority.
2. Authorizations (licences, permits, etc.).
3. Responsibilities of licensees, operators and users.
4. Inspection.
5. Enforcement.
6. Radiation protection.
7. Radioactive material and radiation sources.
8. Safety of nuclear installations.
9. Emergency preparedness and response.
10. Mining and milling.
11. Transport.
12. Radioactive waste and spent fuel.
13. Decommissioning.
14. Civil liability for nuclear damage.
15. Safeguards.
16. Export and import controls.
17. Physical protection.

Finally, it is required that the existing laws that are ancillary to the planned nuclear power programme, covering such areas as: local land use controls; environmental matters (e.g. air and water quality and wildlife protection); economic regulation of electric power utilities; occupational health and safety of workers; general administrative procedures of governmental bodies; transport; intellectual property rights; liability for non-nuclear damage; emergency management; and taxation, be reviewed.

It is essential that the country hosting a nuclear power plant, whether in the framework of a national or regional nuclear power programme, has a comprehensive national legal framework in place which includes a regulatory body with clearly defined responsibilities and covers all areas of nuclear law, i.e. safety, security, safeguards and liability for nuclear damage.

National legislation should reflect the provisions of the international legal instruments to which the State is party or intends to be party. The legal framework should be consistent with the international standards and guidance. The study should contemplate harmonizing the national legal frameworks of all the ECOWAS countries in areas such as civil liability for nuclear damage and emergency planning and response, nuclear security, and import/export controls.

### Study No. 2: Nuclear and Radiation Safety Infrastructure for SMRs

The objectives of the study are:

* To analyse the institutional, organizational and technical elements and conditions that need to be established to provide a sound foundation for a high level of nuclear safety considering the specific conditions in the ECOWAS region.
* To provide the technical basis for the national and regional decisions and the actions that need to be taken to implement the elements and conditions above, commensurate with the activities and facilities to be regulated in each country.

The study should be specific for the actual conditions of the ECOWAS and its countries and should analyse the modalities for sharing efforts at the national and regional levels. It should, inter alia, elaborate on the efforts to develop the safety infrastructure elements for a nuclear power programme in one country or one hosted by more than one country. The study should also describe the necessary steps and actions for developing and implementing each element of the safety infrastructure, with due recognition to those elements that can be shared among ECOWAS countries and those that need to be developed separately in the country hosting the nuclear power plant(s). Whenever available, the experience of other countries in sharing infrastructure should be reflected in the study.

The organizations responsible for addressing all elements of the safety infrastructure should be clearly identified and a milestone schedule for implementation of all actions should be proposed. The following elements should be included in the study. For each element, specific responsibilities at the national and regional levels should be defined, along with a milestone schedule for implementation.

* Institutional safety elements:
* National legal and regulatory framework.
* Human resources development.
* Transparent communications.
* National technical infrastructure.
* Safety research.
* Financing and funding mechanisms.
* International commitments and cooperation.
* Leadership and management for safety.
* Organizational and technical safety elements:
* Regulatory body.
* Technical support organizations.
* The operating organization.
* Radioactive waste and spent fuel safety and decommissioning.
* Emergency preparedness and response.
* Physical protection and security.
* Nuclear installations site selection.

ECOWAS countries would need to consider and decide upon different options and strategies for introduction of a nuclear power programme, such as concentrating all nuclear power development in a single country or, alternately, establishing power plants in different Gulf States. The choice of the development of nuclear plants will have implications for the development of the safety infrastructure and regional cooperation.

The institutional, organizational and technical elements for the development of the safety infrastructure should be addressed in the study and the steps and arrangements necessary for implementing corresponding actions should be proposed.

#### [Organizational and technical safety elements](#_Toc209865643)

* [*Regulatory body*](#_Toc209865644)
* Develop a plan for ECOWAS countries to establish an independent regulatory body at the national level with legal authority, technical competence and resources commensurate with the installations and activities of each country and regulate an umbrella organization for harmonization and coordination at the regional level (see requirements 3–5 in IAEA Safety Standards Series No. GS-R-1).
* [*Technical support organizations*](#_Toc209865645)
* Evaluate options and possibilities, both at the national and international levels, for obtaining technical support and services to the regulatory body.
* [*Operating organization*](#_Toc209865646)
* Identify the financial strength, staff and competencies expected from the operating organization (see requirements 6–8 of IAEA Safety Standards Series No. GS-R-1). This element should be covered in full in Study No. 6, Workforce Planning for Nuclear Power Development.
* [*Radioactive waste and spent fuel safety and decommissioning*](#_Toc209865650)
* Elicit long term safety requirements and cost implications of radioactive waste disposal, spent fuel management and decommissioning.
* [*Emergency Preparedness and Response*](#_Toc209865651)
* Identify national institutions that could support emergency preparedness and response (see IAEA Safety Standards Series No. GS-R-2).
* Identify needs for new arrangements.
* [*Physical protection and security*](#_Toc209865652)
* Identify existing national legislation and institutions that could be used to support physical protection and security (see IAEA Nuclear Security Series No. 4).
* Identify needs for new arrangements.

