

SUSTAINABILITY ASSESSMENT OF INFRASTRUCTURE FOR SMALL MODULAR REACTOR DEPLOYMENT IN VIET NAM USING INPRO METHODOLOGY

Chi Thanh Tran¹, An Trung Nguyen¹, Thi Huong Vo², Nhu Viet Ha Pham²

¹Viet Nam Atomic Energy Institute (VINATOM), Hanoi, Viet Nam

²Institute for Nuclear Science and Technology, VINATOM, Hanoi, Viet Nam

ABSTRACT

Small modular reactors (SMRs) are being considered as a potential solution that can help Viet Nam reach carbon neutrality by 2050. However, most SMRs are still in the design or licensing stage, leading to challenges to assess their sustainability. According to the INPRO methodology, comprehensive sustainability assessment of SMRs is necessary, particularly if an embarking country plans to build and operate them for harnessing nuclear power. Among the assessment areas for SMRs, assessment of infrastructure is essential to ensure a country shall be able to deploy SMRs without excessively investing in national infrastructure. Thus, this work performed a limited scope assessment of infrastructure for SMR deployment in Viet Nam using the INPRO methodology. It was based on the infrastructure previously established for the former nuclear power plant (NPP) projects and aimed to pinpoint infrastructure issues which need to be solved to facilitate SMR deployment in Viet Nam. National energy planning and policy was also taken into account to identify candidate SMR technologies which can be timely deployed for supporting the decarbonization target. The results could provide policy makers with initial recommendations on how to develop adequate infrastructure for future SMR introduction in Viet Nam. Future works are being planned for the respective full scope assessment.

Keywords: small modular reactor, embarking country, INPRO methodology, infrastructure

I. INTRODUCTION

At the UN Climate Summit COP26 held in Glasgow (2021), the Vietnamese Government committed to eliminating coal by the 2040s and achieving the net zero target by 2050. Then, in May 2023, the Government approved the National Power Development Plan 8 (PDP8) for the period of 2021-2030 with a vision to 2050 for clean energy transition [1]. In the PDP8, it is planned to increase the share of renewable energy up to around 70% of total capacity while moving away from coal, showing a strong transition strategy to renewable energy and carbon neutrality. Nuclear power is not mentioned as an option in the PDP8, however, it is still being studied and reserved for future considerations as a clean energy source that can be deployed at an appropriate time [1-3].

It can be seen that implementing the PDP8 would lead to high integration of variable renewable sources during the period of 2031-2050 while phasing out coal. In this regard, nuclear power is being recommended to be carefully considered in the next PDP of Viet Nam to help replace coal and complement renewable energy. In particular, SMRs are being considered as potential energy sources that can be deployed to help Viet Nam reach the net zero target by 2050. Nevertheless, although SMRs have various salient features such as passive safety, modularity, factory fabrication, transportable and flexibility, most of them are still in the design or licensing stage and only a few are being constructed or operated in the world. Therefore, according to the INPRO methodology for innovative and advanced nuclear energy systems, comprehensive sustainability assessment of SMRs is necessary, especially if an embarking country plans to build and operate them for harnessing nuclear power [4-6]. Among the INPRO assessment areas encompassing economics, environmental impact, waste management, proliferation resistance, safety and infrastructure, assessment of infrastructure is essential to ensure that a country shall be able to deploy SMRs without excessively investing in national infrastructure [6-8].

For that reason, this work performed a limited scope sustainability assessment of infrastructure for possible future SMR deployment in Viet Nam using the INPRO methodology. The assessment was based on the available infrastructure previously established for the former Ninh Thuan NPP projects with large power reactors [9-11] and aimed to identify current infrastructure issues which need to be solved to facilitate SMR deployment in Viet Nam. The above-mentioned energy planning and policy of Viet Nam for the period of 2021-2050 was also considered in the assessment of infrastructure to account for selection of potential candidate SMR technologies which can be timely deployed in support of reaching net zero by 2050. The results are expected to provide policy makers with initial recommendations on how to develop adequate infrastructure for future SMR deployment in Viet Nam.

II. ASSESSMENT METHODOLOGY

The INPRO Basic Principle (BP) for assessment of the infrastructure states that a country shall be able to adopt, maintain or enlarge a nuclear energy system (NES) for the supply of energy without making an excessive investment in national infrastructure [7]. It provides various options to assess the national infrastructure necessary for deploying a sustainable nuclear power programme, especially when a country is setting up its first NPP.

Specifically, it comprises six user requirements (UR) with multiple criteria (CR) as shown in Fig. 1. The details of the assessment methodology for the infrastructure area can be found in Ref. [7].

