CIRED Working Paper
N° 2024-97 - December 2024

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Minh Ha-Duong

CIRED corresponding author: minh@haduong.com

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Centre international de recherche sur l'environnement et le développement
Unité mixte de recherche CNRS - Ecole nationale des ponts et chaussées - Cirad - EHESS - AgroParisTech
Site web: www.centre-cired.fr Twitter: @cired8568
Jardin Tropical de Paris -- 45bis, avenue de la Belle Gabrielle 94736 Nogent-sur-Marne Cedex

A review of the IAEA Milestones framework for building nuclear power programs

Dr. Minh Ha-Duong[1], 2024-12-02

English structured abstract

Purpose: To analyze the International Atomic Energy Agency's "Milestones" guidebook which provides a framework for developing national nuclear power programs.

Methods: Review of the IAEA guidebook and recent nuclear industry reports, using architectural metaphors to explain concepts.

Results: The guidebook presents nuclear power development as a system engineering challenge requiring coordinated progress across 19 infrastructure elements through 3 sequential phases over 10-15 years. The systematic approach remains relevant despite dramatic changes in the global energy landscape, where renewables now generate more electricity than nuclear in many markets.

Practical implications: For Vietnam, which is considering restarting its nuclear program, the framework helps identify which foundational elements from previous work remain solid and which need reconstruction. Significant updating will be needed across all infrastructure elements to reach Phase 2 readiness for contracting.

Résumé structuré en français

Objectif: Analyser le guide "Milestones" de l'Agence internationale de l'énergie atomique qui fournit un cadre pour le développement des programmes nucléaires nationaux.

Méthode: Revue du guide AIEA et des rapports récents sur l'industrie nucléaire, utilisant des métaphores architecturales pour expliquer les concepts.

Résultats: Le guide présente le développement de l'énergie nucléaire comme un défi d'ingénierie système nécessitant des progrès coordonnés à travers 19 éléments d'infrastructure en 3 phases séquentielles sur 10-15 ans. L'approche systématique reste pertinente malgré les changements spectaculaires du paysage énergétique mondial, où les énergies renouvelables produisent maintenant plus d'électricité que le nucléaire sur de nombreux marchés.

Implications pratiques: Pour le Vietnam, qui envisage de relancer son programme nucléaire, le cadre aide à identifier quels éléments fondamentaux des travaux précédents restent solides et lesquels nécessitent une reconstruction. Des mises à jour importantes seront nécessaires pour tous les éléments d'infrastructure pour atteindre la Phase 2 de préparation à la contractualisation.

1 Directeur de Recherche CNRS au Centre International de Recherche sur l'Environnement et le Développement (CIRED). Homepage: https://minh.haduong.com. ORCID: https://orcid.org/0000-0001-9988-2100

Tóm tắt có cấu trúc bằng tiếng việt

Mục đích: Phân tích sổ tay "Các mốc phát triển" của Cơ quan Năng lượng Nguyên tử Quốc tế, cung cấp khung phát triển chương trình điện hạt nhân quốc gia.

Phương pháp: Rà soát sổ tay IAEA và các báo cáo gần đây về ngành công nghiệp hạt nhân, sử dụng phép ẩn dụ kiến trúc để giải thích các khái niệm.

Kết quả: Sổ tay trình bày việc phát triển điện hạt nhân như một thách thức kỹ thuật hệ thống đòi hỏi tiến độ phối hợp trên 19 yếu tố cơ sở hạ tầng qua 3 giai đoạn tuần tự trong 10-15 năm. Cách tiếp cận có hệ thống vẫn phù hợp mặc dù có những thay đổi lớn trong bối cảnh năng lượng toàn cầu, nơi năng lượng tái tạo hiện đang sản xuất nhiều điện hơn hạt nhân trên nhiều thị trường.

Ý nghĩa thực tiễn: Đối với Việt Nam, quốc gia đang xem xét khởi động lại chương trình hạt nhân, khung này giúp xác định những yếu tố nền tảng nào từ công việc trước đây vẫn còn vững chắc và những yếu tố nào cần được xây dựng lại. Cần cập nhật đáng kể trên tất cả các yếu tố cơ sở hạ tầng để đạt được sự sẵn sàng Giai đoạn 2 cho ký kết hợp đồng.

