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P01 - AKSIT Simge

Low-carbon power generation scenarios for Türkiye and the role of advanced and innovative nuclear power reactors

P02 - ALSHAKHATREH Abdelrahman Jamal Falah

The Current Status of Jordanian Nuclear Programme (SMRs) Achievements & Challenges

P03 - BALAMI Dennis Solomon

Sustainable Nuclear Energy in Nigeria: Addressing Challenges and Bridging Knowledge Gaps

P04 - DAS Nilormi

INPRO Fusion Study: Cross cutting aspects of safety, security, and legal issues for Deployment of Fusion Plants

P05 - DE GUZMAN Joyce Ann Timbol

The Philippines' Nuclear Fuel Cycle Research and Development Program

P06 - GUERRERO GUTIERREZ Luis Gerardo

Nuclear energy role in achieving NDC goals in Isolated systems (MEXICO)

P07 - ISNAINI Anissa

Comparative Evaluiation of Nuclear Fuel Technology in Indonesia using KIND-ET - A Case Study

P08 - NARTEY Erasmus Tettey

Charting Ghana's Sustainable Energy Future With The Inclusion Of Nuclear Power To Achieve SDG 7

P09 - NIKOLOVA Iva Eduard

Human Resource Managing in Nuclear Energy

P10 - OLARU Claudia

Proliferation resistance assessment using the INPRO methodology: Introducing light water small modular reactor technology in Sweden

P11 - SANONGBOON Pronnapa

Hybrid Energy System Optimization for Nuclear Energy and Sustainable Development

P12 - SAYIN Gaye

IAEA-INPRO collaborative Project on Transportable Nuclear Power Plants

P01

Low-carbon power generation scenarios for Türkiye and the role of advanced and innovative nuclear power reactors

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The Paris Agreement aims to strengthen global socio-economic resilience against climate change and to keep surface temperature increase below 2°C, with a further ambition for 1.5°C, compared to the pre-industrial era [1]. The climate goal requires a gradual reduction in fossil fuel use and peak emissions before 2050, together with a transition towards low-carbon energy technologies [2]. In Türkiye, the largest share of total CO_2 emissions by sectoral distribution was energy-related emissions with $353.0\ MtCO_2$ (share of 70.2% in total emissions) in 2020 [3]. The Türkiye National Energy Plan covers the period until 2035 based on the 2053 Net Zero Emission target. The plan forecasts a battery storage capacity of 7.5 GW in 2035 to reach the net-zero emission target [4]. Türkiye's Hydrogen Technology Strategy and Roadmap were announced in January 2023. This roadmap aims to support the local development of hydrogen technologies by creating a technology development support and implementation program, as well as defining a strategic action plan. According to the roadmap, the target is to achieve an electrolyser capacity of 2 GW in 2030, 5 GW in 2035, and 70 GW in 2053 [5]. In order to achieve the net-zero emission target, Türkiye should increase low-carbon energy technologies including advanced and innovative nuclear power reactors. In this context, the combined production of electricity and heat, with hydrogen as an additional energy carrier, from advanced reactors and SMRs will be evaluated using MESSAGE to achieve the net-zero emissions target.

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P02

The Current Status of Jordanian Nuclear Programme (SMRs)

Achievements & Challenges

By

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Jordan Atomic Energy Commission (JAEC)

Advanced Power Systems Directorate

In Jordan, energy production relies predominantly on oil and coal, constituting approximately 89% of electricity generation, while renewable resources contribute only about 11%[1]. Moreover, the country heavily depends on imports for nearly 96% of its energy requirements, indicating a pressing need to reduce reliance on imported fuels for economic stability. Addressing this energy deficit is vital for fostering sustainable development.[2]

In Addition, Jordan is one of the most water-poor countries in the world for renewable freshwater with around 61 cubic meter per capita in 2021. Climate change and overuse of water resources have further reduced groundwater and surface water resources, while population has grown at a very high rate, placing Jordan among the world's top five countries in population growth historically. Jordan's health, prosperity, and food security require lasting water security.[3] As a result, JAEC is presently conducting a feasibility study on the application of SMR technology for desalinating Red Sea water.