In the present study, we perform an infrastructure assessment using the INPRO methodology in this area to ensure an adequate infrastructure be available for possible future SMR deployment in Viet Nam. Our assessment will be based on the existing nuclear infrastructure that was established for the former Ninh Thuan NPP projects. In line with these former NPP projects for building light water reactors and the experience our nuclear community has with the Dalat nuclear research reactor and the new research reactor to be built under the CNST (Center for Nuclear Science and Technology) project (both of these research reactors are light water cooled), we consider the light water cooled SMRs as the main candidate SMR technology for possible timely deployment in Viet Nam during 2031-2050 supporting the carbon neutrality target, given their technological and commercial readiness levels. Hence, this SMR technology is selected in our assessment. Other candidate SMR technologies may be evaluated in a separate study from this work. The main input data were taken from the Agency's Integrated Nuclear Infrastructure Review (INIR) Mission for Viet Nam during 2012-2014 [10-11] with necessary updates from the current status of the national infrastructure. It is worth noting that the INIR team provided 42 recommendations and 14 suggestions in 17 of the 19 infrastructure issues as specified in the Milestones Approach [12].

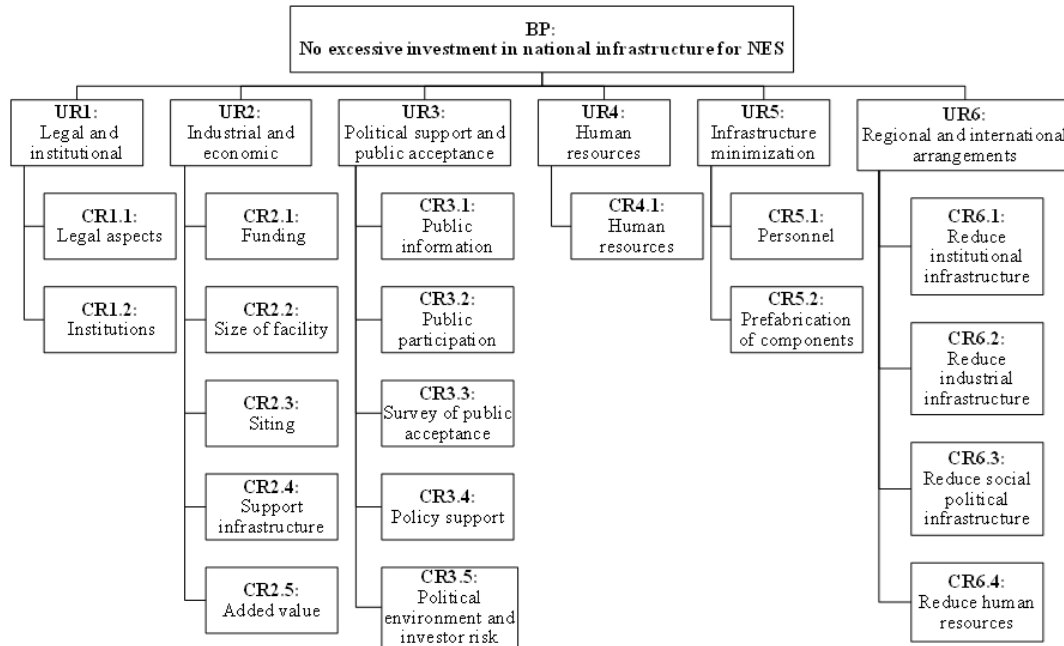


Fig. 1. Basic principle and associated UR for infrastructure assessment

III. RESULTS AND DISCUSSION

III.1 USER REQUIREMENT UR1: LEGAL AND INSTITUTIONAL INFRASTRUCTURE

In this study, the fulfilment of UR1 was checked by evaluating two criteria, CR1.1 and CR1.2, in which each CR has one indicator (IN) and one acceptance limit (AL) as given in Table 1.

Criterion CR1.1 – Legal aspects

To enable the assessment of criterion CR1.1, INPRO has defined a set of the evaluation parameters (EP) for IN1.1 as follows.

- *Evaluation parameters EP1.1.1: Scope of nuclear law*
- *Evaluation parameter EP1.1.2: Adequacy of nuclear law*
- *Evaluation parameter EP1.1.3: International legal arrangements*
- *Evaluation parameter EP1.1.4: Completeness and adequacy of regulations and guidelines*

The major results and findings were obtained as below.

Acceptability of EP1.1.1 and EP1.1.2 is confirmed assuming that the Atomic Energy Law [13] will be revised, taking into account the recommendations of the IAEA INIR team, e.g., “Viet Nam should promptly revise and promulgate its Atomic Energy Law to provide the sound legal framework addressing safety, adequate provisions on emergency preparedness and response, radioactive waste and spent fuel management, decommissioning,

security, safeguards and civil liability for nuclear damage, as well as establishing an independent regulatory body to support the nuclear power programme and delineation of roles and responsibilities.” [11].

