CAN INCREASING PEACEFUL USES OF NON-POWER NUCLEAR SCIENCE AND TECHNOLOGY APPLICATIONS IN DEVELOPING COUNTRIES CREATE AN ENABLING ENVIRONMENT FOR NUCLEAR POWER IN THESE COUNTRIES?

A.K. STOTT
Vienna Center for Disarmament and Non-Proliferation (VCDNP)
Email: astott@vcdnp.org

I. KIRSTEN
Vienna Center for Disarmament and Non-Proliferation (VCDNP)

Abstract

According to the International Energy Agency (IEA), the energy crisis has renewed interest in nuclear power to contribute to energy security and reduce the CO_2 emissions from power generation. About fifty countries have expressed interest in introducing nuclear power, of which 27 are "newcomer countries", considering or actively embarking on a nuclear power programme. The remaining countries are in an early pre-decision phase. Several of these are Low- and Middle-Income Countries (LMICs), with relatively low demand for electricity and small electricity grids. For these countries, with their modest electricity growth projections, and considering the financial and human resources required for a large nuclear power plant, small modular reactor (SMR) technology could provide a viable alternative for their future energy mix. The IAEA Milestones approach describes the national infrastructure that is required for nuclear power, including legal and regulatory framework and human and financial resources within which the nuclear power programme is implemented. The newcomer country is responsible for establishing this infrastructure. In several newcomer countries, IAEA Integrated Nuclear Infrastructure Reviews (INIR) noted delays or difficulties enacting the necessary new or amended legislation, establishing independent regulatory bodies with sufficient human resources and funds, and developing regulations. INIR missions also observed that development of the required infrastructure often takes longer than envisaged. Similar infrastructure, albeit of a different scope, is required in a country implementing peaceful uses applications of nuclear science and technology in food and agriculture, medicine, and industrial sectors. These applications require an appropriate legal and regulatory framework and a regulatory body for safety and security (and safeguards if applicable) that has sufficient financial resources and competent staff. The paper investigates the similarities and differences between infrastructure required for nuclear power and for non-power applications, in particular the infrastructure related to nuclear and radiation safety, security, and safeguards (if applicable). The paper hypothesizes that LMICs that have developed and implemented effective infrastructure for non-power applications will be better prepared and find it easier at a future stage to enhance such infrastructure to the level required for nuclear power. Many of the LMICs require support to develop the infrastructure required for PU. The paper also discusses what support can and should be provided to such countries.

1. INTRODUCTION

Among the many challenges that Low- and Middle-Income Countries (LMICs) face, energy poverty is the most critical and requires immediate action to ensure that these countries have access to clean, affordable and sustainable energy sources. Nuclear power is a low carbon technology that could be considered by these countries for electricity production, as well as for non-electrical applications, such as desalination and use in the chemical industry. Novel and advanced reactor technologies, including Small Modular Reactors (SMRs) (hereafter "advanced reactors"), are increasing the opportunity to bring nuclear power within the reach of many LMICs. The challenge will be one of ensuring the safe, secure and sustainable deployment of these technologies in interested LMICs once they are ready for international markets.

While it is not essential for a country interested in nuclear power to first implement non-power applications of nuclear science and technology, a country that already has a robust infrastructure in place for these applications can benefit from expanding and extending the existing infrastructure and thus may more easily implement a new nuclear power programme.

2. INFRASTRUCTURE FOR NUCLEAR POWER

2.1. IAEA Milestones Approach and development of the infrastructure needed for nuclear power

In 2007, to assist its Member States considering new nuclear power programmes, the IAEA developed the so-called "Milestones Approach", a framework providing guidance on the development of infrastructure needed for nuclear power [1]. Prior to investment in the nuclear power plant (NPP), a country embarking on a new nuclear power programme needs to undertake a wide range of technical studies and evaluations, adopt relevant policies, establish an appropriate legal and regulatory framework, and develop required institutions and human resources. It will also consider what investment will be needed in new or upgraded physical infrastructure (roads, rails, ports, the electrical grid and associated equipment, environmental monitoring systems, etc.). These activities are known as "development of the infrastructure needed for a nuclear power programme". The Milestones Approach identifies nineteen areas of infrastructure development to be addressed during each of three sequential phases.

