TOWARD A LOW CARBON AND CLIMATE RESILIENT POWER SYSTEM: A CASE OF THE INDONESIAN POWER SECTOR

Kamia Handayani, Department of Governance and Technology for Sustainability, University of Twente, the Netherlands and PT PLN (Persero), Indonesia, Email: k.handayani@utwente.nl
Tatiana Filatova, Department of Governance and Technology for Sustainability, University of Twente, the Netherland, Phone: +31534899111, Email: t.filatova@utwente.nl
Yoram Krozer, Department of Governance and Technology for Sustainability, University of Twente, the Netherlands, Phone: +31534899111, Email: y.krozer@utwente.nl
Pinto Anugrah, Department of Electrical Engineering, Universitas Negeri Padang, Indonesia, Email: Pinto Anugrah pinto.anugrah@ft.unp.ac.id

1. Overview

One in five people on the planet today still lacks access to electricity (United Nations Development Programme, 2018). Hence, ensuring universal access to energy services is a vital goal for the power sector worldwide. However, this goal has to be aligned with another pivotal global ambition: curbing climate change. Moreover, while the power sector becomes the target for reducing global carbon emissions, the sector itself is vulnerable to the adverse impacts of the changing climate. Climate change affects the power sector in two ways: through acute, disruptive, severe weather events and gradual long-term changes in climate parameters (Sieber, 2013). This paper aims to analyze the interplay between three goals –electrification, climate change mitigation, and climate change impact and adaptation– taking the Indonesian power sector as a case study. The country strives to achieve near-universal electricity access by 2020 (Government of The Republic of Indonesia, 2014). While today the country's electricity supply relies heavily on fossil fuels, it pledges to reduce its carbon emissions by 29% in 2030 (Government of The Republic of Indonesia, 2016). Meanwhile, the electricity supply in the country is often interrupted by severe weather events (PLN Yogyakarta, 2015), which promise to be even more frequent and severe in the climate-changed world. We address this problem by providing a framework for an integrated analysis of electrification, climate change mitigation, and climate change adaptation for developing a low-carbon and climate-resilient power system.

2. Methodology and data

To address the nexus between electrification, climate mitigation, and climate adaptation ambitions, we employ a mix of methods. This approach allows us to integrate both climate change mitigation and adaptation into the analysis of long-term power sector development in Indonesia. For the mitigation part, we develop a long-term scenario for the power sector development taking into account the country's low-carbon development policy. Subsequently, we use the Long-range Energy Alternative Planning System (LEAP), an energy system model developed by the Stockholm Environment Institute (SEI), to analyze the electrification & climate mitigation scenarios. Furthermore, we carried out fieldwork to identify historical impacts of severe weather and changes in climate parameter on power generations. Subsequently, we setup parameters for integrating climate change impact and adaptation into LEAP.

3. Results

3.1. Electrification and climate change mitigation: LEAP results

The demand for electricity in Java-Bali islands is projected to increase over fivefold from around 175 TWh in 2017 to 904 TWh in 2050. Consequently, the electricity generation from power plants – which also accounts for own consumption and transmission losses – increases at the same pace i.e., 982 TWh in 2050, compared to 182 TWh in 2017. While fossil fuels served most of the demand for electricity in the base year, under the low-carbon pathway scenario, they gradually reduce their share in the Java-Bali electricity mix. Renewables compose 23% and 31% of the electricity mix by 2025 and 2050, respectively (see Fig. 1). Accordingly, there is a significant change in the deployment of energy resources and technologies where biomass, solar, and wind now appear in the electricity mix. The increased deployment of renewable energy in the low-carbon scenario results in a reduction in cumulative CO2 emissions of the Java-Bali power system. By 2025 and 2050, the cumulative CO_2 emissions under the low-carbon scenario are 3% and 23% lower, respectively compared to the reference scenario (least-cost electrification scenario). The low- carbon scenario involves an estimated 76.6 billion USD of total costs by 2050, which is 8% higher compared to that in the reference scenario.