1. Introduction

As the topic of atomic energy has gained renewed relevance in Vietnam[1–3] following the 13th Party Central Committee's 2023 decision to restart the nuclear power development plan, it is time to examine a seminal publication from the world's leading authority on nuclear energy: the International Atomic Energy Agency (IAEA)'s "Milestones in the Development of a National Infrastructure for Nuclear Power" guidebook [4] (see Figure 1).

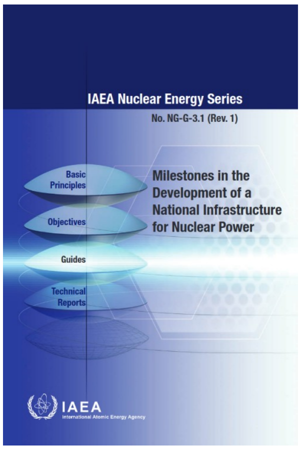

Figure 1: The IAEA "Milestones" guidebook.

A nuclear power program involves much more than building reactors. It requires developing infrastructure across the legal, regulatory, technological, human resource, industrial, and stakeholder dimensions. The program timeframe spans about 100 years through construction, operation, decommissioning, and waste disposal. A guidebook based on international experience in building such a program can help.

We will use an architectural metaphor (Figure 2) to visualize the guidebook's approach. To invite the god of fire, metallurgy, and craftsmanship into their territory, the ancient Greeks built temples that have endured for millennia by carefully coordinating all architectural elements - from foundation to columns to roof. Similarly, the IAEA guide presents nuclear power development as a system engineering challenge. Success is attained by developing 19 infrastructure components in a sequence coordinated by 3 milestones where everything must come together before advancing to the next phase.

This review examines the IAEA's role and purpose in publishing this guide, analyzes its framework for developing national nuclear power programs – the 3 milestones and the 19 infrastructure elements – , and assesses why its systematic approach remains highly relevant today despite being published in 2015. We will explore how the guide's lessons apply to Vietnam's nuclear ambitions while considering recent developments in the global nuclear industry.

2. The International Atomic Energy Agency (IAEA)

The International Atomic Energy Agency (IAEA) is an autonomous intergovernmental organization established in 1957 within the United Nations system. Its mission is to *promote the peaceful use of nuclear energy*. As the world's central forum for scientific and technical cooperation in the nuclear field, the agency counts a total of 178 Member States, including China, France, Iran, India, Pakistan, Russia, USA and Vietnam. The few countries which are not member include North Korea, which withdrew in 1994 to pursue its military programme, South Sudan, and Palestine.

Figure 2: The Temple of Hephaestus, the god of fire, metalworking and craftsmanship in Athens. (c) Storeye 2007 Public Domain / Wikimedia.

Peaceful use of nuclear energy

The IAEA is responsible for defining and implementing nuclear *safeguards,* that is the technical means to verify that nuclear material is not diverted to nuclear weapons. Through monitoring, inspection, and information analysis, the agency verifies nuclear activities to detect and deter their diversion to weapons-related purposes[5].

This task is all the more difficult that nuclear power plants require significant quantities of nuclear material to generate electricity over a long operational lifetime. Significant quantity is a term of art meaning *enough nuclear material for a bomb*. According to the IAEA, a typical nuclear power reactor will maintain approximately 65 significant quantities of nuclear material in fresh fuel storage and 97 significant quantities in its core during operations. Spent fuel removed from the reactor on average every 18 months will contain approximately 36 significant quantities of low enriched uranium and plutonium. In total, over a 60 year lifetime a typical nuclear power reactor will involve the use of about 2250 significant quantities of nuclear material. In other words, loosing track of even a fraction of percent of the fuel is a very serious concern.

The agency's legitimacy is anchored in a number of international treaties, in which States accept the application of safeguards to nuclear material and activities on their territory. The Treaty on the Non-Proliferation of Nuclear Weapons (the NPT) requires its 189 Parties to accept safeguards, and Vietnam accessed the NPT in 1982. Regional treaties, e.g. the 1995 Bangkok Southeast Asian Nuclear-Weapon-Free Zone Treaty, also commit their signatories to accept IAEA's inspections.

