

Structuring First Indonesia Nuclear Power Plan Projects as Emerging Nuclear Nations: A Four-Dimensional AHP Decision Model

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1. Introduction

Indonesia's economy is among the fastest growing in Southeast Asia, with growth of more than 5% annually [1]. At the same time, global climate commitments through the Second Nationally Determined Contribution (2NDC) demand systematic decarbonization to realize the Net Zero Emission (NZE) target by 2060 [2], [3]. Switching away from fossil fuels is a serious challenge as coal-fired power plants currently generate more than 60% of the nation's total electricity [4]. Given the intermittent nature of variable renewable energy (VRE), there is an urgent need for a low-carbon baseload source capable of sustaining grid reliability and supporting industrial growth [5].

Nuclear power has re-emerged in this policy discourse as a strategic option to bridge the gap between large-scale demand and deep decarbonization, offering capacity factors that consistently exceed 90% [6]. Government Regulation No. 40/2025 on National Energy Policy formally repositions nuclear power as new energy rather than a “last-resort” option, while the National Electricity Master Plan (RUKN) and Electricity Supply Business Plan (RUPTL) target a First-of-a-Kind (FOAK) nuclear power plant (NPP) by 2032 and 35 GW of cumulative nuclear capacity by 2060 [7], [8], [9].

Despite this operational target, Indonesia currently lacks an established framework to guide the selection of ownership models and contractual structures for this megaproject. NPPs are characterized by extreme capital intensity, long construction durations, and high sensitivity to the Weighted Average Cost of Capital (WACC) [10]. Without an appropriate governance structure, Indonesia risks a failed financial close, cost overrun, or unsustainable sovereign debt accumulation [11], [12]. This study addresses these specific gaps by introducing a four-dimensional decision model for project structures. The framework analyzes 4 critical areas: project entity ownership, contractual risk allocation, strategic national value, and feasibility and cost of financing capital. We applied Multi-Criteria Decision Analysis (MCDA) using the Analytic Hierarchy Process (AHP) to evaluate five major global megaprojects of NPP (Barakah, Hinkley Point C, Akkuyu, Vogtle, and Flamanville 3) as comparative case studies. To ensure that this model reflects Indonesia's true policy priorities, the weight of the criteria was empirically drawn from a panel of 19 experts. Members of this panel represent 12 different domestic institutions

in the nuclear sector, including academics, industry practitioners, government officials, and regulatory bodies.

2. Methodology

The decision hierarchy decomposes the four dimensions into fourteen sub-criteria (Table 1), structuring the problem from goal to dimension to criteria to alternative (Fig. 1).

Table 1. Dimensions and sub-criteria

Dimension	Sub-criteria
Project Entity Ownership	Domestic Company Capacity; Degree of Vendor Dependence; Project Regulatory Compliance; Government Regulatory Oversight (BAPETEN)
Contractual Risk Allocation	Revenue Guarantee; Construction Risk Allocation; Government Guarantee
Strategic National Value	Alignment with National Energy Security; Transfer of Technology; Domestic Industrial Development (TKDN)
Financing Feasibility & Capital Cost	Project Bankability; Sovereign Risk Sensitivity; Accessibility of Funding Sources; Debt-Equity Structure Feasibility

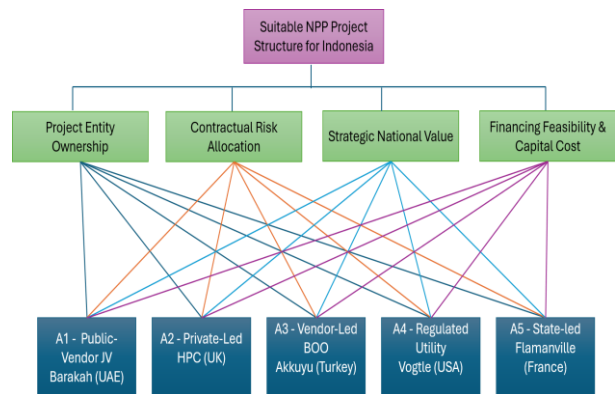


Fig. 1. Four-dimensional AHP hierarchy structure

Dimension and sub-criteria weights were obtained through pairwise comparison (PWC) on Saaty's 1–9 fundamental scale [13], administered to the 19-expert panel. Each expert completed 24 pairwise judgments across five nodes: one at the goal level and one within each dimension. A threshold of $CR \leq 0.10$ was applied, and the AHP-OS platform displayed the consistency ratio after each node and required revision before submission

