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More Risk Than Reward

Assessing the Risks and Hidden Costs of Nuclear Power in the Philippines

Introduction

More than three decades since President Corazon Aquino shelved the USD2.3 billion Bataan Nuclear Power Plant (BNPP), the Duterte administration has decided to re-examine the viability of nuclear power to meet the Philippines' growing energy demand. The Department of Energy recently delivered a draft nuclear power development program to the Office of the President and is reportedly considering rehabilitating BNPP and deploying small modular reactors (SMRs) to meet small island grid loads. These technologies have different operating characteristics, but both require careful review because energy transition has redefined the risk-reward equation for cost-sensitive markets like the Philippines.

Conventional nuclear power is one of the most expensive forms of electricity generation, especially compared to the deflationary cost of domestic renewable resources such as wind, solar, and geothermal, as well as battery storage technologies. Nuclear projects consistently face major completion risks and hidden costs in the form of (1) budget overruns, (2) construction delays, (3) untested reactor designs, and (4) accident liabilities. Despite the theoretical potential for innovative SMR designs, real-world SMR projects have faced similar risks. High capital costs and contingent liabilities mean that a new nuclear power plant (NPP) would require significant government support through cross subsidies and public spending, which would ultimately be shouldered by Filipino ratepayers and taxpayers.

Nuclear power is one of the most expensive forms of electricity generation.

Of particular concern given system challenges in 2020, nuclear power also contradicts the Department of Energy's (DOE) stated goal to deploy flexible, indigenous resources to improve the country's energy security and accommodate an increase in the supply of renewable power.[1] Large-scale nuclear energy is a traditionally inflexible baseload power source that would perpetuate the country's

[1] Department of Energy. DOE Sec. Cusi Declares Moratorium on Endorsements for Greenfield Coal Power Plants. October 27, 2020.

dependence on foreign imported fuel, the costs of which are often passed through to captive ratepayers unable to hedge against fuel price volatility.

The Philippines' location on the Pacific Ring of Fire—an area of intense seismic activity—and the increasing frequency and severity of weather disasters should also raise concerns for old technology large-scale light water reactors. In October 2019, the International Atomic Energy Agency (IAEA) identified 13 "significant actions" that must be taken before the Philippines can begin preparatory work for contracting and construction of a nuclear plant. Critical steps cited include developing emergency response capabilities, establishing an independent nuclear regulatory agency, building a regulatory framework for nuclear safety and security, and reviewing various financing options.

Further studies will certainly be warranted to analyse ownership and financing options, radioactive waste management, and the overall costs and benefits of including nuclear in the energy mix. However, the government must define early on its level of support and its limitations in managing contingent liabilities. DOE should also consider the risks of locking in long-term capacity payments for a nuclear facility. The entry of low-cost intermittent renewable resources, energy efficiency and demand-side management programs, and the implementation of Retail Competition and Open Access (RCOA) could lead to falling load factors for nuclear power. **This means that by the time a nuclear plant is operational—unlikely before the next decade— it might already have been squeezed out of the market, leaving end-users on the hook for unused capacity.**

Given these risks, it would be prudent for the Philippines government to take the following measures to mitigate hidden costs associated with nuclear power generation:

1. **Extend the recently announced moratorium on greenfield coal-fired power plants to all inflexible generators.** DOE should extend its moratorium to cover all inflexible generators, including large nuclear reactors unable to follow load fluctuations due to technical restrictions. To qualify for DOE approval, nuclear power plant developers should be required to prove that flexible operation is incorporated into the reactor design. Until critical transmission and distribution bottlenecks have been addressed, the market will benefit from a level-playing field that ensures generation options are placed in a system management context.

2. **Prevent increases in construction costs from being automatically passed through to consumers.** Given the nuclear sector's long track record of cost overruns, the risk of additional construction expenditures is material. As a result, policymakers should take steps to ensure that lenders and project sponsors bear all appropriate construction risks and are not permitted to burden the system with requests for adjustable tariffs. The Energy Regulatory Commission (ERC) should establish a price ceiling for the allowable tariffs from nuclear power plants to prevent the risk of upside variability in the final tariff from being passed to consumers.

3. **Update the legal accident liability limits for nuclear power plant operators.** The current legal liability limit of USD5 million for nuclear operators would cover only a tiny fraction of the costs associated with a nuclear accident. Congress should bring the liability limits in line with more recent international conventions, such as the 1997 Protocol to Amend the Vienna Convention and the Convention on Supplementary Compensation.

4. **Prohibit two-part tariff structures in Power Supply Agreements (PSAs).** Two-part tariffs are composed of a capacity payment for fixed costs (capital recovery and fixed O&M) and an energy payment for variable costs (variable O&M, fuel cost fluctuations, exchange rate fluctuations). Due to inflexible capacity payments, lower load factors for nuclear power plants can leave ratepayers with a higher average cost of electricity per kilowatt hour (kWh). Variable charges, meanwhile, allow fluctuations in international fuel prices and exchange rates to be passed to consumers. A straight energy tariff would create a more level playing field and benefit consumers by requiring the generator to bear the variable costs and stranded asset risks.

5. **Require *force majeure* provisions in PSAs to share risk of demand shocks between generators, utilities, and end-users.** The COVID-19 pandemic demonstrated how inflexible capacity payments can leave ratepayers with high electricity bills despite surplus electricity capacity. DOE should require standardized *force majeure* clauses to protect end-users from inflexible capacity charges during demand shocks, transferring greater risk to the nuclear power plant developer.

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Overview of Nuclear Power in the Philippines

The debate about the role of nuclear power in the Philippine power market has a long and costly history. In July 1973, President Ferdinand Marcos announced a decision to build a nuclear power plant (NPP) and established a presidential committee to solicit offers for two 620MW nuclear reactors. One year later, Marcos approved an offer from Westinghouse to build the Bataan nuclear facility with an initial cost estimate of USD500 million. However, the offer contained sparse details or specifications, and by March 1975 the estimated cost had inexplicably doubled to USD1.2 billion.

Construction began in 1976 but was halted following the 1979 Three Mile Island nuclear accident in the United States. The project was eventually completed in 1984 with just one 621MW reactor for a total cost of USD2.3 billion—almost five times the initial estimate for two reactors.

