Geophysical Research Abstracts
Vol. 16, EGU2014-3698, 2014
EGU General Assembly 2014

Hydro-economic performances of streamflow withdrawal strategies: the case of small run-of-river power plants

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River flows withdrawals to supply small run-of-river hydropower plants have been increasing significantly in recent years - particularly in the Alpine area - as a consequence of public incentives aimed at enhancing energy production from renewable sources. This growth further raised the anthropic pressure in areas traditionally characterized by an intense exploitation of water resources, thereby triggering social conflicts among local communities, hydropower investors and public authorities. This brought to the attention of scientists and population the urgency for novel and quantitative tools for assessing the hydrologic impact of these type of plants, and trading between economic interests and ecologic concerns. In this contribution we propose an analytical framework that allows for the estimate of the streamflow availability for hydropower production and the selection of the run-of-river plant capacity, as well as the assessment of the related profitability and environmental impacts. The method highlights the key role of the streamflow variability in the design process, by showing the significance control of the coefficient of variation of daily flows on the duration of the optimal capacity of small run-of-river plants. Moreover, the analysis evidences a gap between energy and economic optimizations, which may result in the under-exploitation of the available hydropower potential at large scales. The disturbances to the natural flow regime produced between the intake and the outflow of run-of-river power plants are also estimated within the proposed framework. The altered hydrologic regime, described through the probability distribution and the correlation function of streamflows, is analytically expressed as a function of the natural regime for different management strategies. The deviations from pristine conditions of a set of hydrologic statistics are used, jointly with an economic index, to compare environmental and economic outcomes of alternative plant setups and management strategies. Benefits connected to ecosystem services provided by unimpaired riverine environments can be also included in the analysis, possibly accounting for the disruptive effect of multiple run-of-river power plants built in cascade along the same river. The application to case studies in the Alpine region shows the potential of the tool to assess different management strategies and design solution, and to evaluate local and catchment scale impacts of small run-of-river hydropower development.