### Study No. 3: Technological and Industrial Infrastructure

The objective of this study is to support the formulation of a policy of intent of developing or enhancing, at the national and regional levels, industrial capacity for participation in the nuclear power programme as well as assessing available and proven nuclear technologies, both for electricity production and water desalination.

The study should contain:

* An assessment of technological and industrial infrastructure in ECOWAS countries as relevant to a nuclear power programme.
* An assessment of the appropriate technology and standardized nuclear reactors, both for electricity production and water desalination, and definition of criteria for the acceptability of technology.
* An assessment of the scope and time frame of organizational and technological enhancements and policy decisions required to enable national and regional industrial gradual involvement based on the results of item (1).
* An assessment of the potential for sharing nuclear power infrastructure between ECOWAS countries in terms of similar technologies, physical facilities, common programme knowledge.
* An assessment of multidisciplinary engineering codes and standards, conformity assessment programmes, and nuclear related products and services.
* Recommendations for effective technology transfer and a strategy for developing professional training required for human resources development.

The programmatic objectives and key criteria elements are compiled for use within the Technology Assessment process, especially in communications with NPP supplier candidates that are now new.

* These may be based upon the IAEA Common User Considerations, combined with available sources such as URD (Utility Requirements Document), EUR (European Utility Requirements), or USNRC Design Control Documents, etc.
* This is still an issue for concern as there is no African specific requirements. Relevant cooperation shout be put in place with nuclear power countries.
* These General Criteria may be improved and revised based on feedback obtained during the Technology Assessment process with a lack of previous experience within the region.
* These General Criteria should also form the basis for the general technical requirements established for the potential bid invitation specifications or contract arrangements.

The most important issue for considerations for introducing SMRs in the ECOWAS is to select an appropriate technology as SMRs does not have yet the relevant operation data and still classified as First-Of-A-Kind (FOAK).

As this point, the following three broad categories SMR concepts are being identified as the most appropriate:

* Single-unit LWR-SMRs – use of well-established LWR technology and fuels to provide stand-alone units that may replace small fossil-fuel units or be deployed as distributed generation.
* Multi-module LWR-SMRs – also use LWR technology, and may be either operated as a replacement for mid-size baseload capacity or in a distributed generation framework, depending upon generating capacity, and
* Mobile/transportable SMRs – currently apply LWR technology and are intended to be easily moved from location to location. Floating reactors are included in this category.

Therefore, among the different for the various reactor principal lines that might be available, the **light water reactors** are the reactors that could be more easily introduced in the ECOWAS region. Among the different for the various systems and components, active safety systems and passive safety systems are both of them appropriate for the region. The modularization construction technology is the most appropriate for the SMRs that are acceptable in the sub-region. Modularisation and factory-based construction Modularisation is a way of simplifying construction by splitting the plant up into packages (modules) that can be factory-built, transported and then assembled on-site. In particular, cost reductions from modularisation can be expected from construction and/or pre-assembly of modules away from the construction site in a dedicated factory, where labour productivity and quality control can be expected to be higher and project management risks lower.

Many commodities, components and services are required to construct a nuclear power plant and support its operation. Industrial organizations are needed that can comply with strict codes and standards and rigorous quality programmes.

### Study No. 4: Comprehensive Studies for Developing a Regional Strategy for Sustainable Supplies of Electricity.

Develop an overall long term regional strategy for the development of electricity supplies to maximize social and economic progress in the ECOWAS countries and assess the potential contribution of nuclear energy to electricity services.