whenever the threshold was exceeded [14]. All 95 individual comparison matrices retained for analysis satisfied this criterion, with a maximum CR of 0.0999, and no respondent was excluded. The ratio implemented in AHP-OS uses the linear approximation of Alonso and Lamata rather than Saaty's random-index table, and the two conventions are not interchangeable [15]. Consistency measures internal coherence within a single respondent and therefore does not establish agreement across respondents. Because the five case studies operate under divergent historical, regulatory, and market contexts, they were evaluated by direct rating rather than by pairwise comparison among alternatives. Each expert rated every case on every sub-criterion using an anchored nine-point scale ranging from 1 (fails to meet the sub-criterion) to 9 (fully meets it with strong documentary evidence). Ratings were mapped to the unit interval as $v = (r - 1)/8$, so that each value is independent of the set of alternatives included. Each alternative's transformed rating score was then multiplied by the corresponding global sub-criteria weight (derived from the PWC stage) to obtain its overall priority score, following standard AHP synthesis procedures [14], [16].

3. Case Studies

Barakah, UAE. A Public-Vendor Joint Venture between ENEC (82%) and KEPCO (18%), Barakah One Company. Initial budget of USD 20 billion (2009) rose to USD 24.5 billion at financial close (2016). Construction of Unit 1 began in July 2012; Unit 4 reached grid connection in March 2024 and full commercial operation in September 2024, backed by a fixed-price EPC/turnkey contract, sovereign financing, and Korean export credit support [17].

Hinkley Point C (HPC), UK. Originally planned as an EDF-Centrica JV, restructured after Centrica's 2013 withdrawal into an EDF (65%) - CGN (35%) joint venture formalized in 2015. Financing is underpinned by a Contract-for-Difference (CfD, October 2013) guaranteeing a GBP 92.5/MWh strike price for 35 years, supplemented by an Ofgem grant and a UK government infrastructure guarantee. Construction, begun in 2018-2019, has been delayed to 2029-2030, with EDF's February 2024 update placing total cost at GBP 31-34 billion [18], [19].

Akkuyu, Türkiye. The world's first fully vendor-led Build-Own-Operate (BOO) NPP, initiated via a 2010 intergovernmental agreement. Akkuyu Nuclear JSC is 100% owned and financed by Russia's Rosatom (with provision for up to 49% future divestment), at an estimated cost of USD 20 billion. Turkey's exposure is limited to a 15-year Power Purchase Agreement (PPA) guaranteeing offtake at a premium tariff; full operation of all four units is targeted by 2028 [20], [21].

Vogtle Units 3&4, USA. An expansion owned by a utility consortium; Georgia Power (45.7%), Oglethorpe Power (30.0%), MEAG Power (22.7%), and Dalton Utilities (1.6%) [22]. Construction began in June 2009 amid a regulated cost-recovery framework including

Construction Work in Progress (CWIP) tariffs and federal loan guarantees. Following Westinghouse's 2017 bankruptcy, the project was restructured under Southern Nuclear and Bechtel; Units 3 and 4 reached commercial operation in July 2023 and April 2024, respectively, at a final cost of USD 36.8 billion [23].

Flamanville 3, France. A First-of-a-Kind EPR-1650 unit financed through EDF's corporate balance sheet, with Enel initially holding a 12.5% stake before withdrawing amid cost escalation from EUR 3.3 billion (2007) to EUR 8.5 billion (2012) and ultimately EUR 13.2 billion (2024). Reactor criticality was achieved in September 2024, with commercial operation expected in late 2025 [24].

Table 2. Summary of five global NPP case studies

Case	Ownership Model	Key Lesson
Barakah, UAE	Public-Vendor JV (82/18)	Fixed-price EPC + sovereign backing improves bankability
HPC, UK	Foreign corporate JV (EDF-CGN)	CfD secures revenue but not construction-cost risk
Akkuyu, Türkiye	Vendor-led BOO (100% Rosatom)	No upfront capital, but full vendor dependency
Vogtle, USA	Regulated utility consortium	CWIP shifts overrun risk to ratepayers
Flamanville 3, France	State utility (EDF) balance sheet	No EPC risk transfer; the owner, and ultimately the state, absorbs all FOAK overrun and delay

4. Results

Aggregated results show that Strategic National Value (34.78%) and Financing Feasibility & Capital Cost (31.75%) receive substantially higher weight than Contractual Risk Allocation (16.89%) and Project Entity Ownership (16.59%) (Table 3). This suggests the expert panel regards strategic alignment and financing viability as more decisive than the formal ownership share of the project entity.