Without credible safeguards, one country's nuclear programme could worry all neighbouring countries within ballistic missiles range, leading to arms race, proliferation, and an increased risk of nuclear exchanges threatening the habitability of our planet. This is why the agency is known as the "Atoms for Peace and Development" organization within the United Nations family, and the IAEA with its former director general, M. El Baradei, were awarded the Nobel Peace Prize in 2005.

Promoting nuclear energy

IAEA's mission statement has two keywords: *peaceful* and *promote*. The Milestones guidebook approach to promoting nuclear energy draws on decades of international experience. It incorporates practical lessons from Integrated Nuclear Infrastructure Review missions, and those learned from the 2011 Fukushima Daiichi accident. The guidebook serves three essential purposes for countries considering or planning to develop a nuclear power program:

First, it helps countries recognize the full scope of safeguards commitments and obligations associated with nuclear power. Even with extensive foreign assistance, the responsibility for implementing a nuclear program rests with the host country and cannot be subcontracted.

Second, it provides a structured framework to prepare the entire national infrastructure needed for building and operating nuclear power plants. The document outlines key infrastructure issues to be addressed, from nuclear safety and radiation protection to stakeholder engagement, human resources capacity building, waste management, and all other required elements.

Third, it aims to help countries develop the comprehensive capabilities needed to regulate and operate nuclear power plants safely and securely, while properly managing the resulting radioactive waste. The document stresses the need for proactive thinking across a 100-year time frame from construction through operation, decommissioning and waste disposal.

The document describes three sequential phases of development, with specific milestones marking the completion of each phase:

- Milestone 1: Ready to make an informed commitment to a nuclear program
- Milestone 2: Ready to invite bids/negotiate contracts
- Milestone 3: Ready to commission and operate the first nuclear plant

The IAEA emphasizes that the document is not prescriptive about specific technical solutions or institutional arrangement. Rather, it outlines the key issues that need to be considered while allowing each country to develop approaches suitable to their particular circumstances. This flexibility, combined with comprehensive coverage of infrastructure requirements, makes it a valuable reference for decision-makers and planners involved in nuclear power development. The document is a practical guide to assess readiness and identify gaps that need to be addressed before proceeding to the next phase of nuclear power development.

3. The Milestone Approach

As we said in the introduction, the Milestone approach, that is IAEA's structured framework for countries to systematically develop the necessary infrastructure for a national nuclear power program, takes a Systems Engineering angle. That approach can be likened to the construction of a temple. Just as a well-designed building requires a strong foundation and carefully planned levels, developing nuclear power capability requires going through clear steps, ensuring all critical infrastructure elements are addressed.

The Temple of Hephaestus in Athens (Figure 2) is one of the best-preserved ancient Greek temples. Built in the 5th century BCE to honor Hephaestus, god of metalworking, craftsmanship, fire and technology, it embodies the systematic and precise approach needed for complex technological endeavors. Just as Hephaestus was the master craftsman who forged weapons and devices for the gods with perfect technical skill, developing nuclear power requires mastery of sophisticated technology within a carefully structured framework. The temple's endurance over 2,500 years also parallels the long-term perspective required for nuclear infrastructure - from initial construction through centuries of maintenance and restoration.

Nineteen Structural Elements

The development of a nuclear power program can be seen as the construction of a temple, supported by 19 columns. These 19 elements can be categorized into four areas:

- **Core Governance Elements**: National position, legal framework, regulatory framework, management systems, stakeholder involvement.
- **Nuclear Technology & Safety Elements**: Nuclear safety, nuclear security, radiation protection, safeguards, emergency planning.
- **Site & Technical Infrastructure Elements**: Site and supporting facilities, electrical grid, environmental protection, nuclear fuel cycle, radioactive waste management.
- **Socio-economic elements**: Human resource development, funding and financing, industrial involvement, procurement.

Each column is critical to the building architecture, neglecting any one of them compromises the integrity of the entire temple. In the same way, for example, if the regulatory framework is weak, then nuclear safety is questionable, and that can jeopardize the entire nuclear program.