Before the project became operational, President Marcos was overthrown by the People Power Revolution in February 1986. Two months later, the Chernobyl disaster caused the new president, Corazon Aquino, to shutter the BNPP. Since then, the Philippine government has spent between PHP43.5 billion (USD909 million) and PHP64.7 billion (USD1.35 billion) for principal amortization, as well as another PHP21.2 billion (USD441 million) in interest for the unused facility.[2] [3] BNPP loans were not completely paid off until 2007, but the government is still spending PHP40 million (USD833,000) annually to maintain the plant.[4]

Since the 2000s, there have been numerous efforts to revive the BNPP, all of which have been met with significant political opposition and contradictory reports on feasibility. In 2009, for example, the Korea Hydro & Nuclear Power Co. , a subsidiary of the state-owned Korea Electric Power Corporation (KEPCO) said rehabilitation would cost USD1 billion. KEPCO also said it would be more efficient to "construct a new power plant because [BNPP] is a more than 20-year-old asset."[5]

The Russian state-owned Rosatom submitted its own assessment in 2017, which found that reviving BNPP would cost as much as USD3 billion.[6] The company said the plant was in "relatively good condition" and that "any doubts about Bataan Nuclear Power Plant's safety are unfounded."[7] But according to Russian Ambassador Igor Khovaev, the plant's technology is "absolutely outdated" and its revival is "not possible at all."[8]

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[2] 1 USD = 48.03 PHP as of December 29, 2020.
[3] Business Mirror. What Debt Trap? March 28, 2019.
[4] Rabino, Cristobal. The Story of the Bataan Nuclear Power Plant: An Assessment of Technology Implementation. August 2019.
[5] GMA Network. Korean firm keen on developing nuclear power for PHL. May 31, 2018.
[6] Reuters. In power hungry Philippines, some advocate a nuclear revival. May 22, 2018.
[7] GMA Network. Bataan nuclear plant can be revived, says Russian state firm Rosatom. May 13, 2018.
[8] CNN. Russian ambassador: Bataan nuclear power plant revival 'not possible at all'. April 4, 2018.

Rosatom also signed a Memorandum of Understanding (MOU) with the Philippines DOE in October 2019 to explore the possibility of building SMRs. Other countries interested in developing the Philippines' nuclear capacity include Tractebel, a Belgium-based energy company, and China Nuclear Engineering and Construction.

The interest in developing nuclear projects, however, has not been matched by careful execution of the high-level feasibility work needed to evaluate suitability. Philippines Energy Secretary Cusi said during a recent Senate hearing that the government has not conducted a "concrete study" of the cost or technical feasibility of reviving BNPP.[9] Regardless, the situation is arguably best summarized by Antonio Moraza, former president of Aboitiz Power: "Nuclear is very controversial and if we ever wanted to install it in the Philippines, it would not succeed without very strong intervention by the government."[10]

The Risks and Hidden Costs of Nuclear Power

Nuclear project proposals are inevitably accompanied by a high level of "optimism bias," wherein supporters downplay their costs and risks. This has been true since 1953, when industry advocates in the United States famously hailed nuclear as a power source "too cheap to meter." But there are numerous hidden costs and risks that must be analyzed to understand the full costs and competitiveness of these complex facilities. These include:

- **Construction cost risk**—The "overnight cost" of a proposed plant provides a baseline cost estimate without any increases in financing costs. This includes the direct engineering, procurement, and construction (EPC) costs, as well as the indirect land acquisition, management, and commissioning costs, among others. Based on global studies of the nuclear industry, reactors are almost always subject to cost overruns, which are often far greater than cost increases for other power sources.[11]

- **Construction schedule risk**—Project developers for nuclear reactors typically assume a five-year construction period, but these timelines have consistently proven to be overly optimistic. The 52 nuclear reactors being built as of July 2020 have been under construction for an average of 7.3 years, and many of them are far from completion.[12] Construction delays escalate personnel and equipment costs, while postponing cash in-flows increases interest to be paid on debt.

- **Technology risk**—Plants with new, untested designs often experience unanticipated delays and operational problems, which increase costs. Small

[9] YouTube. Senate Committee on Finance hearing. October 13, 2020.
[10] Reuters, *op. cit.*
[11] Gilbert, Alexander, Sovacool, Benjamin K, Johnstone, Phil and Stirling, Andy. Cost overruns and financial risk in the construction of nuclear power reactors: A critical appraisal. Energy Policy, 102. March 2017, pp. 644-649.
[12] Mycle Schneider Consulting Project. The World Nuclear Industry Status Report 2020. September 2020.

modular reactors, for example, are still a nascent technology but have already demonstrated cost blowouts over their construction periods.

- **Nuclear accident liability risk**—The risk of accidents for NPPs are consistently underpriced even though incident costs are expected to increase in the future.[13] Vendors of nuclear reactors often refuse to bear any financial liability for accident costs. Philippines law holds installation operators liable for a maximum of USD5 million in damages, leaving the public liable for nuclear damages that exceed this limit. Moreover, the Philippines still needs to develop a comprehensive legal framework to identify responsibilities for safety, security, and safeguards and give legal authority to a single independent regulatory agency.

These risks are examined in the following sections.