Acceptability of EP1.1.3 is mostly satisfied. Viet Nam has been a party to all of the international instruments as required for EP1.1.3 excluding the Espoo convention. Also, these signed international instruments have been incorporated into the national nuclear legislation of the country.

Acceptability of EP1.1.4 is fulfilled. It is because Viet Nam had a plan for promulgating legal documents related to nuclear power in the period 2013-2020 that was approved in 2013 by the Prime Minister (PM). Under this plan, regulations (circulars) have been issued by MOST (Ministry of Science and Technology) in some areas such as safety, security, emergency preparedness, siting and waste. The relevant legislation was expected to be developed, revised and promulgated in due time for deploying the former NPP projects.

Since that time, Viet Nam has continued to work on revising its national nuclear legislative framework and the areas identified in the recommendations of the INIR team will be implemented in the future amendment of the Atomic Energy Law [10-11].

As a result, the criterion CR1.1 is mostly met and the overall assessment of CR1.1 is provided in Table 1.

Table 1. Infrastructure Criterion for User Requirement 1 (UR1)

Criterion	Indicator (IN) and Acceptance Limit (AL)	Assessment
UR1: Legal and institutional infrastructure		
<i>An adequate legal framework should be established to cover issues of nuclear liability, safety and radiation protection, environmental protection, control of operation, waste management and decommissioning, security and non-proliferation</i>		
CR1.1: Legal aspects	IN1.1: Status of legal framework	Overall assessment 1.1: The national legal framework and associated regulations/guidelines necessary for the former Ninh Thuan NPP projects were basically established in Viet Nam according to the international standards. The Atomic Energy Law is recommended to be amended and the missing regulations must be timely issued before startup of planned NPP projects (including SMRs) in future.
	AL1.1: Legal framework has been established in accordance with international standards	
CR1.2: Institutions	IN1.2: Status of State organizations with responsibilities for safety and radiation protection, environmental protection, control of operation, waste management and decommissioning, emergency preparedness and response, security and non-proliferation	Overall assessment 1.2: The state organizations as required for a nuclear power program have been basically established in Viet Nam during the former NPP projects in accordance with international standards. This organization structure can be utilized and optimized for future SMR deployment in the country.
	AL1.2: State organizations have been established, in accordance with international standards	

Criterion CR1.2: Institutions

To assess important attributes of the regulatory body, the following evaluation parameters need to be evaluated.

- *Evaluation parameter EP1.2.1: Independence of the regulatory body*
- *Evaluation parameter EP1.2.2: General functions of the regulatory body*
- *Evaluation parameter EP1.2.3: Review of safety regime*
- *Evaluation parameter EP1.2.4: Review of emergency preparedness*
- *Evaluation parameter EP1.2.5: Review of nuclear security regime*
- *Evaluation parameter EP1.2.6: Review of safeguards regime*
- *Evaluation parameter EP1.2.7: Management system*

Acceptability of EP1.2.1 is confirmed if the Atomic Energy Law be amended as previously mentioned. Namely, the structure of regulatory system was being re-considered during the amendment of the Atomic Energy Law to ensure its competency and independence. The roles and responsibilities of regulatory organizations are defined in the Atomic Energy Law. Viet Nam has a system of state authorities to manage atomic energy and NPPs such as the nuclear regulatory body (VARANS), MOST, MOIT (Ministry of Industry and Trade), MONRE (Ministry of Natural Resources and Environment), MOC (Ministry of Construction); and their activities are not integrated. For NPPs, there are various regulators: + Site and FS (Feasibility Study) approval: PM; + Nuclear and

radiation safety: MOST; + Environment: MONRE; + Operation: MOIT; + QA/QC: MOC. VARANS is not an independent regulatory body because it is a member of MOST and joining in compiling regulations on management, supervision and licensing, in which other authorities participate such as MOIT, MONRE, MOC, etc.

Acceptability of EP1.2.2 is fulfilled. General functions of the radiation and nuclear safety agency under MOST are set out in Article 8 of the Atomic Energy Law. The general functions of other regulatory organizations for NPPs are also defined in the Atomic Energy Law.

Acceptability of EP1.2.3 is met. It is recalled that the first Mission of IAEA IRRS (Integrated Regulatory Review Service) to Viet Nam was successfully completed in September 2009. A follow-up IRRS was conducted in September 2014. Viet Nam has taken into account the recommendations and suggestions of the 1st IAEA IRRS Mission and the follow-up IRRS and made the progress in its regulatory framework development.

