THE IAEA MILESTONE APPROACH AND INPRO METHODOLOGY IN SUPPORTING DEPLOYMENT OF NUCLEAR POWER PROGRAMME FOR A NEWCOMER COUNTRY

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ABSTRACT

There is a growing interest from newcomer countries to utilise nuclear energy for electricity generation. The International Atomic Energy Agency (IAEA) has developed two methodologies, namely, the IAEA Milestone Approach and the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) Methodology to help its Member States in assessing the viability of nuclear power programme (NPP) and nuclear energy system. This paper highlights important features of both methodologies in supporting deployment of nuclear power programme for a newcomer country. In summary, the IAEA Milestone Approach focuses for near term while the INPRO Methodology focuses for long term assessment to support the deployment of first NPP in newcomer countries. Depending on newcomer country's priority and resources, both methodologies can be performed either separately or in-parallel.

ABSTRAK

Terdapat peningkatan minat dikalangan negara baru tenaga nuklear untuk membangunkan program kuasa nuklear bagi penjanaan elektrik. Agensi Tenaga Atom Antarabangsa (IAEA) telah membangunkan dua kaedah, iaitu pendekatan tanda aras IAEA dan Metodologi International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) untuk membantu negara-negara anggota melaksanakan penilaian terhadap kebolehlaksanaan program kuasa nuklear dan sistem tenaga nuklear. Kertas kerja ini menekankan ciri-ciri penting bagi kedua-dua kaedah ini dalam menyokong pembangunan program kuasa nuklear oleh sesebuah negara baru tenaga nuklear. Sebagai rumusan, pendekatan tanda aras IAEA memberi tumpuan kepada penilaian untuk tempoh masa terdekat manakala Metodologi INPRO memberi tumpuan kepada penilaian untuk tempoh masa yang lebih panjang dalam menyokong pelaksanaan program kuasa nuklear pertama sesebuah negara baru tenaga nuklear. Bergantung kepada keutamaan dan sumber dimiliki sesebuah negara baru tenaga nuklear, kedua-dua kaedah boleh digunapakai, sama ada secara berasingan atau bersama.

Keywords: IAEA milestone approach, INPRO methodology, nuclear power programme, newcomer country

INTRODUCTION

Despite the aftermath of Fukushima nuclear accident in 2011, interest in nuclear energy has increased steadily, particularly in Asia. It is mainly motivated by the increasing energy need to support growing economies as well as demand for relatively clean energy amid concerns about climate change. According to the International Status and Prospects for Nuclear Power 2014 produced by the International Atomic Energy Agency (IAEA) in August 2014, globally, thirty three countries are considering, planning or starting nuclear power programmes, but have not connected the first nuclear power plant (NPP) to the grid (IAEA, 2014). These countries are classified as newcomer countries.

A decision to embark on nuclear power programme is a major undertaking for any country. It demands careful planning, preparation as well as investment in time, institutions and human resources (IAEA, 2015). In addition, nuclear power programme also requires country's long term knowledgeable commitments in ensuring that nuclear energy is utilised safely, securely and peacefully. In that relation, a holistic assessment on country's nuclear power programme is critical as it provides useful information on country's readiness to construct its first NPP. Such assessments will also build confidence that the countries are able to regulate, construct and operate nuclear power plants safely and sustainably.

The IAEA provides assistance to its Member States, particularly the newcomer country, in their efforts to use nuclear power in a safe and sustainable way. In 2007, IAEA produced a document titled "Milestones in the Development of a National Infrastructure for Nuclear Power" which serves as a principal guidance for countries that are considering or planning their first nuclear power plant (IAEA, 2007). The document detailed out the IAEA Milestone Approach which is outline in three phases, namely Pre-project (Phase 1), Project development (Phase 2) and Construction (Phase 3). Each phase is assigned with a unique milestone as shown in Fig. 1. The IAEA Milestone Approach also identified nineteen infrastructure issues as shown in Table 1, which are embedded in every phase (IAEA, 2015).

