The Economic and Regulatory Landscape of Nuclear Power: Implications for Malaysia

Leong Yuen Yoong and Lee Chean Chung***

Abstract

As Malaysia reconsiders integrating nuclear power into its energy mix, this paper advances the national discourse by analysing the critical economic and regulatory dimensions of its development. Drawing on a comprehensive literature review and field interviews, the study first delineates the prevailing legal, policy, and administrative environment for energy projects. Within this context, it identifies specific market and operational challenges and risks pertinent to nuclear power and proposes eight mitigation strategies. These strategies are strategically linked with the Four Symbols (四象) of Chinese cosmology, presenting a comprehensive, interdependent, and balanced policy framework. The paper further examines the establishment of a robust and efficient regulatory framework for nuclear power, guided by international best practices. Based on this analysis, the study offers recommendations for Malaysia, encompassing areas such as market and operational risks, regulatory frameworks, public engagement and communication, geopolitical realities and strategic partnerships, crucial for navigating nuclear power integration amidst a dynamic energy transition.

Keywords: Nuclear power; Malaysia; Energy transition; Risk mitigation; Regulatory framework.

Introduction

Under the Paris Agreement, Malaysia has pledged to achieve net-zero greenhouse gas emissions by 2050, alongside a 45% reduction in carbon intensity compared to 2005 levels by 2035. To meet these ambitious targets, the country has committed to halting new coal-fired power plant construction and seeks to mitigate overreliance on natural gas.

* Leong Yuen Yoong is affiliated with the UN Sustainable Development Solutions Network (SDSN), Asia Headquarters based in Sunway University.

** B Lee Chean Chung, Member of Parliament for Petaling Jaya, Malaysia.

This necessitates the exploration of cleaner and more sustainable energy sources to support Malaysia's long-term decarbonisation goals.

A significant policy shift occurred in late 2024 with the Malaysian Cabinet's approval of a nuclear roadmap, prepared by the National Energy Council. This roadmap identifies nuclear energy as "one of the options for electricity generation" post-2035. Furthermore, MyPOWER has been designated as Malaysia's Nuclear Energy Programme Implementation Organisation (NEPIO), serving as the national focal point for coordinating the preparatory work to eventually commission nuclear power plants under the International Atomic Energy Agency (IAEA) framework (Teoh, 2024).

Following the recent conclusion of the nuclear power pre-feasibility studies, which yielded encouraging findings and prompted the government to explore implementation pathways aligned with global safety, security, and non-proliferation standards, this paper aims to advance the national discourse. It achieves this by analysing the economic and regulatory dimensions of nuclear power development - critical yet often underexamined aspects of energy policy planning in Malaysia. While these crucial topics are routinely addressed within specialised nuclear energy circles, their complex interdependencies, long-term implications, and intricate details frequently remain underexplored or inadequately integrated into broader energy policy planning, particularly in nations new to or reconsidering nuclear energy. To address this gap, the paper proposes comprehensive recommendations encompassing market and operational risks, regulatory frameworks, public engagement and communication, geopolitical realities, and strategic partnerships.

Regulatory landscape and energy project timelines

Impact of regulatory landscape

Investment in infrastructure usually requires a substantial amount of resources. Throughout the lifecycle of a project, various shocks could occur, and these risks must be mitigated to ensure a return on investment. These risks can include complex regulatory frameworks, evolving government policies, and technological advancements that necessitate major project modifications. For investors and owners, such shocks could create budgetary shortfalls and exacerbate schedule constraints. The pace of energy project implementation is significantly influenced by national regulatory environments. This is evident in a comparison of Germany and the Philippines. Germany's decentralised system, characterised by varying state-level regulations, has historically led to lengthy approval processes for renewable energy projects due to bureaucratic hurdles (KPMG, 2020). In contrast, the Philippines has generally maintained a more streamlined regulatory environment.[1]

Germany is undertaking significant regulatory reforms to accelerate project approvals, with changes commencing in 2025 to streamline bureaucratic procedures for major projects like industrial plants and infrastructure. Key developments include the new Spatial Planning Act, introducing a six-month cap on procedures, eliminating redundant cross-authority reviews, and adopting digital processes to improve efficiency. Furthermore, in 2024, Germany's federal cabinet approved draft legislation to implement the European Union's 2023 Renewable Energy Directive, introducing acceleration areas and streamlined approvals for wind and solar parks, energy storage, and electrolysers for hydrogen production.[2]

Preparing the regulatory landscape for nuclear power in Malaysia

Malaysia's pursuit of nuclear energy, though initially promising, has not led to operational deployment. Following the establishment of the Nuclear Power Development Steering Committee in 2008, a proposal for a small-scale reactor was announced in 2009. This commitment was further solidified in 2011 with the creation of the Malaysia Nuclear Power Corporation (MNPC) under the Prime Minister's Department, which, as the Nuclear Energy Programme Implementing Organisation (NEPIO), superseded the Steering Committee. By 2014, the government had announced plans to commission its first nuclear power plant within a decade. However, this initiative was abruptly halted in 2018 when Prime Minister Mahathir Mohammad reversed the policy direction, declaring a moratorium on nuclear power development and subsequently disbanding the MNPC.[3]

