ASSESSING HYDROPOWER VULNERABILITY UNDER UNCERTAIN CLIMATE CHANGE IN DEVELOPING COUNTRIES: CASE OF ECUADOR

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Overview

Climate change will impact natural and human systems, specially energy systems and the technologies that are most dependant or exposed to climate variations (DOE, 2015). Hydropower is one of the most vulnerable systems to climate change due to its dependence on the hydrological cycle in which temperature and precipitation are dominant drivers. This leads to energy security concerns in countries that are highly dependant on this technology, specially in developing regions such as Africa, Asia and South America where there has been a recent upsurge in hydropower infrastructure (WEC, 2015). Energy system models that usually consider deterministic and constant hydro-climatic conditions collide with climate change uncertainty and the myriad of possible scenarios that result from different climate modelling exercises. This underlines the challenge of incorporating impacts of hydro-climatic change into these models due to its inherent uncertainty (Shadman, Sadeghipour, Moghavvemi, & Saidur, 2016). This research intends to present a framework for generation capacity planning that includes climate change uncertainty and therefore delivers a power generation portfolio that is more robust or adapted to climate change variations. The Republic of Ecuador will be used as a case study to apply the framework, since hydropower currently dominates 46 per cent of total electricity generation (2014) and there are ambitious investment plans to reach more than 90 per cent of hydropower participation in the grid by 2017 (MICSE, 2015). The location of Ecuador also posits interest, i.e. the tropical Andes, which is one of the areas where impacts of climate change are still highly uncertain. The results presented in this extended abstract are initial and part of a wider doctoral research project, which will develop a TIMES energy system model for Ecuador's power sector and later on use a mean-variance portfolio theory approach to handle uncertainty.

Methods

The proposed methodology consists in a three-step approach, which is depicted in Figure 1. The first step, 'Hydro-climate Analysis', uses a statistical hydrological model to assess how inflow into hydropower stations will vary according to projections of a large General Circulation Model (GCM) ensemble, namely the Coupled Model Intercomparison Project 5 (CMIP5), which was used in the latest Assessment Report of the Intergovernmental Panel Climate Change (IPCC-AR5) (Taylor, Stouffer, & Meehl, 2012). This statistical model will be 'signalled' by the changes in temperature and precipitation of the CMIP5. The results of this step are a set of monthly inflow time series into Ecuador's largest hydropower plants. The second step, 'Energy Modelling', consists on building a TIMES energy systems optimisation model at a plant-by-plant detail level that represents the current and future power system of Ecuador up to 2050 (Loulou & Labriet, 2008). The climate change signalled time series of inflow from step one will be used to characterize the availability of hydropower and assess changes in total system generation cost, emissions, etc., according to different generation portfolio options. The optimisation approach of the model and the time-resolution at a monthly level of hydropower availability will bring insights compared to models that consider constant annual availability factors. The third and final step, 'Uncertainty Analysis', seeks to include uncertainty of climate change projections as additional criteria for assessing the least-cost generation portfolios obtained in step two. The range of inflow due to different climate change projections from the CMIP5 will be used as a proxy to parameterise the scenario probability space for hydropower output. This information, additional to the historic volatility of fossil fuel prices, will be used as inputs for a mean-variance portfolio theory approach applied to the power sector as has been initially done by (Awerbuch & Berger, 2003). The outcome of this step is a comparison of different generation portfolio options according not only to their least-cost but to their cost-risk, this being defined as the standard deviation of the portfolio generation cost.

Results

This first step of the proposed methodology has been applied to assess the inflow to Ecuador's largest hydropower station: Paute-Molino, an 1100MW unregulated run-of-river facility in the southeast of the country. Results for 39 GCM models for RCP8.5 and averaged for the last 30years of the century (2071-2100) have been plotted in Figure 2 (*left panel*) and show that the mean of the CMIP5 ensemble (in red) projects an annual increase of inflow of 16% compared to the historic value (in solid black), however mostly during the wet season. The historic standard deviation is plotted (in black dashed lines) and is much narrower than the projected standard deviation of the CMIP5 ensemble (shaded area), meaning that so far there is a wider uncertainty about what the projected inflows could look like by the end of the century. The individual results of 39 GCM have been also plotted (in light grey dotted lines) and show the discrepancies among the models, some accounting for as much as a 300 per cent increase while others projecting a decrease in 80 per cent, as can be seen in Figure 2 (right panel) where projected inflows for ensemble mean and individual GCM have been normalised compared to the historic baseline.

