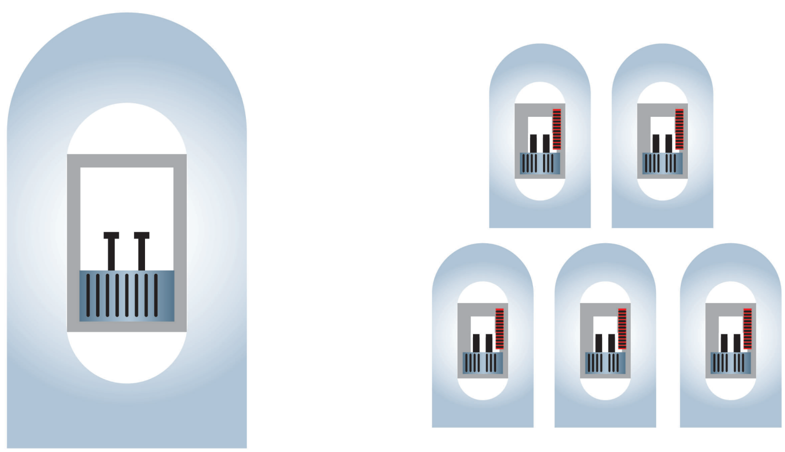
The Nautilus Institute *for Security and Sustainability*

INDONESIAN INSTITUTE FOR ENERGY ECONOMICS FOUNDATION

Nuclear Power and Small Modular Reactors in Indonesia: Potential and Challenges



Bernadette K. Cogswell, Nataliawati Siahaan, Friga Siera R,
M. V. Ramana, and Richard Tanter

Indonesian Institute for Energy Economics
Nautilus Institute for Security and Sustainability

April 2017

Author affiliations and addresses:

Bernadette K. Cogswell,[1] Nataliawati Siahaan,[2] Friga Siera R,[2] M. V. Ramana,[1,4] and Richard Tanter[3]

[1] Program on Science and Global Security, Princeton University, Princeton, USA

[2] Indonesian Institute for Energy Economics, Jakarta, Indonesia

[3] Nautilus Institute for Security and Sustainability and University of Melbourne, Melbourne, Australia

[4] Current address: Liu Institute for Global Issues, University of British Columbia, 6476 NW Marine Drive, Vancouver, BC, Canada V6T 1Z2

Contact email: m.v.ramana@ubc.ca

Cover image

This schematic is modified from a figure in Alexander Glaser et al., *Small Modular Reactors: A Window on Nuclear Energy*, An Energy Technology Distillate (Princeton, N.J.: Andlinger Center for Energy and the Environment at Princeton University, June 2015), http://acee.princeton.edu/distillates/distillates/small-modular-reactors/

Executive Summary

Indonesia has been interested in building nuclear power plants since the late 1950s under the aegis of Badan Tenaga Nuklir Nasional (BATAN, the National Nuclear Energy Agency). Since the turn of the century, BATAN has been actively interested in a new class of nuclear power plants, small modular reactors (SMRs), that are being designed, developed, and advocated by some sections of the nuclear power industry as a way to address some of the challenges confronting the expansion of the technology.

BATAN's interest in SMRs is propelled by reasons that pertain to nuclear power in general, such as low levels of electricity consumption among the population of Indonesia, growing energy needs, and claims about a lack of alternate means to meet these needs, and reasons that are specific to SMRs, such as the presence of remote areas and small islands that do not have the demand level to support construction of a large nuclear reactor, and the lower financial cost of SMRs. BATAN has explored a number of possibilities, including importing a small floating power plant from Russia, an SMR from Korea that can also desalinate ocean water, and a high temperature gas cooled reactor from Russia.

BATAN has conducted a number of nuclear power plant siting studies, including follow-up technical and economic feasibility studies in some cases. These studies have also included some SMR possibilities in much greater detail. But apart from an experimental power reactor (EPR), none of the other proposals has advanced towards actual construction.

Indonesia has an extensive network of government agencies involved in the energy sector and, hence, holding a stake in the nuclear power debate, as well as an extensive body of laws and regulations that could affect the eventual implementation of commercial nuclear power. The potential for adoption of SMRs in Indonesia is affected by a number of regulations, including the requirement that locally made components or services conducted by domestic providers have to be used in energy infrastructure, the requirement that only reactors based on "proven technology" will be licensed, and a requirement that reactors be sited only on land.

Another reason that Indonesia might not choose to construct an SMR is that, as we show through calculations, the cost of generating electricity using SMRs will likely be greater than large nuclear power plants as well as solar photovoltaic plants. Studies testify to the large potential of solar energy in Indonesia and the government has been adopting policies that promise to accelerate the construction of significant amounts of solar capacity.

Because SMRs have lower power capacity, producing the same amount of electricity using these as opposed to large reactors would require dealing with public resistance at many more sites. Public opposition has played a major role in stopping construction of nuclear power plants so far. As a result of all these factors, it would seem that the construction of SMRs is unlikely, especially in large enough numbers to make a sizeable contribution to Indonesia's electricity generation.

1 Introduction

In 2013 the Indonesian news media reported that the Head of Badan Tenaga Nuklir Nasional (BATAN, the National Nuclear Energy Agency) stated that Indonesia was ready to build a Small Modular Reactor (SMR) and that BATAN is enthusiastic about the idea.[1] SMRs are reactors with electrical power outputs of less than 300 megawatts and are being promoted by nuclear establishments in many countries.[2] The term "small" is used to indicate that the power level is much lower than the average power delivered by currently operating reactors. "Modular" means that the reactor is assembled from factory-fabricated parts or modules. Each module represents a portion of the finished plant built in a factory and shipped to the reactor site. Modularity is also used to indicate the idea that rather than constructing one large reactor, the equivalent power output will be generated using multiple smaller reactors that allow for greater tailoring of generation capacity to demand.

Indonesia's interest in building SMRs is not entirely new; Indonesia has been interested in nuclear power since the late 1950s, including in installing small reactors. Indeed, the very first proposed reactor for Indonesia was a small reactor: a mission undertaken by the International Atomic Energy Agency in 1959 reported that some Indonesian authorities felt "that the installation of a small nuclear power plant in a remote eastern region of the country might be feasible in the near future".[3] The potential for building SMRs in Indonesia and the challenges involved in such an effort, within the broader context of the discussion on nuclear power, are the focus of this report.

The report begins with a historical overview of the plans for setting up nuclear power plants in Indonesia, as well as the Indonesian nuclear energy establishment's interest in small reactors. This is followed by short discussions of BATAN's experience with operating small research reactors and public attitudes towards nuclear power. The report then discusses siting studies carried out by BATAN, and specific locations considered for constructing large nuclear power plants. This is followed by a discussion of specific small nuclear power plant proposals. The next section deals with the institutional and regulatory landscape, as well as brief overviews of the government regulations that are relevant to considering SMRs. Following this is a discussion of the electricity landscape and a comparative evaluation of the costs of generating power using different kinds of sources. We conclude with a summary of our findings on the potential role for small modular reactors. A number of appendices with relevant information are also included at the end.

---

[1] Maria Rosary, "Indonesia Siap Bangun Reaktor Nuklir Kecil-Menengah (Indonesia Ready to Build Small-to-Medium-Sized Nuclear Reactors)," *Antara News*, August 19, 2013, accessed December 30, 2015, http://www.antaranews.com/berita/391241/indonesia-siap-bangun-reaktor-nuklir-kecil-menengah.

[2] Giorgio Locatelli, Chris Bingham, and Mauro Mancini, "Small Modular Reactors: A Comprehensive Overview of Their Economics and Strategic Aspects," *Progress in Nuclear Energy* 73 (2014): 75–85; Jasmina Vujić et al., "Small Modular Reactors: Simpler, Safer, Cheaper?," *Energy* 45, no. 1 (2012): 288–295; NEA, *Current Status, Technical Feasibility, and Economics of Small Nuclear Reactors* (Paris: Nuclear Energy Agency, OECD, 2011); D.T. Ingersoll, "Deliberately Small Reactors and the Second Nuclear Era," *Progress in Nuclear Energy* 51, no. 4–5 (2009): 589–603.

[3] IAEA, "Survey in South-East Asia," *IAEA Bulletin* 1 (July 1959): 8.

2 Overview of Interest in Nuclear Power and Public Opposition

2.1 History

Indonesian governments have had an interest in nuclear power from the first decade of the Republic's existence at the height of the Cold War. Concern about radioactive fallout from Pacific nuclear tests led President Sukarno and Prime Minister Ali Sastromidjojo's cabinet to establish a State Committee for the Investigation of Radioactivity (Panitia Negara untuk Penyelidikan Radioaktivet) in 1954.[4] Four years later, in an attempt to shift attention to nuclear power generation, Sukarno established the Council for Atomic Energy (Dewan Energi Atom) and shortly thereafter, the Institute of Atomic Energy (Lembaga Tenaga Atom) in 1959.[5] Five years later, as domestic and regional political tensions mounted in the Guided Democracy period, Sukarno elevated the Institute to ministerial status in 1964 in the form of the National Atomic Power Agency (Badan Tenaga Atom Nasional- BATAN), now the National Nuclear Power Agency (Badan Tenaga Nuklir Nasional – BATAN).[6]

This decade-long institutional process was driven by two connected factors. On the one hand, Indonesia wanted to build the foundations of a modern power sector by accepting U.S. and Soviet offers of nuclear energy assistance. Substantial numbers of Indonesian students went to both the United States and the Soviet Union to study nuclear physics and engineering in the first half of the 1960s. In 1961 under the Atoms for Peace program the United States provided a $350,000 grant to fund the construction of a TRIGA Mark II reactor in Bandung, which reached criticality in 1964, with two other research reactors following.[7] On the other hand, Indonesia's Guided Democracy cabinet (1959-1965) wanted to acquire or develop a nuclear weapons capacity.[8]

The incoming New Order (1966-1998) immediately abandoned Sukarno's nuclear weapons interest after 1966. With its three research reactors BATAN focused on nuclear research and provision of medical isotopes, and its associated academic institutions grew to be the largest nuclear establishment in Southeast Asia, employing hundreds of researchers with degrees in nuclear science and engineering.[9] Early in the New Order, BATAN, the Ministry

---

[4] Daniel Poneman, *Nuclear Power in the Developing World* (London: Allen & Unwin, 1982), 99.
[5] Peraturan Pemerintah No. 65 tahun 1958, pada tanggal 5 Desember 1958 [Government Regulation No.65, 1958, on 5 December 1958].
[6] UU No. 31 tahun 1964 tentang Ketentuan-ketentuan Pokok Tenaga Atom [Law concerning Atomic Energy Provisions]. From 1997 BATAN has been designated as Non-Departmental Government Body [Lembaga Pemerintah Non Departemen] responsible to the President, with its activities coordinated by the Minister for Research and Technology. See UU No. 10 Tahun 1997 tentang Ketenaganukliran [Law No. 10 1997 concerning Nuclear Energy] and Keppres RI No. 64 Tahun 2005 [Republic of Indonesia Presidential Decision No. 64, 2005].
[7] Poneman, *Nuclear Power in the Developing World*, 100; Douglas M. Fouquet, Junaid Razvi, and William L. Whittemore, "TRIGA Research Reactors: A Pathway to the Peaceful Applications of Nuclear Energy," *Nuclear News*, November 2003.
[8] Robert M. Cornejo, "When Sukarno Sought the Bomb: Indonesian Nuclear Aspirations in the mid-1960s," *The Nonproliferation Review* 7, no. 2 (June 1, 2000): 31–43.
[9] In 2000, BATAN employed 98 staff members with doctorates, 233 with masters degrees, 975 with unspecified "scientific and engineering degrees", and another 502 with unspecified bachelor degrees. These figures are gradually increasing. See M. S. Ardisasmita, "Preservation and Enhancement of Nuclear Knowledge towards Indonesia's Plan to Operate First Nuclear Power Plant by 2016" (presented at the International conference on

of Electricity, and the State Electricity Company (Perusahaan Listrik Negara - PLN), in cooperation with the International Atomic Energy Agency (IAEA), showed strong interest in building a nuclear power plant, with several studies resulting in a formal recommendation to the government in 1980 that included possible sites in Central and East Java, as well as Sulawesi. Plans for a strongly nuclear powered future were very much in the air: a national energy seminar conducted in July 1974 by the Indonesian National Committee of the World Energy Conference concluded that nuclear energy would comprise around 23-29 percent of Indonesia's installed electricity capacity by the year 2000, which translated to roughly 15000 to 25000 MW.[10]

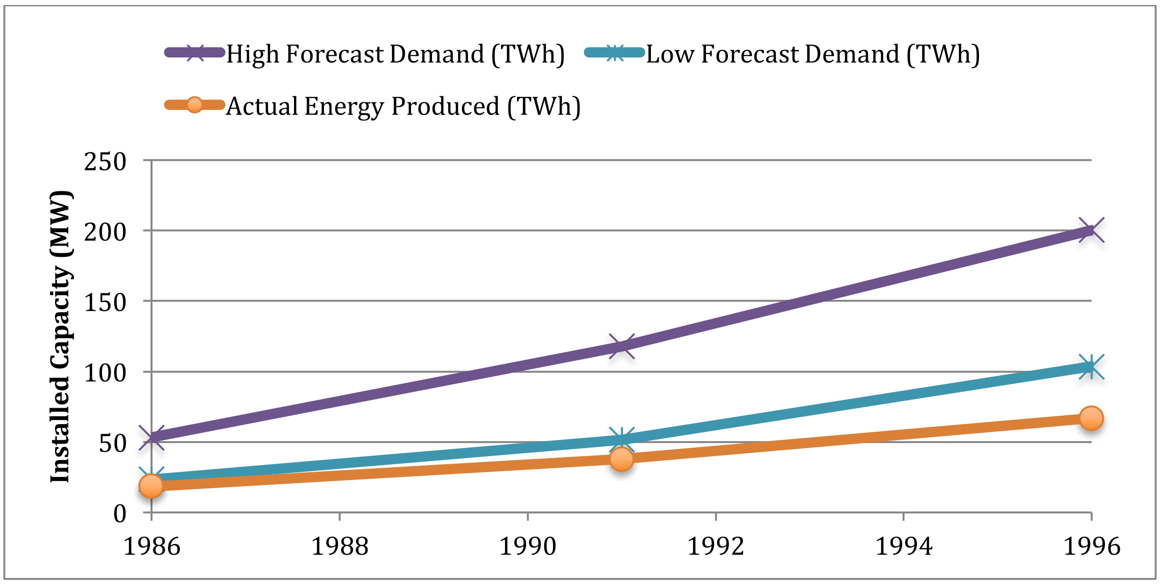


Figure 1: Comparison of electricity projections used in IAEA 1976 planning study and actual consumption for Indonesia from 1986-1996

In 1975, the IAEA conducted a detailed techno-economic study that calculated the optimal additions of different kinds of electrical generation capacity to meet the projected growth in energy demand on the island of Java.[11] The study used two forecasts for projected demand, a high case and a low case. Figure 1 shows a comparison of the high and low scenario IAEA projections for demand in Indonesia for the years 1986, 1991, and 1996.[12]

---

nuclear knowledge management: Strategies, information management and human resource development, Saclay, France: IAEA, 2004), accessed November 29, 2015, https://www.iaea.org/km/cnkm/papers/ardisasmita.pdf. Several of the country's most prestigious universities have substantial undergraduate and programs in nuclear science and engineering feeding into BATAN.

[10] Poneman, *Nuclear Power in the Developing World*, 105.

[11] IAEA, *Nuclear Power Planning Study for Indonesia (Java Island)* (Vienna: International Atomic Energy Agency, 1976).

[12] Ibid., 4.

To put the figure in perspective, actual historical data for the corresponding years is also shown.[13] Evidently, even the IAEA's low forecast over-estimated the demand.

In the 1970s, the Preparatory Commission for Development of a Nuclear Power Plant (Komisi Persiapan Pembangunan Pembangkit Listrik Tenanga Nuklir – KP2-PLTN) was established, which in 1975 proposed to the government fourteen locations on the island of Java for further study.[14] The fourteen sites included, among others, Pasuruan, Bondowoso, Lasem, the Muria Peninsula (Ujung Grengganan, Ujung Watu and Ujung Lemahabang),[15] Tanjung Pujut, Ujung Genteng, Pangandaran and South Malang. Of these, the Muria Peninsula sites emerged as the leading contenders for a nuclear plant.

BATAN and its supporters in the Indonesian government, principally the Ministry of Research and Technology (Kementerian Riset dan Teknologi or Menristek; renamed the Ministry of Research, Technology, and Higher Education or Menristekdikti in 2014), subsequently made three serious attempts to persuade the government to commit to the construction of a large nuclear power plant at its preferred sites on the Muria Peninsula on the north coast of Central Java near the city of Jepara. The first of these attempts to construct a reactor on the Muria Peninsula took place in the late 1980s and was strongly supported by then Minister for Research and Technology B. J. Habibie, but faced opposition from the World Bank and the Ministry of Finance, combined with the then dominant military's suspicion of Habibie's influence and ambition. The second attempt in the mid-1990s ended with the Asian financial crisis of 1997 and the subsequent fall of the New Order.[16] One achievement of this period was the establishment of the Nuclear Regulatory Agency (BAPETEN) as a body independent of BATAN in 1998.[17]

The third version of the Muria proposal emerged in 2002-2003, and gathered strength in the following years, fed by three sets of pressures: concern to alleviate the greenhouse gas emissions from coal-fired electricity plants; the inadequacy of the existing electricity supply in Java; and the desire of Japanese, Korean, and French nuclear power plant manufacturers—and their governments—to find export markets to underwrite the costs of domestic production.

---

[13] EIA, "International Energy Statistics," *International Energy Statistics*, last modified 2015, accessed November 29, 2015, http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=2&pid=2&aid=7; BP, *Statistical Review of World Energy 2015* (London: BP, June 10, 2015), accessed August 23, 2015, http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy.html.

[14] Rangga D. Fadillah, "Indonesia's Long, Winding Road to Nuclear Power," *Jakarta Post*, December 5, 2011, accessed August 5, 2016, http://www.thejakartapost.com/news/2011/12/05/indonesia-s-long-winding-road-nuclear-power.html.

[15] Richard Tanter and Arabella Imhoff, "Site Selection History," *Indonesian Nuclear Power Proposals Briefing Book*, Nautilus Institute for Security and Sustainability, last modified January 19, 2009, accessed August 5, 2016, http://nautilus.org/projects/by-name/aus-indo/aust-ind-nuclear1/ind-np-old/muria/site-selection-history/.

[16] In this period, the IAEA and BATAN considered the Muria project and the Ujung Lemahabang (Desa Balong) site as "one of the best candidate" sites for an SMR. See IAEA, *Guidance for Preparing User Requirements Documents for Small and Medium Reactors and Their Application* (Vienna, Austria: International Atomic Energy Agency, 2000), 75.

[17] Keputusan Presiden Republik Indonesia No. 76 Tahun 1998 tentang Badan Pengawas Tenaga Nuklir tanggal 19 Mei 1998 [Republic of Indonesia Presidential Decision No. 76, 1998, concerning a Nuclear Energy Regulatory Agency].

In the early 2000s, the International Atomic Energy Agency sponsored a research project called the Comprehensive Assessment of Different Energy Sources for Electricity Generation in Indonesia (CADES).[18] The project was conducted by BATAN, Badan Pengkajian dan Penerapan Teknologi (BPPT; Agency for the Assessment and Application of Technology), ESDM, the State Electricity Company (PLN), BPS (Badan Pusat Statistik – Central Statistics Agency) and the Ministry of Research and Technology. The project concluded that the optimum NPP capacity that could be accommodated was determined to be approximately 4,000 MWe. A crucial assumption underlying this conclusion was that nuclear power was less expensive compared to other sources.[19]

In 2004-2005 BATAN began, once again, to publicly press the case for nuclear energy, and in January 2006, a presidential decision by President Susilo Bambang Yudhoyono determined that "new" energy sources, including nuclear power, would make up five percent of the nation's electricity supply by 2025. Later that year, Energy and Mineral Resources Minister Purnomo Yusgiantoro announced that the government expected to be calling for tenders for 4000 MW of nuclear capacity in Muria, aiming for a completion date of 2016.[20]

In 2009 the IAEA conducted an Integrated Nuclear Infrastructure Review (INIR) mission to Indonesia.[21] The IAEA also sent two experts in early October 2012 to meet with personnel from BATAN, BAPETEN, the University of Gadjah Mada, and other experts in order to carry out a Nuclear Energy System Assessment (NESA).[22]

By 2010, and possibly earlier, BATAN had begun to back away from the Muria plan. It was clearly impeded by decades-long local opposition in Jepara, increasing skepticism about seismic safety claims, and lack of support from the larger bureaucratic players within the Indonesian government.[23]

---

[18] Sulfikar Amir, "The State and the Reactor: Nuclear Politics in Post-Suharto Indonesia," *Indonesia* 89, no. April (2010): 101–149.
[19] Ibid., 116.
[20] Xinhua, "Indonesia's Nuke Plant Tender Set for 2007," *People's Daily Online*, June 29, 2006, accessed July 8, 2016, http://en.people.cn/200606/29/eng20060629_278473.html.
[21] K. Huda, B. Rohman, and A. N. Lasman, "Challenges for Indonesia in Embarking to Nuclear Power," *Journal of Energy and Power Engineering* 5, no. 4 (2011): 381.
[22] IAEA, "NESA Review Mission to Indonesia," *Nuclear Power Newsletter*, January 2013.
[23] Richard Tanter, with Arabella Imhoff and David Von Hippel, Nuclear Power, Risk Management and Democratic Accountability in Indonesia: Volcanic, regulatory and financial risk in the Muria peninsula nuclear power proposal, Nautilus Institute, Austral Policy Forum 09-22A, 7 December 2009, http://nautilus.org/wp-content/uploads/2012/01/tanter-muria-risk.pdf. On the opposition to the Muria NPP project in Central Java see Richard Tanter, Nuclear Fatwa: Islamic Jurisprudence and the Muria Nuclear Power Station Proposal, APSNet Policy Forum, Nautilus Institute, December 13, 2007, accessed November 29, 2015, http://nautilus.org/apsnet/nuclear-fatwa-islamic-jurisprudence-and-the-muria-nuclear-power-station-proposal/; Sulfikar Amir, "Nuclear Revival in Post-Suharto Indonesia," Asian Survey 50, no. 2 (March 1, 2010): 265–286; Achmad Uzair Fauzan and Jim Schiller, After Fukushima: The Rise of Resistance to Nuclear Energy in Indonesia (Essen, Germany: German Asia Foundation, July 2011), http://www.asienhaus.de/public/archiv/resistance-in-indonesia-after-fukushima.pdf; Mely Caballero-Anthony, Lina Alexandra, and Kevin D. G. Punzalan, "Civil Society Organizations and the Politics of Nuclear Energy in Southeast Asia: Exploring Processes of Engagement," in Nuclear Power and Energy Security in Asia, ed. Rajesh Basrur and Koh Swee Lean Collin (New York: Routledge, 2012), 170–193.