Three Phases: Sequential Development Milestones

The Milestone Approach outlines three progressive phases, each representing a level of readiness and capability akin to building floors on a structure:

1. **Phase 1: Considerations before a decision to launch a nuclear power program is taken (Foundations, 3–5 years)**. The phase objective is to develop a comprehensive understanding and capacity across all 19 infrastructure elements to make an informed commitment to a nuclear power program. This is like laying the temple's platform ensuring the structural stability of the construction. The platform establishes the basic framework for everything that follows, aligning the bases of the columns. Phase 1 ends at the first milestone: *Ready to make a knowledgeable commitment to a nuclear power program.*

2. **Phase 2: Preparatory work for contracting and construction of a nuclear power plant after a policy decision has been taken (Preparation, 3–7 years)**. The objective here is to strengthen each infrastructure element to the level needed for contracting and construction of the nuclear power plant. This is like building the main structure of the temple. All 19 columns must be erected to carry the upcoming load, and elements must maintain alignment with each other. Phase 2 leads to the second milestone: *Ready to invite bids or negotiate a contract for the first nuclear power plant.*

3. **Phase 3: Activities to implement the first nuclear power plant (Implementation, 7–10 years)**. The objective at this stage is to bring all elements to full capability needed for commissioning and operating the nuclear power plant. This is analogue to completing the temple's entablature, that is the roof structure. The building becomes fully functional but requires continuous maintenance. Phase 3 culminates with the third milestone: *Ready to commission and operate the first nuclear power plant.*

One cannot build the main floor of a temple without laying the foundations first. Skipping a phase for any element compromises the integrity of everything. Within each phase, it is necessary to progress in parallel across elements. While they may develop at different rates, all must reach minimum levels by each milestone. The phased approach forces regular assessments to identify areas needing additional support, ensuring that all elements remain aligned and robust.

A nuclear program continues beyond the third milestone, just as a temple must stand for generations. The structure must remain sound for 60-80 years of operation (the temple on Figure 2 has been standing since 2439 years). Regular maintenance and upgrades are essential. The foundation must support future modifications and improvements.

Knowledge management and human resource development are particularly critical infrastructure elements that span all phases. Organizations must identify the knowledge and skills needed for Phase 3 and beyond, establishing workforce plans based on careful capacity gap analyses. This includes coordinated planning across the owner/operator, regulatory body, and technical support organizations to optimize training and development efforts. The Milestones approach emphasizes having senior staff in place early in Phase 2 to build institutional knowledge.

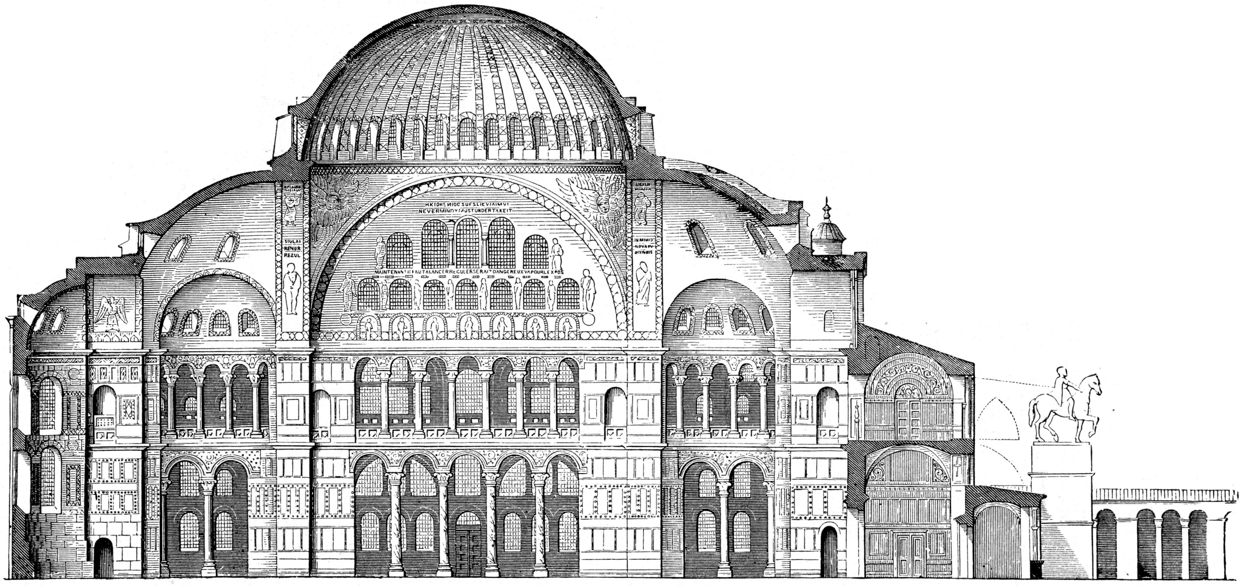

Figure 3: Section of Hagia Sophia by Isidore of Miletus & Anthemius of Tralles for Emperor Justinian, Istanbul, 532-37, from Wilhelm Lübke / Max Semrau: Grundriß der Kunstgeschichte. 14. Auflage. Paul Neff Verlag, Esslingen, 1908

