HYDROPOWER TIME SERIES MODELLING FOR CLIMATE-RESILIENT ENERGY SYSTEM OPTIMIZATION

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Motivation and Application

With the expansion of high shares of renewables, our energy system becomes increasingly dependent on weather conditions. As weather patterns change due to climate change, robust energy system planning requires coherent time series of future production potential for renewables such as solar, wind, and hydropower. Deriving such potentials involves translating weather time series from climate models into input data suitable for energy system models. For hydropower inflows, this is particularly challenging because the relationship between meteorological conditions and energy production is indirect and complex. Unlike wind and solar power, where weather conditions translate into energy output almost instantaneously, hydropower exhibits a time lag between precipitation and resulting river discharge, especially when precipitation falls as snow rather than rain. To address this challenge, we develop a tool [1] that derives hourly inflow time series for run-of-river (RoR) hydropower plants (HPPs). The tool combines geospatially resolved weather and hydro-basin data with a hydrological model and technical HPP characteristics. It is specifically designed for long-term inflow forecasting and for supporting strategic decision-making in energy system planning within the research project iKlimEt [2], providing inflow time series for the Low-carbon Expansion Generation Optimization (LEGO) model [3].

Methodology

Deriving inflows to RoR HPPs from meteorological data requires a multi-stage processing chain. Figure 1 summarizes the key components of this workflow. The procedure can be broadly divided into: (i) building a comprehensive database comprising all fundamental information, (ii) preprocessing the meteorological input data, (iii) creating a hydropower plant database with plant-specific characteristics,

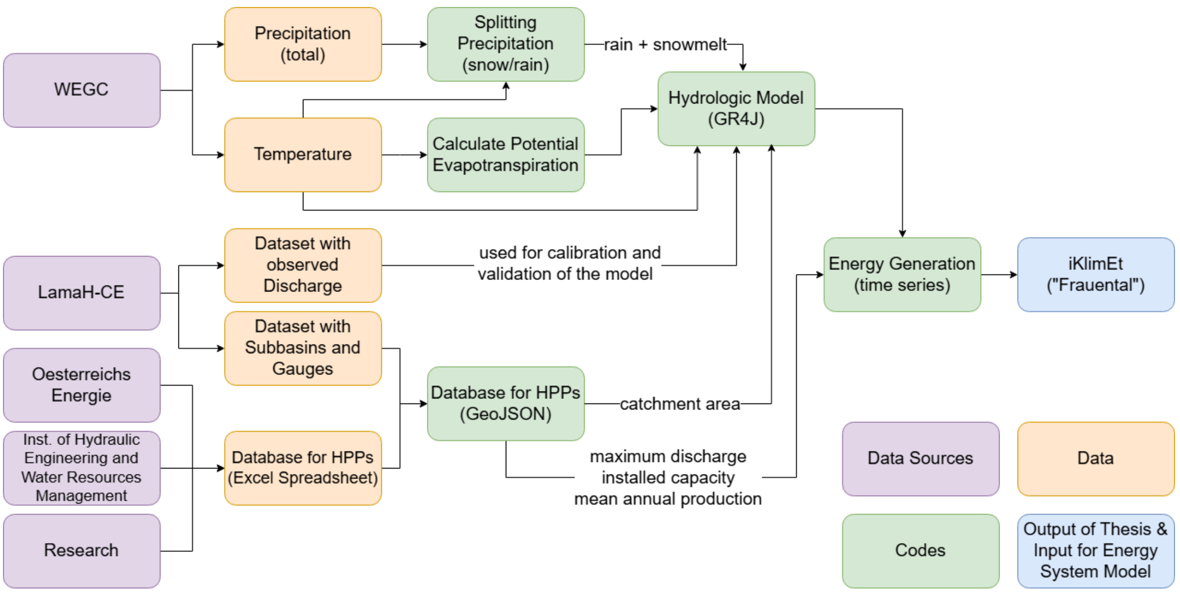

Figure 1:High-level overview of the translation process.

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(iv) calibrating and executing the hydrological model (GR4J [4]), and (v) computing the resulting hydropower inflows and generation for calibration.

For the year 2016, Figure 2 compares the simulated values compared to the observed values of a sample HPP. The correlation between the time series is strong, indicating high-quality hydrological efficiency metrics. This performance is consistent across nearly all of the 77 tested hydropower plants and constitutes a substantial improvement over the currently available inflow data.

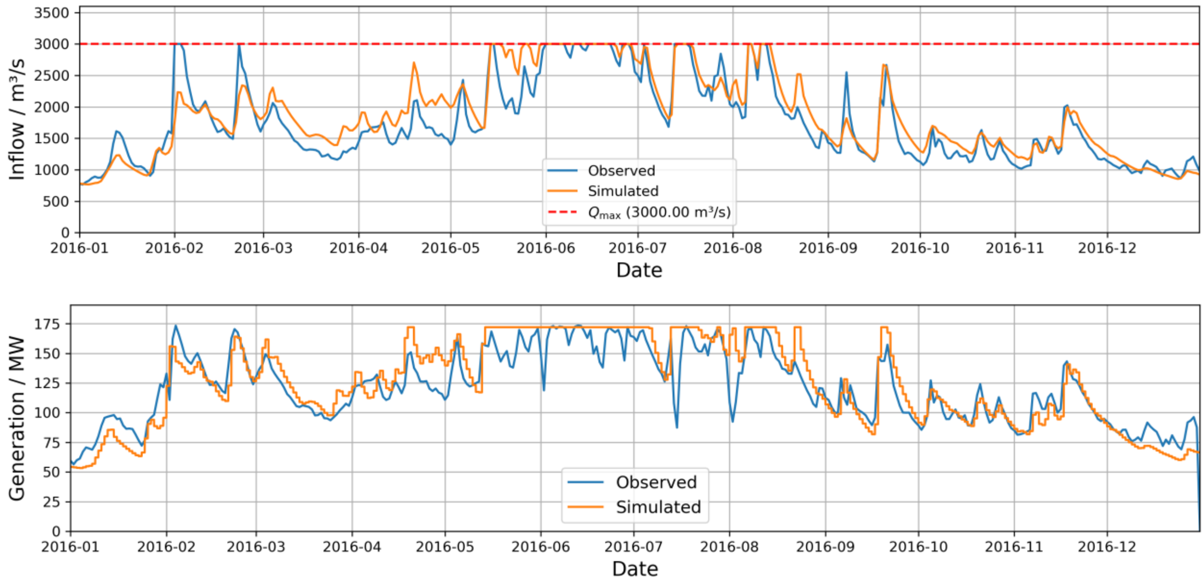

Figure 2: Simulated versus observed inflow (top) and generation (bottom).

Conclusion and Future Perspectives

With the developed tool, inflows to hydropower plants, which account for approximately 40% of annual electricity generation in Austria, can be simulated based on meteorological data with high accuracy. Although the tool already delivers high-quality results, several opportunities remain to further enhance its capabilities, including:

- Expanding the tool across Europe by incorporating additional HPP and river discharge data.
- Extending the tool to account for flood-related plant shutdowns.
- Integrating additional meteorological variables beyond precipitation and temperature to further improve the representation of e.g., potential evapotranspiration and snowmelt.

References

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