BATAN then announced alternatives to the Muria site, focused on the much less seismically sensitive island of Bangka. In June 2009, BATAN signed a memorandum of understanding with the Bangka-Belitung provincial government for the 'Utilization of Nuclear Science and Technology for the Welfare of the Community of Bangka-Belitung.'[24] Two sites were identified: one in West Bangka at Teluk Inggris and another in South Bangka at Tanjung Berani/Tanjung Krasak.[25] Within a few years, a feasibility study had confirmed their suitability, recommending construction of up to ten large reactors, six on the Teluk Inggris site and four on the South Bangka site.[26] Local environmental organizations came out in opposition to the plan, in part because the specific site chosen for the NPP in Teluk Inggris is located in a Protected Coastal Forest (Hutan Lindung Pantai) area.[27]

Despite the many attempts by BATAN to construct power reactors since the 1970s,[28] Indonesia still does not yet have an operational power reactor. Most recent indications are that nuclear power plant construction is unlikely in the foreseeable future. In December 2015, for example, then Energy and Mineral Resources Minister Sudirman Said stated: "We have arrived at the conclusion that this is not the time to build up nuclear power capacity. We still have many alternatives and we do not need to raise any controversies".[29] Subsequently, in March 2016, Minister Sudirman Said stated that nuclear energy might be used if current development and resources of renewable energy fail to meet the energy demand by 2025.[30] In May 2016, President Joko Widodo rebuffed Russian President Vladimir Putin's offer of nuclear technology because he wanted Indonesia to focus on renewable energy.[31] Nevertheless, BATAN still continues on its quest to build nuclear power plants and it is possible that at some point in the future Indonesia might construct one. This report, therefore, evaluates one possibility for the reactor chosen.

---

[24] 'Pemanfaatan Ilmu Pengetahuan dan Teknologi Nuklir untuk Kesejahteraan Masyarakat Bangka Belitung' [Utilization of nuclear science and technology for public welfare in Bangka-Belitung]. Cited in P*enandatanganan MoU BATAN—Bangka Belitung*, Pusat Rekayasa Perangkat Nuklir (PRPN), [Signing of BATAN – Bangka-Belitung MOU, Nuclear Devices Engineering Centre (PRPN)], BATAN, 15 June 2009.

[25] Pengumuman Peringkat Teknis Nomor: 88 IPL 00 OlIPBJ 31201 1, *Pekerjaan: Pengawasan Kegiatan Penyiapan Tapak PLTN di Pulau Bangka Provinsi Kepulauan Bangka Belitung* [Technical rating announcement number: 88 IPL 00 OlIPBJ 31201 1, Job: Supervision of Bangka nuclear power plant site preparation activities, Bangka-Belitung province]. Panitia Pengadaan Jasa Konsultansi, Pusat Pengembangan Energi Nuklir [Committee for Procurement of Consultancy Services, Centre for Nuclear Engineering Development], BATAN, 1 April 2011.

[26] Yarianto Sugeng Budi Susilo, BATAN Feasibility Study Project for SMR Deployment in Bangka-Belitung, IAEA, Jakarta, 19-20 August 2013.

[27] Alza, "Walhi Menentang Pinjam Pakai Kawasan Hutan Lindung (WALHI opposes Usage of Protected Forest Areas)," *Bangka Pos*, last modified March 24, 2011, accessed August 11, 2016, http://bangka.tribunnews.com/2011/03/24/walhi-menentang-pinjam-pakai-kawasan-hutan-lindung.

[28] Daniel Poneman, "Nuclear Policies in Developing Countries," *International Affairs*, Vol. 57, no. 4 (October 1, 1981): 568–584.

[29] JG, "Indonesia Vows No Nuclear Power Until 2050," *Jakarta Globe*, December 12, 2015, accessed December 15, 2015, http://jakartaglobe.beritasatu.com/business/indonesia-vows-no-nuclear-power-2050/.

[30] Pebrianto Eko Wicaksono, "DEN Siapkan Skenario Pengembangan Energi Nuklir [DEN Prepares Nuclear Energy Development Scenarios]," *liputan6.com*, çMarch 18, 2016, accessed July 8, 2016, http://bisnis.liputan6.com/read/2462227/den-siapkan-skenario-pengembangan-energi-nuklir.

[31] Silvanus Alvin, "Jokowi Tolak 2 Permintaan Putin, Apa Saja? [Jokowi refuses Putin's two requests: what are they?]," *liputan6.com*, May 19, 2016, accessed July 8, 2016, http://news.liputan6.com/read/2510495/jokowi-tolak-2-permintaan-putin-apa-saja.

2.2 Indonesian Interest in SMRs

Since the turn of the century, Indonesia's exploration of the nuclear option has expanded to include a new class of nuclear power plants, small modular reactors (SMRs), being designed, developed, and advocated by the nuclear power industry. The hopes placed on these designs is clearly expressed in the words of officials from BATAN who went to a meeting organized by the International Atomic Energy Agency in Cairo on the status and prospects for small and medium sized reactors:

> "[s]ince the late 1970s, the National Nuclear Energy Agency (BATAN) has been involved in convincing the Government of Indonesia on the need to embark on a nuclear power programme. However, no state-owned company is in a position to undertake large investments, hence no nuclear power plant could be built in Indonesia in the foreseeable future. A possible breakthrough would be the introduction of SMR in the form of the fourth generation of nuclear power plants whose goal is low generation cost, able to compete with gas combine cycle; high safety, free from catastrophic accidents; low amount of waste; and proliferation proof".[32]

BATAN officials are not unique in placing such hopes on SMRs. Nuclear establishments in many countries, and developers of these designs, have expressed the expectation that a new generation of reactors can alter the course of nuclear power,[33] whose share of global electricity generation has been declining continuously since the mid-1990s.[34]

However, a decade and a half later it would be fair to say that the possible breakthrough hoped for by BATAN officials and others has not yet occurred. There is no SMR even at the design stage that meets all the criteria specified by BATAN simultaneously.[35] Specific SMR designs often address one or more of the motivations mentioned above, but it is not always possible to address all desirable criteria (safety, proliferation resistance, reduction of waste generation) simultaneously. Most importantly, none of the SMRs that are considered nearly ready for construction meets the low generation cost criterion.

Despite this reality, there has been a major effort undertaken by various reactor vendors to market SMRs. A number of reasons have been advanced to pursue the development and construction of SMRs and these are directed both at industrialized countries and developing countries. The latter, in particular, is a major target market for SMRs, including many countries that have no commercial nuclear capacity at present, such as Indonesia. The IAEA suggests that SMRs "may provide an attractive and affordable nuclear-power option for many developing countries" because of their smaller electrical grids, limited

---

[32] Arbie, Sudarsono, and Subki, "Strategy for Introduction of Small and Medium Reactors in Indonesia," 733.

[33] Benjamin K. Sovacool and M.V. Ramana, "Back to the Future: Small Modular Reactors, Nuclear Fantasies, and Symbolic Convergence," *Science, Technology, & Human Values* 40, no. 1 (2015): 96–125.

[34] M. V. Ramana, "Second Life or Half-Life? The Contested Future of Nuclear Power and Its Potential Role in a Sustainable Energy Transition," in *Energy Transitions*, ed. Florian Kern, Algrave Handbook of the International Political Economy of Energy (London: Palgrave Macmillan, 2016); M. V. Ramana, "The Frontiers of Energy: A Gradual Decline?," *Nature Energy* 1, no. 1 (January 11, 2016): 7.

[35] M. V. Ramana and Zia Mian, "One Size Doesn't Fit All: Social Priorities and Technical Conflicts for Small Modular Reactors," *Energy Research & Social Science* 2 (June 2014): 115–124.

infrastructure and restricted investment capability.[36] Likewise, one analyst from the World Bank argues, "Given their lower capital requirements and small size, which makes them suitable for small electric grids, SMRs can more effectively address the energy needs of small developing countries".[37]

Indonesia has demonstrated an interest in SMRs by being an active participant in the IAEA's meetings on SMRs. In fact, Indonesia was among the first countries that prepared an IAEA "User Requirement Document" for SMRs, having done so in the year 2000.[38]

BATAN's reasons for interest in SMRs fall into two categories. The first category of reasons are common to its general interest in nuclear power, whether with large or small reactors: this includes low levels of electricity consumption among the population of Indonesia, growing energy needs, and (claims about) lack of alternate means to meet these needs.[39] The second category of reasons are specific to SMRs: this includes the fact that there are many remote areas and small islands that do require electricity or energy but do not have the demand level to support construction of a large nuclear reactor, and the fact that the total financial cost of SMRs is expected to be lower than a large reactor.[40]

BATAN has explored the possibility of importing different kinds of SMRs from nuclear vendors in different countries. As we discuss below, this includes the possibility of a small floating power plant from Russia, an SMR from Korea that can also desalinate ocean water, and a high temperature gas cooled reactor (HTGR), one of the four families of SMRs under development around the world,[41] again from Russia. What is odd about the last possibility is that Russia has no experience in constructing HTGRs, unlike for example Germany.

---

[36] See the IAEA website: IAEA, "SMR - Nuclear Power," *Small and Medium Sized Reactors (SMRs) Development, Assessment and Deployment*, last modified 2015, accessed December 25, 2015, https://www.iaea.org/NuclearPower/SMR/. Note that the IAEA includes reactors of up to 700 MW and uses the term Small and Medium Reactors (again with the acronym SMR) rather than Small Modular Reactors in its deliberations. There is, however, a large overlap in the two categories.

[37] Ioannis N. Kessides, "The Future of the Nuclear Industry Reconsidered: Risks, Uncertainties, and Continued Promise," *Energy Policy* 48 (2012): 185–208.

[38] IAEA, *Guidance for Preparing User Requirements Documents for Small and Medium Reactors and Their Application*, 71–93.

[39] Yohannes Sardjono, "SMR Application Study in Indonesia: Case Study for Kalimantan Site," in *Topical Issues on Infrastructure Development: Managing the Development of a National Infrastructure for Nuclear Power Plants* (Vienna, Austria: International Atomic Energy Agency, 2012).

[40] Syahril, JMC Johari, and Sunarko, "Prospects of SMRs in Indonesia's Energy System" (presented at the Technical Meeting on Options to Enhance Energy Supply Security using NPPs based on SMRs, Vienna, Austria: IAEA Headquarters, 2011), http://www.iaea.org/NuclearPower/Downloads/Technology/meetings/2011-Oct-3-6-SMR-TM/2-Tuesday/9_INDONESIA_BATAN_Sunarko_TM3-4Oct2011.pdf; Bakri Arbie, Budi Sudarsono, and Iyos R. Subki, "Strategy for Introduction of Small and Medium Reactors in Indonesia," in *Small and Medium Sized Reactors: Status and Prospects* (Cairo, Egypt: International Atomic Energy Agency, 2001), 733–742, accessed December 31, 2015, http://www-pub.iaea.org/MTCD/publications/PDF/CSPS-14-P/CSP-14_part5.pdf. Syahril et al. states: "Many regions in Indonesia do not have sufficient supply of electricity, esp. in remote areas and small islands [and these] areas may benefit from New and Renewable Energy, including Nuclear through SMR technology."

[41] Alexander Glaser et al., *Small Modular Reactors: A Window on Nuclear Energy*, An Energy Technology Distillate (Princeton, N.J.: Andlinger Center for Energy and the Environment at Princeton University, June 2015), accessed July 29, 2015, http://acee.princeton.edu/distillates/distillates/small-modular-reactors/.

BATAN has also signed an agreement with the French company DCNS,[42] which has traditionally been involved in a range of naval defence systems but more recently is developing a submarine based electricity generating reactor project called Flexblue.[43] The idea is to park the submarine on the ocean floor and run a cable from it to land to supply electricity.

Indonesia also started a "Pre Feasibility Study to introduce SMR to Bangka Belitung Province in 2009" as requested by the then governor of Bangka Belitung Province.[44] There has also been a proposal to consider an SMR for Kalimantan.[45]

BATAN officials have identified several challenges concerning SMRs, including challenges relating to the stability of the electricity grid, the necessary regulatory framework, the regulatory requirement for designs being based on "proven technology" (this concern is discussed in more detail later in section 5.5), safety concerns such as those associated with construction in seismically active areas and emergency preparedness, and the necessity of political commitment from the government and acceptance by the public.[46]

BATAN officials have used one of the standard methods recommended by the IAEA,[47] the Kepner Tregoe methodology, which dates back to the 1960s,[48] to identify potential SMR designs of interest.[49] Based on this approach, BATAN claims to have identified a list of six SMR designs as having the "most potential".[50] However, BATAN officials have been somewhat inconsistent in their identification of these designs. According to a talk presented by BATAN officials at the IAEA in 2011, these were the Chinese HTR-PM, the Russian KLT-40S, the Japanese 4S, the Argentinian CAREM-25, the South Korean SMART, and the American NuScale designs.[51] In contrast, in another talk by a BATAN official at the IAEA in the same year, NuScale was not mentioned at all, but the IRIS, which is no longer

---

[42] Batan, "National Nuclear Energy Agency - France - Indonesia Cooperation to Develop Power Reactor" (Jakarta, Indonesia, February 11, 2015), accessed January 1, 2016, http://www.batan.go.id/index.php/id/berita-bhhk/611-perancis-indonesia-kembangkan-kerjasama-reaktor-daya.

[43] PEI, "Blue Submarine: The Flexblue Offshore Nuclear Reactor," *Power Engineering*, January 5, 2011, accessed January 2, 2016, http://www.powerengineeringint.com/articles/print/volume-19/issue-5/features/blue-submarine-the-flexblue-offshore-nuclear-reactor.html.

[44] Jupiter Sitorus Pane, "An Overview of Developing National Requirements for Proliferation Resistance Assessment of Nuclear Energy System Including SMR in Indonesia," in *3rd Technical Meeting on Option to Incorporate Intrinsic Proliferation Feature to Nuclear Power Plants with Innovative Small and Medium Sized Reactors (SMRs)* (Vienna, Austria: International Atomic Energy Agency, 2011).

[45] Yohannes Sardjono, "Prospects and Technical Requirements on SMR: Indonesian Case Study," in *Consultants' Meeting on the Status of Innovative Small and Medium Sized Reactor (SMR) Technology and Designs with the Potential for Near Term Deployment* (Vienna, Austria: International Atomic Energy Agency, 2011).

[46] Syahril, Johari, and Sunarko, "Prospects of SMRs in Indonesia's Energy System."

[47] IAEA, *Nuclear Reactor Technology Assessment for near Term Deployment* (Vienna: International Atomic Energy Agency, 2013), accessed December 31, 2015, http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1597_web.pdf.

[48] Charles Higgins Kepner and Benjamin B. Tregoe, *The Rational Manager: A Systematic Approach to Problem Solving and Decision Making* (New York: McGraw-Hill, 1965).

[49] Pane, "An Overview of Developing National Requirements for Proliferation Resistance Assessment of Nuclear Energy System Including SMR in Indonesia."

[50] Ibid.

[51] Syahril, Johari, and Sunarko, "Prospects of SMRs in Indonesia's Energy System."

under active development, and a number of other designs were listed as possessing "potential of availability".[52] As with SMR proponents around the world,[53] BATAN has been optimistic about the time frame in which many of the SMR designs they have identified will actually be available. Among the designs identified as being available by 2015 were the KLT-40S, the Advanced Heavy Water Reactor, HTR-PM, PBMR, and the 4S,[54] not one of which has actually been constructed anywhere (as of December 2016).

2.3 Experience with Nuclear Technology

BATAN has several decades of experience with operating research reactors. There are three existing nuclear research reactors in Indonesia:

- ***Triga Mark II Reactor at Bandung***

  The first reactor built in Indonesia was a Triga Mark II, which reached criticality in 1964,[55] and is located close to the Bandung Institute of Technology (Institut Teknologi Bandung/ITB). Initially, the operating power of the reactor was 250 kW. By 1971 the power rating was increased to 1 MW and then in 2000 it was increased again to 2 MW.[56]

- ***Kartini Reactor***

  The second reactor, also a Triga Mark II design, was inaugurated in 1979 and is located in Yogyakarta. The power capacity of this reactor is 100 kW.[57]

- ***G. A. Siwabessy Reactor***

  The most recently built research reactor, which uses local fuel elements fabricated in Indonesia, became critical in 1987. It has a power capacity of 30 MW and is located in Serpong.[58]

---

[52] Pane, "An Overview of Developing National Requirements for Proliferation Resistance Assessment of Nuclear Energy System Including SMR in Indonesia."
[53] Mycle Schneider and Antony Froggatt, *The World Nuclear Industry Status Report 2015* (Paris: Mycle Schneider Consulting, 2015), 68–77, accessed November 13, 2015, http://www.worldnuclearreport.org/-2015-.html.
[54] Pane, "An Overview of Developing National Requirements for Proliferation Resistance Assessment of Nuclear Energy System Including SMR in Indonesia."
[55] Poneman, *Nuclear Power in the Developing World*, 100.
[56] Sriyana, "Current Status of Indonesia's Nuclear Power Programme," in *Technical Meeting/Workshop on Topical Issues on Infrastructure Development: Managing the Development of National Infrastructure for NPP* (Vienna, Austria: International Atomic Energy Agency, 2012).
[57] Ibid.
[58] Huda, Rohman, and Lasman, "Challenges for Indonesia in Embarking to Nuclear Power"; Ratih Langenati, "The Current Status Of Research And Development Activities In Nuclear Fuel At Batan," in *Technical Meeting/on the Nuclear Fuel Cycle Information System* (Vienna, Austria: International Atomic Energy Agency, 2014), accessed December 26, 2015, https://www.iaea.org/OurWork/NE/NEFW/Technical-Areas/NFC/documents/infcis/NFCIS-2014/21-ratih_presentation_draft_win_gks-rev.pdf.

2.4 Public Opinion and Opposition to Nuclear Power

Unfavorable public opinion has been a significant constraint on nuclear power development in Indonesia and in many other countries around the world.[59] Apart from local opposition from inhabitants of the regions identified as potential locations for nuclear power plants, the popularity of nuclear power, or lack thereof, among the general population is often identified as a factor in whether or not a country develops nuclear power, including by the Indonesian government.

There is wide variation in the results of studies of public attitudes towards nuclear power in Indonesia. A poll prepared for the International Atomic Energy Agency by GlobeScan, a commercial polling agency, in October 2005 found that only 33 percent of those polled felt that nuclear was safe and that more plants should be built; in comparison, 28 percent felt that nuclear power was dangerous and all plants should be closed down while 31 percent agreed with the "middle opinion" that what was already there should be used but no new plants should be constructed.[60]

In 2011, an IPSOS poll conducted after Fukushima found that 33 percent of Indonesians strongly oppose nuclear power while 34 percent were somewhat opposed.[61] About two-thirds of those polled said that their opinion was not influenced by the Fukushima accident in Japan.

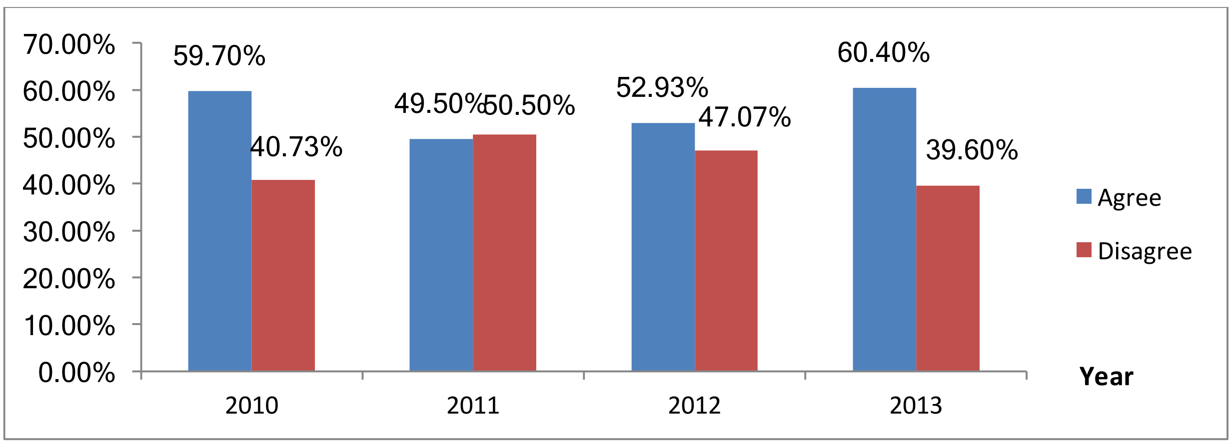


Figure 2: Survey of public acceptance of nuclear power plants by BATAN in 2013

Source: National Nuclear Energy Agency, *Report on Accountability of Performance of Government Institution 2013 National Nuclear Energy Agency*. 2014, National Nuclear Energy Agency: Jakarta. p. 43.

BATAN's surveys give somewhat different results (Figure 2) and its 2013 polls had 60.4 percent of respondents agreeing with the idea of establishing nuclear power plants in

---

[59] M. V. Ramana, "Nuclear Power and the Public," *Bulletin of the Atomic Scientists* 67, no. 4 (2011): 43 –51.

[60] GlobeScan, *Global Public Opinion on Nuclear Issues and the IAEA: Final Report from 18 Countries* (London: Prepared for the International Atomic Energy Agency by GlobeScan Incorporated, 2005), 19.

[61] IPSOS, *Global Citizen Reaction to the Fukushima Nuclear Plant Disaster* (Ipsos, June 2011), http://www.ipsos-na.com.

Indonesia. According to BATAN, the public acceptance of NPPs decreased from 2010 to 2011 in the wake of the events in Fukushima, Japan. In response, BATAN actively undertook activities designed to increase public support for nuclear power, which, according to the survey results, may have been somewhat successful.

As in many countries, there is a strident debate regarding the pros and cons of nuclear power in Indonesia. Civil society organizations have played an important role in this debate.[62] In broad strokes, opposition to nuclear power in Indonesia can be categorized into: 1) a lay segment; 2) a segment consisting of Non-Governmental Organizations (NGOs) and academic circles; and 3) a segment consisting of current and former government officials in the energy, electricity and nuclear sectors. Organizations that have played a part in opposing nuclear reactors are the Indonesian Anti-Nuclear Community (Masyarakat Anti Nuklir Indonesia – MANUSIA), the Indonesian Forum for Environment (Wahana Lingkungan Hidup Indonesia – WALHI), Greenpeace, and religious organizations such as the Nahdlatul Ulama (especially its Central Java division).[63]

Some of the reasons that underlie opposition to nuclear power include concerns about security of reactor operations, the reliability of reactor designs, radioactive waste, the potential for nuclear proliferation, Indonesia's geographical position within the seismically active Pacific Ring of Fire and/or the proximity of nuclear sites to seismic faults or volcanoes, high economic costs, future dependence on foreign parties for nuclear technology or fuel, and a preference for local renewable energy resources.

3 Siting Studies and Large Nuclear Plant Proposals

BATAN has conducted a number of studies of sites that have been considered for commercial nuclear power plants. Two types of studies have been done, those that investigate the feasibility of a specific site for installation of nuclear power, and studies that explore issues that are not site specific although they do relate to the proposed nuclear facility.

The preliminary site study is divided into three phases, which progressively narrows the list of candidate sites:

1. *Potential Site Identification*: A preliminary survey is used to obtain potential sites that may be suitable for a nuclear power plant. At this stage, aspects of local site suitability such as topography, seismology, volcanology, hydrology, meteorology, and human activity in the proposed area are investigated. For example, sites on the north coast of Java passed this preliminary candidacy phase, while sites on the southern part of Java failed for seismic reasons, as did West Sumatra, which is close to the Sunda (Java) Trench, a region well known for high seismic activity.

---

[62] Caballero-Anthony, Alexandra, and Punzalan, "Civil Society Organizations and the Politics of Nuclear Energy in Southeast Asia: Exploring Processes of Engagement."