The Importance of timeframes and expectations

This architectural metaphor helps visualize the IAEA Milestones approach, in which 19 different infrastructure elements develop in parallel, coordinated with three major program decision points. The systematic approach assists countries in avoiding the temptation to focus solely on a few prominent aspects, such as reactor technology or financing, while neglecting other critical components like regulatory frameworks or human resource development. Regular milestone assessments provide opportunities to verify that development across all elements remains balanced and sufficient.

The famous Hagia Sophia in Istanbul (also known as the Church of the Holy Wisdom) is a masterpiece of Byzantine architecture and engineering in the VIth century, see Figure 3. However, because emperor Justinian gave the architects only five years to deliver, the massive central dome collapsed 21 years after completion. The building required the addition of massive exterior buttresses (the thick sloped structures on the side) to stabilize the outward thrust of the dome, and continuous repairs since.

Just as rushing the construction of a temple can compromise its structural integrity, the IAEA emphasizes that rushing through phases without adequately developing infrastructure elements creates risks. The time periods given in the Milestones approach – which say that it takes 13-22 years for country to develop a nuclear program – are minimums. Many countries take longer as they work to develop robust capabilities.

4. Global nuclear industry status

Although the Milestone Guide for National Nuclear Power Programs was published in 2015, its relevance has only increased with the urgency to de-carbonize energy. The outcome of 2023 Climate Conference (COP28) called for "Accelerating zero- and low-emission technologies, including, inter alia, renewables, nuclear, abatement and removal technologies". The inclusion of nuclear as a low emission technology was historic. The momentum continued in Baku at COP29, as 31 countries have now endorsed the Declaration to triple global nuclear energy capacity by 2050.

Curent capacity and generation trends

According to the International Energy Agency (IEA), by 2050 global electricity production is expected to more than double. In the 2024 RDS-1 scenarios, relative to a global nuclear operational capacity of 372 GW at the end of 2023, the low case projects an increase of about 40% to 514 GW by 2050. In the high case global nuclear operational capacity is projected to increase to 2.5 times the current capacity, reaching 950 GW by 2050. These scenario estimate that small modular reactors could account for 24% of the capacity added by 2050 in the high case and for 6% of the capacity added in the low case.

That said, a balanced look at the future requires assessing the current state and trends in the industry. At the end of 2023, the global nuclear capacity was 365 GW. By mid-2024, this capacity had increased slightly to 367.3 GW, indicating a modest growth in operational capacity. This matches the maximum historical capacity reached in 2006. In terms of units, there are 416 reactors operating in 2024, compared to a maximum of 440 reactors in 2005. However, because of high utilisation rates, the sector is on track to reach a new record high in nuclear power generation by 2025, surpassing previous records (Figure 4).

Economic challenges and learning curves

Nuclear remains an extremely capital-intensive industry: typically 8-10 US$ billion for a large reactor. Ensuring construction and cost predictability is pivotal to investor confidence. Nearly two thirds of the total cost per megawatt-hour from a nuclear power plant can be attributed to construction and investment costs. These are acutely sensitive to fluctuations in construction schedules (delays) and finance costs (interest rates and risks).

Nuclear construction costs can be controlled through standardization, series builds and effective project management. Historical experience shows that economies of scale lower costs[6]. Thus, commitment to multiple reactors transforms first-of-a-kind risks and challenges into investment opportunities to achieve construction time and cost predictability.

