The Proposal of an Adaptive Planning Method to Enhance Indonesia's Power System's Supergrid Plan

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ABSTRACT

Indonesia's power generation is still heavily dependent on fossil fuels, with about 80% of its electricity coming from coal- and gas-fired power plants. In late 2024, Indonesia published the National Electricity Plan (RUKN), outlining a roadmap toward net-zero emissions by 2060. The plan projects continued growth in power demand, driven by the emerging economy and increasing electrification. While it encourages renewable integration, it also adds new coal plants, showing Indonesia is still far from aligning with global climate goals. Nonetheless, renewable and climate-focused components must be implemented effectively to ensure progress toward a more sustainable system.

One key policy for climate change mitigation is the supergrid, a transmission network to interconnect Indonesia's main islands, now isolated. Most renewable potential lies outside Java, while most demand is concentrated on the island. A supergrid would transfer renewable energy from remote areas to load centers, addressing this imbalance. Though requiring major investment due to geographical separation of supply and demand, the supergrid offers multiple benefits. It enhances stability, supports high short circuit levels, and strengthens ASEAN's regional electricity trade. This makes it not only a tool for renewable access but also for reinforcing domestic and regional power systems.

Although the supergrid offers significant benefits, its development faces numerous challenges, primarily due to uncertainties. Among many, there are two important uncertainties related to this work. First, climate change poses a serious threat. The author's preliminary insight from ongoing work about the assessment of climate change impacts indicates that Indonesia's power system could be vulnerable to extreme heat, which can reduce generation performance, and to flooding risks driven by sea level rise.

Second, there are uncertainties inherent in long-term planning itself. Project delivery timelines may be delayed, future power demand may fluctuate unpredictably, and costs may vary significantly, all of which add complexity to supergrid development. Moreover, due to the single supergrid timeline, when the conditions change, it is difficult to adapt to the new situation, and the plan needs to be changed. These uncertainties not only increase the technical and financial risks but can also lock the system into suboptimal pathways. Without a more flexible approach, the supergrid plan could face stranded assets, reduced investor confidence, and limited ability to respond to unexpected developments.

One of the approaches to address the mentioned uncertainties and support the stakeholders to make a robust decision is the use of adaptive planning methods. Adaptive planning is designed for complex and wicked problems where stakeholders cannot easily agree on assumptions or outcomes. In such conditions, conventional static planning often fails to capture the wide range of possible futures.

Therefore, a more robust plan is needed. Several methods can support decision-making under deep uncertainty. Among them, the XLRM problem framing, robust decision-making (RDM), exploratory modelling, and adaptive planning approaches will be combined in this work. The common principle of these methods is to stress-test multiple scenarios and identify which strategies remain effective across different possible futures. Together, they offer a way to separate robust pathways from vulnerable ones.

XLRM problem framing is a method to define the: X = uncertainties, L = policy levers, R = resources, and M = measures. By framing the XLRM, stakeholders can initiate a structured view of the overall problem. Due to the technical requirements of the long-term supergrid plan, the XLRM framework will be further operationalized by quantitative simulations using energy system optimization

and power system models within an exploratory modelling environment. This creates a bridge between qualitative framing and quantitative analysis.

Finally, the adaptive planning proposal draws from the Dynamic Adaptive Pathway Planning (DAPP) taxonomy. DAPP helps frame the solution into easy-to-read pathways that anticipate future change by providing transfer points during the plan. It also enables early identification of tipping points, conditions that would otherwise lead to a dead-end. For Indonesia's supergrid, this means decision-makers could maintain flexibility, avoid stranded investments, and prepare timely adjustments when climate or demand conditions shift.

Climate change and the current long-term planning approach in Indonesia create a complex problem with many uncertainties that will affect the supergrid development. This paper does not yet provide quantitative results; rather, it proposes an adaptive planning approach to support decision-makers in finding more robust solutions. The main contribution is to contextualize adaptive planning methods for Indonesia's supergrid, showing their potential to manage risks from climate change and long-term infrastructure challenges. Looking ahead, future work should test these methods through quantitative modelling and stakeholder engagement, so that the proposed pathways can be further developed into actionable strategies for Indonesia's energy transition.

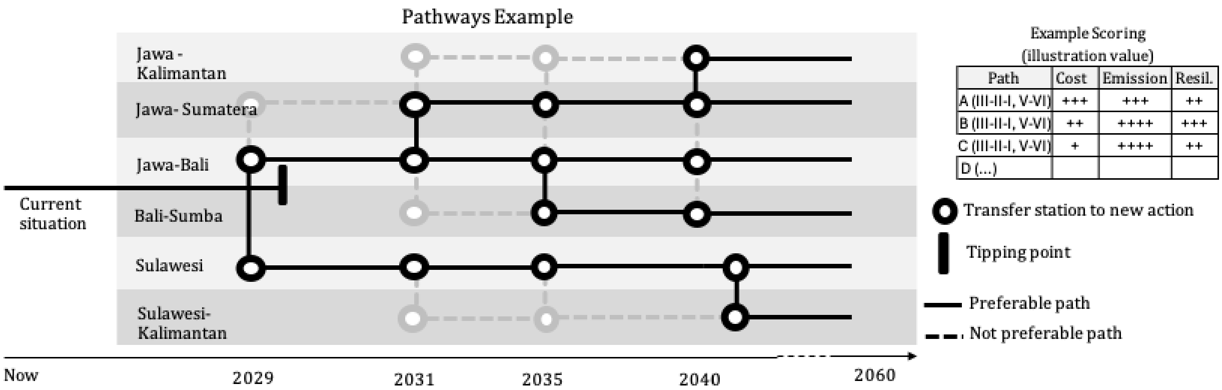

Figure 1. Example of Interconnection Pathways.

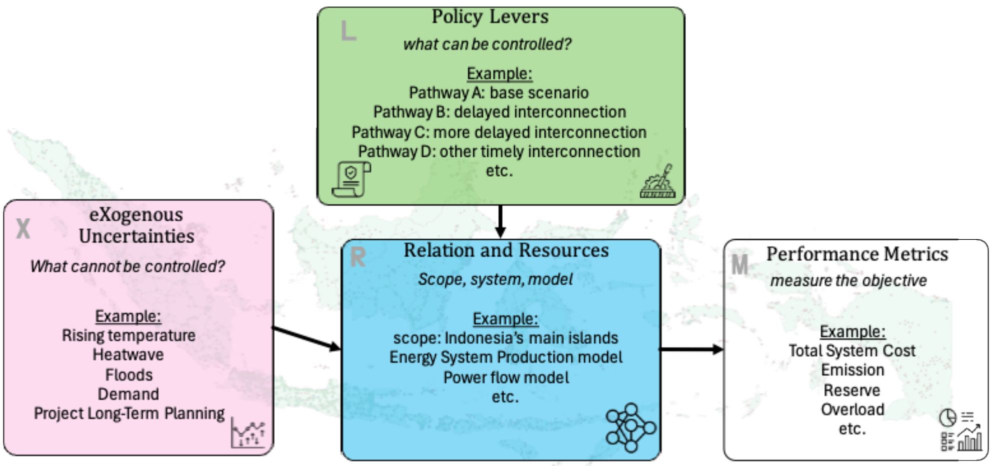

Figure 2. XLRM Problem Framing.

Keywords: *Climate Change, Power System Planning, Indonesia, Supergrid.*

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