Acceptability of EP1.2.4 is satisfied. Emergency Preparedness Review (EPREV) of existing arrangement was implemented in April 2012 by an IAEA expert mission. Subsequently, the PM approved Decision No. 884/QĐ-TTg dated June 16, 2017 promulgating the National Nuclear and Radiation Incident Response Plan and MOST issued Circular 12/2023/TT-BKHCH dated 30 June 2023 regulating preparation and response to radiation and nuclear incidents, preparation and approval of radiation and nuclear incident response plans. In case of deploying SMRs, the EPZ (Emergency Planning Zone) for SMRs can be determined using the graded approach [14] and the national emergency preparedness and response plan should be updated.

Acceptability of EP1.2.5 is confirmed given the followings: (a) The PM of Viet Nam in November 2014 approved the Master Plan for Nuclear Power Infrastructure Development till 2020, instructing relevant Ministries and agencies to carry out their respective duties to ensure nuclear security and safety; (b) In November 2015, Viet Nam invited an IAEA mission to introduce the International Physical Protection Advisory Service (IPPAS) with the aim of utilizing this service for a comprehensive analysis of Viet Nam's physical protection infrastructure; and (c) An IAEA team concluded an International Security Advisory Mission (INSServ) to Viet Nam in March 2023. It is the first of this kind to Viet Nam conducted at the request of the Government and hosted by VARANS from 19 to 31 March 2023. The team said the country has made progress towards establishing an effective national nuclear security regime for nuclear or other radioactive material out of regulatory control. It encouraged Vietnamese authorities to further integrate existing systems and measures into a national nuclear security policy.

Acceptability of evaluation parameter EP1.2.6 is verified. In March 2012, the IAEA OLA (Office of Legal Affairs) Mission reviewed the Atomic Energy Law and gave the recommendations to amendment of the Safeguard Provisions in the Law. Circular No. 17/2013/TT -BKHCH, dated 30 July 2013, guides the implementation of regulation regarding declaration of Additional Protocol (AP) between Viet Nam and IAEA on applying safeguards according to NPT.

Acceptability of EP1.2.7 is fulfilled. EVN (Vietnam Electricity) works to a management system certified to ISO 9001-2008 but has yet to develop plans to identify the enhancements needed. VARANS uses a management system certified to ISO 9001-2008, was studying the IMS (Integrated Management Systems), and intends to develop plans to identify the enhancements needed. VINATOM has experience with a management system for the research reactor and plans to develop its own IMS as a TSO (Technical Support Organization) in the future.

Consequently, the criterion CR1.2 is mostly met and the overall assessment for CR1.2 is given in Table 1.

Thus it can be concluded that UR1 is mostly satisfied.

III.2 USER REQUIREMENT UR2: ECONOMIC AND INDUSTRIAL INFRASTRUCTURE

The fulfilment of UR2 was checked by evaluating five criteria as given in Table 2.

Table 2. Infrastructure Criteria for User Requirement 2 (UR2)

Criteria	Indicator (IN) and Acceptance Limit (AL)	Assessment
UR2: Industrial and economic infrastructure		
<i>The industrial and economic infrastructure of a country with an NES should be adequate to support the project throughout the complete lifetime of the nuclear power programme, including planning, construction, operation, decommissioning and related waste management activities</i>		
CR2.1: Funding of infrastructure	IN2.1: Funding needed for the infrastructure of a nuclear power programme	Overall assessment 2.1: For the former NPP projects, the Master Plan for nuclear power infrastructure development up to 2020 was approved by the Government. It is recommended this plan be revised and updated for use in case of future SMR deployment.
	AL2.1: Sufficiently available to cover the nuclear power programme	

CR2.2: Size of nuclear facility	IN2.2: Size of nuclear installation	Overall assessment 2.2: This criterion is mostly met. The country should establish a clear plan for the final radioactive waste disposal. It is suggested to revise the PDP8 and Master Plan VIII to evaluate the impacts of including SMRs in the energy mix on the overall grid stability.
	AL2.2: Matches local needs	
CR2.3: Siting	IN2.3: Process of siting a nuclear facility	Overall assessment 2.3: Acceptability of CR2.3 is confirmed. For SMR deployment scenarios, a site may be selected in a different location with less strict requirements, but the practice and experience from site selection and evaluation for the former NPP projects can be inherited.
	AL2.3: Siting process has taken safety, security and environmental requirements into account in accordance with international standards	
CR2.4: Support infrastructure	IN2.4: Availability of infrastructure to support owner/operator	Overall assessment 2.4: As above mentioned, the country had a master plan for developing national nuclear infrastructure for the former NPP projects. It can be foreseen that the support infrastructure of the country should be reassessed and minimized in case of SMR deployment considering their novel features such as modularity, factory fabrication and transportability.
	AL2.4: Internally or externally available	
CR2.5: Added value	IN2.5: Added value of a nuclear power programme to society	Overall assessment 2.5: Although the country had clear strategy and actions on public information and communication for the former NPP projects. The added value of the nuclear power programme has not yet been quantitatively studied. Thus it is suggested to carry out such a study in case of introducing SMRs.
	AL2.5: Added value > infrastructure investment by government necessary to support nuclear power programme	