The Hashemite Kingdom of Jordan seeks to achieve energy and water security in addition to keeping pace with the ever-growing demand for these resources. By Law No. 42, JAEC was empowered to lead the development of the Jordanian Nuclear Power Plant, utilizing the strategic projects of Uranium exploration, Jordan Research and Training Reactor, and the development of required national human resources, aiming to eventually achieve the vision of His Majesty King Abdullah II in which he announced that Jordan will be a model in the peaceful utilization of nuclear energy.4

JAEC has actively participated in this project since 2008, facing various challenges that have resulted in delays in its implementation. In this presentation, we will specifically address the current status of Jordanian Nuclear Programme. The presentation is organized into four sections as follows: Country profile, a history of Jordan's nuclear program (Achievements), Infrastructure development (site survey & evaluation of SMRs, environmental impact assessment (EIA), etc.), and the challenges and opportunities of implementation SMRs in Jordan.

Jordan has been working in this project over 18 years, one of the achievements is building the first research reactor in the region and now is fully operated by Jordanian engineers. Also, Jordan has conducted comprehensive studies in this regard, including site surveys and evaluations performed by a reputable companies specializing in the field. More recently, Jordan has shown a keen interest in small modular reactors (SMRs). As a result, the studies initially conducted for large nuclear power plants have been reevaluated to align with the specific requirements of SMRs. The purpose of this presentation is to showcase the current status of Jordanian Nuclear Programme and the future steps.

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[1] Jordan Energy Strategy 2030, Ministry of Energy & Mineral Resources (Page 5-7)
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P03

Sustainable Nuclear Energy in Nigeria: Addressing Challenges and Bridging Knowledge Gaps

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Nigeria faces a significant energy deficit hindering its economic growth. Nuclear energy offers a potential solution for clean and reliable electricity generation [1]. However, a successful nuclear program requires addressing critical research gaps. This paper investigates the feasibility of nuclear energy in Nigeria, considering technological capabilities, waste management, social factors, resource assessment, cost-effectiveness, maintenance culture, environmental impact mitigation, and feasibility studies. Nigeria's power shortage remains a major obstacle to development [2]. While existing hydropower provides some baseload generation, a diversified energy mix is crucial. Nuclear energy offers a high power density, low greenhouse gas emissions, and fuel security [3]. However, a successful program necessitates a comprehensive approach that addresses knowledge gaps and potential challenges. A thorough assessment of Nigeria's current capabilities in nuclear technology is essential. This includes evaluating existing expertise in nuclear engineering, reactor physics, and radiological protection. Collaborations with experienced nations can address skill gaps through knowledge transfer and training programs. Financial constraints require innovative solutions. Public-private partnerships and international financing mechanisms can ease the initial investment burden. Nuclear waste management is a critical concern. Research should focus on safe and long-term storage solutions like geological repositories. Collaboration with international organizations like the International Atomic Energy Agency (IAEA) can provide expertise and best practices in waste management strategies [4]. Public perception and political will significantly influence the program's success. Open communication strategies and educational campaigns fostering transparency and addressing safety concerns are crucial. Public engagement through town hall meetings and workshops can build trust and garner support. Political commitment across administrations is essential for long-term program stability. Detailed resource assessments are vital for optimizing nuclear power plant locations [5]. While large-scale wind and geothermal might not be feasible nationwide, smaller-scale applications in specific regions with favorable geological conditions should be explored. Cost-effectiveness studies comparing nuclear energy with alternative energy sources like hydropower and solar are necessary. Lifecycle costing, considering construction, operation, and decommissioning expenses, provides a more accurate picture [6].

