



## **A methodology to quantify and optimize time complementarity between hydropower and solar PV systems**

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Hydropower and solar energy are expected to play a major role in achieving renewable energy sources' (RES) penetration targets. However, the integration of RES in the energy mix needs to overcome the technical challenges that are related to grid's operation. Therefore, there is an increasing need to explore approaches where different RES will operate under a synergetic approach. Ideally, hydropower and solar PV systems can be jointly developed in such systems where their electricity output profiles complement each other as much as possible and minimize the need for reserve capacities and storage costs. A straightforward way to achieve that is by optimizing the complementarity among RES systems both over time and spatially. The present research developed a methodology that quantifies the degree of time complementarity between small-scale hydropower stations and solar PV systems and examines ways to increase it. The methodology analyses high-resolution spatial and temporal data for solar radiation obtained from the existing PVGIS model (available online at: <http://re.jrc.ec.europa.eu/pvgis/>) and associates it with hydrological information of water inflows to a hydropower station. It builds on an exhaustive optimization algorithm that tests possible alterations of the PV system installation (azimuth, tilt) aiming to increase the complementarity, with minor compromises in the total solar energy output. The methodology has been tested in several case studies and the results indicated variations among regions and different hydraulic regimes. In some cases a small compromise in the solar energy output showed significant increases of the complementarity, while in other cases the effect is not that strong. Our contribution aims to present these findings in detail and initiate a discussion on the role and gains of increased complementarity between solar and hydropower energies.

Reference: Kougias I, Szabó S, Monforti-Ferrario F, Huld T, Bódis K (2016). A methodology for optimization of the complementarity between small-hydropower plants and solar PV systems. *Renewable Energy*, Vol 87(2), pp. 1023-1030.