**The Role of Research Reactor in National Human Capacity Building for Nuclear Power**

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Abstract – *Fossil-based fuels have been powering our economies for years. They account for about 80% of the global energy mix. However, despite their dominance, fossil fuels are finite and have negative impacts on the environment and climate-related changes. Saudi Arabia under Vision 2030 sees this issue and build their Vision to reduce the indecency on oil and achieve net zero emission by introducing renewable and alternative source of energy in their energy mix such as nuclear power. Saudi Arabia is following the IAEA milestones in the development of national infrastructure for nuclear power. Because nuclear technology requires knowledgeable and highly skilled personnel to ensure its safe deployment and sustainability, human resource development (HRD) is 1 of the 19 key infrastructure requirements that the IAEA mentioned. It needs to be implemented during the design, construction and subsequent operationalization of nuclear power plants. Saudi Arabia is constructing the Low Power Research Reactor (LPRR) as a tool to transfer nuclear technology and train future operators for nuclear power plants. This study will focus on the potential role of research reactors that can play in building the nuclear human capacity for nuclear energy generation. Findings show that research reactors can help nuclear human resource capacity, especially with regard to education and training that can be used to not only develop but also maintain the human resources necessary for supporting the safe and sustainable operation of nuclear power programs.*

**Keywords:** Research Reactor, Nuclear Human Capacity Building, Training

I. Introduction

Reports have claimed that in the next three years, the demand for electricity in emerging Asian economies, which includes China, India, and Southeast Asia combined, will increase by 70%. The growth of these economies corresponds with the growing electricity demand [1]. While these countries focus on increasing their capabilities, they focus on reducing carbon emissions and achieving sustainability goals. This increasing demand has led to nuclear power being seen as a viable option. It is gathering pace in Asia, aiming to curb the carbon emission intensity associated with power generation. IEA (2023) report states that from 2023-2025, nuclear power generation would grow 4% on average. This means by 2025, more than 100 TWh of power will be generated by nuclear power. Of this, more than half are said to be from India, China, and Korea. Though these technologies are gaining popularity, there are multiple challenges that countries face in the adoption of nuclear technologies.

Saudi Arabia under Vision 2030 is planning to introduce nuclear energy into its energy mix. Saudi Arabia launched the national atomic energy project to use peaceful nuclear technology for energy development and production. In addition, Saudi Arabia is going forward with this project following international standards and guidelines. The International Atomic Energy Agency (IAEA) has created the Milestones in the Development of National Infrastructure for Nuclear Power which Saudi is following. Based on the guideline, Saudi established the nuclear holding company which will oversee all the nuclear power activities in the nation, and established the Nuclear and Radiological Regulatory Commission (NRRC) as an independent regulatory body. In addition currently, Saudi is construction the Saudi Low Power Research Reactor (LPRR) in King Abdulaziz City for Science and Technology (KACST) which is the first nuclear facility in the kingdom to support the Atomic Energy Project.

 Human capacity building (HCB) is considered a critical aspect of the nuclear field as requires a high standard [2]. HCB includes multiple issues that range from recruitment to planning. It focuses on achieving the required competency, and for this, training and education infrastructure are needed Across studies, including Egieya et al. (2022), HCB is acknowledged as one of the key infrastructure requirements that need to be implemented before the commencement of construction and subsequent operationalization of nuclear power plants. However, for developing economies, implementing HCB is particularly challenging due to the specialized workforce needed for nuclear reactors. Most of these skills are not readily available in these economies and usually require longer periods (about 10 years) to be developed [3]. Research reactors can be used to fill this competency gap. Studies show that the establishment of research reactors can significantly help in this regard.

II. Lack of Nuclear Human Resources

Nuclear power plants, by their very nature, require highly technical and adept personnel for their efficient functionality and overall sustainability. Therefore, sufficient planning for HCB is necessary because the commissioning and operation of a nuclear power plant can span decades. In and of itself, HCB planning comprises evaluating the current capacity of a nation’s workforce, identifying gaps in meeting the required skill sets, and developing appropriate strategies for bridging these gaps [3]. Furthermore, the IAEA, in its bid to assist member countries in developing robust and sustainable HCB frameworks for enhancing their nuclear power program workforce development and planning, has acquired the NPHR (Nuclear Power Human Resources).

At the core of NPHR is the need to develop nuclear research reactors. One important area where nuclear research reactors have a huge contribution is education and training in various nuclear technology areas for plant operators, maintenance and operational personnel of nuclear facilities, as well as radiation protection staff and researchers [4].