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P04

INPRO Fusion Study:
Cross-cutting aspects of safety, security, and legal issues for Deployment of Fusion Plants

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The main objective of the INPRO Fusion Study is to support the fusion community in its effort to accelerate the development and implementation of fusion based facilities and integrated fusion-fission (hybrid) systems, with the early identification of possible gaps in long-term sustainability and needed capabilities utilizing INPRO assessments and analyses. The key topics discussed and considered in this study for early identification of gaps and findings are long-term sustainability issues; main drivers and impediments to deployment of fusion facilities and hybrid energy systems; legal issues and challenges, international conventions and instruments, national legislations and liability; fusion safety and security issues; comprehensive infrastructure issues. This study is achieved through cooperative work on cross-cutting issues conducted by the IAEA and INPRO Member States, along with inter-departmental IAEA cooperation: 6 countries, ITER, more than 40 experts and 10 IAEA divisions and sections.

P05

The Philippines' Nuclear Fuel Cycle Research and Development Program

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The Philippine government has formalized the inclusion of the nuclear energy to the country's energy mix through the signing of Executive Order 164: *Adopting a National Position for Nuclear Energy Program and For Other Purposes* on 28 February 2022. This has signaled the government's commitment to integrate nuclear energy as an alternative baseload power source. In line with the International Atomic Energy Agency's (IAEA) guidelines, the Nuclear Energy Program Inter-Agency Committee (NEP-IAC) in the Philippines, chaired by the Department of Energy (DOE) and co-chaired by the Department of Science and Technology (DOST), is tasked in addressing nineteen infrastructure issues outlined in the IAEA Nuclear Energy Guide No. NG-G-3.1. The main role of the NEPIAC is to direct studies for adoption of the Nuclear Energy Program in the country. In response to the IAEA Mission Report on Integrated Nuclear Infrastructure Review (INIR) – Phase 1 in the Philippines, regarding significant actions in the Nuclear Fuel Cycle, along with other recommendations [IAEA, 2018], one of the strategies identified to support the planning and sustainability of nuclear energy initiatives in the country involves backing research & development focused on nuclear fuel cycle. Thus, we initiated the Nuclear Fuel Cycle Research Program which aims to develop a holistic approach focusing on the front- and back-end of the nuclear fuel cycle. The program has four (4) projects entitled: Nuclear Materials Exploration and Recovery (Project I); Nuclear Reactor Technology Assessment and Development (Project II); Strategy for Radioactive Waste Management Project (III); and Establishment of Nuclear Plant Simulator and Analyzer Facility for R&D and Capacity Building for the Philippine Nuclear Energy Program (Project IV).

The research studies on Nuclear Fuel Cycle in the Philippines were designed to cover various activities associated with the production of reliable electricity from nuclear power reactors focusing on the front-end to the back-end of the cycle. Front-end of the cycle (Project I) will explore the uranium deposits in the country by characterizing the geologic nature and occurrence of radioactive minerals in reported localities in the country, as well as uranium recovery from Philippine seawater [Manalang *et al*., 1976, Palattao *et al*., 2018]. Further, existing nuclear reactor technologies and innovative designs will be assessed to be able to identify the suitable nuclear energy systems applicable in the Philippines (Project II) and establishment of nuclear plant simulator facility (Project IV) and for the back-end, strategies for safe management and pre-disposal of nuclear waste/spent fuel (Project III). The research results will be used as scientific references in pushing for policies and implementation of the nuclear energy program in the Philippines.

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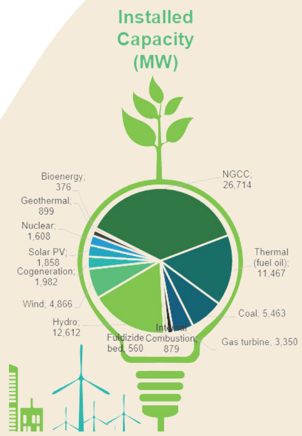
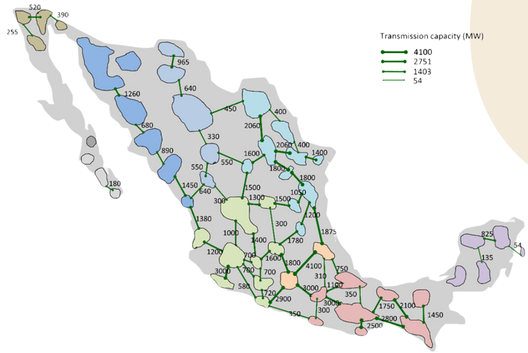
P06