Construction Cost Risk

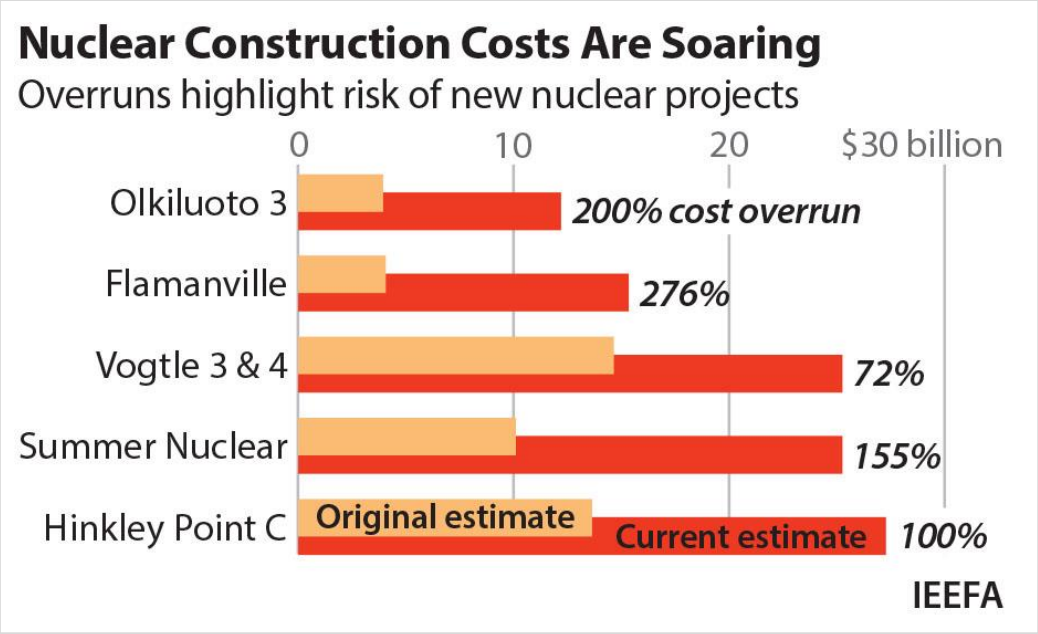
Nuclear power is one of the most expensive forms of electricity generation, along with gas peaking plants, according to financial advisory group Lazard.[14]

The levelized cost of nuclear in 2019 was between USD129 and 198/MWh, more than four times the costs of utility-scale solar and wind (USD31 and USD26 per MWh, respectively). In contrast with renewable technologies, the levelized cost of nuclear has increased almost every year since 2012, from USD102/MWh to USD163/MWh. In several cases, nuclear power projects have demonstrated "negative learning," where costs increase as countries build more nuclear reactors.[15]

Traditional large-scale light water nuclear projects face huge financial risks and often surpass their initial overnight cost estimates. Construction costs in Western Europe and the United States have far exceeded their initial projections, and a 2018 study from the Massachusetts Institute of Technology (MIT) found that it is no longer profitable to build NPPs in those countries because of skyrocketing capital costs.[16]

[13] Wheatley, S., Sovacool, B. and Sornette, D. Of Disasters and Dragon Kings: A Statistical Analysis of Nuclear Power Incidents and Accidents. Risk Analysis, 37: 99-115. March 2016.
[14] Lazard. Levelized Cost of Energy and Levelized Cost of Storage—2020. October 19, 2020.
[15] Grubler, Arnulf. The costs of the French nuclear scale-up: A case of negative learning by doing. September 2010.
[16] Massachusetts Institute of Technology Energy Initiative. The Future of Nuclear Energy in a Carbon-Constrained World. 2018.

Figure 1: Comparison of Overnight Cost Estimates for Recent Nuclear Power Plants in Western Europe and the U.S.



Source: IEEFA, Bloomberg, GreenTech Media, World Nuclear News, Guardian.

For example, the two most recent projects to begin construction in the United States —Southern Company's Plant Vogtle units 3 and 4, as well as SCANA Corporation's Summer Nuclear Generating Station units 2 and 3—have faced major cost blowouts and construction delays.

Southern Company's initial budget for the two additional Plant Vogtle reactors was USD14.5 billion (60% higher than the budget for the first two units), and the company received an USD8 billion loan subsidy from the U.S. Department of Energy. Construction began in 2013 with a targeted completion date in 2017. However, the project has now been delayed five years to 2022, and costs have ballooned more than 70% to USD25 billion.

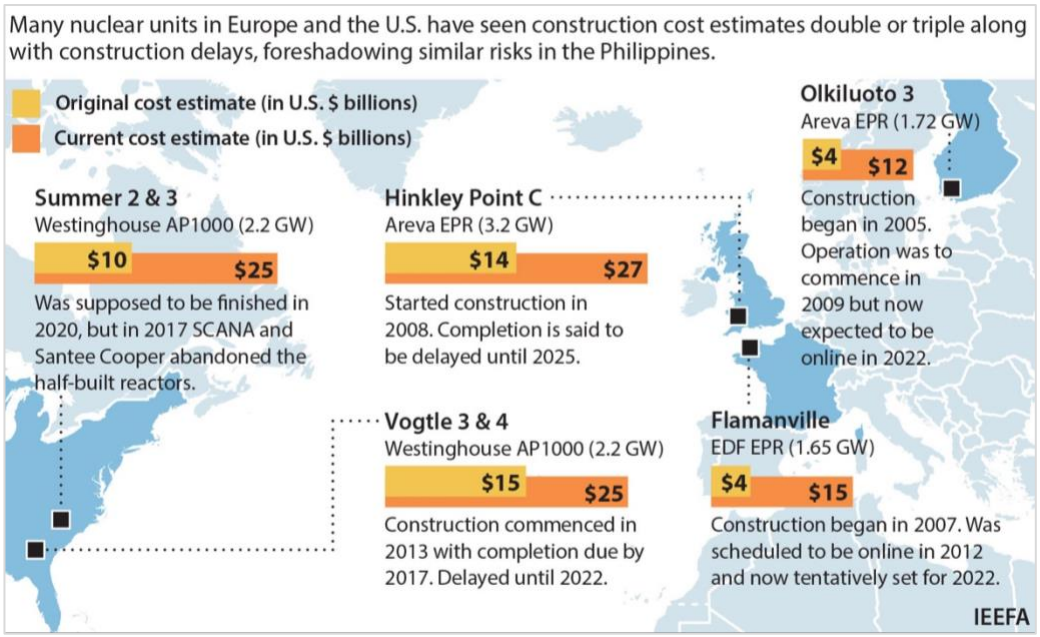
SCANA, meanwhile, filed for a construction and operating license in 2008 with an initial cost estimate for its two units of USD9.8 billion. After construction began in 2013, the cost exploded to USD25 billion. SCANA permanently halted construction on the two reactors in July 2017.