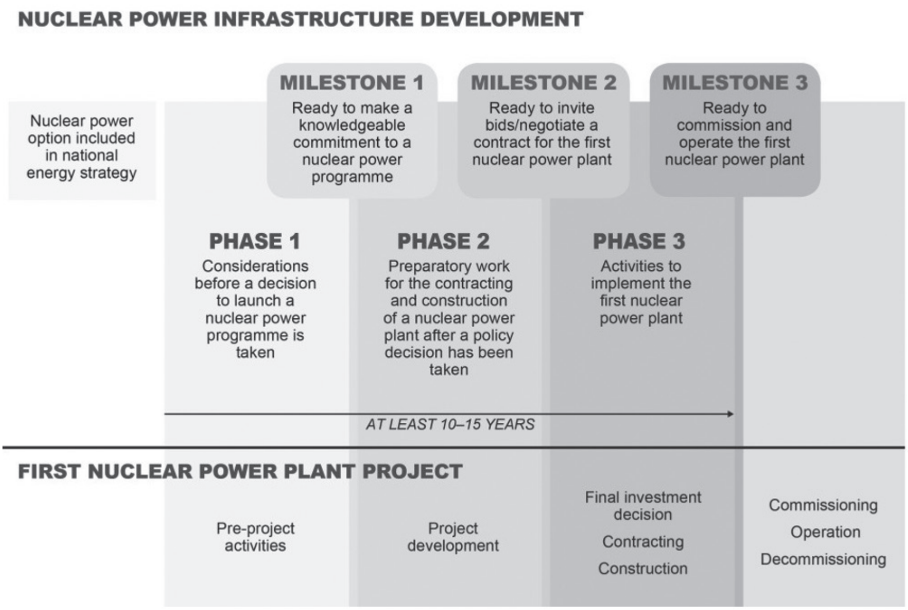
1 Presidential Communications Office, 'Integration of Energy Project Applications, Permitting Processes in Virtual One-Stop Shop Pushed' (1 October 2024) https://pco.gov.ph/news_releases/integration-of-energy-project-applications-permitting-processes-in-virtual-one-stop-shop-pushed/ accessed 30 December 2024.

2 COMAN Software, 'New 2025 Rules: Faster Approvals for Major Projects' (2024) https://blog.coman-software.com/en/blog/neue-regeln-2025-schnellere-genehmigungen-f%C3%BCr-gro%C3%9Fprojekte accessed 30 December 2024.

3 S Surendran, 'Dr M: Nuclear Power Is a No-No for Malaysia' The Edge (19 September 2018) https://theedgemalaysia.com/article/dr-m-nuclear-power-nono-malaysia accessed 2 January 2025.

Within the International Atomic Energy Agency (IAEA) Milestones Approach framework (Figure 1), Malaysia had progressed beyond Milestone 1 fourteen years prior and had entered Phase 2 before this policy reversal. Despite the programmatic changes, the regulatory body, the Department of Atomic Energy Malaysia (Atom Malaysia), formerly known as the Atomic Energy Licensing Board (AELB), continues its operations. Established in 1985 under the Atomic Energy Licensing Act (Act 304), Atom Malaysia remains responsible for overseeing safety and ensuring compliance with the relevant legal and regulatory frameworks.[4]

Figure 1: Three phases and three milestones for nuclear power infrastructure development (International Atomic Energy Agency)



Despite moving away from nuclear power generation, Malaysia continues to advance nuclear technology for other purposes. Malaysia's National Nuclear Technology Policy 2030[5] prioritises six non-power

4 *Wikipedia*, 'Department of Atomic Energy (Malaysia)' (20 November 2024) https://en.wikipedia.org/wiki/Department_of_Atomic_Energy_(Malaysia) accessed 11 January 2025.

5 Ministry of Science, Technology and Innovation, *Dasar Teknologi Nuklear Negara 2030* (Putrajaya, 2023) https://www.mosti.gov.my/en/dasar-teknologi-nuklear-negara-dtnn-2030/#flipbook-df_73771/5/ accessed 16 December 2024.

application areas – medicine and health care; food and agriculture; device and equipment manufacturing; environmental and natural resource management; industrial applications; as well as nuclear safety and security.

Concurrently, spurred by a renewed interest in nuclear power generation, the Malaysian government is actively engaged in a multi-faceted preparatory phase. This phase involves conducting feasibility studies, addressing public perception, establishing the requisite regulatory, governance, and policy frameworks, and cultivating international partnerships. Notably, the Ministry of Energy Transition and Water Transformation (PETRA) and the Ministry of Science, Technology and Innovation (MOSTI) are collaborating to develop a comprehensive legal and regulatory framework to govern the potential utilisation of nuclear energy.[6]

Aligning this framework with international best practices and standards, including International Atomic Energy Agency (IAEA) safety standards covering all stages of a nuclear facility's lifecycle (site selection, design, construction, operation, and decommissioning), is crucial. Ratification of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) serves to build trust (addressing perception) and to put in place verifiable mechanisms against actual diversion (addressing realities).

The existing Atomic Energy Licensing Act 1984 (Act 304) currently governs atomic energy activities, primarily addressing safety, security, and safeguards. However, as Malaysia advances its nuclear energy considerations, this foundational framework must evolve to incorporate crucial elements such as regulatory efficiency, a dimension increasingly underscored by international examples (as discussed in Section 2.1). Furthermore, recent controversies such as the Lynas radioactive materials handling case, have publicly raised concerns regarding the independence and impartiality of the regulatory body. This underscores the critical need for a new or revised regulatory structure that explicitly prevents conflicts of interest and fosters robust public confidence in governance mechanisms for future nuclear energy projects.

6 *The Edge Malaysia*, 'Government to Include Nuclear Energy Policies in 13th Malaysia Plan — Rafizi' (5 November 2024) https://theedgemalaysia.com/node/732817 accessed 30 December 2024.