2.2. Countries interested in or already embarking on new nuclear power programmes

It is well-known that ten countries are actively embarking on a nuclear power programme: four countries are in Phase 3 of the Milestones Approach (constructing their first NPP or are ready to negotiate and sign a contract with an NPP vendor), while another six countries are in Phase 2 (have completed the studies necessary to make a knowledgeable decision and are developing the required nuclear infrastructure to be ready to invite bids or negotiate a contract for their first NPP [2].

A further 17 countries, of which eleven are LMICs, with seven classified as Least Developed Countries (LDCs), are in Phase 1 (undertaking the studies necessary to make a knowledgeable decision whether to continue – or not – with a nuclear power programme) [2]. A review of the IAEA Research Reactor Database [3] shows that six of these Phase 1 countries (Algeria, Indonesia, Kazakhstan, Morocco, Philippines, Thailand) operate a nuclear research reactor facility. The implication is that these countries already have in place the non-power nuclear safety, security and safeguards infrastructure necessary for a research reactor facility and could build on this experience to extend / enhance the infrastructure to the level required for nuclear power, if the decision is made to continue with a nuclear power programme.

2.2.1. Pre-decision (Phase 0) countries

The IAEA Nuclear Technology Review 2022 [2] infers that 24 countries are still in a pre-decision-making phase i.e. have expressed interest in nuclear power but have not yet commenced the activities necessary to make an informed and knowledgeable commitment to nuclear power (pre-Phase 1).

Although these countries are not listed, a review of national statements made during various IAEA General Conferences and of media reports provides a reasonable indication of who these countries are. Only a few of these countries are likely to have experience with research reactor facilities. Similarly, a review of the IAEA Accelerator Knowledge Portal [4] suggests that only a few of these countries have experience with accelerators, cyclotrons, e-beam facilities, or gamma irradiation facilities.

However, an analysis of the IAEA Directory of Radiotherapy Centres (DIRAC) [5] identifies that most of these countries have one or more radiotherapy centres in the country. These countries are also likely to have some experience with industrial radiography. It can thus be assumed that most (if not all) of these countries have some knowledge and experience of radiation control, albeit at different levels of scope and implementation.

The full extent of the implementation of non-power application of peaceful uses in these countries would require more research and analysis. Nevertheless, it is hypothesized that addressing relevant areas of infrastructure development to increase access to and implementation of non-power applications can support a pre-decision country to better prepare itself and create an enabling environment for nuclear power.

3. NON-POWER PEACEFUL USES AND INFRASTRUCTURE

The peaceful use of nuclear science and technology for non-power applications is based on the use of ionising radiation. The source of the ionising radiation can be a radioactive isotope, such as cobolt-60 or cesium-

137, or from a machine, such as an accelerator, a cyclotron, electron beam (e beam) or X-ray. The activity level of the ionising radiation in peaceful use applications varies widely, depending on the source of radiation and the specific application. High activity sources, if not managed safely and securely, can result in the exposure of humans and the environment to the harmful effects of radiation whether by accident or through malicious use. All radioactive sources must be kept under appropriate regulatory control.

Many of the areas of infrastructure development identified by the IAEA Milestones Approach that countries need to address when embarking on nuclear power are also relevant, albeit at a different level, for non-power applications. The following are examples of some, but not all, areas of infrastructure development that are appropriate for non-power applications.

Countries applying non-power technologies require a law or laws (the legal framework) to provide for the establishment and enforcement of regulations, standards, and licensing requirements for the safe and secure application of ionising radiation and the handling of radioactive materials and equipment. The legal framework also provides for the establishment of an appropriate regulatory body. The regulatory framework within which the regulatory body functions and the suite of regulations developed also include regular inspections and audits by the regulator of facilities that use ionising radiation to assess compliance and identify areas for improvement.

Qualified and trained personnel are needed to work with ionising radiation and radioactive materials. Personnel must be aware of the regulatory limits and good practices for the safe and secure handling of radiation and radioactive materials, including storage and disposal requirements. Regular training sessions and ongoing professional development programmes help maintain a high level of awareness and competence among staff.