Other projects in Finland, France, and the United Kingdom also demonstrate the financial quagmire that NPPs can create for developers and governments. Finland's Olkiluoto 3 project is more than a decade behind schedule. Costs have tripled, from an initial estimate of EUR3.2 billion to EUR9.6 billion. French utility EDF's Flamanville is also more than a decade behind and has more than tripled in price (with a targeted start date in 2024). The U.K. government-backed Hinkley Point C project is now expected to cost GBP20 billion, twice the initial estimate; the increase will be paid for largely by ratepayers. In 2016, the U.K. National Audit Office

condemned the government for making households pay for such a "risky and expensive" venture.[17]

Costs for NPPs tend to be lower in Asia, but the MIT study stated that data from South Korea and China was particularly concerning because a lack of transparency made it challenging to validate cost estimates.[18]

Figure 2: Nuclear Projects Face Extensive Delays and Cost Overruns



Studies suggest that even modest increases in capital costs for a nuclear power project in the Philippines could significantly delay the targeted in-service date. According to the DOE's recently released Philippines Energy Plan 2018-2040, a 2017 pre-feasibility study of nuclear infrastructure found, "A 20.0 percent increase of nuclear power plant investment cost delays the entry of nuclear power by five (5) years."[19] Moreover, the same study found, "Entry of variable renewable energy (VRE) sources with storage battery components … delays the introduction of a large reactor by three (3) years." These conclusions demonstrate the fragile competitive position of nuclear power in market scenarios that address the current technology options relevant to the Philippines.

Government financial support is necessary for NPPs because very few project sponsors have the financial capacity to independently raise the capital required for overnight costs and contingent liabilities, especially in energy growth markets without low-cost access to USD debt markets. Government support typically comes in the form of subsidies, competition guarantees, equity investments, and nuclear

[17] The Guardian. Hinkley Point C: rising costs and long delays at vast new power station. August 13, 2019.
[18] Massachusetts Institute of Technology Energy Initiative, *op. cit.*
[19] Department of Energy. Philippines Energy Plan 2018-2040.

liability coverage. Governments can also allow for flexibility in final tariffs, allowing cost overruns to be passed through to ratepayers via PSAs. Given the high likelihood of overnight cost increases and construction delays, both lenders and equity investors are likely to demand significant contingencies in the variability of final tariffs.

In addition, pass-throughs of fuel prices and foreign exchange rates mean that Filipino ratepayers will likely be subject to volatile global fuel prices and currency markets. Although the fuel costs of nuclear reactors are significantly lower than fossil fuel generators, foreign exchange risk is particularly important when large, expensive equipment is imported. Pass-throughs of these costs is one of the primary reasons electricity bills in the Philippines are among the highest in Asia.[20] Keeping ratepayer bills dependent on the foreign imports and exchange rates will not improve the country's domestic energy security and will only perpetuate one of the underlying causes of high electricity prices.

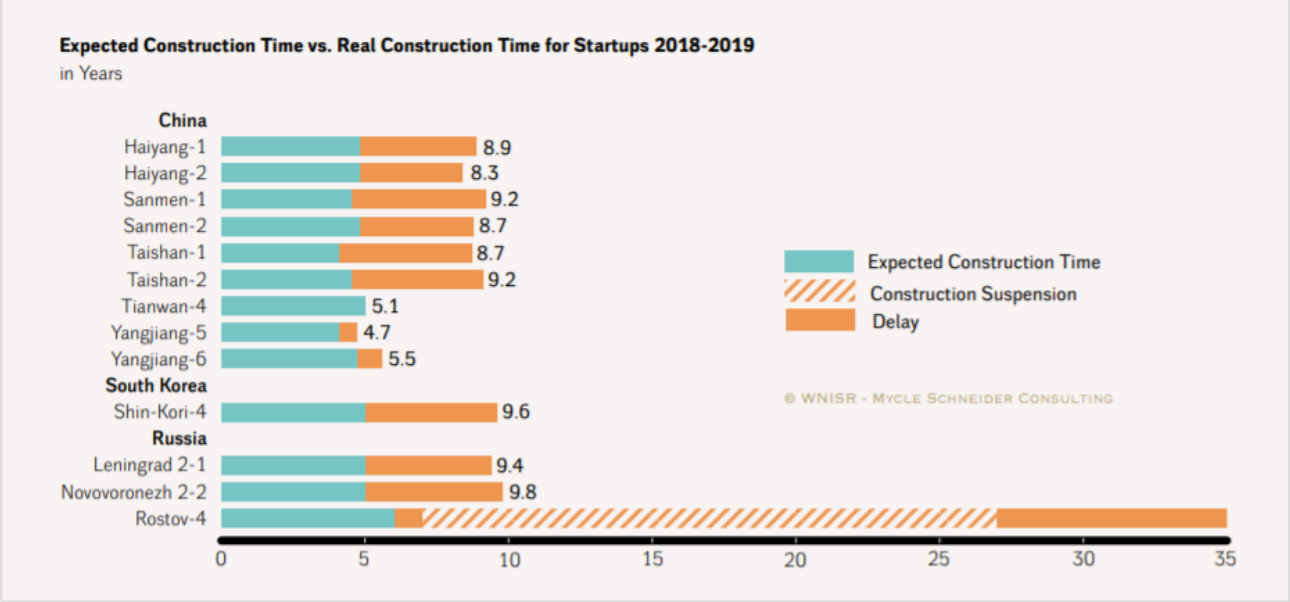
Construction Schedule Risk

Based on the 2018 Philippine Energy Plan, the DOE is aiming to have a nuclear reactor operational as early as 2027.[21] But although developers typically assume a five-year construction period for new reactors, the 52 nuclear plants being built globally in 2020 have been under construction for an average of 7.3 years. The average construction time of the 63 nuclear reactors completed since 2010 was 10 years.[22] Although developers in Asia might argue that delays are more common in Western markets, recently completed reactors have exhibited extensive timelines in Russia, China, and South Korea (see Figure 3 below).

Moreover, planning and pre-construction phases can typically take as long as three years, raising questions about whether a nuclear plant would be operational before the mid-2030s. Caution on this point has already been factored into assumptions about new capacity options. Global ratings agency Fitch Solutions recently said a nuclear facility was unlikely to become operational in the Philippines in this decade.[23]

[20] IEEFA. Carving Out Coal in the Philippines: Stranded Coal Plant Assets and the Energy Transition. October 2017.
[21] Department of Energy. Philippines Energy Plan 2018-2040.
[22] Mycle Schneider Consulting Project, *op. cit.*
[23] Fitch Solutions. Nuclear On The Cards In The Philippines. September 4, 2020.