Table 3. Aggregated dimension weights (19-expert panel)

Dimension	Weight	Rank
Strategic National Value	34.78%	1
Financing Feasibility & Capital Cost	31.75%	2
Contractual Risk Allocation	16.89%	3
Project Entity Ownership	16.59%	4

4.1. Per-dimension breakdown

On Ownership, Barakah leads (24.5%), followed closely by Flamanville 3 (22.9%) and Vogtle 3&4 (22.7%), then HPC (17.2%) and Akkuyu (12.7%). Flamanville 3 and Vogtle 3&4 score nearly as high as Barakah because ownership remains domestic (EDF; Southern Company consortium), preserving regulatory

control. On Contractual Risk Allocation, Barakah again leads (25.9%), reflecting its fixed-price turnkey contract with strict penalty clauses, while HPC scores lowest (18.1%) since construction-cost overruns fall entirely on EDF despite the CfD. On Strategic National Value, Flamanville 3 (25.1%) narrowly edges out Barakah (24.7%), both benefiting from full domestic control, while Akkuyu scores lowest (11.4%) due to its single-vendor dependency across the entire supply chain. On Financing Feasibility, Barakah again leads (24.8%), but Akkuyu ranks second (19.9%) since the BOO structure requires no host-government capital, while Vogtle and Flamanville 3 score lowest here due to their well-documented cost overruns.

Combining dimension weights with rating-mode scores yields the overall priority ranking (Table 4).

Table 4. Overall priority ranking of five alternatives

Rank	Alternative	Score
1	Barakah (Public–Vendor JV)	24.90%
2	Flamanville 3 (State Utility)	21.22%
3	Vogtle (Regulated Utility)	20.79%
4	HPC (Corporate JV)	17.62%
5	Akkuyu (Vendor-led BOO)	15.48%

4.2. Sensitivity analysis

Robustness was tested via (i) dimension-weight perturbation [25] and (ii) leave-one-expert-out jackknife on the 19-expert panel [26].

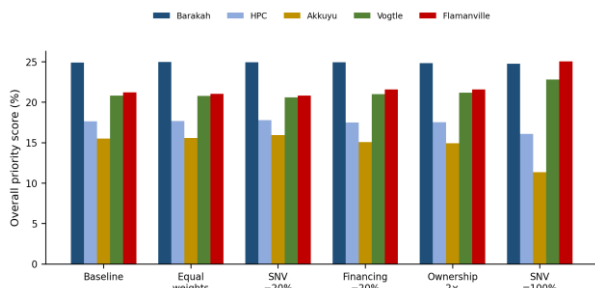


Fig. 2. Overall priority score by alternative across six perturbation scenarios

Barakah remains the top-ranked alternative under equal weighting (25% each), $\pm 20\%$ shifts in the top two dimensions, and even a 2 $\times$ increase in Ownership weight. The ranking flips to Flamanville 3 only when Strategic National Value receives a weight far above the elicited level, but the location of this switching point depends on the aggregation path. Under the group-weight path used throughout this paper (elicited value 34.78%), the flip occurs near 95% of total weight, as shown by the breakeven search in Fig. 3. Under respondent-level aggregation of individual priorities, which preserves each expert's own pairing of weights and ratings, the switching point is 78.0% against an elicited value of 34.4%. Both paths place the threshold far outside the range observed in the panel.

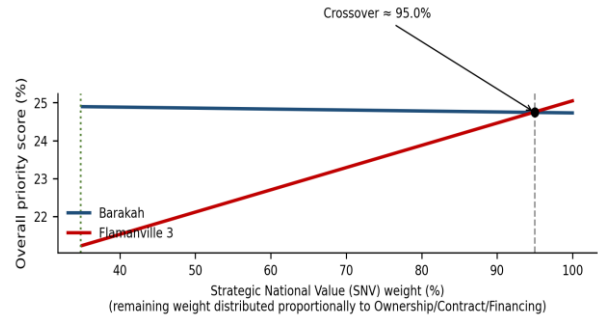


Fig. 3. Breakeven search: Barakah vs. Flamanville 3 score as Strategic National Value weight increases

The jackknife test further shows that the top two dimension ranking (Strategic National Value, Financing Feasibility) is stable across all 19 leave-one-out iterations, whereas the bottom-two (Contractual Risk vs. Ownership, 16.89% vs. 16.59%) reverse order in 14/19 iterations (74%) relative to the official aggregate, indicating this narrow distinction is highly sensitive to aggregation method and panel composition, and should be interpreted with caution.