Facilities utilising radiation and radioactive materials must adhere to safety requirements identified in appropriate regulations. This includes having appropriate shielding and containment structures, including safety measures such as remote handling and interlocks, and implementing operational safety procedures to prevent radiation exposure to workers and the public. A strong safety culture is needed and implies that the leadership and staff in the relevant organisations have a good understanding of radiation safety limits and international safety practices.

Stringent physical security measures are crucial to prevent unauthorised access to radioactive materials and facilities. Access control systems, surveillance cameras, and intrusion detection systems should be in place. Background checks and security clearances for personnel with access to sensitive areas are components of physical security programmes. A robust material control and accountability system should be implemented to track the movement and use of radioactive materials throughout their lifecycle.

Although a few of the pre-decision countries are categorised by the World Bank as high income, the vast majority are LMICs. While all these countries have their own specific priorities and challenges related to socio-economic development, the implication is that these countries are likely to have fewer resources available for the development or expansion of the infrastructure discussed above. The IAEA, through its technical cooperation programme, provides support to these countries to enable access to and implementation of non-power applications. However, the resources available to the IAEA to provide such support are limited and insufficient to meet the needs of the LMICs.

4. ENABLING THE ENVIRONMENT FOR NUCLEAR POWER

In 2009 the IAEA launched the Integrated Nuclear Infrastructure Review (INIR) service, to facilitate the application of the Milestones Approach. INIR is a holistic peer review service, undertaken on request, to assist Member States in assessing the status of their national infrastructure for the introduction of nuclear power. The INIR service helps ensure that the national infrastructure required for the safe, secure and sustainable use of nuclear power is developed and implemented in a responsible and orderly manner.

In 2022 the IAEA published a document describing the lessons learned from the 30 INIR missions conducted in 21 countries in the period 2009 to April 2020 [6]. For example, in several newcomer countries, the INIR missions noted delays or difficulties enacting the necessary new or amended legislation, establishing independent regulatory bodies with sufficient human resources and funds, and developing regulations. INIR missions also observed that development of the required infrastructure often takes longer than envisaged.

A review of INIR Phase 1 mission reports published on the IAEA website [7] suggests that some of the Phase 1 countries have been able to build on infrastructure that is already in place for non-power applications, for example an existing regulatory body for radiation safety, the management and security of radioactive sources, and

human resource development and training programmes. It can be concluded that having infrastructure in place for non-power applications has been beneficial for the development of the infrastructure needed for their nuclear power programmes.

5. CONCLUSION

The non-power applications of peaceful uses have a wide scope, in the medical, food, agriculture, environmental, water, research and industry sectors. Access to and implementation of these applications require that safety and security are taken into account, as well as other factors to ensure sustainability and to derive the full benefits of peaceful uses. These factors correspond to the areas of infrastructure development of the IAEA Milestones Approach, which countries embarking on nuclear power must address, albeit at a different level.

Countries developing a robust infrastructure for non-power applications - from legal and regulatory considerations to human resources – would not only obtain the full benefits of these applications but could also, by expanding and extending this infrastructure, potentially shorten the timeframe for the introduction of nuclear power.

With the advent of advanced reactors even LDCs have the potential to access nuclear power. If the hypothesis - that LMICs that develop and implement effective infrastructure for non-power applications create an enabling environment for nuclear power - is accepted, the argument can be made for greater investment in non-power applications of peaceful uses.

The IAEA should continue providing support to the pre-decision countries to access and implement non-power applications of nuclear science and technology. The IAEA could also assist in identifying the status of infrastructure in the pre-decision countries to facilitate the determination of the full extent of the required support. Consideration could also be given to adopting a graded approach that builds on scalability in the development of regulatory systems that would foster sustainable safety and security cultures and contribute further to creating an enabling environment, particularly in LDCs, to enhance and expand their peaceful uses programme [8].

Given the limited resources of the IAEA, there is an opportunity for other organisations, including international financial institutions and nuclear reactor vendor countries, to provide additional support to the pre-decision countries to develop the infrastructure required for non-power applications in a manner that would facilitate the future expansion of such infrastructure for nuclear power.

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