Figure 3: Delays for Nuclear Power Plant Units Started Up 2018-2019



Source: World Nuclear Industry Report, 2019.

Russia's two floating Akademik Lomonosov units took almost 13 years to complete despite claims about the speed and cost benefits of SMRs (which are discussed in greater detail in the next section). Apart from the Rostov-4 in Russia, which took 35 years to complete, the three large reactors completed in Russia and South Korea during 2018-19 took slightly less than 10 years to finish, nearly doubling their estimated completion times.

The main causes of nuclear project construction delays include delays in resource mobilization, design deficiencies, overly optimistic construction schedules, and significant weather events. (For a table of the primary causal factors of construction delays in NPPs, please see Appendix I.)

Technology Risk

One of the key arguments used to encourage consideration of a new generation of nuclear projects rests on the enthusiastic claims made by backers of the many untested SMR companies concerning the advantages of the new technology. Some of these claims will be impossible to evaluate until the technology has been tested more fully in the market. Nonetheless, power sector experts will know that these claims must be judged in the right context, addressing risks associated with first-of-a-kind (FOAK) reactors. An FOAK reactor is defined as a first commercial plant in which the majority of experience is gained during construction and operation of the specific plant design and typically involves unanticipated delays, cost overruns, and problems during both construction and the initial periods of operation. [24] So far,

[24] IEEFA. India's Plan to Build 12 New Nuclear Reactors Is Fraught With Risk. March 30, 2016.

SMRs have not been immune to these problems, despite claims by project sponsors concerning their cost and construction time advantages.

Russia's Akademik-Lomonosov facility, currently the only operational SMR,[25] took 12.7 years to complete. The facility consists of two floating 30MW KLT-40S reactors and was initially meant to demonstrate that a new generation of SMRs would be faster and cheaper to build. When construction began in 2007, Russia expected the plant to be operational by 2010. However, the first unit did not begin generating power until October 2019, and the initial cost estimate tripled from USD232 million to USD740 million, or roughly USD11,600 per kilowatt (kW). Of the nine nuclear reactors connected to the grid globally from 2018-19, the Akademik-Lomonosov took the longest to complete.

Russia also expected to have the first prototype unit of a different design, the lead-cooled BREST-300 fast reactor, operational by 2016.[26] But Rosatom did not begin pre-construction activities until May 2020. The reactor is now not expected online until 2026.

South Korea has also been developing its own SMR design, the System-Integrated Modular Advanced Reactor (SMART), which was approved by Korea's Nuclear Safety and Security Commission in 2012. The Korea Atomic Energy Research Institute (KAERI) had originally planned to have a prototype of the 100MW reactor operational by 2017, but development was delayed due to the "absence of any orders for an initial reference unit."[27] Instead, KAERI has sought buyers for the reactor design abroad, particularly in Saudi Arabia and Jordan.

In the United States, the Department of Energy has spent USD314 million to advance an SMR design by NuScale. Although the company originally intended to apply for design certification from the U.S. Nuclear Regulatory Commission (NRC) in 2010, the application was not submitted until late 2016. The NRC issued its final safety evaluation report in August 2020, putting NuScale on track to receive final design certification in August 2021.[28]

In October, the U.S. DOE awarded USD1.355 billion over 10 years to the Carbon Free Power Project (CFPP), a subsidiary of the Utah Associated Municipal Power Systems (UAMPS) tasked with constructing a NuScale SMR. NuScale estimated the cost of construction for the plant, which consists of 12 60MW reactors, would be USD3 billion. However, NuScale's 2020 Amended Budget & Plan of Finance said the project cost had increased to USD6.1 billion and that the targeted in-service date would be delayed three years to 2030.[29]

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[25] World Nuclear Association. First small modular reactors open a new world of applications. December 19, 2019.
[26] OECD-NEA Workshop. Nuclear R&D Activities in Russia. July 2015.
[27] World Nuclear News. Korea, Saudi Arabia progress with SMART collaboration. January 7, 2020.
[28] United States Office of Nuclear Energy. NRC Approves First U.S. Small Modular Reactor Design. September 2, 2020.
[29] Los Alamos County, New Mexico. CFPP Update, Joint Meeting of the Board of Public Utilities and County Council. July 28, 2020.

As a result, eight of the 36 public utilities that agreed to purchase power from UAMPS project had backed out by the end of October 2020.[30] Construction will not begin until utilities have fully subscribed to full capacity of the CFPP,[31] but UAMPS members have so far only agreed to take less than 30% of the total output.[32]

As mentioned previously, construction delays can cause significant overall cost increases due to the high fixed costs for each working day, the non-utilization of labor and equipment, increases in financing costs, and increases in commodity prices. Once small reactors begin operating, studies have shown that fixed operation and management (O&M) costs are 19% higher than comparable large reactors due to the loss of economies of scale, which applies to staffing and equipment purchases, among other expenses.[33]

In addition, many newly built reactors, especially those with untested designs, face problems during the initial years of operation that require planned and unplanned outages. Since these outages reduce the overall number of kilowatt hours the plant generates, average fixed costs—which must be paid regardless of whether the plant generates power—increase.

NuScale has stated the project will generate electricity at a "total cost, including construction and operations, of USD65 per megawatt-hour." Other estimates by power companies Pacificorp and Idaho Power range from USD94/MWh to USD121/MWh, respectively.[34] But even assuming NuScale's lower levelized cost of electricity, the U.S. Energy Information Administration calculated that solar photovoltaic and wind costs will fall to USD32.80 and USD34.10 per MWh, respectively, by 2025.[35]

These examples, along with delayed SMR projects in Argentina,[36] China,[37] and India,[38] demonstrate the uncertainty around FOAK reactors, both in terms of cost and construction times. Although there is potential for new, innovative SMR designs in the future, real-world applications of SMR technologies have not been immune to the same risks faced by conventional reactors.