[63] Fauzan and Schiller, After Fukushima: The Rise of Resistance to Nuclear Energy in Indonesia; Amir ,"The State and the Reactor: Nuclear Politics in Post-Suharto Indonesia"; Tanter, Nuclear Fatwa: Islamic Jurisprudence and the Muria Nuclear Power Station Proposal.

2. *Candidate Site Identification*: In this phase, the list of candidate sites is narrowed by investigating additional aspects of the proposed sites, including land and water use as well as local ecology and cultural history that may be impacted by construction.
3. *Selected Site Identification*: In the final phase, the "best and final" site is identified. Additional criteria that are investigated include considerations of radiation dispersion and disaster preparedness.

Following the site studies, additional follow-up technical and economic feasibility studies are then conducted for the selected site, which consist of:

1. *Technical Feasibility Study*: This study is used to determine candidate nuclear technologies for the proposed site. This includes the reliability of a proposed NPP's performance and its fuel security, the availability of the technology, the compatibility of the NPP with the local grid and the selection of a potential nuclear supplier.
2. *Economic Feasibility Study*: This study estimates the electricity generation cost by potential vendor. This cost depends on the selected technology and location of the vendors. Assumptions about different funding scenarios affect the assessed economic feasibility of a given NPP. For example, whether the capital cost will be financed by the government or by international financial institutions impacts the cost estimate.

To date, BATAN has conducted site studies on at least 14 potential sites. Below are the descriptions of some of the main NPP proposals and studies in Indonesia. The status of the main proposals considered during the period 2010-2015 is summarized in Table 1.

Table 1. Status of main NPP proposals considered from 2010-2015

	Location	Region	Purpose	Size	Partners/ Collaborators	Status
1	Tanah Abang, Desa Balong	Muria Peninsula, Central Java	Large NPP	4 x 1,000 MW	BATAN; IAEA	Feasibility study completed (1996); "5 years further study required" (2012)
2	Muntok/Teluk Inggris, West Bangka	Bangka-Belitung	Large NPP	6 x 1,000 MW	BATAN; Bangka-Belitung provincial government	Feasibility study completed (2011)
3	Tanjung Barani (or Berani), South Bangka	Bangka-Belitung	Large NPP	4 x 1,000 MW	BATAN; Bangka-Belitung provincial government	Feasibility study completed (2011)
4	Unspecified	Bangka-Belitung	SMR		BATAN	Proposed August (2013)
5	Berau and East Kutai	East Kalimantan	Large NPP	1,000 MW	BATAN; East Kalimantan provincial government; Ministry of Research and Technology	Min. of Research and Technology support (2012); provincial government support (2015); Feasibility study reported as being in preparation (2015)
6	Dekan Putih, Kubu Raya, and Ketapang	West Kalimantan	Large NPP	30 MW	BATAN; West Kalimantan provincial government	Feasibility study reported as being in preparation (2015)
7	Unspecified	Central Kalimantan			Pertamina; Central Kalimantan provincial government	Feasibility study proposed by provincial government (2015)
8	Gorontalo	Gorontalo	Floating NPP (SMR)	90 MW	Gorontalo provincial government; RAO UES (Unified Energy System of Russia); Rosatom	Enthusiastically pursued by RAO UES/Rosatom and the provincial government in mid-2000s; subsequently dormant but re-

						emerged in 2010
9	Pulau Panjang, Banten	West Java	Large NPP			
10	Kramatwaru-Bojonegara, Banten	West Java	Large NPP			
11	Serpong	West Java		10 MWe	BATAN	
12	Serpong	West Java	NCPR64	30 MWe	BATAN	
13	Subang	West Java		600 MW	BATAN Teknologi; Rosatom	
14	Unspecified		HTGR	10-30 MWe	BATAN/Japan Atomic Energy Agency	Demonstration plant to start operations "by 2020"
15	Tangerang Selatan, Banten[65]		HTGR	10 MWth	BATAN; RENUKO; Rosatom	
15	Unspecified		Travelling Wave Reactor	500 MW	BATAN Teknologi; Terra Power	BATAN Teknologi proposal (2014)
16	Batam	Riau	Large NPP	2 x 1,200 MW	Riau provincial government; Rosatom; BATAN	

Adapted from Richard Tanter, Table: Indonesian nuclear power reactors, under governmental consideration, 2010 – 2015, at http://nautilus.org/network/associates/richard-tanter/publications/ and Richard Tanter, "The Slovakian 'Inspirasi' for Indonesian Nuclear Power – the 'Success' of a Permanently Failing Organisation," Asian Perspective, Volume 39, issue 4 (October-December 2015), pp. 667-694. Those documents include the sources on which the table is based.

---

[64] "Batan may begin construction of nuclear power plant in 2015", *Antara*, 17 Dec 2013, at http://www.antaranews.com/en/news/91826/batan-may-begin-construction-of-nuclear-power-plant-in-2015; and Reno Alamsyah, *Current status of national position on nuclear power: Indonesia*, Building a National Position on a New Nuclear Power Programme, IAEA, Vienna, 24 – 26 June 2014, at https://www.iaea.org/NuclearPower/Downloadable/Meetings/2014/2014-06-24-06-26-TM-INIG/NP_Current_Status_Indonesia.pdf.

[65] Topan Setiadipura, "Indonesia's Experimental Power Reactor Project" (Seminar, Idaho Falls, Idaho, USA, September 23, 2015), https://catatanstudi.files.wordpress.com/2015/09/rde_project_topaninl.pdf; Topan Setiadipura, "Requirements of Pebble Bed Reactor's Plant Information Model" (IAEA Nuclear Knowledge Management, Vienna, Austria, June 22, 2015), https://www.iaea.org/nuclearenergy/nuclearknowledge/Events/2015/2015-06-22-26-TM-PIM/.

Below, we discuss some of the specific sites that have been considered for the construction of (large) nuclear plants.

3.1 Muria Peninsula Study

The Muria Peninsula sites have been the longest studied in Indonesia. This region has been promoted as the appropriate site for a large nuclear power station for around three decades by BATAN, the Ministry of Energy and Mineral Resources (Kementerian Energi dan Sumber Daya Mineral – ESDM), the Ministry of Research and Technology, the IAEA, and some nuclear power vendors (Japan, Korea, and Russia).

In 1983, BATAN, in cooperation with the Italian nuclear engineering firm NIRA (Nuclears Italiana Reacttori Avancatti), studied and selected the Muria Peninsula as BATAN's preferred site.[66] The Muria proposal subsequently involved New Japan Engineering Consultants (NEWJEC Inc.), a Japanese engineering consultant firm and subsidiary of the Mitsubishi complex, which conducted feasibility studies for a potential Japanese-supplied nuclear plant on the Muria Peninsula from 1991-1996. In 1993, NEWJEC produced a three-volume report entitled *Feasibility Study of the First Nuclear Power Plants at Muria Peninsula Region* that again projected the energy demand and supply to make a case for nuclear power.[67] The report advised Indonesia to build twelve 600 MW reactors starting in 1996; these were to start operating commercially by 2003.[68]

NEWJEC focused on three sites on the north coast of the Muria Peninsula regarded as suitable: Ujung Lemahabang and Ujung Grengganan in the village of Balong, and Ujung Watu, a few kilometers east. Ujung Lemahabang emerged as the preferred site according to BATAN; apart from other advantages in terms of land and sea access, relatively low population density and location, and ground characteristics, Ujung Lemahabang had the most favorable ranking of these three sites in terms of volcanic and seismic hazards. Nevertheless, there was serious criticism of the seismic hazards of the site given its proximity to major fault lines and poor soil structure, and proximity to the Muria volcanic complex 25 kilometers away, which IAEA geologists and volcanologists regarded as still capable of erupting in the expected life time of the plant.[69]

3.2 Bangka Island Study

The most recent study of potential nuclear sites carried out by BATAN was on Bangka Island. On June 15, 2009, BATAN signed a memorandum of understanding with the Bangka-Belitung provincial government for the "Utilization of Nuclear Science and Technology for

---

[66] Richard Tanter and Arabella Imhoff, "The Muria Peninsula Nuclear Power Proposal: State of Play," Austral Policy Forum 09-1A, Nautilus Institute, 19 January 2009, accessed November 29, 2015, http://nautilus.org/apsnet/muria-nuclear-power/.

[67] August Schlapfer, *Reactors on the Ring of Fire: Implications for Indonesia's Nuclear Program* (Perth, Australia: Asia Research Centre on Social, Political and Economic Change, Murdoch University, 1996).

[68] Amir, "Nuclear Revival in Post-Suharto Indonesia," 273.

[69] See the academic study by the IAEA volcanology study team: Alexander R. McBirney et al., "Volcanic and Seismic Hazards at a Proposed Nuclear Power Site in Central Java," *Journal of Volcanology and Geothermal Research* 126, no. 1–2 (2003): 11–30.

the Welfare of the Community of Bangka-Belitung".[70] Between 2011 and 2013, feasibility studies were conducted for two sites: Tanjungular, Muntok in West Bangka, and Sebagin Village Coast, Permis in South Bangka.[71] The results of these feasibility studies showed both locations were suitable for nuclear plants and estimated that the combination of six reactors at the Muntok site in West Bangka and four units at the Permis site in South Bangka could accommodate 10 GWe of nuclear capacity.[72]

However, due to a change in provincial government in 2013, continued local support for the Bangka project has receded somewhat.[73] The provincial government of Bangka-Belitung requested that BATAN and BAPETEN review the Bangka NPP development plan, especially in the Muntok region, West Bangka. The request was filed based on the fact that Bangka Island's feasibility as a nuclear site may be compromised by unsustainable mining activities that have damaged the island's land stability, creating disaster-prone areas.[74]

3.3 Banten Nuclear Power Plant Study

The third area where BATAN has considered constructing a nuclear plant is Banten, West Java Province. The specific site that has been considered is Tanjung Pujut, which was listed as a potential site even in the IAEA study in the mid-1970s.[75] In addition, other sites have been considered on the northern coast.

So far no potential sites in that region have, as yet, successfully met all the selection criteria. Coincidentally, as happened at the Muria Peninsula, an earthquake also recently occurred in Banten on November 4, 2015,[76] highlighting the seismic instability of the region. The center of the earthquake was located about 88 kilometers southwest of Pandeglang in Banten, and its magnitude was estimated at close to 5.0 on the Richter scale.

---

[70] Richard Tanter, "The Slovakian 'Inspirasi' for Indonesian Nuclear Power: The 'Success' of a Permanently Failing Organization," *Asian Perspective* 39, no. 4 (2015): 675–676.

[71] IAEA, "Indonesia 2013," Country Nuclear Power Profiles, 2013, http://www-pub.iaea.org/MTCD/publications/PDF/CNPP2013_CD/countryprofiles/Indonesia/Indonesia.htm; Kamis, "Batan Recommends Bangka Belitong as Location for Nuclear Power Plant," Antara News, August 4, 2016, http://www.antaranews.com/en/news/106093/batan-recommends-bangka-belitong-as-location-for-nuclear-power-plant; Sabtu, "Indonesian Nuclear Is Not for War," Antara News, October 15, 2011, http://www.antaranews.com/en/news/76591/indonesian-nuclear-is-not-for-war.

[72] *Nuclear Power in Indonesia*. June 2015 [cited 2015 October 20]; Available from: http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/Indonesia/.

[73] WNA, "Nuclear Power in Indonesia," *World Nuclear Association*, last modified December 2015, accessed December 27, 2015, http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/Indonesia/.

[74] Citing an article in *Tempo* from February 3, 2014 ("Pembangunan PLTN di Bangka diminta kaji ulang" [Review of NPP in Bangka requested] http://nasional.tempo.co), Tanter ("The Slovakian 'Inspirasi' for Indonesian Nuclear Power: The 'Success' of a Permanently Failing Organization," 676.) describes it thus: "by early 2014, following the emergence of local opposition, the head of the provincial Disaster Management Agency wrote to BATAN and the increasingly professional Nuclear Regulatory Agency, BAPETEN, asking for a formal review of the possible effects of BATAN's Bangka NPP plan on the 'fragile condition of Bangka'. He described the condition as 'already very alarming due to rampant mining for about a century' reflecting the region's history of severe environmental degradation."

[75] IAEA, *Nuclear Power Planning Study for Indonesia (Java Island)*, 59.

[76] "5.2 magnitude quake hits Jakarta", *Jakarta Post*, 4 November 2015, http://www.thejakartapost.com/news/2015/11/04/52-magnitude-quake-hits-jakarta.html.

This earthquake in Pandeglang is the third time an earthquake has shaken the area, which is not far from the Krakatau volcano.

4 Small Modular Reactor Proposals

In addition to a general interest in SMRs, the Indonesian nuclear establishment has studied some SMR possibilities in much greater detail.

4.1 Serpong, Banten Experimental Power Reactor (EPR)

In December 2013, the Ministry of Energy and Mineral Resources announced a plan to build a non-commercial power reactor (Reaktor Daya Non-Komersial; or Experimental Power Reactor: EPR[77]) and a gamma irradiation facility at Serpong in Banten Province, on the edge of the city of Jakarta.[78] As the name suggests, this reactor is not intended as a power supply option, but only as an experimental project. The site is next to the BATAN nuclear complex in Serpong.[79]

The Experimental Power Reactor is a High Temperature Gas Cooled Reactor. According to officials, BATAN has examined the feasibility of HTGRs since 2010, and solicited expert insight from HTGR research groups in different countries, including Japan, Russia, and China in 2014.[80] Between 2010 and 2013, researchers at BATAN created a conceptual design of a HTGR using computer-based tools.[81] However, in 2014, BATAN only described the "conceptual design" as "still in progress".[82]

Since then, BATAN seems to have abandoned this design, or at least lowered its priority in comparison to a different HTGR design, to be imported from Russia and in 2015, BATAN entered into an agreement with Nukem Technology, a subsidiary of Russian nuclear

---

[77] Not to be confused with the larger European Power Reactor.
[78] WNA, "Nuclear Power in Indonesia."
[79] Yarianto Susilo, "The Indonesian EPR Project," in *Training Course on High Temperature Gas Cooled Reactor (HTGR) Technology* (Serpong, Indonesia: IAEA, 2015), accessed December 26, 2015, https://www.iaea.org/nuclearenergy/nuclearpower/Downloadable/Meetings/2015/2015-10-19-10-23/DOC/D2_RDE_PROJECT_STATUS_(Oct_2015).pdf.
[80] Taswanda Taryo, "Development of Indonesian Experimental Power Reactor Program: An Approach to Innovative R&D, Nuclear Cogeneration and Public Acceptance," in *INPRO Dialogue Forum on International Collaboration on Innovations to Support Globally Sustainable Energy Systems* (Vienna, Austria: International Atomic Energy Agency, 2014), accessed December 27, 2015, https://www.iaea.org/INPRO/9th_Dialogue_Forum/04_SessionPresentations/Day3_Planery4/7_Taryo-Indonesia-Day-3-Plenary-4.pdf.
[81] M. Dhandhang Purwadi, "Status of GCR Program in Indonesia" (presented at the 23rd TWG - GCR Meeting, Vienna, Austria, March 5, 2013).
[82] Tagor Sembiring, "Current Status of the HTGR Conceptual Design in BATAN," in *Technical Meeting on the Safety of High Temperature Gas Cooled Reactors in the Light of the Fukushima Daiichi Accident* (Vienna, Austria: International Atomic Energy Agency, 2014), accessed December 29, 2015, https://www.iaea.org/NuclearPower/Downloadable/Meetings/2014/2014-04-08-04-11-TM-NPTDS/8_Sembiring01.pdf.

company Rosatom, to build this reactor.[83] Unlike the conceptual design developed by BATAN that had a power output of 200 MW (thermal), the design from Russia has a power output of only 10 MW (thermal).[84] There are other differences as well.

Design work for the Serpong Experimental Power Reactor is to be carried out by the RENUKO Consortium of Russian and Indonesian companies. The lead on the project is NUKEM Technologies GmbH, a formally German company owned by Rosatom, the Russian State Atomic Energy Company. Other Rosatom-linked companies involved include Atomstroyexport and the reactor engineering design company OKBM Afrikantov. Indonesian companies involved include PT Rekayasa Engineering and PT Kogas Driyap Konsultan.[85] The budget for the reactor is reported as being 1.7 trillion Rupiahs (around $130 million).[86]

In August 2016, BATAN signed an agreement with the China Nuclear Engineering Group Corporation (CNEC) to jointly develop HTGRs and train professionals.[87] CNEC has been working with Tsinghua University to commercialize HTGRs.[88] From news reports, it seems this agreement with BATAN resulted from CNEC looking for potential customers.[89] However, the agreement is also similar to agreements that BATAN has entered into with other agencies involved in the promotion of HTGRs. In August 2014, BATAN signed a cooperation agreement with the Japan Atomic Energy Agency on research and development of HTGRs.[90]

---

[83] "Reaktor Daya Eksperimen Batan Akan Dibangun Rusia [BATAN Experimental Power Reactor will be built by Russia]," *Kompas*, April 16, 2015, accessed December 26, 2015, http://print.kompas.com/baca/2015/04/16/Reaktor-Daya-Eksperimen-Batan-Akan-Dibangun-Rusia?utm_source=bacajuga; "Economy in Brief: BATAN Inches Closer to Experimental Reactor," *Jakarta Post*, August 27, 2015, accessed December 27, 2015, http://www.thejakartapost.com/news/2015/08/27/economy-brief-batan-inches-closer-experimental-reactor.html.

[84] Sembiring, "Current Status of the HTGR Conceptual Design in BATAN"; Susilo, "The Indonesian EPR Project."

[85] "Indonesia Rules out Nuclear as Major Power Source," *Nuclear Engineering International*, December 14, 2015, accessed December 15, 2015, http://www.neimagazine.com/news/newsindonesia-rules-out-nuclear-as-major-power-source-4752814.

[86] Muhammad Kurnianto, "Batan to Build Nuclear Reactor Worth Rp1.7tn in Serpong," *Tempo*, July 1, 2015, accessed December 26, 2015, http://en.tempo.co/read/news/2015/07/01/055679905/Batan-to-Build-Nuclear-Reactor-Worth-Rp17tn-in-Serpong.

[87] Yuan Can, "China's Nuclear Giant to Promote HTGR in Indonesia - People's Daily Online," *People's Daily Online*, August 4, 2016, accessed August 7, 2016, http://en.people.cn/n3/2016/0804/c90000-9095521.html.

[88] NECE Shangguan Ziying, "CNEC and THU Made Progress towards Further Cooperation," *CNEC High Temperature Reactor Holdings*, last modified December 31, 2014, accessed August 13, 2016, http://en.cnechtr.com/ContentDetailInfo.aspx?menuid=3&columnid=13&dataid=35.

[89] News reports suggest that Wang Shoujun, chairman of China Nuclear Engineering Group Corporation visited BATAN in June 2016 in order to better understand the Indonesian market. See http://en.people.cn/n3/2016/0804/c90000-9095521.html

[90] WNN, "China and Indonesia to Jointly Develop HTGR," *World Nuclear News*, August 4, 2016, accessed August 7, 2016, http://www.world-nuclear-news.org/NN-China-and-Indonesia-to-jointly-develop-HTGR-0408165.html.

4.2 Gorontalo Floating Small NPP Proposal

The oldest nuclear proposal directly relevant to SMR technology stems from the mid-2000s when the Russian nuclear supplier Rosatom proposed a small Russian floating nuclear power plant to supply electricity to Gorontalo Province, Sulawesi.[91] Floating nuclear power plants are modeled after the reactors used to power a small fleet of nuclear-powered icebreakers operated by Russia for decades. The idea of a civilian floating nuclear power plant project has been around in Russia since the 1990s, but progress has been slow and erratic.[92] The United States also explored the idea of commercial floating nuclear power plants, only to abandon the idea as uneconomical after spending millions of dollars.[93]

In October 2006, the Governor of Gorontalo announced that the province already had an agreement with the then state-owned Raoues (Unified Energy System of Russia) to buy a floating power plant.[94] BATAN confirmed the desire of Gorontalo's local government to obtain a floating NPP.

Despite enthusiasm for the proposal on the part of the Government of Gorontalo, the Indonesian Minister of Research and Technology rejected the idea of using a floating nuclear power plant. As Natio Lasman, then deputy chairman of Indonesia's nuclear agency and later chair of the Nuclear Regulatory Agency (BAPETEN), told the *Wall Street Journal*, "I don't want Indonesia to be used as an experiment".[95] There seemed to be a preference for land-based NPPs. In the meanwhile, construction of the *Akademik Lomonosov*, the first prototype ship based on the floating nuclear plant design, has been significantly delayed, and there have been corresponding cost overruns.[96]

In May 2015, the provincial governments on the island of Sulawesi encouraged the Central Government of Indonesia to build nuclear power plants because the region was experiencing a shortage of power.[97] The Secretary General of the Sulawesi Regional

[91] Tom Wright and Gregory L. White, "Russia Floats Plan For Nuclear Plant Aboard a Boat," *Wall Street Journal*, August 21, 2007, sec. News, accessed December 28, 2015, http://www.wsj.com/articles/SB118765859256303633.

[92] Alexandr Nikitin and Leonid Andreyev, "Floating Nuclear Power Plants" (Oslo: Bellona Foundation, 2011), http://spb.org.ru/bellona/ehome/russia/nfl/nfl8.htm.

[93] Ted Sherman, "Floating Nuclear Plants? The Worst Idea N.J. Utility Has Ever Had?," NJ.com, accessed October 4, 2016, http://www.nj.com/inside-jersey/index.ssf/2016/08/offshore_nuclear_power_plants_nj_utility_once_considered_the_idea.html.

[94] Dian Abraham, "The Battle towards Indonesian First Commercial Nuclear Reactor," in *No Nukes Asia Forum* (Indonesia, 2008).

[95] Wright and White, "Russia Floats Plan For Nuclear Plant Aboard a Boat."

[96] Charles Digges, "Russia Announces yet Newer Delivery Date for First Floating Nuclear Power Plant," *Bellona.org*, last modified October 28, 2014, accessed May 19, 2015, http://bellona.org/news/nuclear-issues/nuclear-russia/2014-10-russia-announces-yet-newer-delivery-date-first-floating-nuclear-power-plant; Charles Digges, "New Documents Show Cost of Russian Floating Nuclear Power Plant Skyrockets," *Bellona.org*, last modified May 25, 2015, accessed December 28, 2015, http://bellona.org/news/nuclear-issues/2015-05-new-documents-show-cost-russian-nuclear-power-plant-skyrockets; M.V. Ramana, Laura Berzak Hopkins, and Alexander Glaser, "Licensing Small Modular Reactors," *Energy* 61 (2013): 555–564.

[97] Muhammad Idris, "Listrik Sering Byar-Pet, Pemda Sulawesi Minta Jokowi Bangun PLTN [Frequent electricity blackouts, the Government of Sulawesi Request Jokowi Build NPP]," *Detikfinance*, last modified May 15, 2015, accessed August 5, 2016, http://finance.detik.com/read/2015/05/15/150358/2915733/1034/listrik-sering-byar-pet-pemda-sulawesi-minta-jokowi-bangun-pltn.

Development Cooperation Agency (Sekretaris Jenderal Badan Kerjasama Pembangunan Regional Sulawesi – BKPRS) also confirmed that opinion.[98] In addition to the need for electricity in these provinces, the second reason advanced for building a nuclear plant in Sulawesi was the discovery of uranium resources in West Sulawesi—reportedly the largest uranium deposit in Indonesia.[99]

The first of the stated rationales—electricity shortages—might no longer provide a strong motivation to build a nuclear plant. In September 2015, PLN started construction of a 100 MW (four 25 MW plants) gas-fired power plant in Pohuwatu, Gorontalo to alleviate the power shortage in the province.[100] The first phase of the plant, capable of generating 50 MW of electricity, started functioning in January 2016.[101] Given that PLN's estimate of the peak electricity demand in Gorontalo is around 80-85 MW,[102] the commissioning of the full plant should ease the power shortage.