The study will include:

* A detailed review of the current energy situation in each member country of the ECOWAS, in the context of the historical development of demography, economy, energy infrastructures and their techno-economic performance, including interconnections, as well as current decisions and plans for future expansion.
* An assessment of future needs for electricity in each member country of the ECOWAS for the next 25–30 years to establish electricity at the regional level.
* An assessment of energy resources based on a dynamic resource concept that considers technology change and price effects, and an evaluation of the future potential of supplies from each country’s own resources and from the region.
* An assessment of technological options, including nuclear energy, for expansion of infrastructure for the supply/production of electricity.
* Development of a set of plausible and internally consistent demand and supply scenarios, including all demand and supply technology options for sustainable supplies of electricity in each country of the ECOWAS.
* Recommendations for long term strategies, medium term plans and regional cooperative projects for the development of electricity systems at the regional (ECOWAS) level.

### Study No. 5: SMRs’ siting and grid analysis.

Site selection and evaluation are the most fundamental parts of establishing a nuclear power programme including a SMR. The siting process of a nuclear power plant is driven mainly by the nuclear safety aspects and by public acceptability. There are, however, several other considerations that need to be studied in selecting a site for a nuclear power plant. These include electric power grid characteristics; water supply; infrastructure for access and transportation; construction and labour resources; and the potential impact of a new nuclear power plant on regional developments.

The objectives of a nuclear power plant siting study are:

* To conduct a site survey in ECOWAS countries planning to host one or more nuclear power plant(s).
* To rank potential candidate sites and to identify the preferred site locations (e.g. three sites).

At a later stage, a separate study would need to be conducted for a detailed site assessment. The ECOWAS will determine how many of the top ranked sites would be included in the site assessment. In the evaluation of the suitability of a site for a nuclear installation, the following aspects should be considered:

* The effects of external events occurring in the region of the particular site (these events could be of natural origin or human induced).
* The characteristics of the site and its environment that could influence the transfer to persons and the environment of radioactive material that could be released.
* The population density and population distribution and other characteristics of the external zone insofar as they may affect the possibility of implementing emergency measures and the need to evaluate the risks to individuals and the population.

The study should also include these stages:

* **First stage.** An investigation of a large region should be carried out to identify or select one or more potential candidate sites. This stage is usually called a ‘**site survey’.** It is followed by a second stage of evaluation of those candidate sites.
* **Second stage.** Referred to as the ‘**site ranking/selection stage’,** in which the identified potential candidate sites from the first stage should be ranked and the final selection of the site, or the so called ‘preferred candidate site(s)’, is done. At the end of this stage the site could be selected preliminarily, and the next stage focuses on this site to demonstrate final acceptability/suitability and to derive the design basis for site related aspects.

In the first two stages of the siting process, i.e. during the survey and ranking/selection stages, the aspects to be considered for identification of potential candidate sites should include:

* Safety and environmental aspects.
* Other considerations, including electric power grid requirements, water supply, access and transport infrastructure, construction and labour resources and the potential impact of a new nuclear power plant on regional developments.

Assessment of the West African Power Pool grid is essential and will directly influence the site selection and decisions regarding nuclear power plant size and plant design characteristics. Therefore, an assessment of the grid’s characteristics in terms of the safe and reliable operation of a nuclear power plant is required. The assessment will evaluate the ability of the power grid to integrate a nuclear power plant. This work could be included as part of the scope of the site study, or be commissioned as a separate study, but in any case, it will have to be considered in the site selection. It should include:

* The existing grids and generating capacity in relation to the available technology.
* The plans of ECOWAS countries for future growth of grid capability.
* The historical stability and reliability of the electrical grids in ECOWAS countries.
* The potential for local or regional interconnections to improve grid characteristics.

The grid characteristics will determine plants requirements and specifications, inter alia, related to unit size, mode of operation and manoeuvrability. IAEA guidance on this subject is currently in preparation based on Technical Reports Series No. 224, Interaction of Grid Characteristics with Design and Performance of Nuclear Power Plants, published in 1983.

A **third stage**, which is beyond the scope of this study, is the detailed evaluation of the selected site(s). This is usually referred as the ‘**site assessment stage’**. During the last stage corresponding to site evaluation, safety and environmental considerations play a decisive role, since the results are directly linked to the licensing process and to the final design of the nuclear installation.

As a deliverable of these stages, the **Site Evaluation Report** (SER) is issued and approved. Part of the SER is incorporated later, usually, as part of the Preliminary Safety Analysis Report (PSAR) prepared by the vendor organization that obtained the contract for construction of the nuclear power plant. The SER is usually part of the licensing process for obtaining the licence for ‘construction start’.

Also, as part of this process, the radiological part of the **Environmental Impact Report** (EIR) is also prepared and approved according to national practice.