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[30] Science Magazine. Several U.S. utilities back out of deal to build novel nuclear power plant. November 4, 2020.
[31] Los Alamos Department of Public Utilities. CFPP Advances to the Next Phase. November 20, 2020.
[32] Bountiful (Utah) City Council. Council Meeting Agenda. October 27, 2020.
[33] B. Mignacca, G. Locatelli, Economics and finance of Small Modular Reactors: A systematic review and research agenda, Renewable and Sustainable Energy Reviews, Volume 118. February 2020.
[34] Oregon Physicians for Social Responsibility. Eyes Wide Shut: Problems with the Utah Associated Municipal Power Systems Proposal to Construct NuScale Small Modular Nuclear Reactors. September 2020.
[35] US Energy Information Administration. Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2020. February 2020.
[36] Nuclear Engineering International. Work resumes on nuclear projects in Argentina. April 23, 2020.
[37] Nuclear Engineering International. Progress at China's HTR-PM. March 26, 2020.
[38] Nuclear Asia. DAE working on Small Modular Reactors: KN Vyas. November 21, 2019.

Nuclear Accident Liability Risk

The inherent risk of a nuclear accident is the most underpriced attribute of nuclear power that Philippine regulators will need to address. Catastrophic accidents at Chernobyl and Fukushima cost USD259billion and USD166 billion, respectively, most of which was paid by the public.[39]

In the Philippines, an operator's liability is limited to USD5 million by the Atomic

Energy Regulatory and Liability Act of 1968.[40] When claims exceed the maximum limit of liability, Congress may consider "appropriation of additional funds to provide compensation to those suffering nuclear damage." In other words, Filipino taxpayers will be responsible for funding liabilities that exceed USD5 million.[41]

The USD5 million amount is in line with the international framework for nuclear liability laid out in the 1963 Vienna Convention on Civil Liability for Nuclear Liability. Subsequent protocols to the Vienna Convention, however, have raised that limit. The Convention on Supplementary Compensation for Nuclear Damage (CSC) and the Protocol to Amend the Vienna Convention (RVC) were adopted in 1997 under the auspices of the IAEA. These set the nuclear operator's liability at 300 million Special Drawing Rights (SDRs)—a unit of account used by the International Monetary Fund based on a basket of weighted currencies—minimum (about EUR360 million).[42] Although the Philippines is a signatory to these liability conventions, it has not yet ratified the CSC or the RVC.

According to the IAEA's Integrated Nuclear Infrastructure Review (INIR), "There is currently no formal plan for the ratification of these international instruments."

President Duterte has said that nuclear safety will be his top consideration in deciding whether to pursue nuclear energy.[43] However, the Philippines' susceptibility to a nuclear accident is heavily debated given the country's geographic location on the Pacific Ring of Fire – an area of the Pacific Ocean where most of the world's earthquakes and volcanic eruptions occur—as well as the increasing frequency and severity of natural disasters.

According to Carlo Arcilla, director of the Philippine Nuclear Research Institute (PNRI) under the Department of Science and Technology, the BNPP can still be rehabilitated. Arcilla has emphasized that a high magnitude earthquake similar to the one that occurred near Japan's Fukushima reactor "will probably not happen" in the Philippines. BNPP's elevation 18 meters above sea level, Arcilla argues, also means that it would not be vulnerable to a post-earthquake tsunami like the Fukushima plant, which was disabled by a 14-meter tsunami. And while Arcilla

[39] Gilbert et al., *op. cit.*
[40] Congress of the Philippines. Republic Act No. 5207. Atomic Energy Regulatory and Liability Act of 1968.
[41] OECD-NEA. Nuclear Operators' Third Party Liability Amounts and Financial Security Limits. February 2019.
[42] World Nuclear Association. Liability for Nuclear Damage. August 2018.
[43] ABS-CBN News. Duterte wants Bataan folk consulted on nuclear plant revival, says Roque. October 1, 2020.

acknowledges the facility's proximity to nearby fault lines, he argues "these do not underlie the plant, which would have made the plant inoperable."[44]

Multiple independent studies, however, indicate otherwise. Geologist Kelvin Rodolfo, a professor at the University of Illinois at Chicago, found in a 2016 study that an active fault line runs through the Mount Natib volcano where the BNPP is located. The study, which is a revised update of a 2010 paper written by Rodolfo and University of the Philippines Professor Fernando Siringan, argues that "the Lubao fault passes through the Natib volcano and emerges at Napot Point."

A 2012 study by University of the Philippines Professor Alfredo Mahar Lagmay found that the Lubao Fault is active based on satellite data. Professor Magmay's study concluded, "When evidence shows the existence of capable faults within 1 km of the nuclear facility, another site must be considered. Such is the case for the BNPP, where capable faults associated with the Lubao Fault were identified within 1 km of the nuclear power plant."[45]

In addition to the earthquake hazard, both Rodolfo and Magmay found that volcanic activity could affect the BNPP site. Rodolfo determined that seismic activity has "broken and displaced large amounts of pyroclastic flows and lahars that underlie the plant. Lava also underlies the site, including flows that came out of a vent only 5.5 kilometers away from BNPP."[46] Magmay similarly found that the nearest eruptive center of Mount Natib is 5.5 km away, and that "the potentials for pyroclastic density currents and lava flows cannot be mitigated by engineering solutions."

Developing the governance capacity to monitor and manage potential seismic risks will be a critical requirement if the Philippines is to move ahead with nuclear technologies. Despite the potential risks of a nuclear accident, the government has not yet established the legal or regulatory frameworks necessary to assign responsibility for safety and security or establish compensation mechanisms for nuclear damage. There is currently no single independent regulator to oversee the safety of nuclear activities. Instead, multiple agencies including the PNRI and the Center for Device Regulation, Health, and Research (CDRRHR) under the Department of Health serve regulatory functions. The PNRI also acts as "the promotional body for the [nuclear] industry."[47]

The IAEA's 2018 Integrated Nuclear Infrastructure Review (INIR), which reviews the conditions necessary for a country to initiate a nuclear review, identified 13 significant actions that must be taken before the Philippines can begin preparatory work for an NPP. These included the development of a comprehensive nuclear law to create an independent regulator, as well as a review of legislation that may affect

[44] Philippine Star. 5 myths about Bataan Nuclear Power Plant, debunked. May 24, 2018.
[45] Lagmay, Alfredo Mahar, et al. Geological hazards of SW Natib Volcano, site of the Bataan Nuclear Power Plant, the Philippines. Geological Society of London Special Publications. January 2012.
[46] Philippine Daily Inquirer. Safety issues hound BNPP revival plan. April 13, 2018.
[47] Business World. Head of nuclear research agency calls for single regulator to oversee industry. December 7, 2020.

a nuclear power program. Without an independent regulator, there is no unbiased agency to establish safety standards and regulations; issue licenses for nuclear facilities and uses of nuclear fuel; inspect and enforce standards; and manage nuclear waste. These steps are critical to establishing proper checks and balances for a well-functioning nuclear power sector. Both consumers and project developers need to have confidence that an independent agency has the authority to inspect and oversee project operations if they do not meet regulatory standards.