III. The Role of the Research Reactor

Research reactors encompass an extensive range of different types of reactors that are not used to generate power. Research reactors have different applications, including research and training. Research reactors could be used to improve the quality of life of individuals. Access to the research reactor would help develop researchers' skills to extract neutrons, allowing them to conduct many research activities in physics, biology, geology, and chemistry [2]. The research allows for understanding the various characteristics of neutrons and their interaction, which could be used in real-life applications.

In addition, research reactors are structurally simpler and operate at comparatively lower temperatures than power reactors. They require far less fuel and, as such, have less fission product accumulation as the fuel is expended. But despite differences in structural setup and fuel consumption needs, [4]. But perhaps the most significant area where research reactors portend huge contribution is in building human nuclear capacity, which for developing economies is critical for facilitating their nuclear power adoption. There are many roles that research reactors play in HCB.

The primary difference between research reactors suitable for training, like TRIGA, and high-power research reactors lies in their intended use, power levels, and capabilities. Training reactors are designed for educational purposes, operating at lower power levels and focusing on safety and simplicity to facilitate learning. In contrast, high-power research reactors are versatile facilities used for advanced research, offering higher power levels, advanced instrumentation, and a broader range of applications, including fundamental research, material testing, and isotope production.

***III.A. Design, Construction and Commission Phase***

The main goal of designing and constructing any reactor is to operate safely. Each reactor has it is own specifications but in the end, all share the main components. Countries that are constructing a research reactor will have the experience and the knowledge to deal with all the requirements of constructing a reactor. This will start with dealing with the regulatory body on how to license the side, the design and so on. This would be very helpful to build a capacity in regulating the construction of a nuclear facility. In addition, building experience in dealing with the vendor and all nuclear project management issues.

During the commission phase, several requirements should the operator to the regulator such as the Final Safety Analysis Report (FSAR) and several other documentation. All of those requirements need people to work on them and it might take several months to years to fill them. The valuable knowledge of preparing and analyzing those documents can be very helpful when dealing with nuclear power plants.

In addition, the construction of nuclear power is estimated to have several workers who are not related to the nuclear sector but are required during construction. Those workers must have some basic knowledge about the importance of safety and safety culture. Research reactors can help to educate those workers by aware them of nuclear reactor technologies and the importance of safety in this field

 ***III.B. Operation Phase***

The nuclear power plant depends heavily on the operation organization to operate the plant. Those ranging from the plant manager, shift manager operators and others. All of those positions should be well qualified to work in those positions. Some qualifications might need experience in operating a reactor or hands-on training in operating a reactor. Research reactors need operators to operate and because of the size and the application of research reactors compared to nuclear power reactor, the requirements to operate a research reactor is usually less but this will give the operators a lot of experience on how to follow procedures and other operating matters that are needed in operate a nuclear power plants.

Because when it comes to nuclear energy, the safety of the entire operations and infrastructure is critical. A nuclear disaster could have a long-lasting impact on the region and could significantly influence the health and existence of people around the region [6 ,7, 8, 9].

In such an accident scenario, engaging in the management and operation of the nuclear power stations are not limited to those who work in the organization but also to employees in nuclear and non-nuclear related firms. The number of individuals required is more than what is seen in nuclear power plants. A wide range of skills and safety practices are to be observed to ensure safety [10]. With the growing number of people required for the increase in nuclear reactors in developing countries, training people on emergency is critical to attaining the required experience. Research Reactors allow for substituting for nuclear reactors and allow individuals to gain the required experience. This creates awareness and the use of research reactors allow the individuals to follow learn safe ways to undertake different emergency activities, which allows them to experience and with the required combination of knowledge when they join as operator or work in other fields related to nuclear reactors. Thus, nuclear-ambitious countries must adopt national human resource development programs and access to research reactors that allow them to develop the required skill set.

It also should be mentioned that each reactor has it is own specifications and tools thus, operating a research reactor does not mean to operate the nuclear power plants. However, comparing a person with experts in operating a research reactor and one who is not, the first person is far more qualifying to operate the NPP after getting some special training.

IV. Conclusions

Research reactors are used for different applications. Regarding human development for aspiring developing countries, research reactors and access to research reactors is critical. Based on nuclear reactor regulations and best practices standards that are in place to ensure the safety of operators and staff are said to require a certain level of skill and training for effective and smooth operation. This is done to ensure safety and avoid accidents that could significantly impact the country.

The training is not limited to prospective employees but is required for anyone in a field related to nuclear reactors. The research reactors allow these people to gain knowledge in working principles, best practices, emergency preparedness, and other. In addition, research reactors can be used for educating and training nuclear engineers, providing them with the practical experience that can be used to develop and sustain the human resources pool that emerging economies need to support the safe and sustainable deployment of their nuclear power programs.

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