With the site selected and approved and all supporting licensing documentation issued, **the design and construction of the nuclear installation can start**. From now on, the site evaluation is a continuing process through the following stages:

* **The pre-operational stage**, i.e. design/construction/commissioning of the nuclear installation.
* **The operational stage of the nuclear installation until the end of its lifetime.**

The site selection process should involve amultidisciplinary effort of earth and engineering sciences that include: tectonics; geology; geophysics; seismology and seismic hazard assessment; soil mechanics and geotechnical engineering; hydrology; hydrogeology; oceanography; tsunami assessment; meteorology and air dispersion; civil engineering; radiological protection; ecology–radioecology; demography; emergency planning; power engineering; nuclear engineering; natural resources; and economic and legal issues.

### Study No. 6: Workforce Planning for Nuclear Power Development

The development of human resources for the establishment of a competent work force is essential in establishing a nuclear power programme. The objectives of this study are:

* To identify competencies and the human resources needed for launching a sustainable nuclear power programme in the ECOWAS region.
* To evaluate existing capabilities in individual countries (e.g. in engineering and other exact sciences subjects) and competencies.
* To propose a plan for the development of the workforce for nuclear power development with due consideration given to opportunities for cooperation and sharing of resources among ECOWAS countries.
* To support the formulation of policies for human resources development and implementation at regional, national and organizational levels.

The study must include:

* A review of the competencies required to staff the organizations planning and implementing a nuclear power programme (including the owner/operator, the nuclear regulatory body[[2]](#footnote-3)\*); technical support organizations; service providers; and spent fuel and waste management facilities.
* An assessment of existing human resources; education and training organizations within the ECOWAS countries; and related education and training systems.
* A strategy for human resources development to fulfil the needs of the various organizations that will be involved in the nuclear power programme; and identification of the qualifications required in terms of experience, education and training. The strategy recognizes the opportunities to be provided by the nuclear power plant vendor, bilateral cooperation agreements with the vendor country (including utilities, the nuclear regulatory body[[3]](#footnote-4)\*, and research institutes) and other countries, international assistance from the IAEA and from other organizations.
* Identification of core competencies that will not be outsourced by the owner/operator and the nuclear safety regulator, and mechanisms for optimizing the use of competencies of countries in the ECOWAS region as well as international expertise.
* Development of a plan for the establishment of education and training activities and facilities (either new or through the expansion of existing ones) that will support competencies for the long-term needs of a nuclear power programme. Consideration should be given to regional and national options commensurate with the intentions of different countries to host nuclear power plants.
* Time scale for developing the human resources required for the introduction of nuclear power, which should also include a suggested staffing plan for the NEPIO, prospective owner/operator and nuclear safety regulator. Also needed is an identification of the recommended staffing plan for the first five years. The staffing plan should indicate the lead times for training and practical experience, the recommended education and experience criteria for selection, and numbers of people in each job position/category.
* Identification of key aspects/requirements and activities for recruitment, selection, training, development, knowledge retention and transfer, including proposals regarding compensation and retention policies at the regional level, as well as in countries where the nuclear power plant will be built, that will attract and retain suitable personnel for the programme.

This study covers all phases of the development of a nuclear power programme, i.e. before a decision is made to embark on a nuclear power programme, during the nuclear power plant construction and during its operation (including plant maintenance function) and running spent fuel and waste management facilities. A competent work force is required to carry out all the major activities to be undertaken in addressing each of the 19 issues for the three phases in developing a nuclear power infrastructure — as identified in the IAEA publication Milestones in the Development of a National Infrastructure for Nuclear Power —and to identify the responsibilities of key organisations for completing these activities. The key organizations to be considered include: the nuclear energy programme implementing organization (NEPIO), the prospective owner/operator, the regulatory body(ies) for nuclear safety, radiation protection and environmental protection, educational and training organizations, local potential suppliers, and the technical support organizations.[[4]](#footnote-5)

In this study the focus is on a competency framework for the regulatory body as contained in IAEA-TECDOC-1254 and IAEA Safety Standards Series No. GS-G-1.1:

* Identify safety competencies and the number of persons needed.
* Identify institutions that could provide education and training (see requirement 12 of IAEA Safety Standards Series No. GS-R-1).
* Identify gaps in training institutions.
* Propose a plan for training and to establish new institutions as needed.

### Study No. 7: Fuel Cycle Back End and Waste Management

During operation and decommissioning of a nuclear reactor, radioactive waste and spent nuclear fuel are generated: They need to be collected and treated through a set of technological operations performed in different facilities, typically storage, processing and disposal facilities. Establishing the necessary organizational and technical infrastructures, selecting technical solutions and selecting the timing for their implementation should be recognized and assessed at the early phases of planning a nuclear power programme to ensure safe and secure control of spent nuclear fuel and radioactive waste.