The Mistake of Prioritizing Baseload Power

The most common justification for nuclear power has been the need for baseload generation sources to meet a minimum level of electricity demand. Proponents of this traditional approach to system planning argue baseload generators (typically coal-fired plants and NPPs) are more "reliable" because they provide continuous, around-the-clock electricity at low variable costs.

Former U.K. Energy Secretary Amber Rudd, for example, championed the 3,200 MW Hinkley Point C megaproject, a multibillion-dollar white elephant,[48] by claiming it was necessary "to secure baseload electricity."[49] More recently, PNRI Director Arcilla stated that nuclear was the best solution to address potential shortages in the Philippines' supply of baseload power.[50]

However, this emphasis on traditional baseload generation is an outdated approach that ignores new technology trends in the Philippines and global energy and power markets. First, DOE has stated its intention to deploy more renewable power sources and is reportedly considering increasing an increase in mandated renewable energy installations under the Renewable Portfolio Standard (RPS) from 1% to 2.52%.[51] DOE is also set to hold its first green energy auction for 2,000 MW of renewable power in June 2021 to facilitate compliance with the RPS, and has stated that there is 8,500 MW of solar, wind, and battery projects currently being processed that are not included in the auction.[52]

A greater supply of renewables such as wind and solar will require operationally flexible resources to accommodate power supply variability. Nuclear generation, however, is traditionally one of the most inflexible power sources. To recoup costs, NPPs are designed to run continuously to recoup large capital costs. Output can be varied somewhat, but not without thermal stresses and potential safety hazards that limit how often and how quickly the plant can adjust output. This means nuclear plants have a limited capacity to follow load or balance variable renewable generators. As a result, nuclear funders have shown no willingness to take market risk in transition markets, instead relying on guaranteed PPAs that reinforce any bias toward lock-in.

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[48] IEEFA. A Half-Built, High-Priced Nuclear White Elephant. October 2017.
[49] The Guardian. New onshore windfarms still possible without subsidies, says Amber Rudd. July 21, 2015.
[50] Business World. Nuclear touted as baseload solution, but risks flagged. November 15, 2020.
[51] Philippine Star. DOE reviews proposal to hike RE capacity. January 2, 2021.
[52] *Ibid*.

The rapid scaling of new cost-competitive renewable technology options could also prove challenging for nuclear projects. Delays in NPP construction add to construction costs and increase the likelihood that variable renewable generators will come online first. A greater supply of low marginal cost renewables places a greater premium on flexibility in the electricity system and potentially reduces the nuclear plant's capacity factor once it becomes operational. In short, nuclear reactors become both more expensive and less necessary as construction delays drag on.

Although there has been a growing trend toward operating large-scale NPPs flexibly, the economics are unfavorable. According the IAEA, nuclear generating units "could experience significant adverse economic impacts if the costs of providing flexible services are not internalized within the energy system."[53] Specifically, operating NPPs flexibly would increase operation and maintenance costs, nuclear fuel cycling costs, as well as the frequency of unplanned outages. Moreover, under a two-part tariff, reducing output from the NPP would raise the average cost of electricity for ratepayers still required to pay inflexible capacity payments despite reduced energy production.

NuScale SMRs also face flexibility issues when operating above 80% capacity factors. According to NuScale spokesperson Diane Hughes, NuScale units cannot adjust their output as quickly when operating at higher capacity factors, and "hence are better suited for baseload power production."[54]

The economics of nuclear energy, already the most expensive form of electricity generation, could therefore suffer with the implementation of the Philippines' RPS, which requires utilities to increase the supply of renewable resources by 1% per year to 2030. As more renewables come online, large-scale nuclear reactors would impose even more burdensome costs on the energy system.

Implementation of RCOA could also reduce the need for nuclear as baseload. RCOA allows large power consumers to choose their own retail suppliers, and the Energy Regulatory Commission recently issued a resolution expanding RCOA coverage to consumers of at least 500 kilowatts beginning February 26, 2021.[55] These contestable consumers will be able to benefit from cheaper renewable energy such as rooftop solar. RCOA will also cause a reduction in contracted capacity required by distribution utilities. Reduced demand from distribution utilities as a result of RCOA implementation could raise the risk of curtailment for an NPP. Without a carve-out clause, which allows distribution utilities to reduce contracted capacity and transfer stranded asset risk to investors, consumers would be left to pay for inflexible capacity payments.

[53] IAEA Nuclear Energy Series. Non-baseload Operation in Nuclear Power Plants: Load Following and Frequency Control Modes of Flexible Operation. 2018.
[54] Utility Dive. Design updates, financial shakeup prompt utilities to rethink structure of NuScale's $6.1B SMR project. November 25, 2020.
[55] Manila Standard. ERC expands coverage of retail competition and open access. December 28, 2020.

Another reason to reconsider long-term guaranteed contracts with inflexible baseload generators is the need for macroeconomic flexibility, demonstrated by the effects of COVID-19. According to DOE, electricity demand fell by 30% in Luzon, 17% in the Visayas, and 25% in Mindanao during the pandemic. Despite a large surplus in electricity supply, consumer groups expressed concerns about high meter readings and the Manila Electric Co. (MERALCO) faced scrutiny in mid-May 2020 for billing consumers double their usual monthly consumption. MERALCO attributed the increase to its inability to read physical meters during lockdown, but IEEFA research suggests that price fluctuations and system instability were due to an overreliance on inflexible baseload generators unable to respond to rapid changes in demand conditions. Depressed demand requires more use of mid-merit plants rather than inflexible baseload generators, and lower load factors lead to an increased cost per kilowatt-hour for end-users.

Pandemics are a feature of climate change, which is also likely to cause more frequent weather-related disasters and shocks to the power system. However, the COVID-19 pandemic has revealed that that the power sector is unprepared to deal with these shocks due to inflexible financing and inflexible generation sources. As demand rebounds, system planners must improve grid flexibility rather than prioritizing baseload capacity additions.