Criterion CR2.1: Funding of infrastructure

- *Evaluation parameter EP2.1.1: Funding of support infrastructure provided by national industry*
- *Evaluation parameter EP2.1.2: Funding of infrastructure provided by government.*

Acceptability of EP2.1.1 and EP2.1.2 is satisfied as they are covered in the Master Plan for nuclear infrastructure development in Viet Nam up to 2020 (PM Decision No. 2241/QĐ-TTg dated 11 December 2014) and the associated activities performed for implementing this master plan for the former Ninh Thuan NPP projects. For instance, EVN, as the NPP project owner, was responsible for developing the infrastructure outside the NPP fence, and the project on resident resettlement for NPP projects in Ninh Thuan was implemented by Ninh Thuan People's Committee.

Hence, the criterion CR2.1 is met and overall assessment for this criterion is shown in Table 2.

Criterion CR2.2: Size of nuclear facility

- *Evaluation parameter EP2.2.1: Size of NPP*
- *Evaluation parameter EP2.2.2: Size of nuclear fuel cycle facilities (other than NPPs)*

Acceptability of EP2.2.1 is confirmed given that the associated requirements were addressed at the time of deploying the former Ninh Thuan NPP projects.

Acceptability of EP2.2.2 is partially met. It is because the sizes of these facilities were not clearly defined for the former NPP projects. However, according to the Atomic Energy Law, the Ministry of Construction (MOC) is responsible for final disposal of low and intermediate radioactive waste.

Thus, CR2.2 is mostly fulfilled and its overall assessment is provided in Table 2.

Criterion CR2.3: Siting

Acceptability of CR2.3 is confirmed as the sites were thoroughly selected and evaluated, in accordance with the international standards, for the former Ninh Thuan NPP projects. Thus, CR2.3 is met and its overall assessment is shown in Table 2.

Criterion CR2.4: Support infrastructure

- *Evaluation parameter EP2.4.1: Survey of the existing capabilities of the national industry*
- *Evaluation parameter EP2.4.2: Plan for the participation of national industry in nuclear power programme.*
- *Evaluation parameter EP2.4.3: Infrastructure provided by the government*

Acceptability of EP2.4.1-EP2.4.3 (CR2.4) is met as the followings were obtained for the former NPP projects: (a) The Subcommittee of the State Steering Committee on Development of Nuclear Power Industry has conducted investigations and surveys to find out what the capabilities are in Vietnamese companies; (b) The Government has planned to improve the capabilities of national industries to gradually meet the requirements of participation in building, manufacturing and installing NPP; (c) PM Decision No. 2241/QĐ-TTg dated 11 December 2014 as above mentioned. Thus, CR2.4 is fulfilled and its overall assessment is given in Table 2.

Criterion CR2.5: Added value

The “National Project on Public Information and Communication for the Development of Nuclear Power in Viet Nam up to 2020” was approved by the PM in February 2013. The associated activities were performed by the relevant ministries and organizations. However, quantitative analysis and evaluation of the added value of the nuclear power programme to the society has not yet been performed. CR2.5 is therefore considered partially met and its overall assessment is presented in Table 2.

Overall, UR2 is considered mostly met.

III.3 USER REQUIREMENT UR3: POLITICAL SUPPORT AND PUBLIC ACCEPTANCE

The fulfilment of UR3 was checked by evaluating five criteria as provided in Table 3.

Table 3. Infrastructure Criteria for User Requirement 3 (UR3)