Market and operational risks and mitigation strategies

Market risks and mitigation

With their high fixed costs and low variable costs, nuclear power plants are well-suited to serve as baseload power suppliers. Unlike generating facilities with low fixed costs and high variable costs—such as natural gas-fired plants, which can readily respond to short-term market fluctuations—nuclear facilities, designed for consistent output, are particularly vulnerable to financial risk when prices fluctuate, even if efficiency remains unaffected (Nuclear Energy Institute, 2023).

The operational strategy of nuclear power plants - whether to operate as baseload resources or engage in load following - is often determined by their proportional contribution to a nation's energy mix. In contexts where nuclear power constitutes a substantial share of the national electricity generation portfolio, utilities have been compelled to implement or significantly enhance the operational flexibility of their nuclear fleets to accommodate diverse variations in electricity demand, including daily and seasonal fluctuations. France serves as a prime example, where nuclear power generates approximately 70% of the nation's electricity, leading some reactors to routinely operate in load-following mode.[7]

Regulatory frameworks are likewise pivotal in shaping a nuclear power plant's load following capability, with critical determinations established during the design and licensing phases. The licensing process is fundamental in defining a plant's operational mode and mandates a comprehensive analysis of all anticipated operational transients. In France, for example, load cycling is not only explicitly addressed within the nuclear power plant operating manuals, but operating licenses also precisely specify the maximum permissible number of load cycles based on the original plant design and the characteristics of anticipated transients (e.g., magnitude and rate of power variation). Conversely, certain countries, such as the United States, impose explicit regulatory limitations on manoeuvring within automatic control modes.[8]

Recent premature nuclear reactor retirements over the past decade have been attributed, at least in part, to market pressures, including

7 A Lokhov, *Load-Following with Nuclear Power Plants* (Nuclear Energy Agency, 2011) https://www.oecd-nea.org/nea-news/2011/29-2/nea-news-29-2-load-following-e.pdf accessed 11 January 2025.

8 Ibid.

suppressed wholesale electricity prices due to sustained low natural gas prices and increased penetration of variable renewable energy sources.[9]

These market pressures are particularly relevant in Malaysia, where the power sector relies heavily on subsidised natural gas. Domestic piped gas supplied to the power sector, primarily sourced from Petronas, is subject to a price cap linked to the Malaysia Reference Price (MRP), which is determined by export prices to Japan. A fixed discount and a price cap of RM30 per million British thermal units (MMBtu) for the first 1,000 million standard cubic feet per day (MMSCFD) further reduce domestic prices.

By contrast, Tier 2 pricing for additional volumes averaged RM62.1 per MMBtu in Q1 2023, while the MRP averaged RM48.14 per MMBtu in Q2 2023 during periods of international gas price volatility.[10]

Given the challenges that fully deregulated electricity markets pose for long-term investment in and operation of nuclear power plants, Malaysia must carefully structure its partially liberalised electricity market to support the integration of nuclear power into its energy mix, while ensuring cost-effectiveness and reliability for consumers.

In the United States, electricity utilities operate under diverse market structures, which differ by state. In fully deregulated markets, utilities are typically restricted from owning generation and transmission assets, and instead focus on distribution, operations and maintenance from the point of grid interconnection to the consumer meter, and billing. Conversely, regulated markets are characterised by vertically integrated utilities that own or control the entire electricity supply chain, from generation to the consumer meter.[11]

Capacity markets, such as the one administered by the Pennsylvania-Jersey-Maryland (PJM) Interconnection in the US, utilise auction mechanisms to determine capacity prices. PJM's annual base residual auctions (BRAs) procure capacity three years in advance of its delivery day. Historically, relatively low-capacity prices in PJM have resulted in some generators, particularly those with inflexible minimum offer

9 Nuclear Energy Institute, Nuclear Costs in Context (2023) https://www.nei.org/resources/reports-briefs/nuclear-costs-in-context accessed 30 December 2024.

10 A Adam, 'Gas Pricing Model Key for Sustainable Power Generation in Malaysia's Energy Transition, Says MGA Chief' *The Edge Malaysia* (23 August 2023) https://theedgemalaysia.com/node/680457 accessed 30 December 2024.

11 US Environmental Protection Agency, 'Understanding Electricity Market Frameworks & Policies' (26 July 2024) https://www.epa.gov/greenpower/understanding-electricity-market-frameworks-policies accessed 30 December 2024.

price rules, failing to secure capacity obligations. This inability to obtain capacity contracts can contribute to generation asset owners' decisions regarding unit retirements.[12]

In contrast to capacity markets, the Electric Reliability Council of Texas (ERCOT) operates an energy-only market, and has relied on market-based energy pricing since 1999. This structure makes ERCOT the only deregulated electricity market in the US operating without Federal Energy Regulatory Commission oversight.[13]

The ERCOT design assumes that sufficiently high energy prices will incentivise investment in, and retention of, generation capacity, including baseload resources such as nuclear power. Prices have at times reached the market's offer cap of $9,000/MWh, although annual averages typically range between from $25-$50/MWh.[14]

While the ERCOT market demonstrated resilience for over two decades in accommodating occasional demand spikes,[15] its inherent vulnerability to extreme events was tragically exposed during the February 2021 winter storm. The absence of forward-procured capacity undermined grid stability, leading to widespread blackouts and contributing to an estimated 250 fatalities in the state. This event underscored the limitations of relying solely on energy-only pricing to ensure resource adequacy during extreme weather conditions.