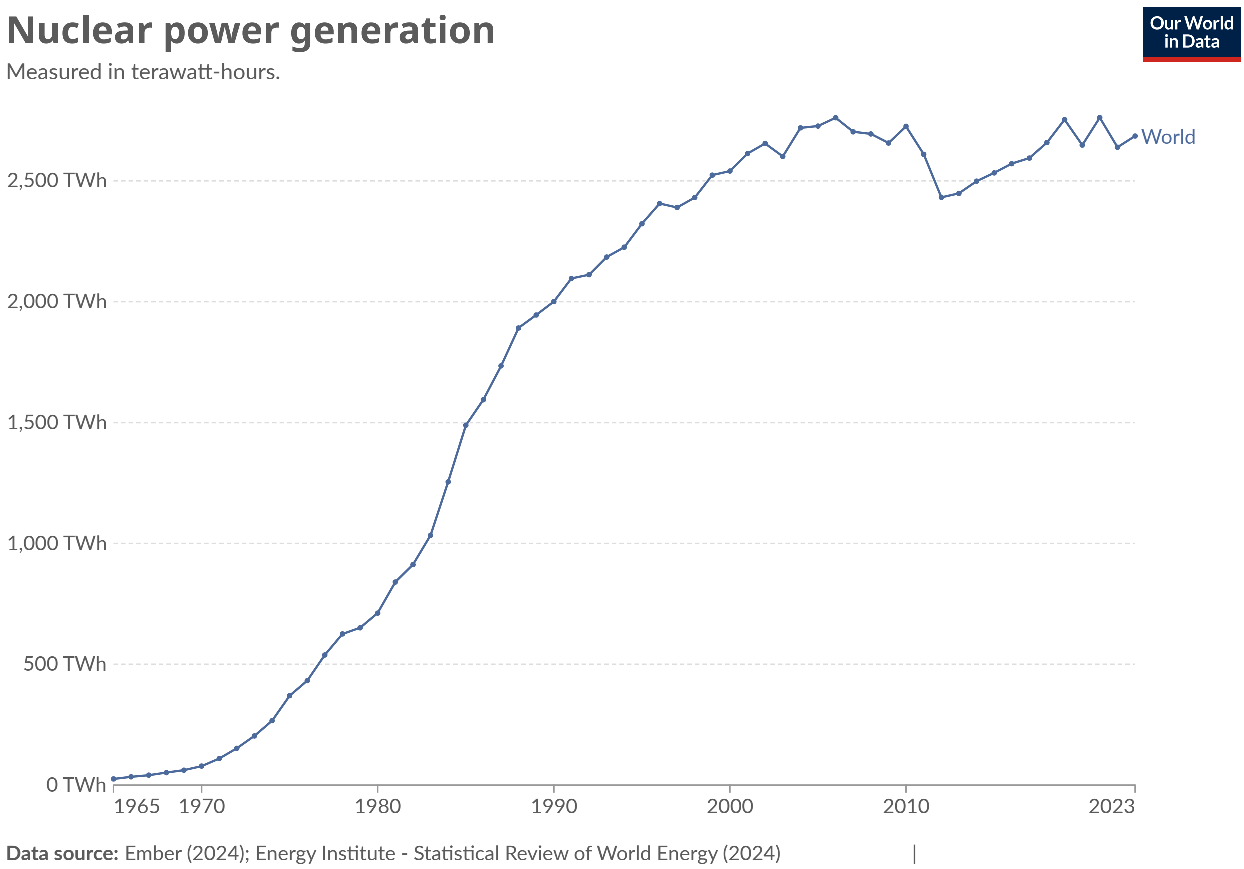

Figure 4: World's annual nuclear power generation, 1965-2023. (c) Our World in Data.

The first large reactor projects built in countries after a one or two decades hiatus are reported to have capital costs of around USD 8 000–11 000 per kilowatt (excluding financing), or more. Consider for example the EPR project in Flamanville-3, France, a new build constructed between 2007 and 2024, just starting up by the end of 2024. Its estimated cost is €13.2 billions for 1 650 MW capacity, resulting in a cost of USD 8 667 per kW. The USD 11 000 per kW costs figure corresponds to the latest estimates for the Hinkley Point C EPR project in UK, still under construction.

In comparison, countries with uninterrupted experience in nuclear new build projects are reported to have capital costs closer to US $2500–5000/kW. In particular, China has established itself as one of the most cost-effective nuclear reactor builders globally[7]. Completing 37 reactors in the past decade at an average construction cost of around $4,000/kW, about half of US costs, Chinese reactors take on average 6 years to build, compared to over 10 years in the US and Europe. One reason for this is that China has standardized its reactor designs and focuses on building multiple units at each site, with 74% of reactors located at plants with 4 or more units.