The objectives of this study are:

* To analyse needs and options for the management of spent nuclear fuel and radioactive waste arising during the operation and decommissioning of a nuclear power reactor, considering proven international approaches.
* Propose a strategy, based on the analysis in item (i), for managing spent nuclear fuel and radioactive waste, considering the national responsibilities to be assumed by the country(ies) that intend to operate nuclear power plants, and the opportunity for an umbrella arrangement for the ECOWAS region.

The study should consist of two major parts:

* An analysis of the current situation about radioactive waste (and, as applicable, research reactor spent fuel) management in each ECOWAS country.
* Recommendations for the development of national and regional policy and implementation strategies for spent fuel and waste management.

In particular, the following areas should be assessed:

* The national legislative framework and applicable international conventions relevant to managing spent fuel and radioactive waste (validity and sufficiency of legislation and its compatibility with international recommendations).
* Institutional structure (allocation of responsibilities for waste generators, regulators — both nuclear and non-nuclear, waste management organization, government, etc.) — and the existing regulatory regime.
* Financing schemes for fuel cycle back end and waste management based on an economic estimate of the spent fuel and radioactive waste management system.
* Present national policies and strategies that have an influence on spent fuel and radioactive waste management (energy, environmental, natural resources, etc.).
* Spent fuel and radioactive waste inventory (current and planned, all sources, including naturally occurring radioactive material (NORM), disused sealed sources, institutional waste).
* Availability of resources (human, financial, and technical) and of existing spent fuel and waste management facilities.
* Identification of potential stakeholders and their expectations and interests.
* Waste classification system and basic characterization of known and anticipated spent fuel and waste streams.

Where applicable, national practices already implemented and/or planned in ECOWAS countries for managing radioactive waste generated outside the nuclear fuel cycle should be considered.

The depth of analysis should be sufficient to provide inputs for outlining regional and national policies and strategies for spent nuclear fuel and radioactive waste management, and to be applicable for a technical and economical evaluation of a feasibility study on embarking upon nuclear energy.

The management of the fuel cycle back end and radioactive waste is required to prevent potential technical constraints for the operation of nuclear power reactors and as a condition for the public acceptance of nuclear energy.

A typical non-nuclear power country generates NORM waste from mining uranium, oil/gas or other raw materials; it has some waste from medical applications; and keeps information on used and disused sealed radiation sources of all categories. Some countries may operate a small research reactor. Spent fuel and waste management facilities are missing; exceptionally, a collection and storage system for unprocessed waste is operated. The country has not formulated a national policy and relevant technical strategies and, thus, has not established spent nuclear fuel and radioactive waste management infrastructure. Nevertheless, there is a governmental body responsible for radiation protection (a national regulator) whose activities are paid from the national budget.

Information about the existing system is a baseline for developing proposals for establishing sound infrastructure, including the allocation of responsibilities, the legislative and regulatory regime, technical and financing schemes and sufficient human resources. The upgrading proposals should respect existing legislation in the country. However, when the legislative system is inadequate, its alteration needs to be included in the recommendations. Recommendations should be formulated with respect to the logical hierarchy and timing of their implementation.

Spent fuel and waste management systems should be outlined in two versions: for a single country and for a group of countries sharing certain activities (e.g. joint waste collection system), facilities (processing, storage or disposal), or equipment (mobile solidification unit, or super compactor). If appropriate, alternative sharing options should be offered.

The proposal for establishing a financing system should be based on a rough estimate of the cost of development, operation and closure of facilities. This information needs to be elaborated to a level that permits a technical and economic analysis of the introduction of nuclear power generation in a country.

Whenever applicable, the potential role of national industries and services should be indicated and specific requirements, if any, formulated.

If the type and size of reactors is not specified by the ordering party, a simplified sensitivity analysis considering different reactor options should be performed to indicate the impacts on anticipated waste and spent fuel inventories.

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2. \* The competencies required for staffing the regulatory body are addressed in detail in Study No. 2, Nuclear and Radiation Safety Infrastructure. [↑](#footnote-ref-3)
3. [↑](#footnote-ref-4)
4. An IAEA publication entitled Workforce Planning for New Nuclear Power Programmes (IAEA Nuclear Energy Series No. NG-T-3.3), currently being developed, examines these issues in detail. [↑](#footnote-ref-5)