Subsequently, in 2023, Texas implemented a new out-of-market mechanism for procuring firm capacity resources: the $10 billion Texas Energy Fund (Walton, 2023). This marks a significant departure from the pure energy-only market design and reflects recognition of the need for supplemental measures to ensure grid reliability.

Some states, such as Virginia, operate under hybrid or mixed market structures that incorporate elements of both regulation and competition.

12 E Howland, 'PJM Capacity Prices Fall 32% with More Nuclear, Solar Capacity Clearing in the Latest Auction' (22 June 2022) *Utility Dive* https://www.utilitydive.com/news/pjm-capacity-auction-nuclear-solar-coal-prices/625861/ accessed 30 December 2024.

13 State Energy Conservation Office and the Texas Industrial Energy Efficiency Program, 'The $9,000 Cap: A Webinar on ERCOT Electric Prices TIEEP Webinar Series' (12 February 2020) University of Houston, Division of Energy and Innovation https://www.uh.edu/uh-energy-innovation/uh-energy/educational-programs/industrial-energy/tieep/the-9000-cap/ accessed 30 December 2024..

14 Ibid

15 M Hourihan, 'Why Doesn't Texas Have a Capacity Market?' (10 April 2019) CPower https://cpowerenergy.com/why-doesnt-texas-have-a-capacity-market/ accessed 30 December 2024.

These mixed markets often employ specific mechanisms to support the viability of baseload generation resources, such as nuclear power, in recognition of their unique operational characteristics and long-term investment needs.

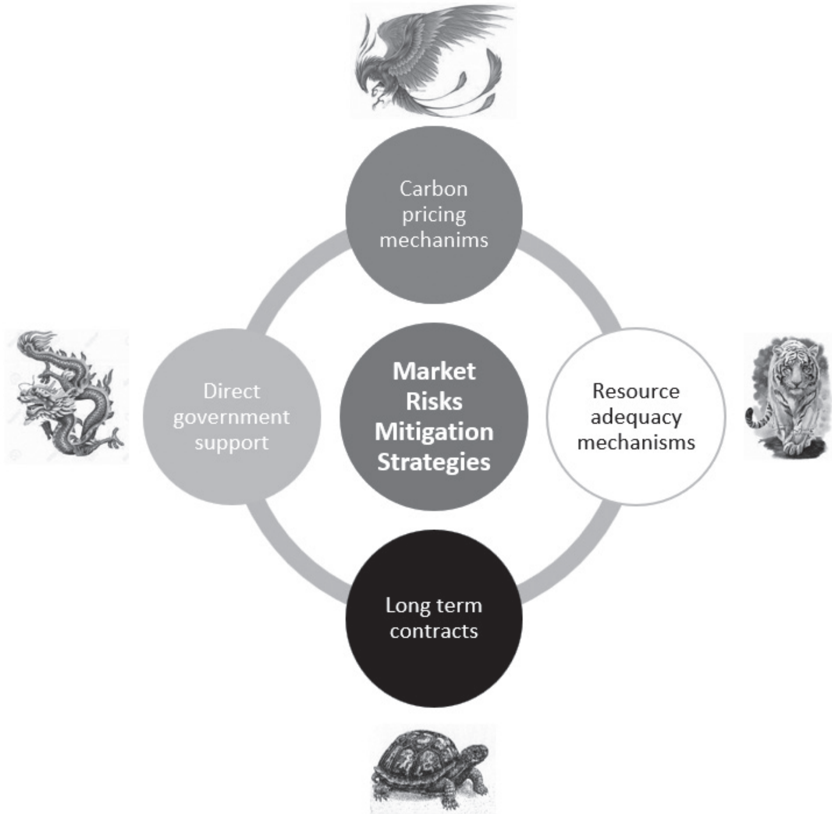
Figure 2 summarises four interconnected and mutually reinforcing mitigation strategies to address these market challenges, several of which have been illustrated in this section. These four strategies are not standalone tools but components of a comprehensive and balanced approach to mitigating market risks. By drawing an association with Chinese cosmology, the framework is transformed into a culturally resonant narrative that enhances its clarity, memorability, and perceived holism for policymakers.

Carbon pricing mechanisms, such as carbon taxes or cap-and-trade systems, place a price on carbon emissions. By internalising the external environmental costs of fossil fuel combustion, these mechanisms incentivise decarbonisation and create a more equitable competitive landscape. This transformative potential, which reshapes markets by phasing out polluting practices and enabling cleaner industries, is aptly symbolised by the Phoenix, representing rebirth and transformation.

Resource adequacy mechanisms, such as capacity market designs, are policy instruments designed to ensure sufficient generation capacity to meet electricity demand, thus maintaining grid reliability and averting power outages. These mechanisms can provide compensation to nuclear generators for their essential grid reliability and stability services. The White Tiger, a symbol of protection and guardianship, represents resource adequacy mechanisms by embodying the strength and defence required to safeguard critical resources and ensure a stable electricity supply.

Long-term contracts are agreements that provide stable pricing and guaranteed supply or demand over long periods, mitigating price volatility and enhancing investment and revenue certainty for large, capital-intensive projects. Examples include Contracts for Difference (CfDs) and Power Purchase Agreements (PPAs). The Tortoise, a symbol of longevity, stability, and foundational strength, represents long-term contracts by embodying the endurance, solid foundation, and predictability they provide in volatile markets.