Criteria	Indicator (IN) and Acceptance Limit (AL)	Assessment
UR3: Political support and public acceptance		
<i>Adequate measures should be taken to achieve and maintain public acceptance of an NES being planned or in operation to enable a government policy commitment to support the deployment and operation of the system</i>		
CR3.1: Public information	IN3.1: Information on nuclear power programme provided to public	Overall assessment 3.1: CR3.1 was mostly met for the former NPP projects. It is worth noting that the government of Viet Nam had a clear policy on public information and communication. In case the country decides to resume the nuclear power program, it is suggested to resume the past activities on public information and communication.
	AL3.1: Sufficient according to national requirements, taking into account international practice	
CR3.2: Public participation	IN3.2: Participation of public in decision making process on a nuclear power programme	Overall assessment 3.2: CR3.2 was not assessed in this study. However, it is suggested that the public opinions should be timely acquired and integrated in the national nuclear power programme.
	AL3.2: Sufficient according to national requirements, taking into account international practice	
CR3.3: Survey of public acceptance	IN3.3: Public acceptance of nuclear power	Overall assessment 3.3: The political risk of policy support can be learnt the former NPP projects and such lesson may be taken into account when the country decides to deploy SMRs. Particularly, public acceptance and political support can be easier to be obtained for SMRs as compared to large reactor projects.
	AL3.3: Sufficient to expect that the political risk of policy support for nuclear power is acceptable	
CR3.4: Policy support	IN3.4: Government policy regarding nuclear power	Overall assessment 3.4: There are positive signals that nuclear power and its innovations such as SMRs can play a role in Viet Nam’s energy transition to reach the net zero target. It is recommended to carefully consider the nuclear option in the energy mix to help phase out fossil fuels and complement renewable energy for grid stability.
	AL3.4: Policy is supportive of nuclear power	
CR3.5: Political environment and investor risk	IN3.5: Long term political commitment to a nuclear power programme	Overall assessment 3.5: This criterion is not assessed as the country currently has no plans for the building NPPs. However, in the case of SMR deployment, it can be completed in significantly shorter time and lower budget, thereby reducing the political environment and investor risk as compared to when deploying large NPP projects.
	AL3.5: Commitment sufficient to enable a return of investment	

CR3.1: Public information

- *Evaluation parameter EP3.1.1: Communication of benefits of nuclear power to the public*
- *Evaluation parameter EP3.1.2: Information on the operation of nuclear facilities*
- *Evaluation parameter EP3.1.3: Addressing concerns raised by the public regarding nuclear installations*
- *Evaluation parameter EP3.1.4: Use of communication experts to match information to the needs of public audiences*

Acceptability of EP3.1.1 is mostly confirmed as the public attitude and knowledge on nuclear power surveys conducted in 2012 by VAEA showed that people are awareness of the preparation for the former NPP projects and of the necessity of the projects for the electricity generation for social economic development.

Acceptability of EP3.1.2 is confirmed as the policy for this requirement was covered in the PM's Decision No 370/QĐ-TTg dated 28 February 2014 approving the Project of Public Information and Communication for the Development of Nuclear Power up to 2020.

Acceptability of EP3.1.3 is fulfilled as Vietnamese people, especially local people around the NPP sites, were provided with information related to the former Ninh Thuan NPP projects and their concerns about the nuclear safety, especially after accident of Fukushima Daiichi NPP in Japan, were properly addressed.

Acceptability of EP3.1.4 is confirmed as the Sub-Committee on Training and Public Information and Communication as well as the relevant organizations, which are responsible for public information on nuclear power, used both Vietnamese and international communication experts.

Thus, the criterion CR3.1 is mostly met.

Criterion CR3.2: Public participation

- *Evaluation parameter EP3.2.1: Appropriateness of participation process*
- *Evaluation parameter EP3.2.2: Acceptability of participation process*

This criterion was not assessed in this study due to lacking of the information by the authors.

Criterion CR3.3: Survey of public acceptance

This criterion is largely satisfied as previously discussed in CR3.1.

Criterion CR3.4: Policy support

Although nuclear power is not mentioned in the PDP8, it is still implied as clean energy source for future considerations of the country to help reach the net zero target [1-3]. Thus, CR3.4 is considered partially met.

Criterion CR3.5: Political environment and investor risk

This criterion is not assessed as the country currently has no plans for the building NPPs.

As a consequence, UR3 is partially met and overall assessment for CR3.1-3.5 is given in Table 3.

III.4 USER REQUIREMENT UR4: HUMAN RESOURCES

The fulfilment of UR4 was checked by evaluating one criterion as shown in Table 4.

Table 4. Infrastructure Criterion for User Requirement 4 (UR4)

Criterion	Indicator (IN) and Acceptance Limit (AL)	Assessment
UR4: Human resources		
<i>The necessary human resources should be available to enable all responsible parties involved in a nuclear power programme to achieve safe, secure and economical operation of the NES during its lifetime</i>		
CR4.1: Human resources	IN4.1: Availability of adequate human resources to establish and operate an NES	Overall assessment 4.1: Viet Nam has basically established a national programme as well as an education and training system on human resources development for the former NPP projects. Such the programme and system can be readily reactivated and updated for use in case of deploying SMRs.
	AL4.1: Sufficient according to international experience	

Criterion CR4.1: Human resources

- *Evaluation parameter EP4.1.1: Educational and training system for human resources needed in a nuclear power programme*
- *Evaluation parameter EP4.1.2: Adequate staff in nuclear institutions*
- *Evaluation parameter EP4.1.3: Attractiveness of the nuclear power sector for future employees*

Acceptability of EP4.1.1 is confirmed as the educational and training system for human resources needed in a nuclear power programme was basically established for the former Ninh Thuan NPP projects. After nearly a decade from postponing the former NPP projects, it can be easier to reactivate this system if the country decides to deploy the SMR based NPP projects owing to their smaller scales as compared to the large reactor ones.