Figure 1 Proposed methodology for assessing the impact of uncertain climate change on hydropower generation.

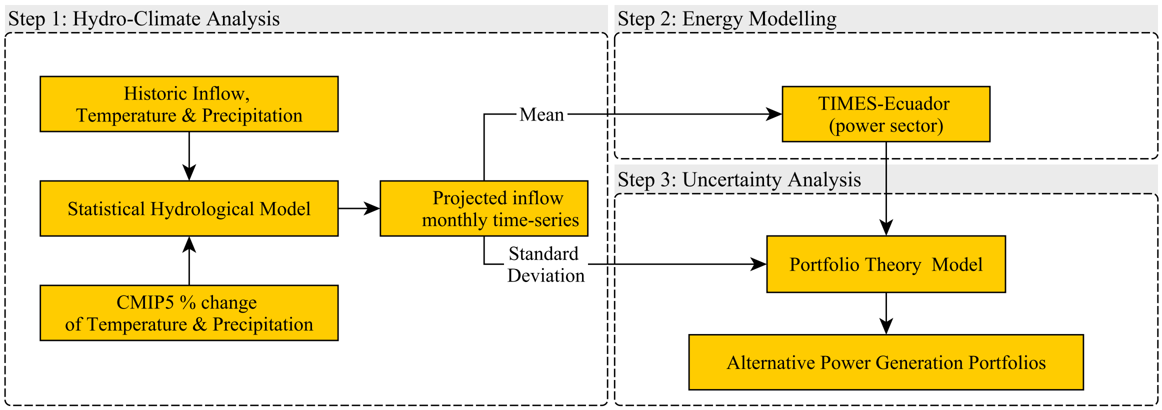
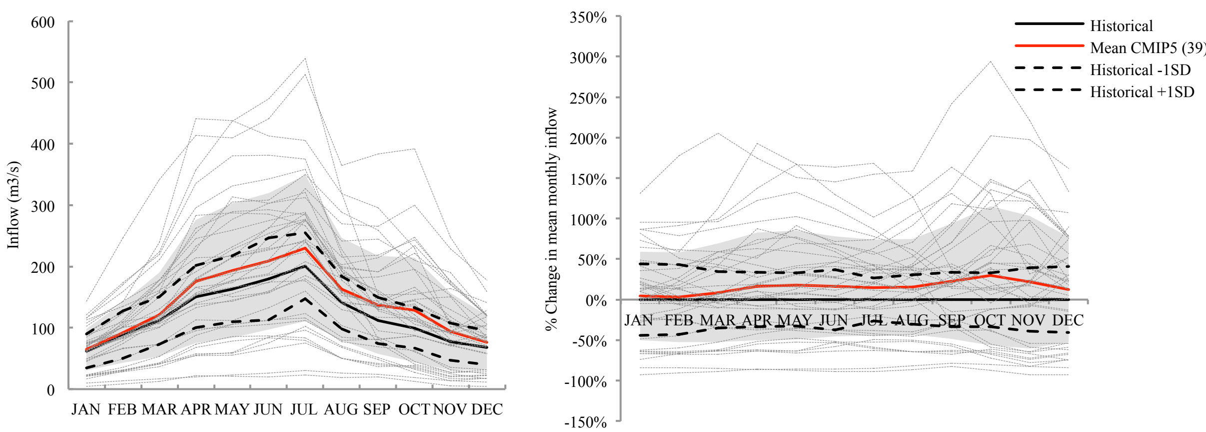


Figure 2 Inflow regime for the baseline, each GCM (39) and the ensemble mean projection in the Paute Hydropower Station for the RCP8.6 and for 2071-2100. The left panel shows absolute values and the right panel percentage changes from the baseline. Shaded area represents the ±1 Standard Deviation of the GCM CMIP5 ensemble.



Conclusions

Working with annual mean availability factors for hydropower in an energy system model to assess a power system with large shares of hydropower can mask monthly variations in inflow that can impact the system cost significantly. Also, working only with the ensemble mean (in red in Figure 1) can mask divergent results from different GCM projections that are also likely to occur thus denoting the need to give a statistical meaning of the results obtained from climate modelling exercises. This underlines the importance of including the abundant results obtained by climate modellers into the energy system modelling process to be able to assess how climate change can impact energy systems and define generation portfolios that have lower cost-risk thus being better adapted for climate change.

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