Figure 2: Four interconnected and mutually reinforcing nuclear power market risk mitigation strategies



Direct government support, delivered through diverse financial instruments such as grants, subsidies, or tax credits, can mitigate the substantial upfront capital costs of nuclear power plants. Such support is particularly vital for emerging industries or strategic national goals, especially in markets where competing generation technologies also receive similar assistance. The Green Dragon, a symbol of power, growth, and benevolent authority, symbolises direct government support by reflecting the powerful role governments play in initiating and nurturing crucial developments.

Operational risks and mitigation

Operational risks fundamentally impact the economic viability of nuclear power. As fixed-cost assets with minimal variable operating costs, nuclear plants face substantially higher per-megawatt hour (MWh) costs during unplanned outages, owing to lost generation. Furthermore, contractual obligations often require procuring replacement power at premium market prices, further compounding financial losses.

Figure 3 presents a comprehensive framework for mitigating operational risks in nuclear power plants. This framework delineates four key strategic pillars, each symbolically aligned with a creature from Chinese cosmology, consistent with Figure 2, and collectively underscoring a holistic and balanced approach to risk management.

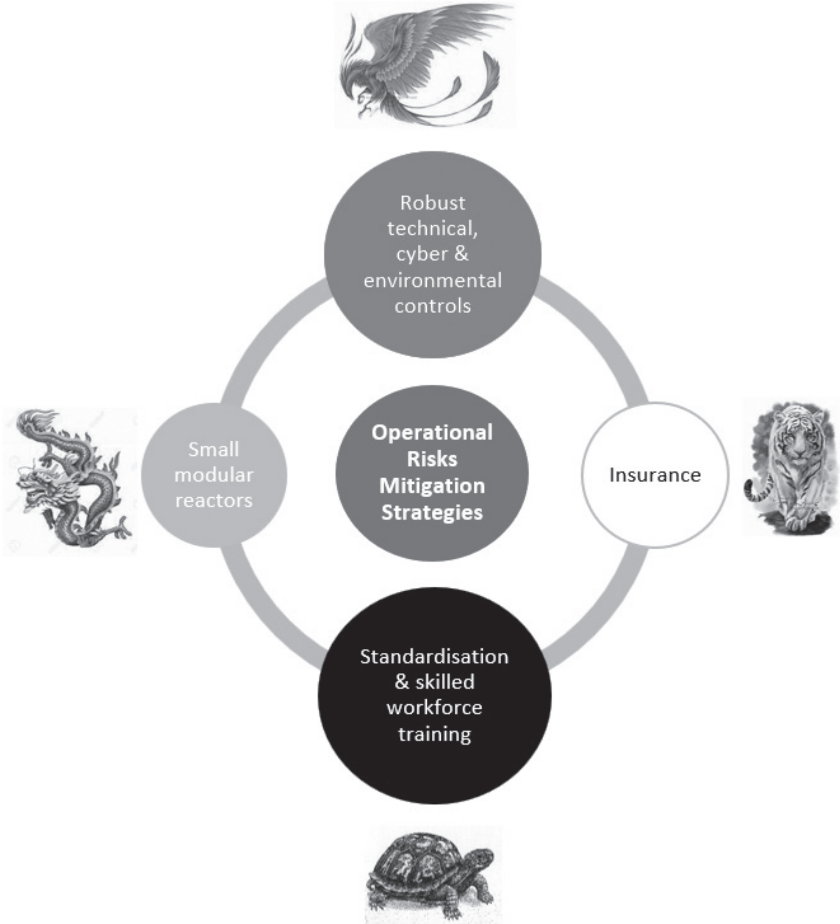
The first strategic pillar for operational risk mitigation encompasses robust technical, cybersecurity, and environmental controls, comprising three critical domains:

- **Robust maintenance programme:** This ensures the physical integrity and optimal performance of plant components through rigorous and routine upkeep.
- **Advanced security measures:** Safeguarding the plant's digital infrastructure requires network segmentation, regular system audits, and advanced threat detection measures that are increasingly vital amid the rise of cyberattacks and vulnerabilities in outdated control systems of conventional plants. The 2010 Stuxnet attack on Iranian nuclear facilities, which exploited industrial control system vulnerabilities to damage centrifuges, powerfully exemplifies this persistent threat.[16]
- **Environmental impact management:** Cooling towers regulate discharge water temperature, while online monitoring enables continuously oversight of critical operational parameters. These measures allow swift anomaly detection and help mitigate risks to aquatic ecosystems from heated water discharge.

This comprehensive pillar, which emphasises vigilance and proactive adaptation to threats, is aptly symbolised by the Phoenix. Representing renewal and the active management of powerful forces, the Phoenix conveys the continuous effort required to operate complex systems safely and adapt to emerging challenges.

16 J Alvarez, 'To Zero Day' (3 February 2015) Stanford Centre for International Security and Cooperation https://cisac.fsi.stanford.edu/news/stuxnet accessed 30 December 2024.

Figure 3: Interdependent and mutually reinforcing nuclear power operational risk mitigation strategies



Insurance functions as a financial risk transfer mechanism, providing a vital safety net of protection and compensation in the event of unforeseen operational incidents or disasters. The White Tiger, a symbol of protection and guardianship, represents the role of insurance in guarding against the catastrophic financial consequences of operational risks.

The third strategic pillar for operational risk mitigation – standardisation and skilled workforce training – emphasises foundational stability and the development of human capital. The Tortoise, known for its longevity, stability, and enduring foundation, aptly embodies these principles, representing the long-term, unshakeable bedrock crucial for safe and reliable nuclear operations. This pillar is underpinned by two core components:

- **Design and process standardisation:** Ensuring consistency and predictability across maintenance, training, construction, and operation throughout a nuclear plant's lifecycle, thereby reducing the likelihood of errors.