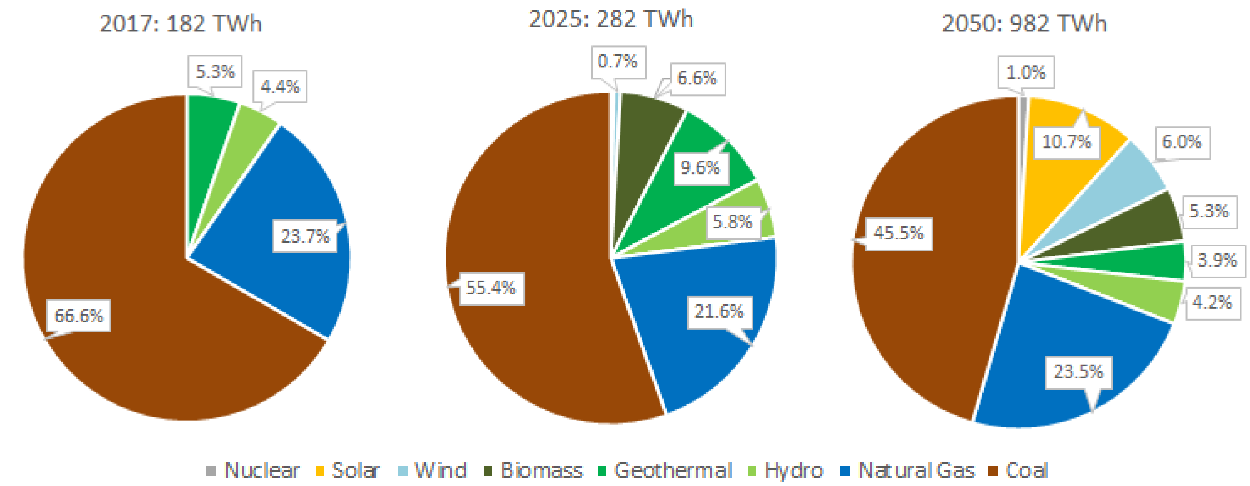

Fig. 1 The Java-Bali electricity mix in 2017, 2025, and 2050

3.2. Climate change impacts for the electricity sector

Based on the fieldwork and reviews of internal power plants documents, we identified a number of effects of severe weather and changes in climate variables on power generation. So far, in Indonesia, severe weather mainly affects fuel coal quality and stock of CFPPs and cooling water supply in CFPPs and NGPPs. Heavy precipitation often reduces coal quality causing reductions in the power plant's capacity factor. Extreme events also cause direct monetary losses for electric power utilities, such as the case of jellyfish inflow in 2016, which forced Paiton#9 to shut down for 20 days, causing an estimated financial loss of 21.3 million USD for the utility. Meanwhile, gradual climate change such as changes in precipitation patterns affect HEPPs' operation. Furthermore, our fieldwork confirms that ambient air temperature influences the power output of NGPPs. To some extent, utilities have implemented adaptation actions in response to severe weather. These actions encompass behavioral, managerial and technological responses. The technological responses include investment in the flood control system in power plants and the application of weather modification technology to create artificial rain to increase water inflow to HEPPs' reservoirs. Behavioral and managerial responses include alteration of coal shipment contract, increase in routine checking of distribution networks in anticipation of the approaching rainy season, and modification of HEPP's operation pattern plan.

3.3. Modeling climate change impacts and adaptations in LEAP

Referring to the effects of climate change as discussed in Section 3.2, we identify the most detrimental effects and transform them into changes in technical characteristics of power plants. The changed technical characteristics include capacity factor and or efficiency of the respective power plants (de Lucena, Schaeffer and Szklo, 2010; Asian Development Bank, 2012; Anugrah *et al.*, 2015). These changes are expected to influence the energy resource/technology mix and installed capacity, and reflect the costs of climate change and benefits of adaptation. Table 1 lists climate change impacts on three types of power plants to be integrated into the LEAP model.

Table 1 Accounting for climate change adaptation in the LEAP Model

Climate change impacts on power generation	Source of impact	Technical characteristics to be adjusted in LEAP
Reduction in power output of the natural gas turbine	Increase in surface air temperature	Capacity factor
Changes in water availability for hydroelectric power plants	Changes in precipitation and temperature	Capacity factor
Reduction in the efficiency of the cooling water system in thermal power plants due to increased temperature of inlet cooling water	Increase in seawater temperature	Efficiency
Reduction in power output of coal-fired power plants due to the wet coal	Increased precipitations	Capacity factor

4. Conclusions

The power sector contributes to climate change and is simultaneously, affected by its adverse impacts. Therefore, it is crucial that the development of the sector not only shifts to the low-carbon path but also improves its resilience to climate change related disruptions.