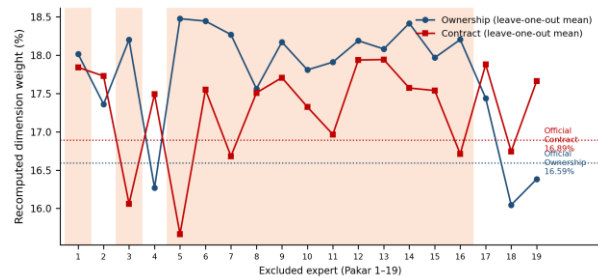


Fig. 4. Leave-one-expert-out estimates for Ownership and Contract weights (shaded = order reversed vs. official baseline)

5. Discussion and Policy Implications

Indonesia, through the renewal of Government Regulation No. 40 of 2025, officially moved nuclear power into the "New Energy" category, abandoning its old status as a last resort. Through this policy change, the RUKN and RUPTL set ambitious targets for the first nuclear power plant in Indonesia by 2032. Although the FOAK target has been set, the government has yet to determine which financing mechanism will be used, whether to rely on private capital to protect the state budget or use government funds to maintain absolute control over the project.

Like Indonesia and many other developing countries trying to build their first nuclear plants, they often face difficult challenges to balance. The government wants strict control over electricity assets, tariffs, and technology transfers. At the same time, they are usually reluctant to take on the huge financial risks associated with construction. These non-conformities often create conditions where the project is not feasible and cause negotiations with vendors to become stalemated. Policymakers must adopt a consistent

approach and realistically divide financial risk from day one.

When analyzing projects dominated by foreign equities, a prominent determining factor is non-equity sovereignty control. We can see this comparison by comparing Hinkley Point C in England and Akkuyu in Türkiye. Although both are heavily dependent on money from abroad, the UK government maintains strong influence over the project through its Contract for Difference (CfD) mechanism and strict regulatory oversight. On the other hand, Türkiye, through the BOO mechanism, acts as a buyer through an electricity purchase agreement, thus giving vendors much greater regulatory power. This suggests that national strategic value is not just how many shares the government owns but depends on strong institutional design and contractual rules.

Given the current tightness of global financial markets against new nuclear development, state intervention is fundamentally necessary. If Indonesia decides to use a Public-Vendor Joint Venture, it can utilize Danantara (which was established under Law No. 1/2025 and GR No. 19/2026) as a state-backed sovereign wealth and investment management institution. As of July 2026, Indonesia's sovereign credit profile remains investment-grade but under pressure (Table 5). Due to this macroeconomic reality, Indonesia needs to combine Danantara's capital with traditional G2G loans or support from export credit agencies (ECAs) [27]. Securing lower discount rates through these combined instruments is the only realistic way to keep the final electricity tariff affordable for the community.

Table 5. Indonesia sovereign credit rating (July 15, 2026)

Agency	Rating	Outlook
S&P Global Ratings	BBB	Stable
Fitch Ratings	BBB	Negative
Moody's	Baa2	Negative

6. Conclusion

The final synthesis of the Multi-Criteria Decision Analysis (MCDA) reveals that the structure representing the Public-Vendor Joint Venture model (exemplified by the Barakah project) obtained the highest overall priority score (24.90%). Based on the assessments of the 19-expert panel, this model excelled in three of the four analytical dimensions. These results reflect a quantitative expression of the expert panel's collective preference for the assessed criteria, rather than a categorical verdict that negates the feasibility of other structures. Each evaluated model carries a distinct trade-off profile and can be relevant depending on the prevailing macroeconomic conditions and the government's policy priorities.

In the Indonesian context, the preferred Public-Vendor Joint Venture model necessitates a strategic sharing of the financing burden between the project owner, specifically PT PLN (Persero) acting as both the state-owned partner and sole off-taker, and the reactor

technology contractor as the vendor partner. As a primary shareholder in the project entity, the state retains the necessary instruments to enforce its energy policy and direct technology transfer. Crucially, this structure facilitates the integration of the nuclear innovation ecosystem under the umbrella of the National Research and Innovation Agency (BRIN), which corresponds to the model's high scores in the Strategic National Value and Ownership dimensions.

By contrast, the Vendor-Led (Build-Own-Operate/BOO) model, exemplified by Akkuyu, ranked fifth (last) out of the five alternatives evaluated. This lower overall ranking was primarily driven by its diminished scores in the Ownership and Strategic National Value dimensions. Nevertheless, the BOO model presents a unique proposition: because the vendor fully bears the capital expenditure, the host country is relieved from providing massive upfront capital. This advantage is reflected in the model ranking second in the Cost of Capital dimension. While this characteristic may be highly attractive if Indonesia's short-term priority is to minimize fiscal exposure, these financial benefits must be carefully weighed against long-term strategic consequences. Relying on a BOO structure implies full dependence on a single foreign vendor across the entire lifecycle from design and fuel supply to waste management, ultimately sacrificing state sovereignty over critical national electrical assets.

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