NUCLEAR ENERGY ROLE in achieving NDC goals in Isolated systems (MEXICO)

BY LUIS GERARDO GUERRERO



Mexico target is to reduce 35% by 2030 of GHG relative to its baseline, with at least 30% coming from domestic resources and 5% through international cooperation and financing dedicated to clean energy.(Mexico NDC, Update 2022)



BCS Isolated system

- Cities that rely on tourism as their most important income
- Two nodes, (La Paz and Los Cabos)
- More than 1,000 km of empty desert
- No natural gas pipelines.
- Electricity Generation mainly through fossil fuels

Clean energy options

The country benefits from a high potential for renewable resources. It enjoys abundant solar resources, particularly in the northern regions, while wind resources are considerable especially in coastal areas

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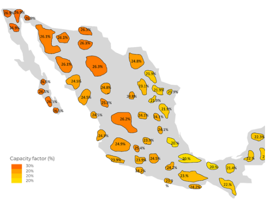
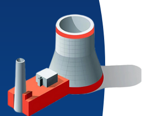


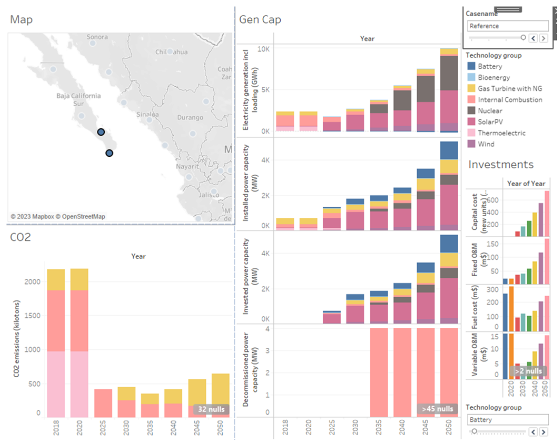
Nuclear

Restriction regarding the amount of nuclear energy expansion that the model could take. In BCS, specifically in the La Paz region, it used feasibility studies as an option for the installation of a medium or small nuclear reactor.

ISOLATED SYSTEMS AND NUCLEAR ENERGY



Nuclear energy is expected to play a mayor role for achieving NDC goals in isolated systems.



Further studies are being carried out to study the sensitivity analysis for nuclear energy costs against other technologies. The model used for this studies is BALMOREL energy model which is a partial equilibrium model, which supports modelling and analysis of the energy sector with emphasis on the electricity and the combined heat and power sectors..

P07

Comparative Evaluation of Nuclear Fuel Technology in Indonesia using KIND-ET – A Case Study

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[1]*Research Organization for Nuclear Energy – Indonesia National Research and Innovation Agency Affiliation 1*

Indonesia's archipelagic geography, characterized by thousands of islands with diverse sizes and population densities, presents unique challenges in developing large-scale electricity grids, necessitating differentiated nuclear energy strategies. To accommodate the varied needs of its electricity infrastructure, Indonesia is exploring water-cooled nuclear reactor technologies, such as PWR, for its densely populated areas, while considering gas-cooled HTGR technology for smaller, isolated grids. Supporting these initiatives, research and development efforts focus on two types of nuclear fuels: pin-type for PWRs and pebble-type for HTGRs. A significant part of this endeavor was the application of the KIND-ET tool for a comparative evaluation of the technology feasibility of fuel production facilities. This initial analysis revealed that pin fuel fabrication technology (NFC-1) ranked higher than pebble fuel fabrication technology (NFC-2), highlighting its relative advantages within Indonesia's current infrastructure and strategic framework. This finding underscores the importance of continued evaluation and adaptation in advancing Indonesia's nuclear energy capabilities, particularly in the pursuit of sustainable, safe, and efficient nuclear fuel technologies to support the diverse reactor technologies suited to both large-scale and small-grid applications, reflecting the nation's strategic approach to overcoming the complexities of nuclear energy system planning in an archipelagic context.