Secondly, although Indonesia is not the only country to talk about the availability of uranium in the country as a factor in deciding to consider nuclear power plants, there is no good reason to connect the two. Uranium is a very minor element in the cost of generating nuclear power and there is little or no difficulty in procuring nuclear fuel on the international market at competitive prices.

4.3 Madura Desalination Small NPP Proposal

Madura is a large island north of the port of Surabaya in East Java. In October 2001, under the framework of the Interregional Technical Cooperation Project of the IAEA, BATAN signed an agreement with Korea Atomic Energy Research Institute (KAERI) to undertake a joint study entitled "A preliminary economic feasibility assessment of nuclear desalination in Madura Island".[103] KAERI has been developing a small modular reactor called the System-Integrated Modular Advanced Reactor (SMART) since 1996.[104] This plant design involved two reactor units that could each produce 100 MW of electrical power as well as

---

[98] Ibid.

[99] Dewanti Lestari, "Indonesia miliki cadangan uranium 70.000 ton' ['Indonesia has 70,000 tons of uranium reserves]," *Antara*, May 20, 2013, http://www.antaranews.com/berita/375792/indonesia-miliki-cadangan-uranium-70000-ton. "Listrik Sering Byar-Pet, Pemda Sulawesi Minta Jokowi Bangun PLTN," Detikfinance.

[100] "Economy in Brief: PLN to Build New Power Plant in Gorontalo," *Jakarta Post*, September 11, 2015, accessed December 29, 2015, http://www.thejakartapost.com/news/2015/09/11/economy-brief-pln-build-new-power-plant-gorontalo.html.

[101] PT PLN, "PLN Starts Operating Gas Power Plant Gorontalo," *Rambu Energy*, last modified January 18, 2016, accessed August 5, 2016, http://www.rambuenergy.com/2016/01/pln-starts-operating-gas-power-plant-gorontalo/.

[102] Ibid.

[103] Si-hwan Kim et al., "A Preliminary Economic Feasibility Assessment of Nuclear Desalination in Madura Island," *International Journal of Nuclear Desalination* 1, no. 4 (2005): 466– 476.

[104] Kyoo Hwan Bae et al., "Safety Evaluation of the Inherent and Passive Safety Features of the Smart Design," *Annals of Nuclear Energy* 28, no. 4 (2001): 333–349.

4,000 cubic meters/day of fresh water through desalination.[105] The initial project envisioned plant operations to commence in 2015.[106]

Under the feasibility study, BATAN along with other partners projected a gap between water demand and supply and argued that nuclear desalination was an appropriate solution to this deficit.[107] They then conducted a series of workshops in Madura to promote the idea. BATAN also conducted seismic and economic feasibility studies.[108] However, the idea does not seem to have been pursued in recent years.

4.4 West Kalimantan NPP Proposal

Another region that has been identified by BATAN as a potential site for small modular reactors is West Kalimantan, in part because of the paucity of grid infrastructure in the area. This plan appears to have the support of the provincial government, which issued the West Kalimantan Governor's Decree No. 4 [Bappeda/2013].[109] The decree promulgates the formation of a Nuclear Power Plant Development Coordination Team, taking into consideration the fact that West Kalimantan has local uranium reserves in both the Nanga Ella district and the Melawi district. As in the case of Sulawesi, why this local availability of uranium has any relevance to constructing a nuclear reactor in this area has not been clarified. An argument that is technically more sound is that the total installed electricity capacity in the West Kalimantan grid is relatively low, less than 350 MW,[110] and is not expected to grow sufficiently even in the long term to be able to accommodate a large nuclear power plant. Therefore, *if* a nuclear plant were to be built at all, then it would

---

[105] Kim et al., "A Preliminary Economic Feasibility Assessment of Nuclear Desalination in Madura Island," 469.

[106] International Nuclear Desalination Advisory Group, "Indonesia and Korea, Rep. of," *INDAG Newsletter*, September 2003.

[107] Bambang Suprawoto, Aziz Jakfar, and Ida Ekawati, "Feasibility Study for Nuclear Desalination Plant Construction in Madura Island," in *International Conference on Non-Electric Application of Nuclear Power* (Oarai, Japan: International Atomic Energy Agency, 2007), 451–460, accessed December 29, 2015, http://www-pub.iaea.org/MTCD/publications/PDF/P_1354_CD/PDF/P_1354.pdf.

[108] Ngadenin et al., "Pemetaan Geologi Dan Identifikasi Sesar Aktif Di Lokasi Calon Tapak Instalasi Pembangkit Listrik Tenaga Nuklir (PLTN) Ketapang Dan Sekitarnya; Madura [Geological Mapping and Identification of Active Fault Location in On Nuclear Power Plant (NPP) Candidate Sites in Ketapang and Surrounding; Madura]," in *Seminar Geologi Nuklir Dan Sumberdaya Tambang Tahun 2004 [Seminar on Nuclear Geology And Mining Resources 2004],* (Jakarta, Indonesia: Pusat Pengembangan Bahan Galian Dan Geologi Nuklir - BATAN, 2004), 164–183; Sudi Ariyanto, Moch. Djoko Birmano, and Suparman, "Economic and Financial Assessment of Nuclear Desalination Plant in Madura Island," in *International Conference on Non-Electric Application of Nuclear Power* (Oarai, Japan: International Atomic Energy Agency, 2007), 238–249, accessed December 29, 2015, http://www-pub.iaea.org/MTCD/publications/PDF/P_1354_CD/PDF/P_1354.pdf.

[109] Keputusan Gubernur Kalimantan Barat No. 4 [Bappeda/2013] tentang Pembentukan Tim Koordinasi Pembangunan Pembangkit Listrik Tenaga Nuklir (PLTN) di Kalimantan Barat. 2013 [Decision of the Governor of West Kalimantan, No.4 (Bappeda/2013) on the Formation of a Coordinating Team for the Development of a Nuclear Power Plant in West Kalimantan, 2013), http://database.kalbarprov.go.id/_hukum/berkas_hukum/SK%20Gub%20Nomor%204%20Tahun%202013.pdf.

[110] Hendro Tjahjono, "Recent Status of Nuclear Power Assessment in Indonesia" (presented at the Technical Meeting on Technology Assessment for New Nuclear Power Programmes, Vienna, Austria, September 1, 2015), accessed August 6, 2016, https://www.iaea.org/NuclearPower/Meetings/2015/2015-09-01-09-03-NPTDS.html; PT PLN, *Statistic of Electricity 2014* (Jakarta, Indonesia: Ministry of Energy and Mineral Resources, 2014).

necessarily have to be a SMR. That, of course, is not the same as asserting that a SMR should be built.

The Nuclear Power Plant Development Coordination Team consists of local government officials, mainly from the Development Planning Agency at the Sub-National Level, regional PLN officials, and academicians and is tasked with the following duties:

1. To develop a "General Development Planning of Nuclear Power Plant" in West Kalimantan;
2. To coordinate the results of the General Development Planning of Nuclear Power Plant in West Kalimantan with the Ministry/Institution, related Regional Working Group (Satuan Kerja Perangkat Daerah – SKPD) in the regency/City;
3. To facilitate the planning policy program of the Ministry/Institution to the related SKPD in the province and city/district;
4. To conduct monitoring of program implementation and coordination of planning for a NPP in West Kalimantan.

BATAN has identified four locations as being suitable for potential nuclear power plant construction. In current priority order they are: (i) Kendawangan sub-district of Ketapang; (ii) Sukadana district in North Kayong district; (iii) the sub-district of North Matan Hilir; and (iv) the sub-district of South Matan Hilir, Ketapang.[111]

5 Institutional and Regulatory Landscape

5.1 Relevant Government Agencies

A comprehensive list of governmental agencies involved with the energy sector in Indonesia, and hence the nuclear power decision-making framework, would be lengthy because of the archipelagic nature of Indonesia, which has led to an extensive hierarchy of agencies that have a voice in the energy debate from the national down to the local level. Additionally, such a long list would not shed light on how these and other players interact in reality. However, an orientation to the political ecology affecting nuclear power in Indonesia is a useful starting point. Table 2 provides an overview of many of the key participants in the nuclear debate, divided among four broad sectors: government, nongovernmental, foreign, and multilateral.[112] This gives a snapshot of the many voices and interests at play in the nuclear debate in Indonesia. For a brief description of key Indonesian agencies, the reader is referred to Appendix 8.2.

---

[111] Susiati, H., Penentuan Tapak Potensial PLTN Dengan Metode Sig Di Wilayah Pesisir Propinsi Kalimantan Barat [Determination of Potential NPP Sites In Coastal Areas of West Kalimantan Province, Using Sig Methods], B. Pusat Kajian Sistem Energi Nuklir - PKSEN, Editor. 2014, Pusat Kajian Sistem Energi Nuklir - PKSEN, BATAN. In its 2014 Indonesia Nuclear Energy Outlook, BATAN mentions five potential areas in West Kalimantan.

[112] Derived from Richard Tanter, "Democratic Accountability and Risk Assessment in Indonesian Nuclear Power Proposals" (GoNERI Project, School of Engineering, Tokyo University, March 4, 2010), http://nautilus.org/network/associates/richard-tanter/talks/.

Table 2: Overview of the Indonesian nuclear political ecology and key players (agencies marked with an asterisk (*) are described in Appendix 8.2)

Indonesia – Government	
National Level	*Regional Level*
President Cabinet /coordinating ministers National legislature [DPR] /parties DPR Komisi VII BATAN (National Nuclear Energy Agency)* BAPETEN (National Nuclear Regulatory Agency) * Ministry of Research & Technology* Ministry of Energy & Mineral Resources* Ministry of Finance Ministry of State Enterprises Ministry of Environment Indonesian National Armed Forces (TNI)	Regional and district (*propinsi/ kabupaten*) governments

Indonesia – Nongovernmental			
National Level	*Regional Level (e.g. Jepara/Balong)*	*Corporate*	*Nuclear Establishment*
WALHI Greenpeace WWF Indonesia Indonesian Institute for Energy Economics Institute for Infrastructure Reform Pelangi Indonesia Anti-Nuclear Society (Manusia) CSIS Scientific groups	Persatuan Masyarakat Balong (Balong Community Union) MAREM (Masyarakat Rekso Bumi) Garda Muria; Muria Institute Nahdlatul Ulama Central Java/Jepara and NU-related Local industry	PLN* Indonesian proposed partners Coal and gas electricity generators	Universities BATAN alumni Pro-nuclear groups

5.2 Government Regulations Pertaining to Nuclear Power

Like the existence of an extensive network of government agencies involved in the energy sector and, hence, holding a stake in the nuclear power debate, there is an equally extensive body of laws and regulations that could affect the eventual implementation of commercial nuclear power in Indonesia. An overview of relevant regulation relating to licensing, safety, liability concerns and so forth, which could affect nuclear power development in Indonesia, is included in the Appendices. Only the key laws and broader framework are reviewed in this section.

The overall hierarchy of rules in Indonesia, as regulated by Law No. 12/ 2011 on the formulation of Law and Regulations, is as follows:

1) Constitution of the Republic of Indonesia 1945 (*Undang-Undang Dasar Negara Republik Indonesia 1945 or UUD'45*);
2) People's Consultative Council Decree (*Ketetapan Majelis Permusyawaratan Rakyat*);
3) Law and/or Government Regulation in lieu of Law (*Undang-Undang/Peraturan Pemerintah Pengganti Undang-Undang*);
4) Government Regulation (*Peraturan Pemerintah*);
5) Presidential Regulation (*Peraturan Presiden*);
6) Provincial Regulation (*Peraturan Daerah Provinsi*);
7) Regency and/or Municipality Regulation (*Peraturan Daerah Kabupaten/Kota*).

In the post New Order period, there has been a significant increase in the constitutional position of provincial, district and city (propinsi/kabupaten/kota) authorities and will influence any nuclear decision-making process. This has been the case in the Bangka and the various Kalimantan proposals.

In addition, there are other legal instruments in the form of Presidential Instructions or Decrees and Ministerial Decrees that provide more detailed rules that support the larger Laws and Government Regulations. The three most important pieces of regulation affecting nuclear power are summarized below.

Law No. 10/1997 on Nuclear Energy

The legal basis for nuclear energy in Indonesia is Law No. 10/1997 on Nuclear Energy (in lieu of Law No. 31/1964 on Atomic Energy). Law No. 10/1997 aims to balance considerations regarding advances in the use of nuclear energy that can benefit people with considerations regarding radiation hazards inherent in nuclear power and that require the regulation and supervision of nuclear energy for the safety, security, peace, and health of workers, the public, and the environment. The Law highlights regulation concerning institutions, research and development, radioactive waste management, and liability for nuclear damage.

Law No. 30/2007 on Energy

The legal basis for energy regulation is Law No. 30/2007 on Energy. The Law highlights energy resources, the energy buffer reserve, energy crisis and energy emergency issues, energy price, safety and the environment, local content requirements, national energy policy and the establishment of the national energy council, energy management, and the authority of the central and local government.

Government Regulation No. 79/2014 on National Energy Policy

The Government of Indonesia recently issued its new national energy policy under Government Regulation No. 79/2014 to replace the older national energy policy (Presidential Regulation No. 5/2006). One of the policies supported under the new regulation is "energy diversification." One goal of this piece of national energy policy legislation is to help achieve the optimal energy mix for Indonesia. The share of new and renewable energy is expected to be 23 percent by 2025 and 31 percent by 2050. However, the specific share for nuclear energy, which falls under new and renewable energy, is not explicitly stated in the document. This suggests that nuclear energy has not yet become a main priority in Indonesia and/or that there is not yet any sense of urgency in defining a role for nuclear power in Indonesia, since no explicit, legislation-driven targets have been set.

5.3 Local Content Requirements

One area of regulation policy that may especially impact SMR adoption in Indonesia is the local content requirement. Indonesia has shown interest in boosting the adoption of local content, i.e., locally made components or services conducted by domestic providers, by issuing regulations affecting electricity infrastructure. An overview of the various local content requirements and minimum local content targets for various goods and services, which vary widely across plant types and with plant size, is presented in the Appendices. The ranges for the various local contributions vary from between 25 to 100 percent.

At present, the Government of Indonesia has not yet established local content regulations for large nuclear power plants, since there has been no firm Government decision on pursuing commercial nuclear power. According to the Minister of Industry's regulation No. 54/2012 on Guidelines for the Use of Domestic Product to Electricity Infrastructure Development, the local content requirement is applied on a case-by-case basis to each auction and contract. Yet, according to interviews that IIEE (Indonesian Institute for Energy Economics) conducted in 2015 with experts, the regulation is not strictly enforced since local industry has been unable to meet the requirements.

This may prove an area of active debate if SMRs are seriously considered by Indonesia in the future. SMR designers and vendors often highlight the modular nature of these small reactors, meaning that the various elements of the reactors are to be fabricated in a facility located in the vendor's host country and then shipped to the final site for assembly into the reactor, thereby minimizing the amount of construction to be done in the country that is importing the reactor. Given Indonesia's push for increased local content, to support local industry, a number of issues are highlighted: How would Indonesia decide on the SMR and/or NPP components and services that it might consider for regulation under a local content requirement? Would the local content requirement vary between large NPP projects and smaller SMR projects? This would also be a problem with the build-own-operate (BOO) model that Rosatom has followed in the case of the Akkuyu project in Turkey, where the vendor will construct, operate, and maintain most aspects of the nuclear power plant for several years initially.[113]

If Indonesia were to consider purchasing a floating power plant, it is possible that it would be covered under a BOO model. If so, it is not clear how local content requirements affect Indonesia's consideration of such a project. There are many other such details that would have to be settled in the event of Indonesia going forward with acquiring an SMR.

5.4 Land-Based Siting Requirements

Another piece of existing legislation could affect the kind of SMR designs under consideration now or in the future. According to existing regulations (Government Regulation No. 54/2012 and Government Regulation No. 43/2006), Indonesia only officially recognizes land-based nuclear reactor site proposals. The language of Government Regulation No. 43/2006 stipulates that the term "site" refers to "the location on land which is used for the construction, operation, and decommissioning of one or more nuclear reactors along with other related systems."

Therefore, there appears to be a contradiction between existing policy and, for example, the Gorontalo floating power plant proposal, and may rule out Indonesia's consideration of SMR designs based on floating nuclear propulsion reactors, like the Russian KLT-40S. The KLT-40S design is intended to be deployed on a floating platform. What form would a site study take if the reactor is capable of floating from location to location? What unique requirements in assessing feasibility might this present?

Furthermore, it is unclear how this land-based requirement may or may not impact Indonesia's consideration of other even more speculative SMR concepts. Take, for example, France's Flexblue. Flexblue's design is derived from that of nuclear reactors used to power French submarines and the power plant is to be installed on the ocean floor. However, this technology has never seen operational experience and there are several questions that would come up with respect to such a mode of deployment.

How will Indonesia engage in a debate regarding the definition of the term "site" if certain local stakeholders or foreign vendors continue to champion one of these more unconventional SMR designs? Would the list of attractive SMR designs and

[113] Mycle Schneider and Antony Froggatt, *The World Nuclear Industry Status Report 2016* (Paris: Mycle Schneider Consulting, 2016), 46, accessed August 3, 2016, http://www.worldnuclearreport.org/The-World-Nuclear-Industry-Status-Report-2016-HTML.html. At the four-unit Akkuyu project in Turkey, Rosatom has entered into a 15-year Power Purchase Agreement (PPA), which guarantees the purchase of 70 percent of the electricity produced from units 1 and 2 and 30 percent of units 3 and 4, with the rest to be sold on the electricity market.

vendors narrow, or would the regulatory definitions broaden? As with the local content requirement, existing policy in Indonesia raises more questions than it answers with regards to the adoption of SMRs.

5.5 Proven Technology Criteria

One last element of current policy in Indonesia that will likely affect nuclear power in Indonesia, and especially the adoption of SMRs, is the proven technology criterion. In accordance with existing regulation, nuclear reactors that can obtain licenses include both commercial and non-commercial power reactors and commercial and non-commercial non-power reactors. Originally, as stipulated in Government Regulation No. 43/2006, the license for a commercial power reactor could be granted where the relevant technology had already been "proven". The Regulation states: "What is meant by tested technology (proven technology) is a technology used in a design that has been proven through a reactor operating experience of minimum 3 (three) years safely with an average capacity factor of at least 75% (seventy five percent) [Article 4, Para. 2]."

However, through the new Government Regulation No. 2/2014, the term "proven" has been extended to include all structures, systems and components of nuclear reactors important to the reactor's safety, in a relevant environment or in accordance with operating conditions, and that are applied in a prototype [Article 6, Para. 4a]. Additionally, in terms of technology use, having a commercial operating license from the regulatory body of the vendor's home country, for a country that has already built a commercial NPP, now constitutes a demonstration of proven technology.

Therefore, the new legislation less strictly defines "proven technology" by relaxing the requirement of a demonstrated history of safe operation of the design in favor of relying on the assessment of the regulatory body of the vendor's home country. This shift could perhaps smooth the regulatory path toward the adoption of, as yet, largely unproven SMR designs while leaving the regulatory topography essentially the same for future large power reactors. While the original definition did not preclude the possibility of Indonesia approving SMR designs for regions such as West Kalimantan, it would have significantly slowed the licensing process, since any designs would have had to have a demonstrated operational history in another country prior to obtaining licensing approval in Indonesia. The newer, more relaxed definition, shortens the time to approval and opens up the possibility that Indonesia could choose to be the first to operate a novel SMR design supplied by a foreign country.

6 Electricity Landscape and Comparison of Costs

In June 1998, the International Atomic Energy Agency conducted an Advisory Group Meeting and Consultancy Meeting on "SMR User Requirements for Developing Countries" in Vienna. At that meeting, BATAN enunciated an economic target in simple terms: "the levelled [sic] cost of electricity from nuclear plants should be lower than from coal plant with cleanup system based on prevailing national regulation".[114] Elsewhere, BATAN has claimed that a small-sized reactor "can enter the cost-optimal solution by 2027 and only when the overnight cost is below 4,000 USD/kWe (3,500 USD/kWe)."[115] Although this statement is unclear about what all is included in the cost figure and the significance of the year mentioned, it clearly establishes that the cost of electricity from SMRs is a critical component of any decision making process regarding their acquisition. In this section, we examine the likely cost of electricity generation from SMRs and compare that with other sources of electricity.

6.1 Current Sources of Electricity

Indonesia is the largest archipelago in the world. The country is made up of five large, densely populated islands, but contains more than 17,000 islands total, with around 900 or more islands being permanently inhabited.[116] Therefore, the country's geography inherently presents a unique challenge to meeting the country's evolving electricity needs. For an overview of the institutional framework affecting the electricity sector, see the Appendices. In this section the discussion focuses on what in the Indonesian government's terminology is regarded as "new and renewable energy," which, somewhat unusually, includes nuclear energy as one such source.[117]

Indonesia is endowed with both fossil and non-fossil energy resources. Based on the Ministry of Energy and Mineral Resources' data in 2015, it is estimated that almost 94 percent of Indonesia's total primary energy supply (not just electricity) comes from fossil fuel resources.[118] Of the estimated 13 Million tonnes of Oil Equivalent (MTOE) of new and renewable energy sources that were utilized in 2015, the Ministry of Energy and Mineral Resources lists geothermal as constituting 6 MTOE, biofuel as comprising 4 MTOE, biomass as comprising 2 MTOE, and hydropower

[114] IAEA, *Guidance for Preparing User Requirements Documents for Small and Medium Reactors and Their Application*, 90.

[115] Syahril, Johari, and Sunarko, "Prospects of SMRs in Indonesia's Energy System." Both $4000/kWe and $3,500/kWe have been mentioned but without any clarification on what the two numbers signify.

[116] Embassy of the Republic of Indonesia, Washington D.C., Accessed November 2015, http://www.embassyofindonesia.org/wordpress/?page_id=494; Wikipedia, Accessed November 2015, https://en.wikipedia.org/wiki/List_of_islands_of_Indonesia. Note that there are disagreements about the exact number of islands, although these differences are irrelevant for our purpose.

[117] According to Government Regulation No. 79/2014 on National Energy Policy, nuclear is categorized as a new energy resource since it can be produced by new technology.

[118] Rida Mulyana, "Renewable Energy as A National Development Priority," in *Climate Change and REDD+ in the National Medium Term Development Plan* (Jakarta, Indonesia, 2015), accessed December 31, 2015, http://www.unorcid.org/upload/Ministry_of_Energy_and_Mineral_Resources_UNORID_Dialogue_Series_9_March_2015.pdf.

comprising only 1 MTOE.[119] However, other data sources show that hydroelectric power constitutes 3.4 percent of the total primary energy.[120]

Coming to just electricity, the shares of different sources, according to the state-owned utility PT PLN and including what was purchased from other utilities, are shown in Table 3, in contrast to the 2013 figures.

Table 3 Shares of electrical energy production 2013 and 2014 (including purchases from other utilities)

Source	**Electrical Energy Produced (GWh)**		**Share (%)**	
	2013	2014	2013	2014
Coal	74,269	84,076	51.50	47.96
Natural Gas	41,254	49,312	28.61	28.13
Hydropower	13,010	26,433	9.02	15.08
Oil	11,307	11,164	7.84	6.37
Geothermal	4,345	4,285	3.01	2.44

Source: PT PLN, PLN Statistics 2013 (Jakarta, Indonesia: Ministry of Energy and Mineral Resources, 2013), iii.