Acceptability of EP4.1.2 is mostly satisfied when deploying the former NPP projects, e.g., in planning of human resources development for the VARANS (the regulatory body) and EVN (the utility).

Acceptability of EP4.1.3 is fulfilled as for the former NPP projects, to address recruitment and retention incentives, a number of initiatives have been taken by the Government and associated ministries and organizations. For example, the Government promulgated a decree on regulating preferential policies in support of people being dispatched for training in the field of atomic energy (October 2013) and assigned MOST to formulate a policy for preferential treatment to attract highly qualified specialists and experts working in the atomic energy field.

Consequently, CR4.1, i.e., UR4 is mostly satisfied and its overall assessment is provided in Table 4.

III.5 USER REQUIREMENT UR5: MINIMIZATION OF INFRASTRUCTURE

The fulfilment of UR5 was checked by evaluating two criteria and the results are shown in Table 5. Consequently, UR5 is partially met.

Table 5. Infrastructure Criterion for User Requirement 5 (UR5)

Criterion	Indicator (IN) and Acceptance Limit (AL)	Assessment
UR5: Minimization of infrastructure		
<i>The NES should be designed to minimize the necessary infrastructure for a nuclear power programme</i>		
CR5.1: Personnel	IN5.1: Human resources needed for operation, maintenance and repair and decommissioning	Overall assessment 5.1: This criteria is not assessed as currently there is no available information regarding the implementation of automation to reduce operational personnel for SMRs as discussed in Refs. [6, 8].
	AL5.1: Amount of human resources is reduced in comparison to an existing facility.	
CR5.2: Prefabrication of components	IN5.2: Extent of prefabrication of components	Overall assessment 5.2: This criteria is met when deploying SMRs as they are fabricated as modules in factory in the country of origin and transported to the construction site. However, the host country should carefully consider for a trade-off between this aspect and its expected participation of the national industry in the SMR projects.
	AL5.2: Extent is increased in comparison to an existing facility.	

III.6 USER REQUIREMENT UR6: REGIONAL AND INTERNATIONAL ARRANGEMENTS

The fulfilment of UR6 was checked by evaluating four criteria and the results are given in Table 6. As a result, UR6 is fulfilled.

Table 6. Infrastructure Criterion for User Requirement 6 (UR6)

Criteria	Indicator (IN) and Acceptance Limit (AL)	Assessment
UR6: Regional and international arrangements		
<i>Regional and international arrangements should provide options that enable a country with an NES to minimize the infrastructure for a nuclear power programme</i>		
CR6.1: Options to reduce institutional infrastructure	IN6.1: Have regional and/or international arrangements to reduce the institutional infrastructure been considered?	Overall assessment 6.1: For SMR deployment scenarios, simplification and international harmonization of licensing should be considered to reduce investment in institutional infrastructure and facilitate the deployment, such as by using the graded approach, harmonization of the prescriptive and goal-setting (performance-based) regulatory approaches [14] and adoption of the standards of the supplier country. Thus, CR6.1 is fulfilled.
	AL6.1: Yes	

Criteria	Indicator (IN) and Acceptance Limit (AL)	Assessment
CR6.2: Options to reduce industrial infrastructure	IN6.2: Have regional and/or international arrangements to reduce the industrial infrastructure been considered?	Overall assessment 6.2: These options should be considered when deploying SMRs in Viet Nam, e.g., the type of contracts or the way of managing spent fuel to reduce the industrial infrastructure. Hence, CR6.2 is satisfied.
	AL6.2: Yes	
CR6.3: Options to reduce social political infrastructure	IN6.3: Have regional and/or international arrangements to reduce the social political infrastructure been considered?	Overall assessment 6.3: The country should consider enhancing regional/international cooperation to help increase public acceptance and trust in nuclear power and facilitate the SMR deployment if planned. CR6.3 is therefore met.
	AL6.3: Yes	
CR6.4: Options to reduce human resources	IN6.4: Have regional and/or international arrangements to reduce human resources been considered?	Overall assessment 6.4: Viet Nam has been in good collaboration with various advanced nuclear countries and international organizations such as IAEA, EU, Russia, Japan, Korea, US, etc. for supporting its human resources development. In case of deploying SMRs, such collaborations can be readily enhanced. CR6.4 is thus fulfilled.
	AL6.4: Yes	