Technology developments

Dozens of startups promote Small Modular Reactors (SMRs) as a solution to the cost and complexity challenges of traditional nuclear power plants. They claim several advantages: SMRs would be largely "shop-fabricated" to control costs, have simplified licensing procedures, allow predictable expenses, and enable gradual capacity additions as needed since each would be less than 300 MW. SMR advocates also argue these reactors would be safer, making them suitable for deployment in densely populated areas.

However, the promised revolution faces hurdles. In the United States there is still not a single SMR under construction. South Korea's SMART design received approval but has received no orders, while the UK's Rolls-Royce SMR is still undergoing regulatory review expected to complete in 2026. While SMRs remain promising on paper, climate experts note it would be difficult for them to play a significant role in meeting urgent near-term emission reduction targets like the EU's 55% reduction by 2030.

Two developments in 2024 have thrown cold water on the enthousiasm around the promises of SMRs in the west. The first was NuScale's decision to cancel its 462 MW (six modules of 77 MW) flagship project in Idaho, despite receiving conditional safety approval, after costs increased to $9.3 billion, with resulted in an electricity target price of $89 per MWh, up from a previous estimate of $58 per MWh. Then, French utility EDF announced that it had suspended the development of its Nuward SMR and reoriented the project “to a design based on proven technological building blocks.”

Meanwhile, in Changjiang, Hainan, China (460 km East of Hanoi), the construction of Linglong One, also known as the ACP100 SMR, is on track for commercial operation by 2026. The main control room of went into operation in May 2024. This would be the world’s first SMR on land, since Russia's Akademik Lomonosov – the world's only operational nuclear power plant on a barge – can be described as a floating SMR with its two 35 MW KLT-40S reactors. In operation since 2020, it currently provides power and heat in Pevek, Chukotka, in the Russian far east region.

Renewable energy competition

Nuclear is facing stiff competition from renewable energy sources. Consider for example China, which is as of 2024 the only country in the world with a significant nuclear power expansion program. In China, solar PV produced a total of 578 TWh of electricity in 2023, 40 percent more than nuclear’s 413 TWh. Wind power generation first exceeded nuclear in 2012: in 2023, wind produced 877 TWh, more than doubling nuclear generation. Adding other non-hydro renewables like biomass to solar and wind, the net total generation of 1,643 TWh in 2023 was four times the nuclear output.

The competition from renewable energy sources is even more striking when looking at global data. In 2023, wind and solar together supplied over 13% of global electricity, surpassing nuclear power's contribution at around 9%. This shift has been driven by dramatic cost reductions - wind and solar are now the cheapest forms of new electricity generation in most markets. The cost of utility-scale solar PV fell by about 89% from 2009 to 2024, while new nuclear projects have often seen cost increases. Hybrid systems combining solar with storage are increasingly competitive not just with new nuclear plants but even with existing nuclear and fossil fuel facilities. Industry analysts suggest this trend could fundamentally reshape the energy landscape, as renewables paired with storage increasingly provide reliable baseload power at lower costs than traditional sources.

5. Vietnam's position relative to the milestones

Vietnam's nuclear power development can be examined through the lens of the IAEA's infrastructure framework. The Milestone Approach helps identify which foundational elements remain solid, and which need reconstruction.

Previous progress and assets

Vietnam's previous nuclear power program, initiated in 2009, was suspended in 2016 before reaching the second milestone[8]. Before suspension, significant groundwork was laid[9].

The site selection process was particularly thorough. Among 8 potential locations studied, two sites in Ninh Thuan were selected as having the most potential and safety[1], with the Prime Minister approving this orientation in Decision No. 906/QD-TTg on June 17, 2010. A key safety feature was the placement of the main plant at Phuoc Dinh commune in Thuan Nam district at 12m above sea level, meeting Vietnamese, Russian and IAEA requirements for protection against tsunamis and earthquakes. This achievement remains valuable - site selection is one of the most complex and time-consuming elements of nuclear infrastructure development.