The numbers given in the table undercut one of the arguments often advanced by proponents of nuclear power in Indonesia, namely that oil will run out, thereby necessitating the construction of reactors. An illustration is a statement made by a senior BATAN researcher to the *Jakarta Post* in 2011 to the effect that "considering the construction of nuclear power plants would be necessary given that Indonesia's petroleum reserves would be used up by 2025".[121] This is misleading because oil is not a significant source of electricity in Indonesia.

Further, although Indonesia has an abundance of local new and renewable energy resources, the installed capacity to generate electricity from these available resources is still quite small, as shown in Table 4. The most developed in the New and Renewable Energy category is hydro, which makes use of about 10 percent of the available resources. There is thus ample scope for expansion of these renewable sources of electricity. Although the table indicates that there is some uranium based (i.e. nuclear) capacity, this is somewhat misleading. To date, there is no contribution of nuclear power to electricity production in the country. The only reactors based on uranium that have been set up are for research purposes.

---

[119] Ibid., 10.

[120] BP, *Statistical Review of World Energy 2015*.

[121] "Nuclear Power Needed before 2025, Warn Experts," *Jakarta Post*, November 12, 2011, accessed January 1, 2016, http://www.thejakartapost.com/news/2011/11/12/nuclear-power-needed-2025-warn-experts.html.

Table 4. Potential and realized capacity of new and renewable energy resources

New & Renewable Energy	Resources	Installed Capacity (IC)	Ratio of IC/Resources
Hydro	75,000 MW	7,572 MW	10.1%
Geothermal	28,910 MW	1,403.5 MW	4.9%
Biomass	32, 654 MW	1,717.9 MW	5.4%
Solar	4.80 kWh/m^2/day	48.05 MW	-
Wind	3-6 m/s	1.87 MW	-
Ocean	49 GW***)	0.01 MW****)	-
Uranium	3,000 MW*)	30 MW**)	-

*Notes: *) Only in Kalan-West Borneo; **) As a center of research, non-energy; ***) Source: National Energy Council; ****) BPPT's Prototype; Source: Mulyana, Rida. "Renewable Energy as A National Development Priority," in Climate Change and REDD+ in the National Medium Term Development Plan. Jakarta, Indonesia, 2015.*
http://www.unorcid.org/upload/Ministry_of_Energy_and_Mineral_Resources_UNORID_Dialogue_Series_9_March_2015.pdf.

Among the various renewable resources, solar has not yet been developed to any significant extent within Indonesia. Independent estimates suggest that the total potential for grid connected photovoltaic electricity could be as high as 1492 TWh per year.[122] In comparison, according to PT PLN, Indonesia generated a total of 175.2 TWh in 2014.[123] Thus, solar energy has a vast capacity in comparison with the amount of electricity used in Indonesia, and this may be one reason Indonesia is accelerating the installation of solar energy.

In December 2015, President Joko Widodo inaugurated a 5 MW solar power plant, currently the biggest in Indonesia, located in Kupang.[124] Several more projects are under development; for example, in October 2015, the local providers PT Buana Energy Surya Persada and PT Indo Solusi Utama signed a contract with the German energy firm Conergy to develop three 1MW projects to provide power to homes in three towns in the East Nusa Tenggara province.[125] (More discussion of the status of solar projects operated by PT PLN can be found in the Appendices.)

---

[122] A. J. Veldhuis and A. H. M. E. Reinders, "Reviewing the Potential and Cost-Effectiveness of Grid-Connected Solar PV in Indonesia on a Provincial Level," *Renewable and Sustainable Energy Reviews* 27 (November 2013): 322.

[123] PT PLN, *Statistic of Electricity 2014*.

[124] Yohanes Seo, "Jokowi Inaugurates the Biggest PLTS in Indonesia," December 28, 2015, accessed January 2, 2016, http://en.tempo.co/read/news/2015/12/28/056731067/Jokowi-Inaugurates-the-Biggest-PLTS-in-Indonesia.

[125] Kathie Zipp, "Conergy Completes Plant in Indonesia and Closes Projects in Asia," *Solar Power World*, October 15, 2015, accessed August 6, 2016, http://www.solarpowerworldonline.com/2015/10/conergy-completes-plant-in-indonesia-and-closes-projects-in-asia/.

6.2 Electrification within the Archipelago

Indonesia's geographic profile of a collection of many islands is reflected in the variability of the installed capacity and electrification rates of various regions. The Indonesian National Electrification System can be divided into two main categories: an interconnected electrification system and isolated electrification systems.[126] Generally speaking, Indonesia consists of several main islands (in addition to many smaller ones), which are Sumatra, Java, Kalimantan, Sulawesi, the Nusa Tenggara Islands, the Maluku Islands, and Papua. Electricity provision in Jawa-Madura-Bali and Sumatra are the most developed, as compared to other regions. The electrification system in areas outside of Jawa-Madura-Bali and Sumatra is still being developed and has not been fully interconnected to any sort of centralized grid.

As of 2015, the total installed capacity in Indonesia is estimated to be around 53,065 MW.[127] The largest shares of this capacity are in the Java region (Java, Bali, and Madura) and the Sumatra region (comprising Sumatra, Riau, and Bangka Belitung). This accounts for roughly 86 percent of the total installed capacity in the country. In contrast, smaller outlying islands such as the Nusa Tenggara region (including West and East Nusa Tenggara) had an installed capacity of 747 MW or only about 1.4 percent of the country total. The countrywide electrification ratio was 84.35 percent in 2014, but this varies from a low of 58.91 percent in East Nusa Tenggara to 95.53 percent in Bangka Belitung.[128]

The problematic variance in installed capacity is compounded by nearly 10 percent energy losses.[129] This comprises losses of 2.37 percent at the transmission level and 7.52 percent at the distribution level. In comparison, the corresponding figures in 2013 for Thailand, Singapore, and Malaysia were 6 percent, 0 percent, and 4 percent respectively, according to the World Bank.[130] Understanding the causes of the relatively high levels of losses in Indonesia is difficult. The primary electricity provider PT PLN does not maintain metering devices on its distribution network.[131] This complicates managing the flow of electricity since accurate data on demand cannot be obtained. Furthermore, the lack of metering obscures illegal connections and the additional load they place on the system. Taken in combination, these

---

[126] IEA, *Indonesia 2015* (Paris: International Energy Agency, 2015), accessed August 6, 2016, https://www.iea.org/publications/freepublications/publication/energy-policies-beyond-iea-countries---indonesia-2015.html.

[127] RUKN, *Rencana Umum Ketenagalistrikan Nasional 2015 - 2034* [*National Electricity General Plan 2015 - 2034],* (Jakarta, Indonesia: Kementerian Energi dan Sumber Daya Mineral, 2015), 42, accessed August 6, 2016, http://www.djk.esdm.go.id/index.php/rencana-ketenagalistrikan/rukn-djk.

[128] Direktorat Jenderal Ketenagalistrikan, *Statistik Ketenagalistrikan 2014 [Electricity Statistics 2014],* (Jakarta, Indonesia: Kementerian Energi dan Sumber Daya Mineral, 2015), 26, accessed August 6, 2016, http://www.djk.esdm.go.id/index.php/statistik-ketenagalistrikan.

[129] Ibid., 27.

[130] World Bank, "Electric Power Transmission and Distribution Losses (% of Output)," *Data*, last modified 2013, accessed August 6, 2016, http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS.

[131] IEA, *Indonesia 2015*, 109.

features of Indonesia's present electricity supply structure have made it prone to widespread service disruptions. For further information regarding various aspects of the distribution network and installed capacity, the reader is referred to Appendix 8.6 and Appendix 8.8.

The recent plans to construct solar photovoltaic (PV) plants in East Nusa Tenggara province provides a good example of the geography-specific challenges that impact electrification plans in Indonesia and which will impact the broader discussion regarding nuclear power and small modular reactors. It is estimated that almost 50 percent of the residents of Sumba Island lack access to reliable electricity, and for Sumba residents with service, 85 percent of the available electricity is sourced from diesel.[132]

There is therefore an underlying tension between meeting the increasing electricity demands of densely populated areas that already have access to large grids and fulfilling the desire to complete electrification of the country so as to provide at least a little electricity to communities and regions with limited or no grid access. The first constraint is borne out by PLN's statistics, which suggests that in several areas the growth of power generation capacity does not keep up with increasing consumption demands.[133] In Sumatra, the average demand growth is 9.4 percent per year, whereas power generation capacity is only growing at 5.2 percent per year. In Kalimantan, the 1 percent growth of power generation capacity is far from balancing out the 10.7 percent demand growth per year. In Sulawesi, the average demand growth is 11 percent per year, whereas the average growth capacity of power generation is 2.7 percent per year. The continued discrepancy between demand growth and generation capacity growth has caused chronic power crises in many areas.

Many of Indonesia's small islands do not have access to the electric grid; the majority of people still use electrical appliances powered by individual diesel generators. However, diesel fuel is often expensive on small islands and diesel generators can only be operated for limited hours each day. Since 2010, the government has stated that the development of small islands is a State priority, with a focus on underdeveloped, outermost, and post-conflict regions in Indonesia. As already mentioned, because Indonesia is an archipelagic country with the largest number of islands in the world, it faces particular challenges in addressing the gap between big and small islands in terms of providing infrastructure like access to electricity. According to Law No. 27/2007 concerning Management of Coastal Areas and Small Islands, a small island is defined as "an island with an area less than or equal to 2000 km^2, including its ecosystem unity."

---

132 Zipp, "Conergy Completes Plant in Indonesia and Closes Projects in Asia."

133 "Electricity Supply Business Plan PT PLN (RUPTL PT PLN) for 2015-2024" (Jakarta, Indonesia: Ministry of Energy and Mineral Resources, 2015), 27–28, http://www.pln.co.id/dataweb/RUPTL/RUPTL%20PLN%202015-2024.pdf; "Electricity Supply Business Plan PT PLN (RUPTL PT PLN) for 2016-2025" (Jakarta, Indonesia: Ministry of Energy and Mineral Resources, 2016), 53–54, http://www.pln.co.id/dataweb/RUPTL/RUPTL%20PLN%202015-2024.pdf.

In recent years, the electrification of small islands seems to have become more urgent, due to the current President's plan to strengthen Indonesia's maritime position, which has inspired an acceleration in developing the infrastructure of small islands in the Indonesian archipelago. A number of government institutions have been involved in programs for developing solar power for small islands, which is more easily accommodated to lower electrical base loads, dispersed and isolated populations, and areas with limited access to transmission lines.

This pattern of demand for electricity is one argument for nuclear power, both the proposals based on large power reactors (such as in Muria or Bangka-Belitung) and proposals based on small reactors (such as in West Kalimantan). But, there are also other efforts at increasing electricity generation capacity that may be delivering results earlier. The Indonesian government has launched an acceleration program in the power sector in 2006, which include two phases of Fast Track Programs, which involved the construction of a mixture of geothermal, hydropower, coal and natural gas; many of these are to be constructed and operated by private companies.[134] More recently, the government has set a target of adding 35,000 MW of new generating capacity by 2019.[135] To the extent that these plans have been successful, they would have reduced the demand for nuclear power.

6.3 Proposed Electricity Targets

In-country projections of the future energy mix by 2050 seek to increase the share of new and renewable energy. The fuel mix in the power sector is projected to be dominated by coal and gas based plants.[136] The total NRE target for Indonesia's energy is set at 31 percent by 2050 (as shown in Figure 3). The national energy policy targets an electricity supply of 115 GW by 2025 and 430 GW by 2050, and electricity per capita to grow to around 2,500 kWh in 2025 and to 7,000 kWh by 2050.[137] In light of past failures to meet various targets, whether these targets will be achieved remains to be seen.

According to the same projections, nuclear power plants are "estimated to enter the Java-Bali electricity system in 2030 with a capacity of 2 GW" and this is projected to "increase up to 6 GW in 2050".[138] Other organizations involved in energy policy have put out other scenarios. According to one such scenario, the 2014 National Energy Policy Scenario (Skenario Kebijakan Energi Nasional), nuclear power grows from zero in 2020 to 74.89 TWh in 2050 (Table 5). Given that such scenarios have

[134] IEA, *Indonesia 2015*, 103.
[135] BPPT, *Outlook Energi Indonesia 2015* (Jakarta, Indonesia: Pusat Teknologi Pengembangan Sumber Daya Energi, 2015), 22, accessed August 11, 2016, http://repositori.bppt.go.id/index.php?action=download&dir=_data%2FDownload%2FOUTLOOK+ENERGI+2015&item=BPPT-Outlook+Energi+Indonesia+2015.pdf&order=name&srt=yes&lang=en.
[136] Ibid., 70–73.
[137] Ibid., 21.
[138] Ibid., 67.

been drawn up before, and not materialized, these should be treated as just that—scenarios—rather than any prognosis of what is likely to be constructed.

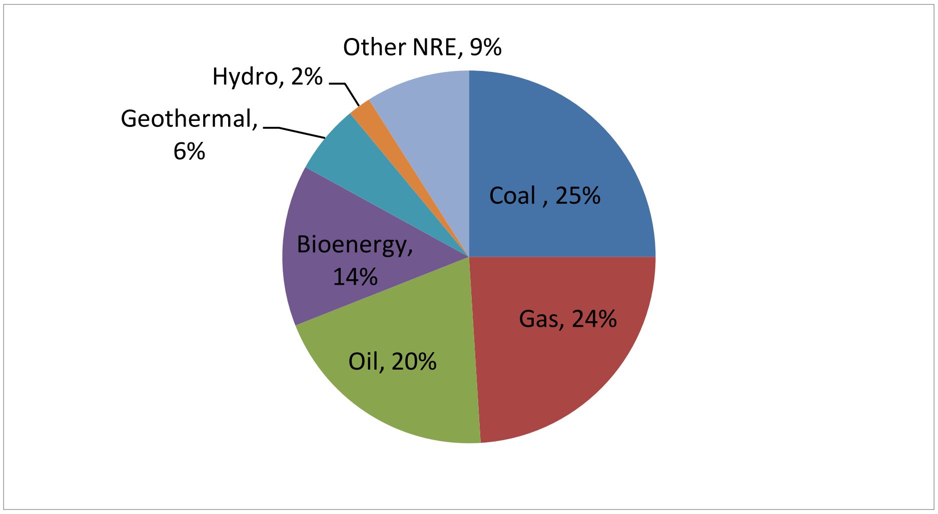


Figure 3: Indonesia's target energy mix by 2050: 1000 MTOE

Source: Rida Mulyana, "Renewable Energy as A National Development Priority," in Climate Change and REDD+ in the National Medium Term Development Plan (Jakarta, Indonesia, 2015), http://www.unorcid.org/upload/Ministry_of_Energy_and_Mineral_Resources_UNORID_Dialogue_Series_9_March_2015.pdf.

The National Development Planning Agency has incorporated plans for nuclear energy into the National Mid-Term Development Plan 2015-2019 (RPJMN) and nuclear is also included in the most recent Government Work Plan.[139] The former document lists plans for construction of a pilot nuclear power plant with an output of 10 MW, and the latter mentions an ongoing procurement process.[140] A pilot power plant would, of course, not contribute to meeting the electricity demand.

The longer–term scenario does not specify what kind of nuclear reactors will be built. To the extent that there is any mention of nuclear power, these projections seem to implicitly assume that only large NPPs would be constructed and do not generally discuss small SMR-type plants. Of course, as mentioned earlier, this is only a scenario rather than a clear statement of plans for construction and thus the absence of SMRs in these scenarios does not mean that the country will not construct small reactors—or that it will indeed construct large nuclear power plants in preference to SMRs.

---

[139] MNDP, *National Mid Term Development Plan 2015-2019, Book I of National Development Agenda* (Jakarta, Indonesia: Ministry of National Development Planning, 2014).
[140] *Ibid,* 219; *Government Work Plan 2016* (Jakarta, Indonesia: Ministry of National Development Planning, 2014).

Table 5. Projection for nuclear power plants under the 2014 National Energy Policy scenario

Year	Electricity Production of NPP (TWh)	Installed Capacity of NPP (GW)
2013	-	-
2020	-	-
2025	5.18	1
2030	4.69	1
2035	27.88	6
2040	28.50	6
2045	29.40	6
2050	74.89	15

Source: Dewan Energi Nasional. Outlook Energi Indonesia 2014. Jakarta, Indonesia: Dewan Energi Nasional, December 23, 2014, pp. 151-152.

6.4 Comparison of Costs of Generating Electricity

The total cost of generating electricity for a given type of power plant consists of a combination of investment costs, fuel costs, and both fixed and variable operation and maintenance (O&M) costs. The calculation of the generation cost for a given plant type is sensitive to several factors, including the plant's efficiency, capacity factor (the ratio of the amount of electricity generated in a year to the amount of electricity that would be produced if the plant ran 24 hours a day, 365 days a year), and projected lifetime. Another important variable is the discount rate, which is a measure of how future benefits are valued relative to current costs.

An implicit variable that is especially important to this study is the scale of the project, which can determine the investment cost as well as the efficiency of the plant. As discussed in the appendix, the smaller scale of SMRs is an advantage in some respects but poses an economic challenge because the capital cost of the project per unit of electricity generation capacity becomes lower for larger nuclear reactors, i.e., economies of scale. This is also true for solar photovoltaics; per unit of capacity, utility scale projects are typically much cheaper than small rooftop photovoltaic installations. SMRs also tend to be less efficient in their use of fuel.

There are two broad categories of power plants in Indonesia, namely fossil-fuel power plants and renewable energy power plants. Despite the government's categorization of nuclear power as part of "Renewable & New Energy", nuclear energy fits neither of these categories. Renewable energy power plants in Indonesia include solar (Pembangkit Listrik Tenaga Surya – PLTS), wind (Pembangkit Listrik Tenaga Bayu – PLTB), hydro power (Hydro Power, Mini Hydro Power and Micro Hydro Power), biomass, and ocean, which is currently at the development stage.

Table 6: Estimate of costs of generating electricity in Indonesia by type of power plant and fuel used.

Technology	Fuel	Size (MW)	Capital Cost (USD/kW)	Life time (Years)	Specific Fuel Consumption [1]	Fuel Price [2]	Capacity Factor	Generation Cost (USD/kWh)	Generation Cost (IDR/kWh)
Steam PP	Coal	600	2,031	30	0.502 kg/kWh	80 USD/ton	0.729	0.081	842.40
	Natural Gas	120	2,314	30	0.01 mscf/kWh	7 USD/mscf	0.220	0.221	2309.48
	Oil (Java grid)	120	2,314	30	0.382 liter/kWh	0.7 USD/liter	0.067	0.753	7875.12
Gas Turbine PP	Natural Gas	120	591	30	0.013 mscf/kWh	7 USD/mscf	0.123	0.155	1619.47
Combined Cycle PP	Natural Gas (Java grid)	500	1,123	30	0.008 mscf/kWh	7 USD/mscf	0.472	0.088	917.26
Diesel PP	Oil	3.5	1,978	30	0.266 liter/kWh	0.86 USD/liter	0.129	0.451	4721.22
Hydro PP	Hydro-large	>10	2,268	50	-	-	0.425	0.073	762.99
Solar PV	Solar	0.001	3,517	25	-	-	0.070	0.823	8612.52
Geothermal	Geothermal (Java Grid)	55	1,686	30	-	-	0.870	0.053	553.94

Sources: [1] Electricity statistics, 2013, the Director General of Electricity, Ministry of Energy and Mineral Resources & [2] Electrical Power Supply Business Plan of PT PLN (Persero) 2015-2024.

Fossil-fuel power plants in Indonesia include steam coal (Pembangkit Listrik Tenaga Uap Batubara – PLTU-B), steam natural gas (Pembangkit Listrik Tenaga Uap Gas Alam – PLTU-GA), steam oil (Pembangkit Listrik Tenaga Uap Minyak – PLTU-M), diesel (PLTD), oil gas turbine (Pembangkit Listrik Tenaga Gas Minyak – PLTG-M), gas turbine (Pembangkit Listrik Tenaga Gas Alam – PLTG-GA), oil combined cycle

(Pembangkit Listrik Tenaga Gas dan Uap Minyak – PLTGU-M), natural gas combined cycle (Pembangkit Listrik Tenaga Gas dan Uap – PLTGU-G) and oil gas (Pembangkit Listrik Tenaga Minyak Gas – PLTM-G).

The generation costs for power plants that have already been set up in Indonesia are given in Table 6.[141] These use a discount rate of 10 percent. For comparison, Table 16 in the appendix shows PT PLN's reported values of the national average of generation costs by plant type.

The capacity factor (CF) values used in the estimates were calculated by taking the ratio of the electricity produced by a certain plant type in a given year as reported by PT PLN in 2013 to the maximum production capacity if the plant were operated at full capacity for an entire year. The importance of the CF will be apparent when considering the potential costs of future large-scale PV plants. The solar plants operating in 2013 in Indonesia were mostly household-scale installations. These tend to get disrupted frequently due to a lack of capacity of local operators or communities to maintain the equipment. Additionally, while utility-scale plants can be designed to maximize light collection throughout the day in order to maximize the capacity factor, small solar installations, especially fixed-direction rooftop designs, do not have this flexibility, leading to lower capacity factors. In contrast, utility-scale PV plants can have capacity factors that are a factor of three larger.

BATAN has long argued that nuclear power is affordable. In 2014, BATAN presented its estimates of the economics of a potential Indonesian NPP at a meeting convened by the International Atomic Energy Agency.[142] BATAN made a number of assumptions in its calculations, including some technical parameters concerning the nuclear reactor itself, such as its power output, the internal consumption of electricity at the power plant itself, the anticipated capacity factor, and the length of period for which the reactor would operate in an economical fashion, the costs of the different elements of the construction of the reactor, the initial fuel, and the various financing parameters, such as the interest during construction. Two cases were discussed, a reactor in West Bangka and one in South Bangka.

The various assumptions used by BATAN are presented in Table 7 and Table 8, and the results of BATAN's calculation are presented in Table 9. These assumptions and the results raise more questions than they answer. One puzzle is that the reactor output was assumed to be 1,180 MW, which does not correspond to any reactor that was actually on the market in 2014. It is, instead, the output of the Watts Bar II reactor that was under construction in the United States since the 1970s and came online in 2016.[143] No other country is constructing a reactor with that power output level.

---

[141] Indonesian Institute for Economics (IIEE), in-house calculation, Jakarta, 2015.
[142] Suparman, "Economic Indicators Assessment of NPP Project in Indonesia," in *8th INPRO Dialogue Forum: Toward Nuclear Energy System Sustainability: Economics, Resource Availability, and Institutional Arrangements* (Vienna, Austria: International Atomic Energy Agency, 2014), https://www.iaea.org/INPRO/8th_Dialogue_Forum/index.html.
[143] Schneider and Froggatt, *The World Nuclear Industry Status Report 2016*.

Table 7. Cost assumptions made in BATAN's Bangka nuclear power cost calculation

Item	W. Bangka	S. Bangka
Mechanical & Electrical system cost (million USD)	6,107	6,107
Building cost (million USD)	659	571
Civil cost (million USD)	1,060	987
Initial core fuel cost (million USD)	553	553
Contingency (million USD)	1,676	1,644
Owner's cost (million USD)	1,398	1,385
IDC (million USD)	1,467	1,442
VAT (million USD)	1,175	1,154
Total (million USD)	14,095	13,843
Unit cost (USD/kW)	5,972	5,866

Source: Suparman, "Economic Indicators Assessment of NPP Project in Indonesia," in *8th INPRO Dialogue Forum: Toward Nuclear Energy System Sustainability: Economics, Resource Availability, and Institutional Arrangements* (Vienna, Austria: International Atomic Energy Agency, 2014).