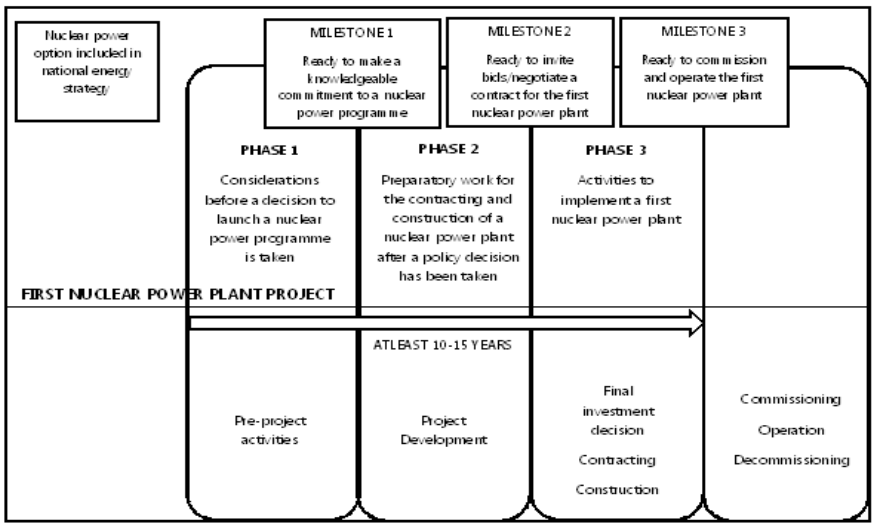

Fig. 1. IAEA Milestone Approach

These infrastructure issues cover both 'hard' infrastructure (i.e. electrical grid and sites, etc.) and 'soft' infrastructure (i.e. nuclear law, regulations, training, etc.) needed for a nuclear power programme (IAEA, 2015). Each of the 19 infrastructure issues requires specific actions at each phase. Completion of the actions in respective phase represents attainment of the associated milestone.

Table1. List of 19 infrastructure issues

19 infrastructure issues	
1. National Position	11. Stakeholder Involvement
2. Nuclear Safety	12. Site and Supporting Facilities

3. Management	13. Environmental Protection
4. Funding and Financing	14. Emergency Planning
5. Legislative Framework	15. Nuclear Security
6. Safeguards	16. Nuclear Fuel Cycle
7. Regulatory Framework	17. Radioactive Waste Management
8. Radiation Protection	18. Industrial Involvement
9. Electrical Grid	19. Procurement
10. Human Resource Development	

In 2000, the IAEA initiated the International Project on Innovative Nuclear Reactors and Fuel Cycle (INPRO) following a resolution during the 44th IAEA General Conference (IAEA, 2000). The formation of INPRO is driven by the fact that world's fast-growing energy needs constitute one of the major challenges in the 21st century. Therefore, nuclear energy is anticipated as an important energy supply option in the future that will help meeting increasing energy needs as well as supporting global initiative to reduce carbon emissions (INPRO, 2010). In 2001, the IAEA developed the INPRO Methodology that aims at assessing the sustainability of innovative nuclear energy systems (NES) until the 21st century. The INPRO Methodology evaluates a NES in a holistic manner covering seven assessment areas namely, economics, infrastructure, waste management, proliferation resistance, physical protection, environment and safety. In that relation, Nuclear Energy System Assessment (NESA) is introduced as a tool that used INPRO Methodology to assess long term NES sustainability.

This paper highlights important features of both methodologies in supporting deployment of nuclear power programme for a newcomer country.

GLOBAL TREND

Presently, there were 441 operational nuclear power reactors worldwide, with a total capacity of 382.9 GW(e) and 68 reactors were under construction (IAEA, 2016). According to World Nuclear Association (WNA, 2016), as of October 2016, there are over 45 newcomer countries. To date, INPRO has 41 Members, of which 15 Members have adopted the INPRO Methodology to assess nuclear energy system in the respective countries. Majority of newcomer countries applied the IAEA Milestone Approach.

The status of nuclear power programme in eleven selected newcomer countries is presented in Table 2. It shows that the status of nuclear power programme varies among these newcomer countries. Countries with the most advanced stage are Belarus and the United Arab Emirates (UAE), which have begun construction, and Turkey, which has ordered its first NPP but not yet started construction.

