**WMO Global Energy Resilience Atlas: Climate Risk Indices for Hydropower**

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## 1. Background and Objectives

The supply of electricity from clean energy sources must double within the next eight years to limit global temperature increase [1]. Increasing the climate-dependent sources of energy means more vulnerability to potential climate changes. Therefore, exploring climate change effects on key renewables is important for strategic planning [2]. The World Meteorological Organization (WMO) is developing a Global Energy Resilience Atlas with the aim of providing early indications of the risk of climate change on renewable energy systems (Solar, Wind and Hydro). In this study, four Climate Risk Indices are developed for the hydropower sector as the largest renewable electricity technology with more than 4300 TWh global generation [3]. The final product will be globally available as an open-access interactive map that will be useful for policy decisions and investments in the hydropower sector.

## 2. Method and data

The general approach of this study is based on the proposed method by Hamududu and Kilingtveit [4]. A climate-based Hydro Risk Index (HRI) is defined based on precipitation, as this parameter has a more direct influence on river runoff, and the data is readily available for all countries. Equation 1 is proposed using the same logic in [5] for calculating climate risk index by multiplication of hazard, exposure, and vulnerability.

***HRI = Climate Hazard Indicator (CHI)* NIC * Hyp*** *(1)*

Where **NIC** is normalized installed hydropower capacity and **Hyp** is the proportion of hydropower generation of country energy mix. The following four CHI are defined: mean annual precipitation, precipitation variability as an indication of likelihood and frequency of extreme events, standardized precipitation index (SPI)_wet as an indication of flooding, and SPI_dry as an indication of drought. The HRI mean value for each indicator is calculated for 30-year periods by aggregating the grid cells (1 degree) values for each country (Figure 1). ERA 5 reanalysis data and CMIP6 data based on the three following Shared Socioeconomic Pathways (SSP) climate scenarios are used: SSP126 (sustainability), SSP245 (middle of the road), and SSP585 (Fossil fuelled development) [6]. **NIC** data is extracted from the global power plant database [7] and the Atlas of hydropower in Africa [8]. **Hyp** data is extracted from the IRENA database [9].

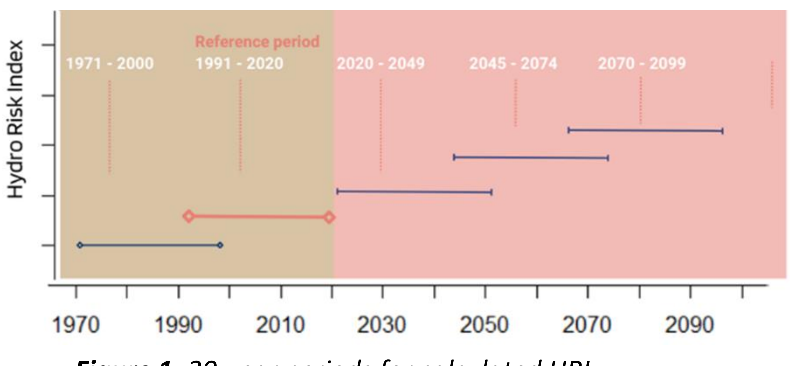


***Figure 1**: 30-year periods for calculated HRI*

## 3. Results and discussion

We have chosen Sweden as an example here to show the results. Figure 2.a is in agreement with the increased trend of river runoff reported in [4]. For SPI_wet index, the values for climate scenarios (except for the ssp585) are lower than the historical period and the risk of severe dry periods (SPI_dry index) decreases over time, showing that the increase in total precipitation (Fig 2.a) is more likely related to a reduction in prolonged periods with no rain, rather than an increase in extremely wet months.