- **Skilled workforce training:** Developing and maintaining a highly competent and well-trained workforce is paramount, since human error is a critical factor in operational safety. In Malaysia, existing nuclear science programmes in public universities focus primarily on non-power applications (Nahrul & Ainul, 2009), and often lack specialised subjects essential for operating power plants, such as reactor design, nuclear safety engineering, nuclear fuels and materials. This gap highlights an important educational challenge requiring strategic attention.

Small modular reactors (SMRs) represent a technological and design innovation aimed at inherent risk mitigation. They offer potential cost advantages through modularity and factory fabrication. Owing to their smaller size and incorporation of advanced passive safety features, SMRs are designed for simpler operation, enhanced safety, and distributed deployment with potentially lower individual risk profiles than conventional large-scale reactors. The Green Dragon, symbolising growth, innovation, and potent yet benevolent power, aptly represents SMRs as a new wave of nuclear technology that promises safer, more flexible, and more sustainable energy development.

The circular arrangement in Figure 3 underscores the interdependence of the four strategies, which together form a comprehensive system for managing operational risks in nuclear power. The framework spans a wide range of risk mitigation measures, from active technical management and cybersecurity to financial protection, foundational human and process excellence, and innovative technological design. The integration of the four symbols highlights the goal of a harmonious and robust system crucial for ensuring safety and reliability in this highly critical industry.

The value of nuclear and policy support

The economic viability of nuclear power is strongly influenced by inherent market and operational risks, as evidenced in Sections 3.1 and 3.2. While economies of scale, particularly at multi-unit sites, offer significant cost mitigation-evidenced by 2022 average total generating costs for multi-unit plants ($28.64 per MWh) being substantially lower than those of single-unit plants ($41.08 per MWh)[17]- current market designs often do not provide sufficient compensation to nuclear power generation for its firm, baseload, and carbon-free attributes.

To bridge the gap between abstract planning and operational realities, power system and sectoral models should incorporate a negative feedback loop based on outage costs. Such a design elevates reliability from a purely technical consideration to a core economic and social variable, thereby directly influencing investment decisions, policy formulation, and long-term strategic planning, including the appraisal of capital-intensive nuclear power projects. Consequently, preserving the resilience and zero-emission characteristics of nuclear power necessitates an appropriate market valuation. This valuation must accurately reflect both the positive externalities of carbon-free generation and the associated market and operational risks.[18]

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Policymakers are increasingly recognising the broader value of nuclear energy. This is evident in the United States, where federal legislation such as the Bipartisan Infrastructure Law, the Inflation Reduction Act, and the Nuclear Fuel Security Act aims to foster a more stable long-term business environment for the nuclear sector. Properly valuing nuclear power's social and environmental benefits is crucial not only for

17 Nuclear Energy Institute, *Nuclear Costs in Context* (2023) https://www.nei.org/resources/reports-briefs/nuclear-costs-in-context accessed 30 December 2024.

18 Ibid.

19 YY Leong and LM Feng, The ASEAN Power Grid Tree of Life: A Living Blueprint for Regional Energy Integration (Working Paper, June 2025).

preserving existing carbon-free generation capacity but also for enabling future expansion and contributing to broader clean energy goals.[20]

Countries like France and South Korea, which depend heavily on nuclear power, demonstrate the technology's feasibility through robust policy frameworks. Emerging economies, including India and China, are also expanding their nuclear capacity to meet growing energy needs while reducing carbon emissions. Therefore, in the transition to a low-carbon future, nuclear power warrants proactive and sustained policy support as a crucial bridge between fossil fuels and renewable energy.

Regulatory efficiency and international cooperation

Regulatory challenges

The crucial role of efficient regulatory frameworks in enabling the widespread deployment of nuclear technologies for climate change mitigation and energy security has gained increasing international recognition.[21] The World Nuclear Association's Harmony programme, targeting 25% of global electricity generation from nuclear sources by 2050, necessitates the construction of approximately 1000 GWe of new nuclear capacity.[22]

However, the industry's performance over the past decade, averaging approximately 6.7 GWe (equivalent to about seven new reactors) connected annually, highlights a significant gap. Assuming a 50/50 split between gigawatt-scale reactors and small modular reactors (SMRs) contributing to the 1000 GWe target, achieving this goal would require connecting approximately twenty gigawatt-scale reactors and seventy 300 MW SMRs to grids annually for the next 25 years—a total of 2,250 new reactors.[23] This starkly underscores the substantial acceleration in reactor deployments required to realise these ambitious objectives.

20 Nuclear Energy Institute, *Nuclear Costs in Context* (2023) https://www.nei.org/resources/reports-briefs/nuclear-costs-in-context accessed 30 December 2024.

21 A Carson, M Nichols and S Mirmiran, *A Framework for International Regulatory Efficiency to Accelerate Nuclear Deployment* (World Nuclear Association, 2023) https://cna.ca/wp-content/uploads/2023/09/A-Framework-to-Accelerate-Nuclear-Report.pdf accessed 27 December 2024.

22 A Rising, 'Harmony — The Future of Electricity' (November 2017) *IAEA Bulletin* 58(4), 24–25 https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull58-4/5842425.pdf accessed 30 December 2024.