Table 2: Status of Nuclear Power Programme in eleven Selected Newcomer Countries

Newcomer Country	**Status of Nuclear Power Programme**
Bangladesh	Contracts signed, legal and regulatory infrastructure well-developed or developing
Belarus	2 power reactors under construction. National infrastructure to support nuclear power programme is developing
Egypt	Committed plans, legal and regulatory infrastructure developing
Indonesia	Well-developed plans but commitment pending

Jordan	Committed plans, legal and regulatory infrastructure developing
Kazakhstan	Well-developed plans but commitment pending
Malaysia	Active without decision
Thailand	Well-developed plans but commitment pending
Turkey	Has ordered its first NPP but not yet started construction. Legal and regulatory infrastructure well-developed or developing
United Arab Emirates	4 power reactors under construction. National infrastructure to support nuclear power programme is developing
Vietnam	Contracts signed, legal and regulatory infrastructure well-developed or developing

Table 3 shows the comparison of eleven newcomer countries approach in assessing their nuclear power programme. Those are active countries planning to introduce nuclear power programme and started preparing the appropriate infrastructure, including those with no final decision. It shows that only three performed the INPRO Methodology.

Table 3: Newcomer Countries Approaches in Supporting Deployment of Nuclear Power Programme

Newcomer Country	**Region**	**IAEA Milestone**	**INPRO Methodology**
Bangladesh	Asia	Yes	
Belarus	Europe	Yes	Yes
Egypt	Africa	Yes	
Indonesia	Asia	Yes	Yes
Jordan	Asia	Yes	
Kazakhstan	Asia	Yes	Yes
Malaysia	Asia	Yes	
Thailand	Asia	Yes	
Turkey	Europe	Yes	
United Arab Emirates	Asia	Yes	
Vietnam	Asia	Yes	

Table 3 shows that the IAEA Milestone approach is commonly used as the main guidance for newcomer countries to assess the state of their nuclear power programme. Only three countries adopted the INPRO Methodology. This may be explained by the fact that the IAEA Milestone is developed to cater the need of countries to construct their first nuclear power plant in the near term. The INPRO Methodology is focus to assess sustainability of nuclear energy system strategy in the long run that may include future technology options, which might not be the primary focus of newcomer country.

COMPARISON BETWEEN THE IAEA MILESTONE APPROACH AND THE INPRO METHODOLOGY

The IAEA Milestone approach and the INPRO Methodology are two assessment tools provided by the IAEA to its Member States to support deployment of nuclear power programme for newcomer country. Table 4 shows the comparison of important aspects of the IAEA Milestone Approach and the INPRO Methodology.

Table 4. Comparison between the IAEA Milestone Approach and the INPRO Methodology

Aspect	**IAEA Milestones Approach**	**INPRO Methodology**
Assessment Areas	Assessment in 19 infrastructure issues	Assessment in 7 main areas: Economics, Infrastructure Waste management Proliferation resistance Physical protection Environment Safety
Timeframe	Near term (within the upcoming 15–20 years)	Long term (50 to 100 years, or at least until the end of the 21st century)
Target users	5 relevant users: Decision makers, advisers and senior managers in government, industry and regulatory bodies in newcomer countries Countries that already have nuclear power Suppliers Nuclear energy agencies Utilities	3 relevant users: Nuclear technology developer Nuclear technology users, including researchers Prospective first time nuclear technology users
Methodology	3 phase approach, namely: Phase 1-Pre-project Phase 2-Project development Phase 3-Construction Each of the 19 infrastructure issues requires specific actions during each of the three phases. Completion of the actions in respective phase represents attainment of the associated milestone.	Identifies a set of Basic Principles, User Requirements, and Criteria in a hierarchical manner as the basis for the assessment of an innovative and sustainable nuclear system. The criteria comprise of indicators and acceptance limits. For newcomer, graded approach may be undertaken with the following sequence: i. Awareness NESA ii. Limited Scope NESA iii. Full Scope NESA
Implementation approach	The implementation approach with the following sequence: Familiarisation with the IAEA Milestone documents and identify key elements for assessment Perform self-assessment using the IAEA	It can be implemented in the following sequence: Assemble national team to get familiar with INPRO methodology and define scoping National team conduct self-assessment

	Milestone document Perform Integrated Nuclear Infrastructure Review (INIR) mission that can be conducted at each phase of IAEA Milestone to review self-assessment findings Formulate and implement action plan to close gaps identified during INIR mission	using INPRO Methodology Perform IAEA review mission to review the self-assessment findings Formulate and implement action plan to close gaps identified during IAEA review mission

The IAEA Milestone Approach and the INPRO Methodology can be used to assess the infrastructure development to support the deployment of first NPP in newcomer countries. Both methodologies required the energy system planning to be performed as pre-requisite in order to identify the clear role of nuclear energy in the respective country's energy mix. The main issues related to developing nuclear energy are covered under both methodologies, even though the number of assessment areas differs (IAEA, 2010). Both methodologies initiate the implementation with familiarisation of methodology, follow with self-assessment activity, IAEA review mission and lastly, formulation of action plan to close the gaps.