P08

Charting Ghana's Sustainable Energy Future With The Inclusion Of Nuclear Power To Achieve SDG 7

Erasmus T. Nartey [1], Mark A. Nyasapoh [1,2] , and Felix Ameyaw PhD. [2]

Ghana's ambitious energy transition strategy is geared towards achieving Sustainable Development Goal 7 (SDG 7) and supporting the country's economic transformation objectives, with the key aim of attaining net-zero emissions by 2070. This strategy is underpinned by robust economic and demographic growth projections, including an anticipated annual GDP growth rate of 5% leading to a GDP of USD 863.69 billion by 2070, a population increase to 72.2 million, and an urbanization rate reaching 85%, all of which inform the forecasted rise in total energy demand to 485,260GWh by 2070. To meet this demand, electricity production is expected to increase significantly from 23,163 GWh in 2022 to 344,272 GWh by 2070. This paper aims to explore the crucial role of nuclear energy in Ghana's energy landscape, particularly in providing cost-effective, reliable, and sustainable electricity to support the country's expanding population and rapidly growing economy. While highlighting the pivotal role of electricity in driving advancements across various sectors, including industry, agriculture, technology, and overall living standards, the paper emphasizes the importance of a robust and diversified energy mix for Ghana's development.

This paper is expected to complement existing literature by providing a detailed analysis of Ghana's energy transition strategy, specifically focusing on the role of nuclear power in achieving sustainability goals. The expected outcome of this research is to provide valuable insights into how Ghana can effectively integrate nuclear energy into its energy mix, leading to a more sustainable and resilient energy future.

The findings of this research are expected to have significant implications for Ghana's energy policy and planning, as well as for other developing countries seeking to transition to sustainable energy systems. By highlighting the benefits of nuclear power in achieving SDG 7, this paper aims to inform decision-makers and stakeholders about the potential of nuclear energy to contribute to a sustainable and inclusive energy future.

Human Resource Managing in Nuclear Energy

I. NIKOLOVA

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The functioning of any organization is related to the combination of the main types of resources: financial, material, information and human. The distinguishing attribute of the human capital is that the person can integrate, coordinate, assess and present. However, the human is also a conscious organism, in addition to being a resource. This requires coordinated and systematic approach to his management so that on the one hand it matches his qualities as a person and is in line with the strategic goals of the organization on the other. After 50 years of operation, Kozloduy NPP recognizes that the people, with their knowledge and skills, are the most valuable asset. Their management in the company embraces the following aspects:

- *Attracting and providing the necessary personnel through professional recruitment.*

Staff recruitment supports the Company's management in the process of securing sufficient, competent and motivated personnel for Kozloduy NPP. A 10-year workforce plan has been developed and is regularly updated to meet production needs. Furthermore, a 30-year staffing scenario has been elaborated to forecast the demand and supply of qualified personnel for the plant justified long-term operation period. A large number of initiatives to attract the next generation of technical talents to the nuclear community are underway.

- *Training and competence development*. The fundamental understanding of training is that it is an educational process aimed at filling gaps in the knowledge, skills and attitudes necessary to perform job tasks. The training process at Kozloduy NPP aims to build and maintain a high safety culture and expert knowledge to understand the technical, human and organizational aspects as well as skills related to facilities and activities.

- *Managing the risk of nuclear knowledge loss in the Company and ensuring succession*.

Within the framework of the plant's knowledge management process, the importance of the experience and competencies possessed by the staff as a core element of corporate knowledge is assessed and relevant procedures are developed to ensure that this knowledge is captured and reused to achieve the Company's business goals and improve the decision-making. To this end, a tailor-made KM information system is in place to assess the risk of loss of undocumented knowledge and plan and assign measures to retain/transfer critical knowledge.

- *Performance management*. The assessment of individual work performance in the Company is a systematic process leading to continuous improvement of organizational effectiveness. Performance management establishes a shared understanding of what needs to be achieved and what approach should be implemented to integrate and combine the various policies and management systems in the organization to achieve the strategic goals.