Table 8. Technical inputs used in BATAN's Bangka nuclear power cost calculation

Reactor Output (2 reactors/unit)	1,180 MWe
Economic Life Time	40 years
Internal Consumption	5%
Availability	93%
Discount Rate	10%

Source: Suparman, "Economic Indicators Assessment of NPP Project in Indonesia," in *8th INPRO Dialogue Forum: Toward Nuclear Energy System Sustainability: Economics, Resource Availability, and Institutional Arrangements* (Vienna, Austria: International Atomic Energy Agency, 2014).

Table 9. BATAN's estimated cost of generation of nuclear power

Generation Cost	W. Bangka	S. Bangka
Capital cost (USD/kWh)	0.036	0.0353
Operation and maintenance cost (USD/kWh)	0.011	0.011
Fuel costs (USD/kWh)	0.0122	0.0122
Decommissioning cost (USD/kWh)	0.0017	0.0017
Total (USD/kWh)	0.0609	0.0602

Source: Suparman, "Economic Indicators Assessment of NPP Project in Indonesia," in *8th INPRO Dialogue Forum: Toward Nuclear Energy System Sustainability: Economics, Resource Availability, and Institutional Arrangements* (Vienna, Austria: International Atomic Energy Agency, 2014).

The results also raise important questions. At a discount rate of 10 percent, a project with a unit capital cost of 5972 USD/kW implies that just the capital cost component of the generation cost will be 7.9 cents/kWh. This is more than twice the figure of 3.6 cents/kWh that BATAN has estimated. It is therefore not clear what methodology or other assumptions were used.

Finally, it is not evident what BATAN has assumed about one critical variable: the time period it takes to construct a nuclear power plant. Because of the dependence on financing parameters, the levelized cost is sensitive to this assumption. This is a particular problem for nuclear reactors, because they not only take long periods to construct, but many projects have experienced major construction delays that have resulted in huge cost overruns.[144] Even without delays, building a country's first nuclear power plant can take a considerable period of time. Some numbers for the construction times—between the first pour of concrete and the plant being declared commercial—for the first reactors in developing countries that have just one nuclear power plant (with 1 or 2 reactors) are 19 years (Brazil), 16 years (Mexico), and 38 years (Iran).

This is a significant period of time that must be taken into consideration when comparing the economic competitiveness of nuclear power to renewables; solar projects typically have a 1 to 2 years construction period. Therefore, any fair cost comparison must be based on what alternative sources of electricity generation might cost in 2030, or at least 2025, rather than today's costs. This is particularly relevant to renewable sources of energy, in particular, solar photovoltaic systems because their costs have been falling very rapidly.[145]

Therefore, as described below, we carry out a separate calculation with the same cost figure. As a comparison, we also calculate what the cost of generating electricity at a utility-scale solar power plant might be in Indonesia. As mentioned earlier, the experience so far has only been with relatively small-scale solar plants that would generate electricity at significantly higher costs than large-scale plants. However,

[144] Benjamin K. Sovacool and C. J. Cooper, *The Governance of Energy Megaprojects: Politics, Hubris and Energy Security* (Cheltenham: Edward Elgar Publishing, 2013); Benjamin K. Sovacool, Alex Gilbert, and Daniel Nugent, "An International Comparative Assessment of Construction Cost Overruns for Electricity Infrastructure," *Energy Research & Social Science* 3 (September 2014): 152–160.

[145] Arnaud de La Tour, Matthieu Glachant, and Yann Ménière, "Predicting the Costs of Photovoltaic Solar Modules in 2020 Using Experience Curve Models," *Energy* 62 (December 1, 2013): 341–348; Galen Barbose et al., *Tracking the Sun VI: An Historical Summary of the Installed Price of Photovoltaics in the United States from 1998 to 2012* (Berkeley, CA: Lawrence Berkeley National Laboratory, July 2013), accessed September 26, 2015, http://escholarship.org/uc/item/2j2888zv; Stefan Reichelstein and Michael Yorston, "The Prospects for Cost Competitive Solar PV Power," *Energy Policy* 55 (2013): 117 – 127; Mark Bolinger, Samantha Weaver, and Jarett Zuboy, "Is $50/MWh Solar for Real? Falling Project Prices and Rising Capacity Factors Drive Utility-Scale PV toward Economic Competitiveness," *Progress in Photovoltaics: Research and Applications* (May 1, 2015), accessed September 21, 2015, http://onlinelibrary.wiley.com/doi/10.1002/pip.2630/abstract.

the Indonesian government has been promoting utility-scale solar photovoltaic plants, with plans for setting up 5000 MW of capacity within 2 or 3 years.[146]

For the capital cost of a large NPP, we first start with the average of the two BATAN figures (5972 and 5866 USD/kW) to obtain 5919 USD/kW. We inflate this to 2015 currency using the GDP deflator data estimated by the World Bank,[147] to come up with a capital cost of 6500 USD/kW (rounded off). This is lower than the cost estimates for some new nuclear plants in the United States; for example, the North Anna plant in Virginia is estimated to cost 8,593 USD/kW.[148] For comparison, the cost of a utility scale (5 MW) solar plant built by PT Len Industri in Kupang, East Nusa Tenggara is said to be Rp 125 billion, which translates to about 1825 USD/kW.[149]

For photovoltaic plants in the 2025-2030 time frame, we use the International Energy Agency's projection that "utility-scale capital expenditures cost would fall below USD 1/W by 2030 on average, but the cheapest systems would reach that mark by about 2020".[150] This translates to a unit capital cost of 1000 USD/kW.

The operational and fueling costs for nuclear plants are derived from the latest report on *Projected costs of generating electricity* by the OECD's Nuclear Energy Agency.[151] For SMRs, which are assumed to be 200 MW capacity, the construction, fueling and operational costs are estimated to be higher than those of a large NPP by 40 percent for reasons explained in Appendix 8.3.3.[152] The discount rate chosen is the same as BATAN's assumption, i.e., 10 percent.

Because of the lack of experience with SMR construction, we have assumed a nearly even distribution of costs, with equal annual expenditures during most of the years except for the first and last year. For a large nuclear power plant, we assume the same distribution as in the case of the Summer 2&3 nuclear plants being built in South Carolina in the United States.[153] These distributions are shown in Figure 4. It is assumed that solar PV plants will be constructed in one year.

---

[146] "Indonesia Plans to Add 5 GW of Solar PV Capacity in 2–3 Years," *Solar Server*, August 15, 2016, http://www.solarserver.com/solar-magazine/solar-news/current/2016/kw33/indonesia-plans-to-add-5-gw-of-solar-pv-capacity-in-2-3-years.html.

[147] World Bank, "GDP (current US$)," *Data*, last modified 2015, accessed August 13, 2016, http://data.worldbank.org/.

[148] OAG, *Direct Testimony & Exhibits* (Richmond, Virgina, USA: Office of the Attorney General, September 15, 2015), accessed August 13, 2016, http://www.scc.virginia.gov/docketsearch/DOCS/34bx01!.PDF.

[149] BISNIS.COM, "Indonesia's Largest Solar Power Plant Ready for Operation," *Tempo*, December 16, 2015, accessed December 29, 2015, http://en.tempo.co/read/news/2015/12/16/056728193/Indonesias-Largest-Solar-Power-Plant-Ready-for-Operation.

[150] IEA, *Technology Roadmap: Solar Photovoltaic Energy, 2014 Edition* (Paris: OECD Publishing, 2014), 22.

[151] NEA, *Projected Costs of Generating Electricity* (Paris: Nuclear Energy Agency, OECD, 2015).

[152] Alexander Glaser, Laura Berzak Hopkins, and M.V. Ramana, "Resource Requirements and Proliferation Risks Associated with Small Modular Reactors," *Nuclear Technology* 184 (2013): 121–129.

[153] David A. Schlissel, *Bad Choice: The Risks, Costs and Viability of Proposed U.S. Nuclear Reactors in India* (Cleveland, OH: Institute for Energy Economics and Financial Analysis, March 2016), 26.

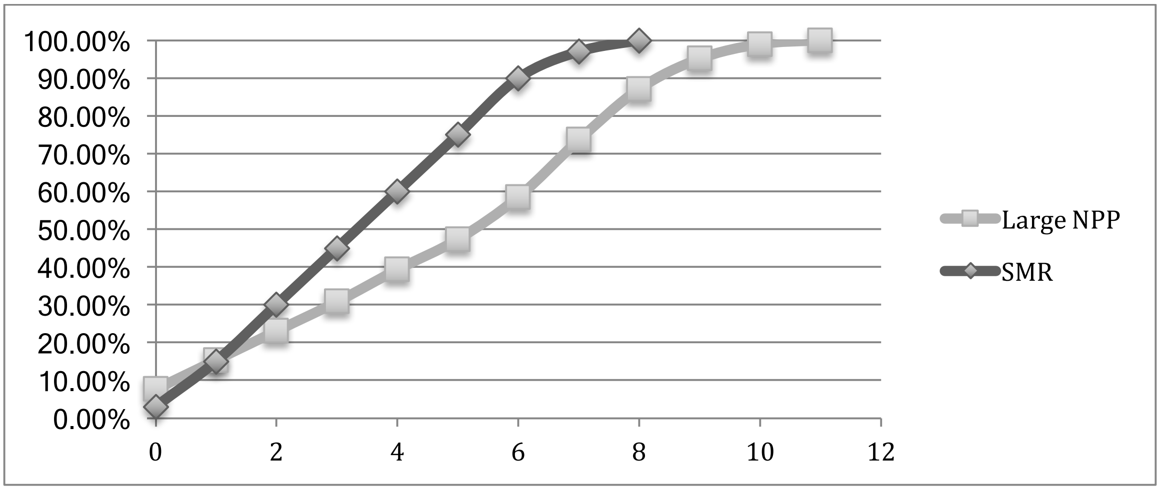


Figure 4: Cumulative expenditure pattern for large nuclear power plants and small modular reactors

Table 10: Costs of generating electricity using large nuclear power plants, small modular reactors, and utility-scale solar photovoltaic plants

	Nuclear (NPP)	**Nuclear (SMR)**	**Solar (PV)**
Unit capital cost [2015 $/kW]	$6,500.00	$9,100.00	$1,000.00
O&M [$/MWh]	$13.17	$18.44	$10.00
Fueling costs [$/MWh]	$10.00	$14.00	$0.00
Economic life [years]	40	40	25
Capacity factor	90%	90%	20%
Auxiliary consumption	5%	5%	0.50%
Discount rate	10%	10%	10%
Generation cost [$/MWh]	**$183.63**	**$222.15**	**$73.25**
Generation cost [cents/kWh]	**18.36**	**22.22**	**7.32**
Generation cost (IDR/kWh)	**2416.13**	**2923.09**	**963.78**

The results of our calculations are shown in Table 10. The currency conversion rate assumed is 1 Indonesian Rupiah equals 0.000076 US Dollar. One can draw at least two conclusions from these results. The cost of generating electricity using SMRs will likely be greater than large NPPs, by over 20 percent. As solar PV technology becomes cheaper and more efficient, it will cost significantly less to generate electricity using this technology than nuclear power plants.

There are, of course, significant uncertainties involved, especially with the SMR numbers. This will be true for any such calculation involving this technology. Since no SMRs have been actually constructed, the data simply does not exist on which to base a detailed cost of energy calculation. Nevertheless, the qualitative picture suggests that one cannot be too optimistic that SMRs will succeed in being economical where large NPPs have not.

There is one objection that is usually brought up by promoters of nuclear energy when it is compared with renewable energy technologies, that of intermittency. The argument is that solar and wind energy can be generated only when the sun is shining or the wind is blowing, and this characteristic makes them unsuitable for supporting the grid. While intermittency is a challenge, it is by no means insurmountable. To start with, intermittency becomes a problem only when the share of renewables in electricity generation becomes quite high. A 2014 study in one of the large electrical grids in the United States concluded that there would not be "any significant reliability issues operating with up to 30 percent of its energy (as distinct from capacity) provided by wind and solar generation".[154] Indonesia is far from those levels. And finally even at high levels of renewables, there are a range of strategies that can be implemented to deal with the intermittency, including the incorporation of storage and the use of demand side management to shift loads.

7 Conclusions

The purpose of this report has been to survey and synthesize the historical and contemporary factors affecting nuclear power in Indonesia, specifically for SMR development in Indonesia. Among the elements that support the potential construction of SMRs in Indonesia, the most notable is a host of institutional actors, including agencies like BATAN, that have had a long-standing interest in nuclear power, including the construction of SMRs, and regions of the archipelago with decentralized, limited capacity electrical grids that would be better suited to a small (rather than large) nuclear power plant. Growing energy demands in the regions of Indonesia that have more developed electrical infrastructure also offers an argument for nuclear power, but the general consensus seems to be that such demands will be better met using large nuclear reactors. As a result, there have been a number of proposals for large nuclear reactors (Table 1), although none of them have progressed beyond the planning stage to actual construction.

Interest within important institutions associated with energy planning is apparent from the many projections for future electricity generation capacity that involve nuclear power, especially in the 2030 to 2050 time frame. However, these have to be seen in the context of a history of projections for nuclear power since the 1970s that have not materialized.

This report has also outlined many challenges that would have to be overcome before any SMRs are constructed in Indonesia, including a lack of support for

[154] PJM, "Renewable Integration Study Reports," *PJM Interconnection*, last modified February 28, 2014, accessed August 14, 2016, http://www.pjm.com/committees-and-groups/subcommittees/irs/pris.aspx.

nuclear power at the highest (and lower) political levels, public opposition to nuclear power, the absence of tested SMR designs, and the higher electricity generation costs associated with SMR technology. There are also legislative regulations that could become obstacles for specific technologies, such as floating power plants, and the model of SMR construction that involve fabrication of the bulk of the reactor in factories.

The first factor, the absence of widespread and sustained political support, has been the major roadblock for the establishment of nuclear power in general. The Indonesian nuclear establishment has been trying to set up nuclear power plants since the 1970s but has so far not managed to persuade government leaders. Indeed, in December 2015, then Energy and Mineral Resources Minister Sudirman Said announced publicly that the government had concluded that "this is not the time to build up nuclear power capacity. We still have many alternatives and we do not need to raise any controversies".[155] Although this decision might be revised in the future, it testifies to lack of broad-based political support. Given this context, those advocating constructing SMRs in a country like Indonesia that has no nuclear power capacity face the basic conundrum: building untested nuclear technologies that might lead to higher electricity generation costs is going to be more of a political challenge than constructing nuclear reactor designs that have been operated in other countries.

The higher electricity generation cost associated with SMRs should be seen not just in comparison with the cost of generating electricity with a large NPP but also with a range of alternatives that are available in Indonesia. Of these, the declining cost of solar photovoltaic technology is particularly relevant. Studies testify to the large potential of solar energy in Indonesia and the government has been adopting policies that promise to accelerate the construction of significant amounts of solar capacity.

The smaller power level of SMRs also implies that producing the same amount of electricity using these as opposed to large reactors would require dealing with public resistance at many more sites. Because public opposition has played a major role in stopping construction of nuclear power plants so far, constructing SMRs might be even more of a challenge than large reactors; for SMRs, the potential benefits accruing from electricity generation comes at a higher economic and social cost. As a result, it would seem that the construction of SMRs is unlikely, especially in large enough numbers to make a sizeable contribution to Indonesia's electricity generation.

[155] NEI, "Indonesia Rules out Nuclear as Major Power Source."

Acknowledgements

The authors would like to thank all those who participated in the workshop on "Nuclear Power and Small Modular Reactors (SMRs) in Indonesia: Potential and Challenges" in Jakarta on 25 June 2015 and offered their views. We would also thank those who met specially with us to discuss issues related to the subject of this report, in particular, Arnold Soetrisnanto, Nengah Sudja, Fabby Tumiwa, Ai Melani, Dahlia Sinaga, and Dian Abraham. MVR would also like to thank Ali Ahmad, Alex Glaser, and Zia Mian for their inputs. None of them, however, are responsible for the contents or the conclusion of this report. This work was supported in part by a grant from the MacArthur Foundation.

8 Appendices

8.1 Table of Abbreviations

Abbreviation	English	Indonesian
BAKOREN	National Energy Coordinating Agency	Badan Koordinasi Energi Nasional
Bapeten	Nuclear Energy Regulatory Agency	Badan Pengawas Tenaga Nuklir
Bappeda	Regional Body for Planning and Development	Badan Perencana Pembangunan Daerah
Bappenas	Ministry of National Development Planning Agency	Badan Perencanaan Pembangunan Nasional
BATAN	National Nuclear Energy Agency	Badan Tenaga Nuklir Nasional
BKPRS	Secretary General of the Sulawesi Regional Development Cooperation Agency	Sekretaris Jenderal Badan Kerjasama Pembangunan Regional Sulawesi
BPPT	Agency for the Assessment and Application of Technology	Badan Pengkajian dan Penerapan Teknologi
BPS	Central Agency on Statistics	Badan Pusat Statistik
CADES	Comprehensive Assessment of Different Energy Sources for Power Generation	
CF	Capacity Factor	
DEN	National Energy Council	Dewan Energi Nasional
EPR	Experimental Power Reactor	
ESDM	Ministry of Energy and Mineral Resources	Kementerian Energi dan Sumber Daya Mineral
GIS	Geographic System Information	
GW	Gigawatt	
GWe	Gigawatt electrical	
HTGR	High Temperature (Gas-cooled) Reactor	
HVDC	High Voltage Direct Current	
IAEA	International Atomic Energy Agency	
IDT	Site Data Information	Informasi Data Tread
IO non-BBM	Non-Fossil Fuel Operating Permit	Izin Operasi non Bahan Bakar Minyak
IPP	Independent Power Producer	
ITB	Institute of Technology Bandung	Institut Teknologi Bandung
JBIC	Japan Bank for International Cooperation	
KAERI	Korean Atomic Energy Research Institute	

Abbreviation	English	Indonesian
KEN	National Energy Policy	Kebijakan Energi Nasional
KKP	Ministry of Marine Affairs and Fisheries	Kementerian Kelautan dan Perikanan
KP2-PLTN	Preparatory Commission for Nuclear Power Plant	Komisi Persiapan Pembangunan Pembangkit Listrik Tenaga Nuklir
kV	Kilovolts	
kWh	Kilowatt hour	
kWp	Kilowatt peak	
LDT	Site Data Report	Laporan Data Tread
LET	Site Evaluation Report	Laporan Evaluasi Tread
LIPI	Indonesian Institute of Science	Lembaga Ilmu Pengetahuan Indonesia
MANUSIA	Indonesian Anti-Nuclear Community	Masyarakat Anti Nuklir Indonesia
MAREM	Earth Nurturing Society	Masyarakat Rekso Bumi
MED	Multiple-Effect Distillation	
Menristek	Ministry of Research and Technology	Kementerian Teknologi, Riset, dan Perguruan Tinggi
Menristekdikti	Ministry of Research, Technology, and Higher Education	Kementerian Riset, Teknologi dan Pendidikan Tinggi
MSF	Multi-Stage Flash	
MW	Megawatt	
MWe	Megawatt electrical	
MWp	Megawatt peak	
MTOE	Million Tons of Oil Equivalent	
NEPIO	Nuclear Energy Program Implementing Organization	
NESA	Nuclear Energy System Assessment	
NEWJEC	New Japan Engineering Consultants	
NIRA	Nuclears Italiana Reacttori Avancatti	
NRE	New and Renewable Energy	
PBMR	Pebble Bed Modular Reactor	
Pertamina	State Oil and Natural Gas Mining Company	
PGI	Communion of Churches in Indonesia	Persatuan Gereja Indonesia
PLN	State Electricity Company	Perusahaan Listrik Negara
PLTB	Wind Generated Power Plants	Pembangkit Listrik Tenaga Bayu

Abbreviation	English	Indonesian
PLTD	Diesel Power Plants	Pembangkit Listrik Tenaga Diesel
PLTG-GA	Gas Turbine Power Plant	Pembangkit Listrik Tenaga Gas Alam
PLTG-M	Oil Gas Turbine Power Plant	Pembangkit Listrik Tenaga Gas Minyak
PLTGU-G	Natural Gas Combined Cycle Power Plant	Pembangkit Listrik Tenaga Gas dan Uap
PLTGU-M	Oil Combined Cycle Power Plant	Pembangkit Listrik Tenaga Gas dan Uap Minyak
PLTM-G	Oil Gas Power Plant	Pembangkit Listrik Tenaga Minyak Gas
PLTS	Solar Power Plants	Pembangkit Listrik Tenaga Surya
PLTU-B	Steam Coal Power Plant	Pembangkit Listrik Tenaga Uap Batubara
PLTU-GA	Steam Natural Gas Power Plant	Pembangkit Listrik Tenaga Uap Gas Alam
PLTU-M	Steam Oil Power Plant	Pembangkit Listrik Tenaga Uap Minyak
PPA	Power Purchase Agreement	
PPU	Private Power Utility	
Puspitek	Center for Science, Research, and Technology	Pusat Penelitian Ilmu Pengetahuan dan Teknologi
PUTL	Public Works and Power	Pekerjaan Umum dan Tenaga Listrik
PV	Photovoltaic	
PWR	Pressurized Water Reactors	
RAO UES	Unified Energy System of Russia	
RDE	Experimental Power Reactor	Reaktor Daya Experimental
RDNK	Non-Commercial Power Reactor	Reaktor Daya Non-Komersial
Rosatom	State Atomic Energy Corporation (Russia)	
RPJMN	National Medium-Term Development Plan	Rencana Pembangunan Jarak Menengah Nasional
RPJPN	National Long-Term Development Plan	Rencana Pembangunan Jarak Panjang Nasional
RUEN	Rencana Umum Energi Nasional	General Plan on National Energy
RUKN	Rencana Umum Ketenagalistrikan Nasional	National Electricity General Plan
SKPD	Regional Planning Unit	Satuan Kerja Perangkat Daerah

Abbreviation	English	Indonesian
SMART	System integrated Modular Advanced Technology	
SMR	Small Modular Reactor	
Sumbagut	North Sumatra Region	Sumatera bagian Utara
SUTET	Extra High Voltage Transmission Line	Saluran Udara Tegangan Extra Tinggi
SUTT	High Voltage Transmission Line	Saluran Udara Tegangan Tinggi
TWh	Terawatt hour	
USGS	United States Geological Survey	
WALHI	The Indonesian Forum for Environment	Wahana Lingkungan Hidup Indonesia

8.2 Appendix - Agencies in Indonesia Affecting Nuclear Power

In this appendix, the main national-level government institutions involved in policymaking and regulation of the energy sector, with an emphasis on nuclear power, are listed in alphabetical order (by acronym) and briefly described.

***Nuclear Energy Regulatory Agency* (*BAPETEN*)**

Badan Pengawas Tenaga Nuklir

BAPETEN is the Indonesian nuclear regulatory body. It supervises all activities involving the utilization of nuclear energy by organizing regulations, licensing, and inspections related to those activities under the auspices of Government Regulation No.12/2014. In order to build a nuclear power plant in Indonesia, a series of permits must be obtained from BAPETEN that cover the entire lifecycle of the plant, including site, construction, commissioning, operation, and decommissioning licenses.