Russia had agreed to finance and build 2400 MW of nuclear capacity from 2020, and Japan had agreed similarly for another 2200 MW. The technology selection phase reached concrete results, selecting generation III+ reactor designs. For Ninh Thuan 1, the Russian AES-2006 iteration of the VVER technology (using light water as both a coolant and neutron moderator) was selected. For Ninh Thuan 2, studies did not reach a final decision between the two Japanese designs AP1000 and ATMEA1. EVN submitted the project's Site Approval Document and Feasibility Study Report to authorities in September 2015, with initial plans targeting commercial operation of Units 1 and 2 in 2028 and 2029 respectively.

Human resource development saw substantial investment, with 447 students trained in Russia through 2018. Fifteen graduates gained practical experience working on ROSATOM nuclear power plant construction projects in Bangladesh and Belarus. However, nuclear knowledge and skills are perishable. Many graduates have moved to other sectors as opportunities in nuclear specialization did not materialize.

Current Status Assessment

Looking at Vietnam's readiness through the IAEA framework reveals varying levels of infrastructure preservation across different elements:

Core Governance requires significant updating. National energy planning studies need revision to reflect current conditions. The legal framework must incorporate post-Fukushima safety standards and emerging security requirements. Management systems need harmonization with ongoing electricity market reforms.

For Nuclear Technology & Safety elements, the regulatory framework needs modernization. International requirements have evolved substantially since 2016, particularly around nuclear security and emergency preparedness. Past work provides a foundation but significant capacity building will be needed to reach current standards.

Site & Technical Infrastructure shows mixed readiness. The rigorous site selection process remains valid, though some updating of environmental and safety assessments may be needed. Grid capacity and stability require fresh evaluation given the power system's evolution. Nuclear fuel cycle strategy should be reviewed considering current market conditions and technology options.

Human & Industrial elements face particular challenges after the program pause. A systematic assessment is needed of currently available nuclear expertise. The industrial involvement strategy requires updating to reflect changes in both domestic capabilities and international supply chains. Procurement systems need modernization to meet current nuclear quality requirements.

Path Forward

To rebuild infrastructure capabilities systematically, Vietnam could:

1. Establish a new Nuclear Energy Programme Implementing Organization (NEPIO) to coordinate infrastructure assessment and development.
2. Update key technical studies from Phase 1 - energy planning, grid evaluation, technology assessment.
3. Modernize the legal and regulatory framework. Amend nuclear power-related content in laws for National Assembly promulgation.
4. Assess available nuclear expertise and develop a new human resource development plan

5. Review and update industrial involvement strategy. Add the option for nuclear power into the Power Development Plan VIII update and the Energy Masterplan.
6. Maintain stakeholder engagement through transparent communication about program plans, specially towards the communities in the planning areas[10].

Previous achievements, particularly in site selection[3] and human resource development, provide valuable foundations. However, significant work will be needed across all infrastructure elements to reach Phase 2 readiness for contracting. The IAEA framework provides guidance for completing necessary infrastructure activities across three progressive phases of development, helping ensure the best use of resources. This systematic approach will be crucial as Vietnam rebuilds its nuclear power program.

6. Conclusion

The IAEA Milestones framework provides essential guidance for countries grappling with the energy trilemma: how to ensure energy security, affordability, and environmental sustainability while balancing these three objectives. As COP28 recognized nuclear power as part of the solution alongside renewables, the framework's systematic approach to infrastructure development becomes increasingly relevant.

First, the framework's architecture of 19 infrastructure elements across three sequential phases provides a proven development path. Like the Temple of Hephaestus in Athens, which has endured for 25 centuries, nuclear infrastructure requires coordinated development and maintenance of all foundational elements - from policy and financing to technical capabilities.

Second, the timeline - 10-15 years of preparation, 60-80 years of operation, and decades of waste management - shows why rushing development creates risks. The Hagia Sophia's dome collapse, caused by an unrealistic 5-year schedule, exemplifies how compressed timelines can lead to structural failures requiring costly fixes.

Third, success depends more on systematic infrastructure development than technical elements. While solar and wind costs have fallen dramatically, making them the cheapest forms of new electricity in most markets, China's experience shows that all low-carbon technologies have their place: in 2023, wind produced 877 TWh, solar 578 TWh, and nuclear 413 TWh. For countries considering nuclear power, the IAEA framework provides a comprehensive systems perspective essential for success.

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