- *Maintaining a high level of staff motivation*. Motivating and stimulating human resources is an ongoing activity that is carried out by plant's managers at all levels. It includes: 1) Establishing effective communication methods; 2) Improving working conditions and limiting risks to staff health; 3) Providing effective incentives for staff motivation; and 4) Measuring and monitoring the motivation of the Company's staff.

P10

Proliferation resistance assessment using the INPRO methodology: Introducing light water small modular reactor technology in Sweden

Claudia Olaru [1] , Erik Branger [1] , and Sophie Grape [1]

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The Academic-industrial Nuclear technology Initiative to Achieve a sustainable energy future (ANItA) is a competence centre recently established in Sweden, aiming at conducting research on how the introduction of small modular reactors (SMR) based on light water technology could contribute to a sustainable Swedish energy system. In line with this objective, this work describes a research study on non-proliferation and nuclear safeguards implications of SMR deployment, performed by employing the methodology developed by INPRO. Central to this analysis is the evaluation of proliferation resistance in an envisioned Swedish nuclear energy system, encompassing legal frameworks, technological considerations, and safeguards implementation. We first define a deployment scenario where the introduction of SMRs is seen as an extension of the Swedish nuclear power programme. Then, we present the steps taken to acquire the necessary input for performing the nuclear energy system assessment, and our experience and progress in applying the methodology in the case of Sweden. Lastly, we discuss the outcome of the work, as well as the exploration of technical and non-technical solutions for an increased proliferation resistance in SMR deployment, that could add value to the overall sustainability in future energy planning.

P11

Hybrid Energy System Optimization for Nuclear Energy and Sustainable Development

Pronnapa Sanongboon, Travis Pettigrew, and Mohammad Tohidi

Canadian Nuclear Laboratories

Canada's commitment to achieve net-zero emissions (NZE) by 2050 requires a transition to cleaner energy. As part of this effort, we conducted a high-level analysis to specify the plausible nuclear energy deployment in the year 2050 to meet the intent of the NZE policy. The scope of the study included determining an optimal energy mix and estimating the probable SMR deployment rate using the Hybrid Energy System Optimization (HESO) model [1]. First, we used HESO to determine the installed capacity and hourly generation by minimizing the total energy cost using historical energy consumption between 2000 and 2019 [2]. Hourly renewable energy sources were used to account for the variability of energy supply and to ensure system flexibility. Two scenarios were considered: business as usual (BAU) and NZE. Linear regression was used to estimate future energy in 2050 for the BAU scenario where there was no significant shift in electricity use to reach decarbonization goals. For the NZE scenario, electrification and hydrogen fuel cells were assumed across sectors to enable the decarbonization of some applications. Low and high capital costs for nuclear [3] were assumed to capture the effects of capital cost uncertainty. The results show that a significant increase in nuclear-installed capacity is required by 2050 regardless of capital costs.

Undoubtedly, substantial expansion of all clean energy technologies especially SMRs will cause significant challenges. Thus, we further investigated the potential SMR deployments concerning provincial energy trends and policies that included the determination of reactor technologies and maximum deployment rates. By using a provincial adoption strategy, four SMR technologies were considered: BWRX-300, ARC-100, SSR-W, and IMSR-400. In determining the maximum deployment rates, we used the technology S-curve to study the timescale from invention to widespread commercialization in energy supply and end use technology [4]. Based on the target installed capacity for low capital cost, the results showed that a total of 570 SMR units were identified for deployment in the 2050 NZE scenario. For this target of new nuclear deployment of approximately 135 GW, roughly 119 GW can be achieved by 2050 with the remaining capacity installed afterward. By assuming high capital cost, a total of 400 SMR units were identified for deployment. For this target of new nuclear deployment of approximately 94 GW, roughly 83 GW can be achieved by 2050.

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P12

IAEA-INPRO collaborative Project on Transportable Nuclear Power Plants

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The International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) assists Member States in implementing sustainable nuclear energy, one of the ways being by initiating collaborative projects on transportable nuclear power plants.

Definition:

A transportable nuclear power plant (TNPP) is a factory-built, mobile, and/or relocatable nuclear facility that, when fuelled, can generate end-use energy products like electricity, heat, and desalinated water.