23 A Carson, M Nichols and S Mirmiran, *A Framework for International Regulatory Efficiency to Accelerate Nuclear Deployment* (World Nuclear Association, 2023) https://cna.ca/wp-content/uploads/2023/09/A-Framework-to-Accelerate-Nuclear-Report.pdf accessed 27 December 2024.

A key factor hindering progress is the complexity and inefficiency of existing regulatory frameworks. While rigorous, independent safety regulation is paramount, several challenges related to regulatory efficiency must be addressed to facilitate timely and cost-effective deployment.

Solutions

Regulatory control is critical to nuclear power plant development and operation, ensuring safety and environmental protection but it can also slow progress and increase costs. These challenges include varying levels of nuclear expertise and regulatory capacity among national bodies, which can lead to project approval delays, particularly for international operators. Divergent national safety codes and standards pose obstacles for international vendors, increasing costs and potentially compromising safety. Furthermore, a significant impediment is the persistent duplication of regulatory review efforts in the localisation of previously approved designs, stemming from a lack of mutual recognition of safety assessments and limited international regulatory cooperation. This duplication inflates project costs, delays crucial carbon emissions reductions, and compels costly and time-consuming country-specific design modifications.[24]

To address these challenges and streamline deployment, two key objectives must be prioritised: minimising the time and cost of adapting previously licensed designs for new jurisdictions and modernising existing regulatory frameworks. The former can be achieved through enhanced international regulatory cooperation and harmonisation, facilitating the leveraging of expertise and reducing redundant review processes. The latter requires updating regulations, key policy and technical positions, and licensing and oversight processes to effectively reflect the innovative features and inherent safety characteristics of advanced reactor technologies, ensuring efficient and timely approval of safe designs while maintaining rigorous safety standards.[25]

24 Canadian Nuclear Association and Nuclear Energy Institute, *Canadian and United States Regulatory Cooperation for New Nuclear Deployment* (2023) https://www.nei.org/resources/reports-briefs/canadian-and-us-reg-cooperation-new-nuclear accessed 25 December 2024.

25 Ibid.

Recommendations for Malaysia

In light of the foregoing analysis, the following recommendations are advanced, integrating key strategic considerations, analytical approaches, and operational initiatives essential to shaping Malaysia's energy future.

Addressing market risks

- ***Natural gas price sensitivity analysis***

A comprehensive analysis of natural gas price sensitivity, incorporating potential carbon pricing mechanisms and other market interventions, is crucial for accurately assessing the long-term economic viability of nuclear power in Malaysia. This analysis should consider the impact of existing natural gas subsidies and evaluate scenarios involving the reduction or removal of such subsidies.

- ***Explore and adapt suitable market mechanisms***

To ensure fair compensation for nuclear power's baseload generation and carbon-free attributes, Malaysia should conduct a thorough assessment of various market mechanisms, including contracts for difference (CfDs), capacity market designs, and carbon pricing schemes. These mechanisms should be adapted to the specific context of the Malaysian electricity market, which currently lacks a fully developed capacity market and an established framework for CfDs in the power sector.

- ***Establish strategic international partnerships for market design***

Establishing strategic partnerships with nations possessing extensive experience in operating nuclear power plants within competitive electricity markets is crucial. These collaborations offer critical guidance on the design and implementation of effective market mechanisms and robust regulatory frameworks tailored to the specific context of Malaysia.

Addressing operational risks

- ***Prioritising operational excellence***

Malaysia should prioritise developing a highly skilled nuclear workforce and establishing robust operational and maintenance programmes to minimise unplanned outages and ensure plant reliability. Collaboration with international partners that possess strong operational track records can support knowledge transfer and the adoption of best practices.

- ***Evaluating advanced reactor technologies***

A comprehensive evaluation of advanced reactor technologies, particularly SMRs, is crucial for Malaysia's future energy landscape. SMRs offer several potential advantages over conventional large-scale reactors, including: enhanced safety (e.g., passive safety systems), deployment flexibility (e.g., suitability for smaller grids and diverse locations), improved load-following capabilities (e.g., integrating with intermittent wind and solar), expanded value streams (e.g., providing process heat for decarbonising heavy industry, generating high temperature steam for cost-effective hydrogen production, and enabling co-generation applications), and the potential for reduced capital and operational costs compared to conventional large-scale reactors.[26]

Several SMRs, such as X-energy's Xe-100, a Generation IV High-Temperature Gas-Cooled Reactor (HTGR), and TerraPower's Natrium reactor, are projected for deployment within this decade. Adopting pre-approved SMR designs could streamline regulatory approval processes, while fostering international collaborations may further accelerate deployment in Malaysia.

Establishing a robust regulatory framework

- ***Streamlining licensing and regulatory processes***

Malaysia should develop a clear, efficient, and internationally harmonised regulatory framework for nuclear power based on international best practices. Collaboration with experienced and credible regulatory bodies is crucial to ensure safety, build regulatory capacity, and minimise licensing costs and timelines. For example, the UK's Office for Nuclear Regulation (ONR) developed the Generic Design Assessment (GDA) process for pre-approving reactor designs before site-specific applications, and the United States Nuclear Regulatory Commission (NRC) has implemented a similar licensing framework for SMRs to accelerate approvals.