IV. CONCLUDING REMARKS

This paper performed a limited scope assessment of infrastructure for possible future deployment of SMRs in Viet Nam using the INPRO methodology. The current energy planning of the country for energy transition to reach the net zero target by 2050 was considered in this assessment. In this regard, the main candidate SMR technology for timely deployment in Viet Nam during the period of 2031-2050 was identified as light water cooled SMRs due to their technological and commercial maturity levels. Accordingly, the overall assessment results are positive, showing that the currently existing national nuclear infrastructure of Viet Nam which was previously established for the former NPP projects can be utilized and adapted for deploying light water cooled SMRs. In particular, the country is recommended to prepare the legal and regulatory framework for SMRs to cover the novel features of SMRs such as small size and footprint, types, modularity, factory fabrication, transportable, scalability, and deployment in remote areas. Correspondingly, early joining international collaborations for simplification and harmonization of licensing frameworks, codes and standards could be beneficial for future SMR deployment in Viet Nam. As a result, this study can be considered valuable to provide policy makers with initial recommendations on how to develop adequate infrastructure for future SMR introduction in Viet Nam. Further works will be conducted to improve the results of this assessment by analysing more comprehensive and detailed data of the national infrastructure. In addition, a full-scope assessment of the sustainability (covering the six assessment areas: economics, environmental impact, waste management, proliferation resistance, safety and infrastructure) of deploying SMRs in Viet Nam based on the INPRO methodology is being planned.

ACKNOWLEDGEMENT

The authors would like to express sincere thanks to the INPRO Section of the Agency for guidance in the use of the INPRO methodology. We also highly appreciate the Viet Nam Atomic Energy Agency for providing the input data for this study regarding the Agency's INIR Mission for Viet Nam during the period of 2012-2014.

REFERENCES

1. PM Decision No. 500/QD-Ttg approving the National Power Development Plan for the 2021-2030 period, with a vision to 2050 (PDP8), dated 15 May 2023; followed by PM Decision 262/QD- TTg dated 1 April 2024 approving the Plan to implement the PDP8.
2. PM Decision No. 896/QD-TTg approving the National Strategy for Climate Change until 2050, dated 26 July 2022.
3. PM Decision No. 893/QD-TTg approving the National Energy Master Plan for the period of 2021 - 2030, with a vision to 2050 (Master Plan VIII), dated 26 July 2023; followed by PM Decision No. 338/QD-TTg approving a plan to implement the Master Plan VIII, dated 24 April 2024.
4. G. Ilhan, C. Scherer, B. Boyer, Recent Applications of the INPRO Methodology for Innovative and Advanced Nuclear Energy Systems, Proceedings of the INMM & ESARDA Joint Annual Meeting, May 21-25, 2023.

5. IAEA, INPRO Assessment of the Planned Nuclear Energy System of Belarus: A Report of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), IAEA-TECDOC-1716, 2013.
6. R. Bikmurzin, C. Scherer, B. Boyer, Using INPRO Methodology for a Sustainability Assessment of Advanced and Innovative Small Modular Reactors, Proceedings of the INMM & ESARDA Joint Annual Meeting, May 21-25, 2023.
7. IAEA, INPRO Methodology for Sustainability Assessment of Nuclear Energy Systems: Infrastructure, INPRO Manual, IAEA Nuclear Energy Series No. NG-T-3.12, 2014.
8. J.M.C. Johari, J.S. Pane, W., Dewayatna, et al., Evaluating the Performance of Indonesia's Nuclear Energy Program Using INPRO Methodology, KERNTECHNIK: Independent Journal for Nuclear Engineering, (2023).
9. C.T. Tran, V.H. Le, B.N. Tran, N.V.H. Pham, Chapter 6 - Atomic Energy, in Viet Nam Energy Outlook (2022 Edition), Power Engineering Consulting Joint Stock Company 2 (PECC2), ISBN: 978-604-388-221-6, Dong Nai General Publishing House, 2022.
10. Ministry of Science and Technology of Viet Nam, Report of Self-Assessment of the Status of Nuclear Power Infrastructure Development in Viet Nam (Self-Evaluation Report), September 2014.
11. IAEA, Mission Report on the Integrated Nuclear Infrastructure Review (INIR) Follow-up Mission, Technical Cooperation Project: VIE2012, Hanoi, Viet Nam, 10-14 November 2014.
12. IAEA, Milestones in the Development of a National Infrastructure for Nuclear Power, IAEA Nuclear Energy Series No. NG-G-3.1 (Rev. 1), 2015.
13. Atomic Energy Law of Viet Nam, No. 18/2008/QH12, 2008.
14. IAEA, Lessons Learned in Regulating Small Modular Reactors: Challenges, Resolutions and Insights, IAEA-TECDOC-2003, 2022.