A TNPP offers a novel solution to growing energy demands, being particularly suitable for diverse settings such as remote and harsh environments.

History

Historically, marine-based nuclear power started in the 1960s where the United States launched a floating nuclear power plant, the Sturgis, in January 1967 in the Panama Canal where it provided electricity for the city and canal operations until 1976.

Rosatom commissioned the Akademik Lomonosov in May 2020 in northeast Russia to supply electricity to the city of Pevek, consisting of 2 KLT-40S nuclear reactors, for 70 MW electricity and 50 Gcal/h heat. The refuelling schedule is 3-3.5 years with a fuel cost 1.5 times lower in the overall cost of electricity production.

IAEA International Symposium on Floating Nuclear Power Plants (FNPP)

The first IAEA International Symposium on FNPPs, 14-15 November 2023, attracted 168 participants from 44 Member States and four International Organizations. This event united a diverse array of stakeholders crucial to the development and deployment of FNPPs, including representatives from the nuclear and maritime industries, regulatory bodies, maritime classification societies, and legal experts. INPRO, alongside NS and other departments, played a pivotal role in organizing the symposium.

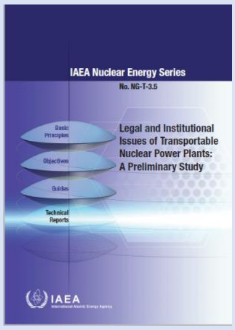
The symposium yielded several significant outcomes, most notably raising awareness among key stakeholders about challenges and the importance of enhanced coordination and awareness – building.

There was a consensus on the need to unite major stakeholders within a coordinated or cooperative framework. The symposium highlighted four key focus areas for future FNPP projects:

1. Industry Cooperation: Collaboration between developers and shipyards for efficient production.
2. Regulatory Cooperation: International collaboration for export licensing and safety standards.
3. Industry/Regulatory Coordination: Early alignment to ensure regulatory readiness.
4. Safety, Security, and Safeguards (3S): Early integration into design to address unique FNPP challenges.

Case Studies for TNPP-1

The INPRO collaborative project conducted a preliminary study from 2008 to 2013, on Transportable Nuclear Power Plants (TNPP-I) documented in the NE Energy Series Technical Report No. NG-T-3.5.



The study aimed to examine legal and institutional challenges, including ownership and contracts for TNPP deployment, identify challenges, and analyse the impact of TNPPs on the infrastructure of recipient countries.

Two TNPP options were considered:

- factory-assembled, fuelled, and tested reactors,
- factory-assembled and pre-tested reactors with on-site fuelling.

Two scenarios for legal and institutional frameworks were analysed:

- The supplier operates and the host state regulates,
- The host state entity operates and regulates.

INPRO Case Study on TNPP-2

The INPRO collaborative project on Transportable Nuclear Power Plants (TNPP-II) initiated in 2015, marks a collaborative effort between member states and various IAEA departments.

The study aimed to This comprehensive study aims to explore the legal and institutional complexities involved in the export deployment of a specific type of TNPP with a factory-fuelled, tested, and sealed reactor. Additionally, it examines broader aspects of transportable and modular reactor facilities.

Participating Member States:
Armenia, China, France, Finland, Indonesia, Romania, Russian Federation, and the USA.

The study is currently in the publication process.

Preliminary Conclusions:

- The case study TNPP-1 analysed various aspects of FNPPs, including infrastructure, safeguards, legal, safety, regulation, security, and international legal instruments. It highlighted the need for IAEA verification, legal clarity, and coordination for nuclear security.
- Export challenges for transportable nuclear modules (SMRs) span their entire lifecycle, requiring compliance with international norms and IAEA standards, focusing on legislative, safeguards, safety, licensing, and security issues.
- Four focus areas for FNPP projects: industry cooperation for efficient production, regulatory cooperation for international collaboration, early industry/regulatory coordination for licensing readiness, and the integration of safety, security, and safeguards from the design phase and throughout the lifecycle.

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