In the past BAPETEN has been able to lean heavily on IAEA and international experience gained in other countries with traditional light water reactor designs. More recently, however, it appears that BAPETEN has been engaged with the challenge of trying to determine how to draw on a smaller body of existing expertise as it navigates making licensing decisions with regards to HTGR designs,[156] which are the currently preferred reactor design for BATAN's plans at the EPR Serpong facility. There are two different elements to BAPETEN's current situation. The first is the small body of expertise globally available on HTGRs and SMRs more generally. The second is that as BAPETEN assumes full regulatory responsibility it must become more independent of BATAN, from which its staff were initially drawn,

[156] Interview with stakeholders.

since its primary task is to regulate BATAN-related activities. This reduces its locally available pool of expertise.

BAPETEN's experience and the decision-making framework that will result from this process of considering HTGRs are of interest since the global body of expertise regarding SMRs is even more limited than that for HTGR's. Therefore, future plans in Indonesia regarding the adoption of SMR technology may draw upon lessons learned from BAPETEN's experience with licensing HTGRs. However, how exactly this will play out in the evolution of the national nuclear debate remains to be seen.

National Nuclear Energy Agency (*BATAN*)

Badan Tenaga Nuklir Nasional

BATAN carries out government duties in the field of research, development, and utilization of nuclear science and technology. Although it is outside BATAN's mandate to be directly involved in the development or operation of a commercial nuclear power plant, the agency has consistently sustained the national debate regarding such facilities and has often been a prime force involved in feasibility and site studies. It also engages in the promotion of the idea of nuclear power as a potential source of energy for Indonesia.

The National Mid Term Development Plan 2015-2019 mentions that BATAN is expected to support the preparation of NPP construction by (1) increasing mastery of nuclear power plant technology for the deployment of commercial nuclear power plants, (2) capacity building for NPPs human resources, (3) training in project management for commercial NPPs, and (4) increasing public acceptance of NPPs. Also, preparation includes improving the ability of BATAN to produce nuclear fuel and to manage nuclear waste for NPPs.[157]

Agency for the Assessment and Application of Technology (BPPT)

Badan Pengkajian dan Penerapan Teknologi

BPPT is a non-Ministerial institution (LPNK), like BATAN and BAPETEN, which reports directly to the President and is under the coordination of the Ministry of Research and Technology. BPPT has the authority to draw up a comprehensive national plan and formulate policies to support national-scale development initiatives. In addition, it is authorized to formulate and implement specific policies in the field of assessment and application of technology as well as to provide recommendations and perform audits of the application of various technologies.[158] The agency is also tasked with fostering technology transfer.

---

[157] MNDP, *National Mid Term Development Plan 2015-2019, Book I of National Development Agenda*.
[158] BPPT, "Tugas Dan Fungsi [Tasks and Functions]," *Badan Pengkajian Dan Penerapan Teknologi*, last modified 2015, accessed August 14, 2016, http://www.bppt.go.id/index.php/profil/tugas-dan-fungsi.

With regards to the development of nuclear power in Indonesia, BPPT has been supportive of nuclear power and has called for making a construction decision by 2020, so that a nuclear plant can be in operation by 2030.[159] BPPT has consistently included in their outlook documents projections involving the use of nuclear energy. In its *Indonesia Energy Outlook 2015*, nuclear is listed as one of the new and renewable energy contributors to be included in the energy mix by 2025 and which is to be increased until 2050.[160]

National Energy Council (DEN)

Dewan Energi Nasional

DEN was established in 2008 to handle energy policy, under the mandate of Law No. 30/2007 on Energy and Presidential Regulation No. 26/2008 concerning the Establishment of the National Energy Council and Screening Procedures for members of DEN. Within the council, the President of Indonesia serves as the Chairman and the Indonesian Vice President serves as the Vice Chairman, while the Minister of Energy and Mineral Resources has a position as daily Chairman. The council also has additional members from government sectors (seven ministers) and from stakeholder organizations. The main tasks of DEN are:

- To design and formulate a National Energy Policy (Kebijakan Energi Nasional – KEN) to be determined by the Government with the approval of Parliament;
- To determine a General Plan on National Energy (Rencana Umum Energi Nasional – RUEN);
- To determine mitigation measures in response to situations of energy crisis and emergency;
- To oversee the implementation of energy policies across energy sectors.

Like BPPT, DEN included nuclear power as one of the options for the national energy policy scenario in its earlier *Indonesia Energy Outlook 2014*, which included projections for the addition of capacity from nuclear power plants beginning in 2025. In the specific case of nuclear energy, the National Energy Policy document places it as a "last resort",[161] given that Indonesia has many alternative clean energy options, such as natural gas, solar, hydro, wind, biomass, etc.

The formulation and issue of the first KEN in 2014, six years after the establishment of the Council, suggests that drawing up the National Energy Policy was a lengthy

---

[159] BPPT, "Kongres Teknologi Nasional 2016 : Teknologi Untuk Wujudkan Ketahanan Energi Nasional," Badan Pengkajian Dan Penerapan Teknologi [National Technology Congress 2016: Technology to Achieve National Energy Security]", July 31, 2016, http://www.bppt.go.id/layanan-informasi-publik/2680-kongres-teknologi-nasional-2016-teknologi-untuk-wujudkan-ketahanan-energi-nasional.

[160] BPPT, *Outlook Energi Indonesia 2015* (Jakarta, Indonesia: Pusat Teknologi Pengembangan Sumber Daya Energi, 2015), 74, accessed August 11, 2016, http://repositori.bppt.go.id/index.php?action=download&dir=_data%2FDownload%2FOUTLOOK+ENERGI+2015&item=BPPT-Outlook+Energi+Indonesia+2015.pdf&order=name&srt=yes&lang=en.

[161] RUKN, *Rencana Umum Ketenagalistrikan Nasional 2015 - 2034 [National Electricity General Plan 2015 - 2034]*, 10.

process. This may be a reflection of the diversity of voices in DEN that are engaged in the national energy policy, including government elements (Ministry of Finance, Ministry of National Development Planning Agency, Ministry of Transportation, Ministry of Industry, Ministry of Agriculture, Ministry of Research, Technology and Higher Education, and the Ministry of Environment and Forestry) and other stakeholder elements as well (two academics, two representatives from the industry sector, a representative from the technology sector, a representative from the environment sector, and two representatives from the consumer sector).

Given the number of interest groups involved in policy-making, this suggests that obtaining or implementing a decision on nuclear power will not be an easy road in Indonesia (as also already evidenced by the lengthy historical debate) since policy decisions will continue to be influenced by many actors with strong direct influence on the policy-making process and with different vested interests with regards to the development of nuclear power. The diversity of viewpoints is further complicated by Indonesia's current political structure. At present, the country has ten political parties in Parliament for the period 2014-2019, each with their own interests. The structure of DEN suggests that navigating the diverse political landscape in Indonesia, in order to successfully push through a definitive decision on nuclear power, and especially novel SMR technology, will likely pose a significant and lengthy challenge.

Ministry of Energy and Mineral Resources (ESDM)

Kementerian Energi dan Sumber Daya Mineral

The ESDM oversees affairs related to energy and mineral resources. One of its functions is national policy formulation, policy implementation and technical policy in the field of energy and mineral resources. According to Article 17 of the Energy Law, ESDM is in charge of developing the General Plan on National Energy with reference to the National Energy Policy. At present, the government is drafting this policy, which involves cross-sector collaboration of multiple government elements at the national level. It is still not known whether or not the General Plan will adopt NPP construction in the Plan. Considering that it is assumed that the General Plan shall be in keeping with the KEN, it is argued that NPPs will not be incorporated in the plan, since nuclear is listed only as a last resort.

In 2014, the Directorate General of Electricity within the Ministry undertook a study to estimate the nuclear power plant capacity needed. The result, contained in a so-called White Book, projects that a total installed NPP capacity of 5,000 MW is expected to be necessary by the period 2024-2025. At present, a lack of transparency regarding the assumptions and simulations used to obtain the figures in the White Book has raised questions among various stakeholders. However, the release of these figures is in keeping with a general trend toward support of the nuclear power option within Indonesian government agencies.

Ministry of National Development Planning/National Development Planning Agency (PPN/Bappenas)

Kementerian Perencanaan Pembangunan Nasional/Badan Perencanaan Pembangunan Nasional

Bappenas is the Ministry in charge of policy-making for the National Long-Term Development Plan (Rencana Pembangunan Jarak Panjang Nasional – RPJPN), the National Medium-Term Development Plan (Rencana Pembangunan Jarak Menengah Nasional – RPJMN), and the Government Work Plan. Nuclear power plant development and preparation has been mentioned in both the RPJPN and RPJMN national development plans. The RPJPN mentions the possibility of developing nuclear power and discusses a number of in-depth research activities relating to safety of the technology, geographic location, and potential risks for the construction of nuclear power plants. Furthermore, the RPJMN 2015-2019 and the Government Work Plan (Rencana Kerja Pemerintah) for 2016 also contain a number of references to nuclear power plants.

Ministry of Research and Technology (RISTEKDIKTI)

Kementerian Riset Teknologi dan Pendidikan Tinggi

The Ministry of Research, Technology and Higher Education has the task of conducting affairs of government in the field of research, technology, and higher education in service of the President. RISTEKDIKTI is also assigned to coordinate some LPNKs, or Non-Ministerial Bodies, including BATAN, BAPETEN, and BPPT.[162] One can presume that RISTEKDIKTI supports nuclear power development in Indonesia from its role in the creation of the Nuclear Energy Advisory Council (Majelis Pertimbangan Tenaga Nuklir ; MPTN) in 2014.[163] The MPTN consists of seven members, made up of experts, academics, and community leaders. This Council is an independent body and exists under the auspices of the President. MPTN is responsible for advising the President regarding the use of nuclear energy.

PT Industri Nuklir Indonesia

PT Industri Nuklir Indonesia, formerly known as PT Batan Teknologi, is a State-owned company, which acts as a service provider for radioisotope production, production of nuclear material and nuclear engineering services as well as in the application of nuclear technology in various fields.

---

[162] RISTEKDIKTI, “LPNK [Non-Ministerial Bodies],” *Ministry of Research Technology and Higher Education of the Republic of Indonesia*, last modified 2016, accessed August 14, 2016, http://ristekdikti.go.id/lpnk/.
[163] Gusti Grehenson, “Ristek Bentuk Majelis Pertimbangan Tenaga Nuklir [Research and Technology Forms Nuclear Energy Advisory Council],” *Universitas Gadjah Mada*, August 28, 2014, accessed August 14, 2016, https://ugm.ac.id/id/berita/9226-ristek.bentuk.majelis.pertimbangan.tenaga.nuklir.

PT PLN

Persero

PT PLN is a State-owned utility company, whose main task is to provide electricity for public use. The company oversees activities pertaining to the planning, development, and construction of facilities to provide electrical power; generating and distributing electrical power; and power supply sales. In addition, the company also provides electricity support and other services.

As a reference to the public, the company prepares an *Electricity Supply Business Plan* (*Rencana Umum Penyediaan Tenaga Listrik* - RUPTL). In its RUPTL 2015-2024, PT PLN did not include nuclear power in its business plan for this period, but the company has considered nuclear power plants as an option for the future, since fossil energy prices are projected to become more expensive and to reduce carbon emissions, while also expressing the idea that it should be used as a last resort.[164]

8.3 Appendix - Overview of Small Modular Reactors

This appendix offers a brief description of small modular reactors and outlines some of the features that help evaluate the attractiveness of SMRs, including possible deployment, cost, and safety issues.[165]

8.3.1 Description of Small Modular Reactors (SMRs)

Small modular reactors (SMRs) refers to proposed nuclear reactor designs that are envisioned to be distinct from most commercial reactors operating today in two principal ways. First, as the adjective small in the name suggests, SMRs will have an operating capacity of less than 300 MW, much less than the typically 1,000 to 1,500 MW reactors that are common of reactors under construction. Second, "modular" refers to the fact that many components of the reactor are to be fabricated in factories by the manufacturer and the resulting component(s) or reactor unit(s) shipped to the purchasing country, essentially ready to be installed. Therefore, it is hoped, some of the uncertainties associated with manufacturing on-site will be reduced.

More than the modularity, it is the smaller capacity of SMRs that affects how proposed SMR designs would compare to currently operated NPPs in terms of cost, safety, and deployment scenarios.

8.3.2 SMR Deployment Scenarios

How would SMRs be deployed? The small modular design of SMRs permits two different types of installations. The first kind of emplacement would be single SMR

[164] RUKN, *Rencana Umum Ketenagalistrikan Nasional 2015 - 2034 [National Electricity General Plan 2015 - 2034]*, 10.
[165] Glaser et al., *Small Modular Reactors: A Window on Nuclear Energy*.

units installed at various individual sites, a "lone unit" scenario (also known as the "one-at-a-time" strategy). The second kind of emplacement would be groups of SMRs installed at a single site, a "multi-unit" scenario. Each emplacement is envisioned to be able to address different energy mix needs, according to local grid capacity.

The lone unit deployment scenario is suited to areas with limited electrification resulting in a small grid (low total electricity demand) where a large NPP would represent a too-large share of the supplied power, subjecting the grid to unnecessary systemic risk. There is a rule of thumb that no single generation unit in the electricity mix should account for more than a 10 percent share of the total generation capacity. This protects the robustness of the overall grid should one generation facility experience a failure.

In contrast, the multi-unit deployment scenario is suited to areas with larger grids. In this case multiple SMR units could be installed in place of one large NPP, for example, five 200 MW SMRs instead of one 1,000 MW NPP. Or, alternatively, SMR units could be continually added to a site over time in order to accommodate a growing electricity demand.

The other deployment decision has to do with where the SMR is constructed, on land or in the sea. In some SMR designs, the reactor would be placed on a ship (or some floating platform) or on the ocean floor. Although there is one floating nuclear power plant under construction in Russia,[166] there is no commercial reactor deployed on a floating platform or in a submarine.

8.3.3 Cost of SMRs

At present cost comparisons between SMRs and NPPs are speculative since SMRs have yet to be built or operated. However, there are two economic principles that will come into play.

The first principle is economy of scale. It is typically cheaper to produce one unit of electricity from a large power plant than from a small power plant using the same technology. For example, electricity from a 1,000 MW NPP would typically be cheaper than electricity from a 200 MW NPP with essentially the same design. This is because the 1,000 MW plant does not require five times as much concrete, nor does it employ five times as many workers as the 200 MW plant.

---

[166] WNA, "Akademik Lomonosov 2," *WNA Reactor Database*, last modified 2015, accessed May 23, 2015, http://world-nuclear.org/NuclearDatabase/reactordetails.aspx?id=27570&rid=A0D78EB7-B62A-48FF-9D78-21A8E4534D90; "Baltiysky Zavod Shipyard Starts Harbor Tests of World's First Floating Nuclear Power Plant Akademik Lomonosov," *PortNews*, last modified July 1, 2016, accessed July 29, 2016, http://en.portnews.ru/news/222051/.

The general rule of thumb governing capital costs of production facilities is known as the 0.6 power rule.[167] This rule states that the capital costs, K_1 and K_2, of two plants of size S_1 and S_2 are related as:

$$\frac{K_1}{K_2} = \left(\frac{S_1}{S_2} \right)^{0.6}$$

This implies that, all else being equal, if a 1,000 MW nuclear power plant costs $6.5 billion (i.e., $6500/kW), an SMR with a power capacity of 200 MW would be expected to have a construction cost of $2.5 billion or around $12,400/kW (90% higher cost per unit capacity). Similarly, operating an SMR will also be more expensive in comparison with a large reactor due to diseconomies of scale.

The second influencing principle is economies of serial production. As a technology is produced repeatedly over time, the process becomes increasingly efficient as a result of lessons learned. This brings down the cost of production as production methods are streamlined. Therefore, the cost of building a later unit will be less expensive than the cost of building an earlier unit. In this way, the capital cost per SMR unit may decrease over time as a result of economies of serial production. The rate at which this decrease will occur is a measure of the effect of learning, and there is little factual information to base any reliable estimate of this learning rate. Indeed, large nuclear power plants have shown negative learning rates, with costs increasing over time.[168]

Therefore, even assuming relatively optimistic learning rates one would expect the unit costs of SMRs to be higher than those of large reactors. This is also the conclusion of experts drawn from, or closely associated with, the nuclear industry.[169] Reflecting this prediction, the generation cost estimate presented in this report assumes that the construction cost, the operation and maintenance costs associated with SMRs would be only 40 percent higher than that of a large reactor. In other words, we are assuming $9100/kW rather than $12,400/kW that would result from the usual 0.6 power law scaling. Fueling costs would also be higher in the case of SMRs because of lower efficiencies of use of uranium.[170]

---

[167] National Research Council, *Nuclear Wastes: Technologies for Separations and Transmutation* (Washington, D.C.: National Academy Press, 1996), 421.

[168] Arnulf Grubler, "The Costs of the French Nuclear Scale-up: A Case of Negative Learning by Doing," *Energy Policy* 38, no. 9 (2010): 5174–5188; Jonathan G Koomey and Nathan E Hultman, "A Reactor-Level Analysis of Busbar Costs for US Nuclear Plants, 1970–2005," *Energy Policy* 35 (2007): 5630–5642; Nathan E. Hultman, Jonathan G. Koomey, and Daniel M. Kammen, "What History Can Teach Us about the Future Costs of U.S. Nuclear Power," *Environmental Science & Technology* 40, no. 7 (2007): 2088–94.

[169] Ahmed Abdulla, Inês Lima Azevedo, and M. Granger Morgan, "Expert Assessments of the Cost of Light Water Small Modular Reactors," *Proceedings of the National Academy of Sciences* 110, no. 24 (2013): 9686–9691.

[170] Glaser, Hopkins, and Ramana, "Resource Requirements and Proliferation Risks Associated with Small Modular Reactors."

8.3.4 Safety and SMRs

There are both inherent and potential differences in the safety features of SMRs as compared to NPPs. One safety advantage with small reactors is that they can more easily incorporate passive safety features, which do not require power to be actively supplied to the reactor unit to help with their functions. The smaller physical size, for example, means that the walls can dissipate some of the heat from the core.

The smaller generating capacity of SMRs means they have a smaller inventory of radioactive materials when compared to large nuclear power plants. Therefore, in the event of a catastrophic accident, there is less radioactive material that could be released as compared to a single large reactor at an NPP. While this is the case with a single SMR unit, this safety feature might not extend to a multi-unit SMR deployment and it is unclear how the increase in the number of units and their specific on-site deployment would affect the likelihood or projected outcomes of various accident scenarios. The multiple reactor accidents at the Fukushima Daiichi nuclear power plant in Japan in March 2011 illustrated how managing accidents at sites with multiple nuclear reactors is far more complicated and events at one reactor could cause problems for other reactors at the same site. Despite the safety complications, nuclear reactor vendors and utilities pursue multi-unit deployment for economic reasons, an example of the difficulty in simultaneously pursuing the different priorities confronting SMR designers.[171]

At this point, much of this is speculative. Since SMR designs are mostly conceptual, there are still questions about whether safety features will operate as expected. Again, the SMR deployment strategy will also likely affect the overall safety. Hence, there is no clear-cut way to compare the safety of SMRs relative to NPPs.

8.3.5 History of SMRs

Although SMRs are talked about as new, there is in fact a long history of nuclear advocates promoting the idea that small reactors could help electrify developing countries.[172] Small reactors were also supposed to be a good fit for electric utilities in the United States and several such models were constructed. All of them shut down well before their licensed lifetimes because of poor economics.[173]

---

[171] Ramana and Mian, "One Size Doesn't Fit All."

[172] At the 1955 Geneva conference, for example, the Department of Economic and Social Affairs of the United Nations argued: "The present volume of energy consumption in most under-developed countries, however, does not justify the employment of large thermal power stations and the same will be true, in many cases, of large-size reactors. In other words, nuclear power in underdeveloped countries would have to be generated in plants with a relatively small capacity". Department of Economic and Social Affairs, United Nations, "Some Economic Implications of Nuclear Power for Under-Developed Countries," in *First International Conference on the Peaceful Uses of Atomic Energy* (Geneva: United Nations, 1955), 341–345.

[173] M.V. Ramana, "The Forgotten History of Small Nuclear Reactors," *IEEE Spectrum*, May 2015, accessed May 24, 2015, http://spectrum.ieee.org/energy/nuclear/the-forgotten-history-of-small-nuclear-reactors.

There is also some experience with the HTGRs that BATAN has been interested in. In particular, there were four commercial HTGRs constructed in Germany and in the United States and some test reactors were constructed in the United Kingdom, Japan, and China. All of these operating HTGRs underwent a wide variety of small failures and unplanned events, including ingress of water or oil, and fuel failures; all had poor load factors and did not operate for the expected lifetimes.[174] There is thus reason to expect poor performance with future HTGRs as well.

Coming to the more recent period, despite the expectation that developing countries with small grids and limited financial resources that are interested in developing nuclear power would choose an SMR in preference to a large reactor, so far none of them have actually purchased an SMR. Jordan, a prime candidate, has recently entered into an agreement with Russia to acquire two large conventional light water reactors. It turns out that although SMRs would be much better suited to Jordan's circumstances, the SMR option raises new problems, including locating sites for multiple reactors, finding water to cool these reactors, and the higher cost of electricity generation.[175] Likewise, Ghana, another country that has been considered a potential customer for SMRs, may also purchase a large reactor from Russia. The explanation for this decision is partly because the Ghana Atomic Energy Commission prefers a large reactor in comparison to an SMR because it allows GAEC to position itself as a complete, one-stop solution to Ghana's electricity crisis.[176]

In short, an examination of the history of SMRs suggests that there will likely be a big gap between how SMRs will do in the real world and how SMRs operate theoretically on paper.

8.4 Appendix – Summary Tables of Regulations Relating to Nuclear Power in Indonesia

Table 11 below lists the regulations that pertain to nuclear power in Indonesia. In addition, the table also briefly mentions the purpose or impact of the regulation.

Table 11. Regulatory framework affecting nuclear power in Indonesia

Regulations Related to Nuclear Power	Remarks
Government Regulation No. 63/2000 on Safety and Health in the Utilization of Ionic Radiation	It regulates the dose limitation system requirements, radiation safety management systems, calibration, preparedness and mitigation of radiation accidents.

[174] M. V. Ramana, "The Checkered Operational History of High Temperature Gas Cooled Reactors," *Bulletin of the Atomic Scientists* 72, no. 3 (2016): 171–179.
[175] M. V. Ramana and Ali Ahmad, "Wishful Thinking and Real Problems: Small Modular Reactors, Planning Constraints, and Nuclear Power in Jordan," *Energy Policy* 93 (2016): 236–245.
[176] M. V. Ramana and Priscilla Agyapong, "Thinking Big? Ghana, Small Reactors, and Nuclear Power," *Energy Research & Social Science* 21 (November 2016): 101–113.