- ***Promoting multi-unit deployment, regional collaboration and shared oversight***

Multi-unit nuclear power plant deployments offer the potential for significant cost reductions and improved efficiency through learning-

26 X Energy, 'High-Temperature Gas-Cooled Reactors (HTGRs)' (2024) https://x-energy.com/resource/htgr accessed 11 January 2025.

curve effects. This is evidenced by the Vogtle project in the United States, where Unit 4 achieved a reported cost reduction of 40% compared to Unit 3.[27] Similarly, at the Barakah Nuclear Power Plant in the United Arab Emirates, successive units have demonstrated increasing construction efficiency. Unit 3, for instance, was completed four months ahead of the Unit 2 schedule and five months ahead of the Unit 1 schedule, highlighting the benefits of phased, multi-unit construction.[28]

Recognising the significant economies of scale associated with multi-unit nuclear power plants, Malaysia could consider pursuing collaborative ventures with other Southeast Asian nations to establish a shared nuclear power site. This regional approach would distribute costs, enable shared regulatory oversight, enhance economic viability, and maximise the utilisation of generated power. Advancements in low-loss, long-distance transmission technologies, particularly those developed in China, further enhance the feasibility of such regional energy sharing.

- ***Adopting risk-informed regulation***

Recognising that regulatory standards often evolve in response to new technologies or incidents (e.g., Fukushima), a shift from prescriptive, one-size-fits-all regulations to risk-informed approaches is crucial. These approaches tailor requirements to specific technologies and their respective risk profiles.

Fostering public engagement and communication

A critical element of successful nuclear power development in Malaysia lies in proactively addressing public concerns about plant siting. This requires a long-term and transparent public engagement strategy encompassing the entire project lifecycle, from planning and construction through operation and decommissioning. This principle of "engage early, think long-term" is crucial for building public trust, mitigating anxieties, dispelling misconceptions, and minimising opposition.

27 J Krellenstein, 'Vogtle Part 4: Can Positive Learning Happen Next?' (16 April 2024) *Decouple* https://www.decouple.media/p/vogtle-part-4-can-positive-learning-6a5 accessed 30 December 2024.

28 *Nuclear Newswire*, 'Barakah-4 Is Connected to the UAE Grid' (27 March 2024) https://www.ans.org/news/article-5897/barakah4-is-connected-to-the-uae-grid/ accessed 30 December 2024.

- ***Emphasising the socioeconomic and environmental benefits***

The public engagement strategy should effectively communicate the socioeconomic and environmental advantages of nuclear power. Highlighting the industry's contributions to the national economy, such as job creation, local tax revenue, and GDP growth, can foster public acceptance. Additionally, emphasising the environmental benefits of nuclear power, such as clean air and reliable baseload generation, can position it as a viable strategy for decarbonisation. To illustrate the economic advantages, quantitative data from reliable sources should be incorporated.[29] [30]

- ***Enabling stakeholder participation through democratic institutions***

Strategically engaging stakeholders through newly established democratic institutions can facilitate informed decision-making. Platforms like the Parliamentary Special Select Committee (PSC) on Environment and Science and the All-Party Parliamentary Group Malaysia on Sustainable Development Goals and Disaster Risk Management offer valuable avenues for public participation.[31]

Navigating geopolitical realities and strategic partnerships

Nuclear power presents a complex and contentious energy landscape. Since 2000, 96 nuclear reactors have been connected to electricity grids across 13 countries. Notably, China has constructed 45 of these reactors domestically, while Russia has built 12. Furthermore, four Chinese-designed reactors and seven Russian-designed reactors have been deployed in five additional nations. This signifies that approximately 71% of global reactor deployments since 2000 have been directly attributable to either domestic construction within China and Russia or the export of their reactor designs. This trend is further amplified by the current construction landscape: of the 54 reactors presently

29 Nuclear Energy Institute, *Nuclear Costs in Context* (2023) https://www.nei.org/resources/reports-briefs/nuclear-costs-in-context accessed 30 December 2024.

30 US commercial nuclear industry contributes approximately $60 billion to the US GDP and generates $2.2 billion in state and local taxes, offering high-quality, long-term employment with significantly higher wages than the national median.

31 Parliament Malaysia, 'All-Party Parliamentary Group Malaysia (APPGM)' (10 January 2025) https://www.parlimen.gov.my/kumpulan-rentas-parti-parlimen-malaysia-krppm.html?uweb=dr&lang=en accessed 10 January 2025.

under construction in 20 countries, over half involve either Chinese or Russian technology.[32]

This dominance has prompted calls from within the United States for the formation of a coalition of allied nations to compete with China and Russia in providing nuclear technology, fuel, and services, particularly to emerging economies experiencing rapid growth in energy demand and seeking international partnerships.[33]

In this context, Malaysia's evaluation of potential international partners for nuclear power development requires careful consideration. The nation stands to gain most from partnerships that offer substantial advantages in technology transfer, regulatory frameworks, financing, market design, and project management, while minimising the risk of undue influence on domestic political processes.

When a major power offers to fully fund and operate a large, strategic infrastructure project such as a nuclear power plant, the underlying intent is often less about delivering the lowest-cost or most efficient electricity to the recipient nation (a practical concern) and more about advancing geopolitical influence, securing long-term economic engagement, and demonstrating technological capabilities on the global stage (political objectives). Consequently, Malaysian leaders, drawing upon a comprehensive understanding of the economic and regulatory landscape of nuclear power, must critically assess whether the political significance of these offers outweighs their practical benefits.

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32 M Wooten, 'UGA Researchers Call for New International Coalition of Civilian Nuclear Partners' (7 December 2020) College of Engineering, University of Georgia https://engineering.uga.edu/uga-researchers-call-for-new-international-coalition-of-civilian-nuclear-pa/ accessed 30 December 2024.

33 Ibid.

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