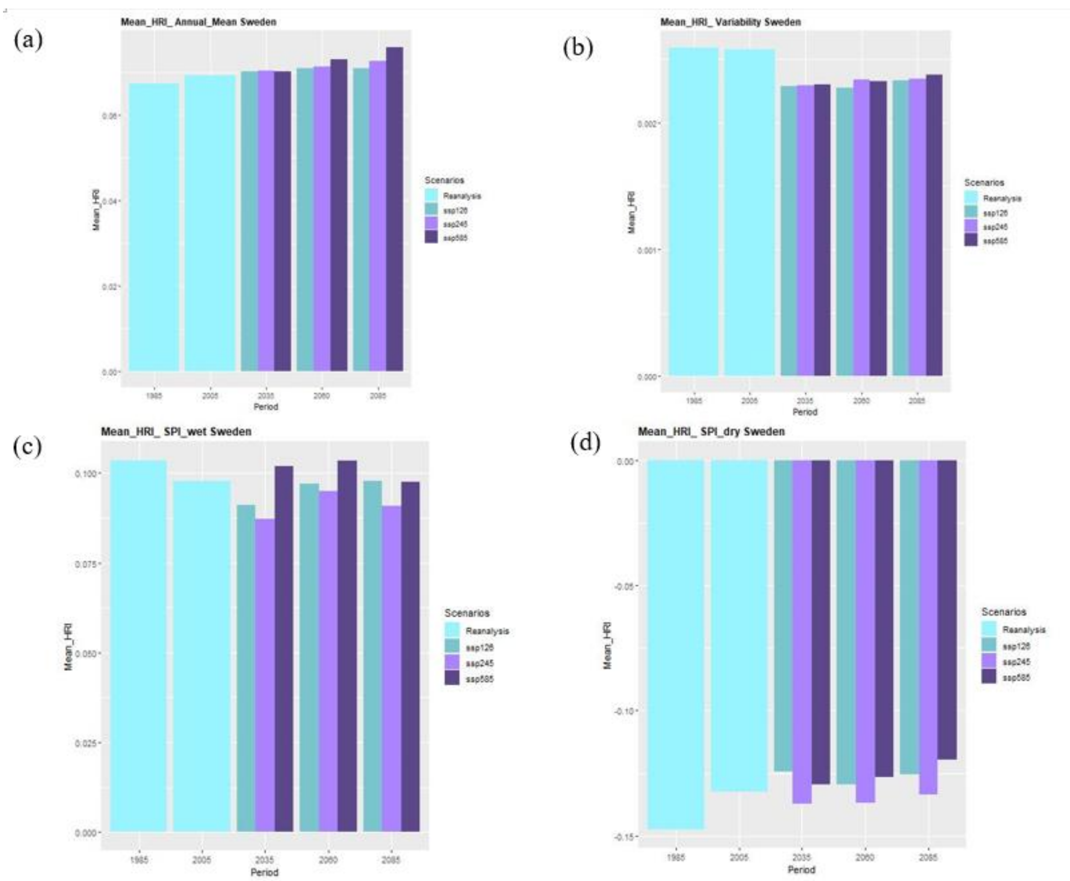


***Figure 2**: Results for Sweden for climate hazard indicators*

Figure 3 shows an example of the final product as an interactive map, built on the Teal tool ([https://tealtool.earth/](https://tealtool.earth/)) developed by WEMC.

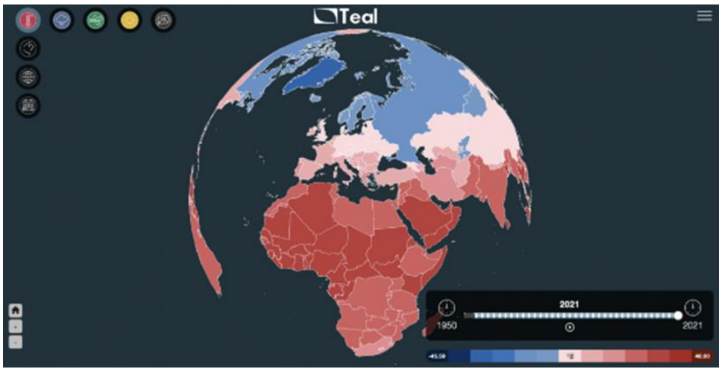


***Figure 3**: Example of the final product*

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