# *Evaluating the impact of climate change on hydropower availability in the Java-Bali power system, Indonesia*

Kamia Handayani, Department of Governance and Technology for Sustainability, University of Twente, the Netherlands and PT PLN (Persero), Indonesia, Email: k.handayani@utwente.nl
Pinto Anugrah, Department of Electrical Engineering, Universitas Negeri Padang, Indonesia, Email: pinto.anugrah@ft.unp.ac.id
Tatiana Filatova, Department of Governance and Technology for Sustainability, University of Twente, the Netherland, Email: t.filatova@utwente.nl
Faris Al Rasyid, PT Pembangkitan Jawa Bali, Indonesia, Email: faris.al@ptpjb.com

## 1. Overview

Hydropower is a cost-effective technology to generate electricity. To date, the hydropower installed capacity has reached nearly 1.3 terawatts worldwide (IRENA, 2018). Since hydropower is also a clean source of electricity, it plays an important role in mitigating climate change. However, climate change is expected to intensify the global hydrological cycle, resulting in modifications of river flows' size and seasonality, which may influence the water availability for hydropower (Sample et al., 2015). This paper aims to assess the impacts of climate change on the water availability for hydropower in Java-Bali islands, Indonesia, and successively, on the future electricity supply mix of the Java-Bali power system.

## 2. Methods

We employ the Water Evaluation And Planning system (WEAP) and the Long-range Energy Alternatives Planning system (LEAP) software tools to quantify the impacts of the future climate on hydropower availability and subsequently, evaluate the impacts on the electricity supply mix in the Java-Bali power system. Both WEAP and LEAP are developed by the Stockholm Environment Institute and are sister tools that share many of the same design feature and approaches. Moreover, WEAP has a built-in link with LEAP, allowing the integration of WEAP outputs into the system-wide LEAP model (Sieber, 2019).

Firstly, we quantify the impacts of climate change on the availability of water for hydropower using WEAP. After which, we input the WEAP modeling results into the LEAP model. Secondly, we simulate the expansion of the Java-Bali power system from 2019 through to 2050, taking into account the objective of meeting Indonesia's renewable energy targets and the impacts of the future climate on hydropower. We develop five scenarios for the Java-Bali power system expansion. The first scenario, i.e., reference scenario, does not consider climate change impacts. Meanwhile, the four other scenarios taking into account climate change impacts based on Representative Concentration Pathway (RCP) scenarios used in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. The low-emission scenario (RCP2.6) assumes that the concentration of $CO_2$ reaches approximately 490 $CO_2$eq. by 2100. RCP4.5 is one of the medium stabilization scenarios assuming a stable radiation intensity at approximately 4.5 W/m$^2$ or equivalent to 650 ppm $CO_2$ eq. after 2100. RCP 6.0 assumes the $CO_2$ concentration keep stable at approximately 850 $CO_2$eq. after 2100. RCP8.5 is the one very high baseline emission scenario, which assumes a constant rise pathway leading to 8.5 W/m$^2$ of the radiation intensity (more than 1,370 ppm $CO_2$ eq.) in 2100 (Zhang et al., 2017)

## 3. Results

Our results indicate that the annual water availabilities are similar across climate change scenarios except those in the RCP4.5 scenario where the water availabilities are higher from 2040 onwards, as depicted in Fig.1 for Cirata and Saguling HEPPs. These two HEPPs are located in the Citarum river basin and are the largest HEPPs in Indonesia. We extrapolate these results to the rest of HEPPs throughout the Java-Bali islands when simulating the Java-Bali power system expansion. The simulation results show a slight increase in the Java-Bali hydropower production from 2020 to 2039 in all climate change scenarios compared to the reference scenario (Fig. 2). However, from 2040 onwards, a slight decrease in hydropower production is observed under the high-emission scenario (RCP8.5). Likewise, the increased percentage of hydropower production is lower under the RCP2.6 and RCP6.0 scenarios. Moreover, the electricity production under RCP8.5 scenario decreases below the reference scenario. Meanwhile, under the RCP4.5 scenario, hydropower production rises even higher.

(a) (b)

**Fig. 1** Annual availability of water for Cirata HEPP (a) and Saguling HEPP (b)

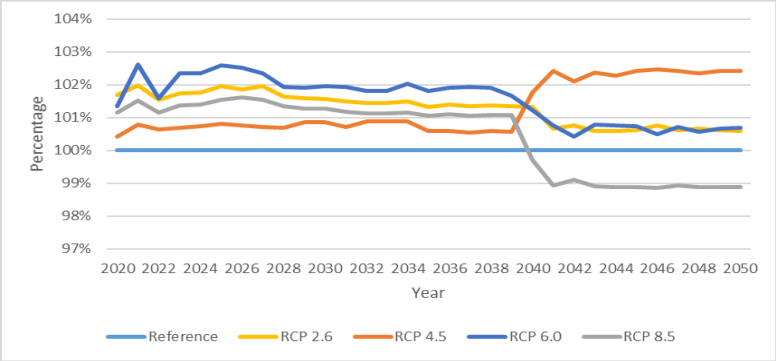


**Fig. 2** The percentage of electricity production variations in climate change scenarios compared to the reference scenario

Meanwhile, we observe no significant differences in term of the electricity mix between the reference and climate change scenarios (Fig. 3). This is partly because our simulations consider the target of renewable energy share in the national energy mix by 23% and 31% in 2025 and 2050, respectively. Hence, the configuration of the electricity mix should comply with these targets. Moreover, the hydropower potential is limited compared to other sources such as coal and solar. During the time horizon of this study, all hydropower potential in Java-Bali is gradually exploited to meet the renewable energy targets; therefore any additional capacity required to meet the electricity demand are added from other energy sources, resulting in relatively similar electricity mix across all scenarios.

(a) (b)

**Fig. 3** Electricity supply mix of the Java-Bali power system in 2025 (a) and 2050 (b)

## 4. Conclusions

As far as gradual changes in temperature and precipitation are concerned, climate change has no significant impacts on the water availability for hydropower in the Java-Bali islands. Likewise, the impacts on the electricity supply mix in the Java-Bali power system as a whole is minor. However, hydropower contributes to the achievement of Indonesia's renewable energy targets and plays an essential role as peaker power plants in the Java-Bali power system. Extreme weather events, such as droughts may have implications on its role to serve the peak electricity demand. Meanwhile, days of extreme precipitation may trigger water spill from the reservoirs, causing flooding downstream. The consideration of these extreme events on power system expansion is an essential topic for future work.