Regulations Related to Nuclear Power	**Remarks**
Government Regulation No. 64/2000 on License for Nuclear Energy Use	This regulation contains the requirements and procedures for obtaining permits, the term of license, obligations and responsibilities of the license holder.
Government Regulation No. 26/2002 on Safety in the Transportation of Radioactive Substances	It regulates the safety of the transport of radioactive substances, covering license, duties and responsibilities, packaging, radiation protection programs, training, programs on quality assurance, type and limit of radioactive substances, radioactive substances activity with its danger, and emergency countermeasures.
Government Regulation No. 27/2002 on Radioactive Waste Management	It regulates the classification of radioactive waste, permissions management, processing, transportation, and storage of radioactive waste, quality assurance program, management and monitoring of the environment, and processing of radioactive waste from mining and decommissioning programs.
Government Regulation No. 43/2006 on License for Nuclear Reactor	It regulates the licensing of nuclear reactors for each stage in the development, operation, and decommissioning of nuclear reactors.
Government Regulation No. 33/2007 on Safety of Ionizing Radiation and Security of Radioactive Sources	It regulates radiation safety for workers, communities, and the environment, security of radioactive sources, and inspection of nuclear energy utilization.
Government Regulation No. 29/2008 on License for Ionizing Radiation Source and Nuclear Substance Utilization	It regulates requirements and licensing procedures for ionizing radiation sources and nuclear substance utilization. The requirements include administrative, technical and special requirements.
Government Regulation No. 46/2009 on Limit of Liability for Nuclear Damage	This regulation highlights the nuclear damage liability limit that shall be fulfilled by entrepreneurs of nuclear installations and nuclear installation vendors.

Regulations Related to Nuclear Power	**Remarks**
Government Regulation No. 54/2012 on Safety and Security of Nuclear Installations	This regulation deals with the technical safety of nuclear installations (site monitoring before design and construction, design and construction, commissioning and operation, safeguards changes and physical protection systems, safety evaluation, and decommissioning), safety and security of nuclear installation management, preparedness and countermeasures in case of a nuclear emergency.
Government Regulation No. 2/2014 on License for Nuclear Installations and Nuclear Utilization	It regulates nuclear reactor licensing, nuclear installation licensing, and nuclear material utilization licensing.
Presidential Regulation No. 74/2012 on Nuclear Liability	It regulates the liability limit for entrepreneurs of nuclear installations in terms of nuclear damage for each nuclear installation occurring either within the nuclear installation or during the transport of nuclear fuel/spent fuel.
Presidential Regulation No. 46/2013 on National Nuclear Energy Agency	It regulates the existence, tasks, and responsibilities of the National Nuclear Energy Agency.

As discussed in Section 5.3, one area of regulation policy that may especially impact SMR adoption in Indonesia is the local content requirement. These are listed below in Table 12.

Table 12. Local content requirements for electricity infrastructure[177]

Generation Type	**Installed Capacity**	**Minimum Level of Local Content for Goods**	**Minimum Level of Local Content for Services**	**Minimum Level of Combined Local Content for Goods and Services**	**Remarks**
PLTU / Steam Power Plant	Up to 15 MW	67.95%	96.31%	70.79%	Goods component: steam turbine,
	> 15 – 25	45.36%	91.99%	49.09%	

[177] According to Article 6-13 in the Minister of Industry's Regulation No. 54/2012 on Guidelines for the Use of Domestic Product to Electricity Infrastructure Development. Original Title of the regulation: Peraturan Menteri Perindustrian Republik Indonesia No. 54/M-IND/PER/3/2012 tentang Pedoman Penggunaan Produk Dalam Negeri Untuk Pembangunan Infrastruktur Ketenagalistrikan.

	MW				boiler, generator, electrical, instrument and control, balance of plant and/or civil and steel structure Services: feasibility study, engineering, procurement and construction, inspection, testing, certification and/or supporting service
	> 25 – 100 MW	40.85%	88.07%	44.14%	
	> 100 – 600 MW	38.00%	71.33%	40.00%	
	> 600 MW	36.10%	71.33%	38.21%	
PLTA / Hydro Power Plant-Non Storage Pump	Up to 15 MW	64.20%	86.06%	70.76%	Goods component: civil, metalwork, turbine, generator, electrical, instrument and control Services: feasibility study, engineering, procurement and construction, inspection, testing, certification and/or supporting service
	> 15 – 50 MW	49.84%	55.54%	51.60%	
	> 50 – 150 MW	48.11%	51.10%	49.00%	
	> 150 MW	47.82%	46.98%	47.60%	
PLTP/ Geothermal Power Plant	Up to 5 MW	31.30%	89.18%	42%	Goods component: steam turbine, boiler, generator, electrical, instrument and control, balance of plant and/or civil and steel structure Services:
	> 5 – 10 MW	21.00%	82.30%	40.45%	
	> 10 – 60 MW	15.70%	74.10%	33.24%	
	> 60 – 110 MW	16.30%	60.10%	29.21%	
	> 110 MW	16.00%	58.40%	28.95%	

					feasibility study, engineering, procurement and construction, inspection, testing, certification and/or supporting service
PLTG / Gas Turbine Power Plant	Up to 100 MW per block	43.69%	96.31%	48.96%	Goods component: gas turbine, generator, electrical, instrument and control, balance of plant, civil and steel structure Services: feasibility study, engineering, procurement and construction, inspection, testing, certification and/or supporting service
PLTGU / Combined Cycle Power Plant	Up to 50 MW per block	40.00%	71.53%	47.88%	Goods component: gas turbine, generator, heat recovery system generator, steam turbine, electrical, instrument and control, balance of plant, civil and steel structure Services: feasibility study, engineering, procurement and construction, inspection,
	> 50 – 100 MW per block	35.71%	71.53%	40.00%	
	> 100 – 300 MW per block	30.67%	71.53%	34.76%	
	> 300 MW per block	25.63%	71.53%	30.22%	

					testing, certification and/or supporting service
PLTS / Solar Power Plant – Solar Home System		30.14%	100%	53.07%	Goods component: solar module, battery and accessories, battery control unit, lamp, accessories and support Service: delivery, installation
PLTS / Solar Power Plant – Centralized/ Communal		25.63%	100%	43.85%	Goods component: solar module, battery control unit, inverter, light system, electricity distribution system, accessories and support Service: delivery, installation

8.5 Appendix - Institutional Structure of Electricity Generation in Indonesia

The main legislation that governs the electricity sector in Indonesia is Law No. 30/2009 on Electricity.[178] Passed in 2009, the law ruled that the state-owned PT PLN would no longer have a monopoly on the electricity sector and increased regional autonomy and the participation of the private sector in the business of power supply, including power generation, transmission, distribution and the sale of power to consumers. The government and regional governments, in accordance with their respective authority, determine policies, regulation, supervision, and management of the power supply business. Figure 5 illustrates schematically the current institutional landscape of the Indonesian power sector.

[178] IEA, "Electricity Law (No. 30/2009)," *Policies and Measures: Indonesia*, last modified March 20, 2015, accessed August 1, 2016, http://www.iea.org/policiesandmeasures/pams/indonesia/name-140166-en.php.

The role of the private sector in Indonesia's power supply business is mostly still limited to power generation; there is little private sector participation in electricity transmission and distribution. Investors tend to participate in power generation because the investment in generation is cheaper and more profitable. Independent power producers (IPPs) may generate and sell electricity to PT PLN under a Power Purchase Agreement (PPA). Meanwhile, in terms of the transmission and distribution networks, government regulation provides the opportunity for joint use of transmission and distribution networks between the license holder of a power supply business and those who will utilize the transmission and distribution networks. The price for the lease of electricity transmission and distribution networks must be approved by the government.

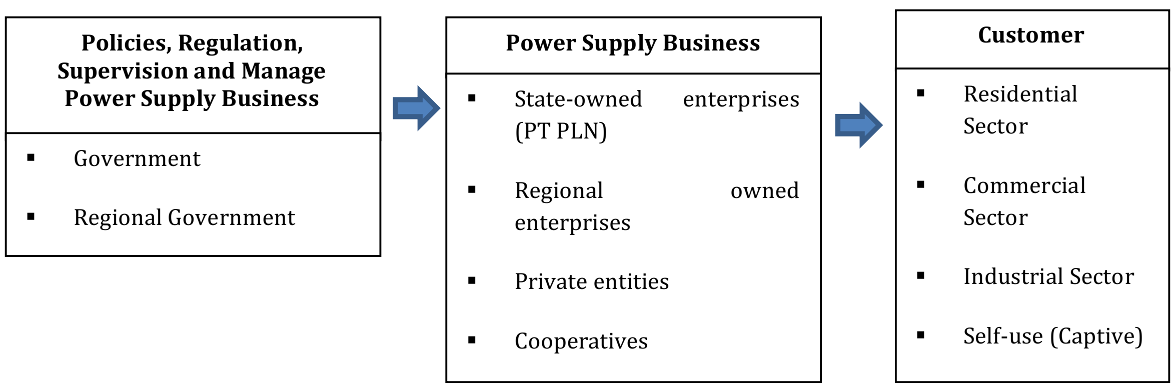


Figure 5: Schematic of Structure of Electricity Sector in Indonesia

8.6 Appendix - Energy Distribution Efficiency in Indonesia

Although total energy losses in Indonesia have been decreasing for the past 7 years, the numbers are still high (see Table 13), hovering around 10 percent. In the table, the percentages are calculated by dividing the energy lost during transmission and distribution by the total net energy produced (in kWh). Net energy production comes from all PT PLN plants as well as IPP providers, after subtracting off the energy used at the point of generation.

According to the World Bank, the corresponding figures in 2013 for Thailand, Singapore, and Malaysia were 6 percent, 0 percent, and 4 percent respectively.[179] Large energy losses in Indonesia contribute to a lack of efficiency between energy production and distribution to consumers, potentially inflating the apparent need for electricity growth. Mitigation of energy losses in the transmission and distribution systems could help reduce the overall generation cost of electricity and the need for significant target capacity increases.

[179] World Bank, "Electric Power Transmission and Distribution Losses (% of Output)."

Table 13. Energy losses in the Indonesian electricity system in recent years

Year	Transmission (%)	Distribution (%)	TOTAL (%)
2008	2.17	8.29	10.45
2009	2.18	7.93	10.11
2010	2.25	7.64	9.89
2011	2.25	7.34	9.41
2012	2.44	6.95	9.21
2013	2.33	7.77	9.91
2014	2.37	7.52	9.71

Source: PLN Statistics, 2014

8.7 Appendix - Solar Power in Indonesia

The development of solar power has strong potential in a tropical location like Indonesia. The total potential for grid-connected solar photovoltaics in Indonesia has been estimated at 1492 TWh, much more than the total electricity generated in the country currently.[180] The installed capacity of solar power in 2014 reached 71.02 MW in the country, and was comprised of 5 MW of power inter-connected to PT PLN's grid (on-grid) and 66.02 MW off-grid.[181] Table 14 describes the three types of solar power installations currently found on Indonesian small islands, based on data recorded by Directorate of Development of Small Islands and the Ministry of Marine Affairs and Fisheries (Kementerian Kelautan dan Perikanan – KKP) for 2014.

In addition, PT PLN has launched a number of programs to foster solar power development in Indonesia:

1. *Tourist Islands PV Program*: 6 locations with a total capacity of 0.92 MWp.
2. *Frontier Islands PV Program*: 8 locations with a total capacity of 1.34 MWp.
3. *100 Islands PV Program*: phase 1 includes 36 locations with a total capacity of 7 MWp and phase 2, which is still in the planning stages, is scheduled to include 78 locations with a total capacity of 13 MWp.
4. *1,000 Islands Solar PV Program*: which is still at the stage of funding preparation, but was launched in 2012; the number of locations in this project may be as many as 672 sites with a total capacity of 119 MWp.

---

[180] Veldhuis and Reinders, "Reviewing the Potential and Cost-Effectiveness of Grid-Connected Solar PV in Indonesia on a Provincial Level."

[181] ESDM, "Rencana Strategis Kementerian ESDM Tahun 2015-2019 [Ministry of Energy and Mineral Resources Strategic Plan 2015-2019]," (Jakarta, Indonesia: Menteri Energi dan Sumber Daya Mineral, April 10, 2015), 43, http://prokum.esdm.go.id/renstra%202015/DATA%20to%20MAIL%20NEW%20REV%20BUKU%20RENSTRA%202015.pdf.

Table 14. Types of solar power installations on Indonesian small islands

Type	Implementation	Number of Islands
Solar Home System (SHS)	This type is individually operated and people can directly turn on and off the electricity supply. Electricity is provided from solar panels with capacity of around 50-80 Wp, which are usually installed in 3-5 points to turn on 3 watt LED light bulbs.	By 2014, 47 small islands in Indonesia have been electrified by SHS
Hybrid System	This type uses 2 or more power generation plants with different energy sources, such as Solar Power Plants, micro hydro, and wind power. This kind of system is suitable for areas out of reach from PLN or Diesel Power Plants (Pembangkit Listrik Tenaga Diesel – PLTD)	By 2014, 9 small islands in Indonesia have been electrified by Hybrid Systems
Centralized System	All the major components in a centralized system, such as solar modules, regulators, inverters, and electric power breakers, are installed in one location. This type has the capacity of 1 to 500 kWp, which can cater to the electricity needs of up to 200 households. Energy supplied by a centralized Solar Power Plant is distributed to houses through low voltage (200V) and medium voltage (20kV) alternative current.	By 2014, 11 small islands in Indonesia have been electrified by Centralized System

Source: Directorate General of Electricity, Statistic of Electricity 2014, Ministry of Energy and Mineral Resources: Jakarta.

To boost the utilization of solar power, the government has recently issued a program to develop solar power on rooftops. In RUPTL 2015-2024, PT PLN has set up a plan for small-scale solar power plants with a total installed capacity of 321 MWp by 2024.[182] Furthermore, in a bid to attract private sector participation in solar PV development, the government has also issued regulation setting a ceiling price for solar PV.

Despite its low utilization at present, the contribution of solar power to the electricity sector is projected to increase in the future. According to one scenario in the National Energy Policy Outlook 2014, the installed capacity of solar power in the period 2013-2050 is projected to increase by an average of 14 percent per year.[183]

---

[182] Oo Abdul Rosyid, "Opportunities and Challenges for Solar PV Rooftop in Indonesia" (presented at the The 2nd Asia Renewable Energy Workshop "from Research to Industrialization," Jakarta, Indonesia, December 2, 2015), accessed August 1, 2016, https://www.asiabiomass.jp/item/arew2016/arew02_08_4.pdf.

[183] Dewan Energi Nasional, *Outlook Energi Indonesia 2014* (Jakarta, Indonesia: Dewan Energi Nasional, December 23, 2014), 120.

8.8 Appendix – Summary Table of Electrification in Indonesia

Table 15. Power Generation and Power Transmission in Indonesia

Area	Power Generation	Power Transmission
Sumatra (all provinces in Sumatra Island, Riau Islands, and Bangka Belitung)	Installed power plant capacity as of 2014 was 10,295 MW which consists of 7,269 MW by PT PLN, 980 MW by Independent Power Producer (IPP), 689 MW by Private Power Utility (PPU), and 1,358 MW by Non-Fossil Fuel Operating Permit (Izin Operasi non Bahan Bakar Minyak – IO non-BBM).	Two main interconnected electrification systems owned by PT PLN: North Sumatra Interconnection System (Sumatera bagian Utara – Sumbagut), connecting Aceh and North Sumatra province through 150 kV High Voltage Transmission Line (Saluran Udara Tegangan Tinggi – SUTT). Central and South Sumatra Interconnection System (Sumatera bagian Selatan Tengah – Sumbagselteng), connecting West Sumatra, Riau, Bengkulu, Jambi, South Sumatra, and Lampung through 150 kV SUTT. However, Lahat and Kiliran Jao are served by 275 kV Extra High Voltage Transmission Line (Saluran Udara Tegangan Extra Tinggi) SUTET. In Batam Island, a 150 kV SUTT is owned and operated by PT PLN Batam. In August 2006 Sumbagut and Sumbaselteng were connected by a 150 kV SUTT, however due to technical reasons the systems are still separated.
Java (all provinces in Java Island, Bali, and Madura)	Installed power plant capacity as of 2014 was 35,783 MW which consists of 25,342 MW by PLN, 8744 MW by IPP, 1518 MW by PPU, and 179 MW by IO non-BBM.	Jawa-Bali Interconnection System, consisting of three voltage types: 500 kV Extra High Voltage Air Transmission (SUTET) as the backbone 150 kV and 70 kV High Voltage Air Transmission (SUTT) as the connecting line to the central charge
Kalimantan (all provinces in Kalimantan and Tarakan	Installed power plant capacity as of 2014 was 2,512 MW which consists of 2,027 MW by PLN, 282 MW by IPP, 143 MW by	A small 150 kV SUTT have been installed in small areas of West and East Kalimantan, as well as some areas in Central Kalimantan which are connected to South Kalimantan's

Area	Power Generation	Power Transmission
Islands)	PPU, and 55 MW by IO non-BBM.	electricity generation system.
Sulawesi (all provinces in Sulawesi Island)	Installed power plant capacity as of 2014 was 2942 MW which consists of 1560 MW by PLN, 898 MW by IPP, and 485 MW by IO non-BBM.	Sulbagut electrification system connects North Sulawesi and Gorontalo by a 150 kV SUTT Sulselbar electrification system connects South Sulawesi and West Sulawesi by a 150 kV SUTT. A 275 kV SUTET is used for energy transfer from PosoWind Generated Power Plant to the Sulselbar system
Nusa Tenggara Islands (West Nusa Tenggara and East Nusa Tenggara Islands)	Installed power plant capacity as of 2014 was 747 MW which consists of 611 MW by PLN, 16 MW by IPP, and 120 MW by IO non-BBM.	In West Nusa Tenggara, a 150 kV SUTT is used for energy transfer from Lombok Steam Generated Power Plant to the central charge. Neither SUTET nor SUTT are installed in East Nusa Tenggara due to isolated and scattered electrification system and low power generation capacity.
Maluku Islands (Maluku and North Maluku)	Installed power plant capacity as of 2014 was 295 MW by PLN.	Neither SUTET nor SUTT are installed in Maluku due to isolated and scattered electrification system and low power generation capacity.
Papua (Papua and West Papua)	Installed power plant capacity as of 2014 was 491 MW which consists of 275 MW by PLN, 21 MW by IPP, and 195 MW by IO non-BBM.	PT Freeport installed a 230 kV SUTET for individual use.

Source: *RUKN draft report, 2015, see Rencana Umum Ketenagalistrikan Nasional 2015 - 2034* (2015): Kementerian Energi dan Sumber Daya Mineral.

8.9 Appendix – Estimate of Current Cost of Electricity Generation

The average generation cost of electricity for various types of power plants, based on 2014 PT PLN data, is presented in Table 16.

Table 16. PT PLN's self-reported average cost of generating electricity in 2014

Generation Type	Average Generation Cost per kWh (Rp/kWh)						Total
	Fuel*	Mainten ance	Deprecia tion	Other s	Person nel	Total	USD/kWh ****
Hydro	23.97	41.65	99.31	3.47	20.80	189.19	0.02
Steam	565.30	48.94	106.11	1.44	4.57	726.37	0.06
Diesel**)	2,448.35	356.07	128.37	14.76	116.75	3,064.30	0.26
Gas Turbine	2,472.46	127.97	270.56	2.82	18.99	2,892.80	0.25
Geothermal	1,007.56	137.87	144.56	1.62	15.28	1,306.88	0.11
Combined Cycle	1,203.06	48.11	75.26	3.52	5.79	1,335.74	0.12
Solar	-	465.85	3,144.13	0.95	-	3,610.93	0.31
Average	1,115.37	62.84	105.68	2.56	10.27	1,296.73	0.11
Rented***	-	-	-	-	-	375.49	0.03

*Note: * Including lubricant; **) Including diesel gas; *** Rental cost of diesel and gas turbine power plants; **** Assumption: Exchange rate in 2014, 1 USD = 11,600 IDR*

There is also a sizeable bill for subsidies for electricity in the state budget, which tends to increase every year. To overcome the heavy electricity subsidy the government, together with PT PLN, has engaged in a number of efforts, such as reducing the basic cost of the electricity supply and adjusting the electrical power tariff. Figure 6 shows the trend in various electricity-related costs in recent years.

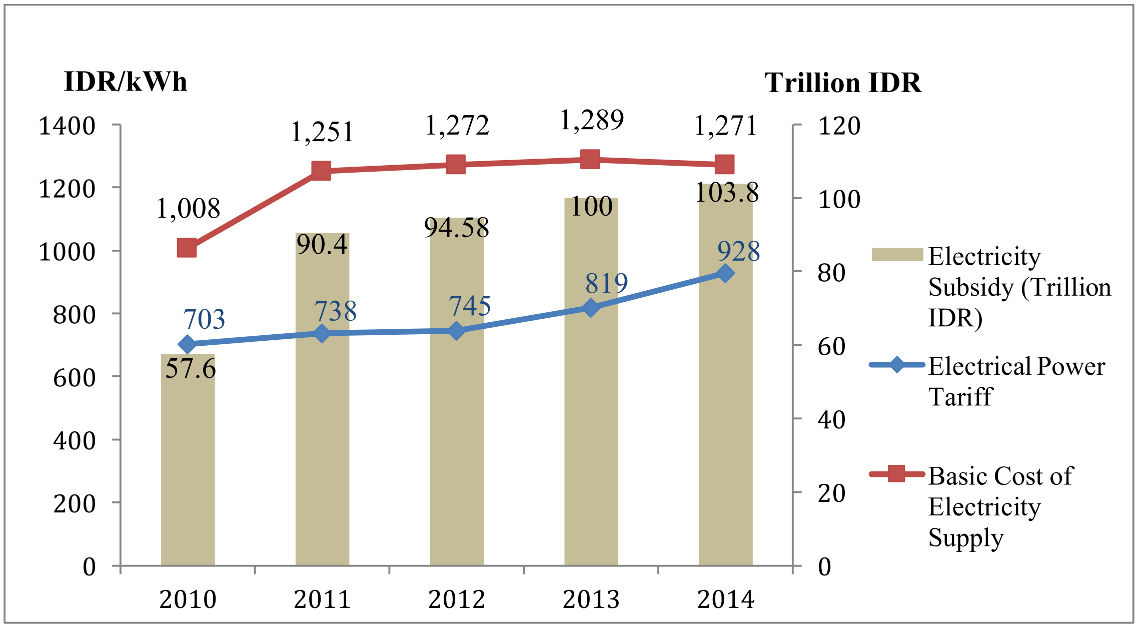


Figure 6: The evolution of electricity subsidies, power tariffs, and the basic cost of electricity from 2010-2014

Note: Electricity subsidy figure in 2014 in accordance with Revised State Budget; Source: State Budget 2015 and Ministry of Energy and Mineral Resources, 2015

8.10 Appendix – Overview of Workshop

On 25 June 2015, members of the Program on Science and Global Security, Princeton University and the Indonesian Institute of Energy Economics (IIEE) organized a workshop in Jakarta on "Nuclear Power and Small Modular Reactors (SMRs) in Indonesia: Potential and Challenges". A wide variety of policy makers and officials attended. Some of the institutions that sent representatives included the Directorate of Various New and Renewable Energy, the Directorate General of Electricity, the Directorate of Defense Strategy - Ministry of Defense, BATAN, Indonesia Nuclear Society, and the National Energy Council. Others who participated included various stakeholders in the national debate on the role of nuclear energy in Indonesia, including present and former members of government, academia, and civil societies. This group of leaders and experts were brought together and through a series of brief talks and open discussions, their views on nuclear power in Indonesia were elicited.

The discussions reflected the polarized nature of the debate over nuclear power in Indonesia. There were many who felt that nuclear power was inevitable because other sources of energy would not meet projected demand, and many who felt that nuclear energy was economically unattractive and could, at best, be considered the last option for supplying Indonesia's energy needs. For the most part, these views did not differentiate between nuclear power based on small reactors and large reactors. One exception was a speaker from the Indonesia Nuclear Society who made a case for constructing SMRs in West Kalimantan based on the limited electrical grid capacity there.