The IAEA Milestone Approach focuses in near term deployment of first nuclear power plant, which covers the period of 10 to 15 year. Meanwhile, the INPRO Methodology can be used to assess NES being considered for deployment in the near term as well as longer term. The IAEA Milestone Approach outlines 3 phases for the deployment of first NPP. Each phase requires specific actions in order to effectively address the 19 infrastructure issues and attainment of associated milestone. However, the INPRO methodology adopted a hierarchy of demands (basic principles, user requirements and criteria) directed at different stakeholders in a nuclear power programme.

RELATIONSHIP BETWEEN THE IAEA MILESTONE APPROACH AND THE INPRO METHODOLOGY

The newcomer country has an option to apply either the IAEA Milestone approach or the INPRO Methodology or both. As shown in Table 3, some countries namely, Belarus, Indonesia and Kazakhstan have adopted both methodologies to support the deployment of the first nuclear power programme in their country.

Fig. 2 shows the relationship between the IAEA Milestone approach and the INPRO Methodology. It shows that the INPRO methodology are tools for long term considerations related to the sustainability of a NES, while the IAEA Milestones approach involves near term activities which are required to deploy the first nuclear power plant in the country. Both methodologies provide a systematic approach for a country to assess its preparation to implement peaceful nuclear power safely, securely, and efficiently.

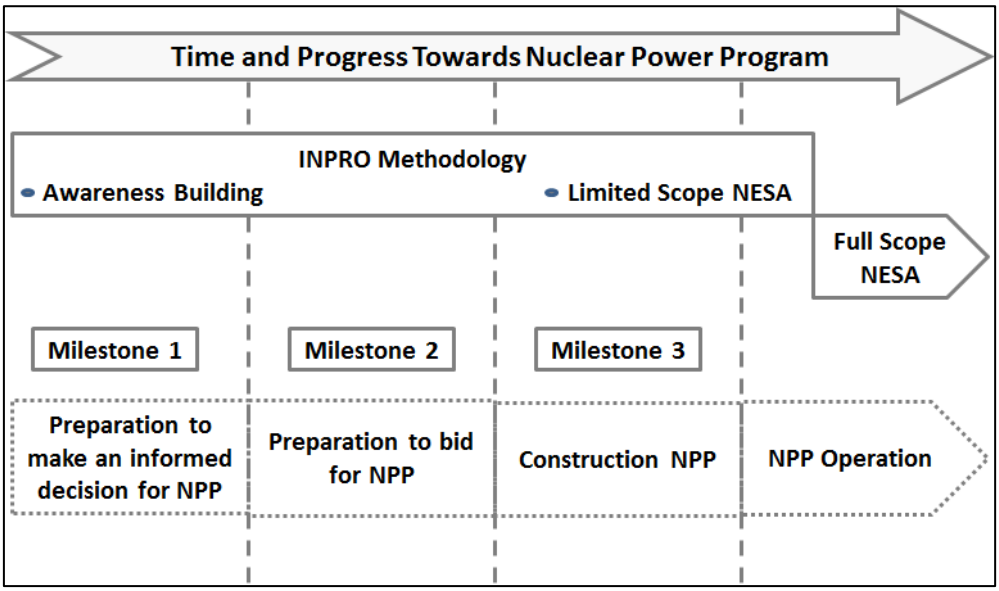

Fig. 2. Relationship between the IAEA Milestone approach and the INPRO Methodology (IAEA, 2010)

The Milestones approach primarily considers the time period up to 20 years from a decision was made, to explore the possibility of including nuclear power into a national grid until the operation of a first nuclear power plant.

The INPRO Methodology covers the period of 50 to 100 year into the future and may be undertaken on a periodic basis after a first nuclear power plant has been built and commissioned.

SUMMARY

In summary, the IAEA Milestone Approach focuses for near term while the INPRO Methodology focuses for long term assessment to support the deployment of first NPP in newcomer countries. Depending on newcomer country's priority and resources, both methodologies can be performed either separately or in-parallel.

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