Conclusion and Recommendations

There are numerous other full life-cycle risks involved in nuclear power that are not touched on here that could prove critical to any thorough review of nuclear power in the Philippines, including the challenges of land acquisition, spent fuel storage, and inadequate provisions for decommissioning. However, the financial risks and hidden costs alone raise a red flag concerning the work that needs to be done to evaluate the economic case for nuclear energy and to understand the impact of any new technology developments.

Construction delays and overnight cost overruns can significantly raise the final tariffs necessary for capital cost recovery. These risks are amplified by untested FOAK reactors such as SMRs. Moreover, safety concerns at the site of the BNPP and the Philippines' current lack of an independent regulator significantly raise the risk of major accident liabilities. In the event of a nuclear accident, reactor operators would only be liable for a tiny fraction of the toll.

More broadly, energy planners' historical focus on baseload generation mistakenly assumed that large, centralized generators with guaranteed long-term contracts would result in the least-cost electricity system. To date, that has not proven to be the case. On the contrary, capacity lock-in has led to system inflexibility, high electricity prices, and a dependence on imported fuel and expertise. In light of recent changes to RCOA, implementation of the Renewable Portfolio Standard, and climate-related shocks to the electricity system, the Philippines must prioritize flexibility in generation to reduce electricity prices and improve the country's energy security.

The IAEA's INIR identified significant actions necessary to begin preparatory work for an NPP, including creating an independent regulator, developing emergency response capabilities, auditing existing environmental legislation, and identifying financing strategies. Along with these recommendations, it would be prudent for the Philippines government to take the following measures to mitigate the risks associated with nuclear power generation:

1. **Extend the recently announced moratorium on greenfield coal-fired power plants to other inflexible generators such as large nuclear reactors.** DOE should extend its moratorium to cover all inflexible generators, including large nuclear reactors unable to follow load variations due to technical restrictions. To qualify for DOE approval, NPP developers should be required to prove that flexible operation was incorporated into the reactor design through stress and fatigue analysis, sophisticated monitoring technologies, and load following control systems, among other methods. Until critical transmission and distribution bottlenecks have been addressed, the market will benefit from a level-playing field that ensures generation options are placed in a system management context.

2. **Prevent increases in construction costs from being automatically passed through to consumers.** Given the risk of additional expenditures incurred during construction, it is highly likely that the cost of electricity delivered by the NPP from the start of operations will be higher than the initially expected electricity price. As a result, lenders and project sponsors are likely to demand significant contingencies in contractual ratemaking in the form of an adjustable tariff. The ERC should establish a price ceiling for the allowable tariffs from NPPs to prevent the risk of upside variability in the final tariff from being passed to consumers.

3. **Raise the legal accident liability limits for NPP operators.** The current liability limit of USD5 million for operators would cover only a fraction of the costs imposed by a nuclear accident. Congress should bring the liability limits in line with more recent international conventions, such as the 1997 Protocol to Amend the Vienna Convention and the Convention on Supplementary Compensation, which raised liability limits to 300 million SDRs. According to the IAEA's INIR, "There is currently no formal plan for the ratification of these international instruments." These must be ratified swiftly to clarify an operator's liability for nuclear accidents.

4. **Prohibit two-part tariff structures in PSAs.** Two-part tariffs are composed of a capacity payment for fixed costs (capital recovery and fixed O&M) and an energy payment for variable costs (variable O&M, fuel cost fluctuations, exchange rate fluctuations). Due to inflexible capacity payments, lower load factors for NPPs can leave ratepayers with a higher average cost of electricity. In January 2021, for example, MERALCO announced that power bills would rise despite lower demand due to fixed costs being spread over a

lower energy volume.[56] Variable charges, meanwhile, allow fluctuations in international fuel prices and exchange rates to be passed to consumers. In contrast, a straight energy tariff would benefit consumers by requiring the generator to bear the variable costs and stranded asset risks.

5. **Require *force majeure* provisions in PSAs to share risk of demand shocks between generators, utilities, and end-users.** From April to September 2020, MERALCO reportedly saved PHP2.4 billion from *force majeure* claims due to the COVID-19 pandemic. Without *force majeure* claims, the total rate charged to electricity consumers would have increased by 14 centavos per kWh in September.[57] DOE should require standardized *force majeure* clauses and a procedure for settling such claims. These clauses would protect end-users from inflexible capacity charges during demand shocks, transferring greater risk to the NPP developer.

[56] Manila Standard. Meralco says power rates may rise in January despite reduced demand. January 5, 2021.
[57] Business Mirror. Meralco: Force majeure claims bring down electricity rates in September. September 9, 2020.

Appendix – Primary Causes of Nuclear Power Plant Delays

Reason for NPP Delay	Main Causal Factors
Missing Schedule Updates	a. No schedule updates were received b. Not all activities requiring an update were updated
Design Error/ECRs	a. Design omissions and/or error b. Engineering Change Request (ECR) / Engineering Operability Constraint (EOC) c. Inaccurate drawings or specifications
Scope Change	a. Scope increase b. Altering scope
Contractor	a. Missed milestone/deliverable b. Late proposal from contractor c. Late decision from owner
Materials/Vendor	a. Contractor/vendor not producing the work to meet the dates b. Materials not ordered with enough lead time c. Vendor materials do not meet specifications d. Materials damaged
Funding	a. Appropriation is not granted b. Purchase orders were not written
Schedule Productivity	a. Inaccurate duration estimate b. Inaccurate schedule logic c. Not enough details
Resources Productivity	a. Inaccurate manpower estimate b. Resource skills level c. Inaccurate resource levelling d. Delay in resource mobilization
Plant Support Engineering (PSE)	a. Activities scheduled to be completed by plant support are not completed b. Document delivered late to the Plant Support Engineering
Rework	a. Faulty design b. Faulty implementation
Owner decision	a. Plant Support Engineering /Security/Maintenance/Operations b. Online/outage management c. Project Evaluation Review Committee
Weather	a. Severe weather that resulted in stopping work in the field.
Other/Delays	a. Tools/Equipment b. Poor coordination c. Differing site conditions

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