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Run-of-river power plants in Alpine regions: whither optimal capacity?

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Hydropower is the major renewable electricity generation technology worldwide. The future expansion of this technology mostly relies on the development of small run-of-river projects, in which a fraction of the running flows is diverted from the river to a turbine for energy production. Even though small hydro inflicts a smaller impact on aquatic ecosystems and local communities compared to large dams, it cannot prevent stresses on plant, animal, and human well-being. This is especially true in mountain regions where the plant outflow is located several kilometers downstream of the intake, thereby inducing the depletion of river reaches of considerable length. Moreover, the negative cumulative effects of run-of-river systems operating along the same river threaten the ability of stream networks to supply ecological corridors for plants, invertebrates or fishes, and support biodiversity. Research in this area is severely lacking. Therefore, the prediction of the long-term impacts associated to the expansion of run-of-river projects induced by global-scale incentive policies remains highly uncertain. This contribution aims at providing objective tools to address the preliminary choice of the capacity of a run-of-river hydropower plant when the economic value of the plant and the alteration of the flow regime are simultaneously accounted for. This is done using the concepts of Pareto-optimality and Pareto-dominance, which are powerful tools suited to face multi-objective optimization in presence of conflicting goals, such as the maximization of the profitability and the minimization of the hydrologic disturbance induced by the plant in the river reach between the intake and the outflow. The application to a set of case studies belonging to the Piave River basin (Italy) suggests that optimal solutions are strongly dependent the natural flow regime at the plant intake. While in some cases (namely, reduced streamflow variability) the optimal trade-off between economic profitability and hydrologic disturbance is well identified, in other cases (enhanced streamflow variability) multiple options and/or ranges of optimal capacities may be devised. Such alternatives offer to water managers an objective basis to identify optimal allocation of resources and policy actions. Small hydro technology is likely to gain a higher social value in the next decades if the environmental and hydrologic footprint associated to the energetic exploitation of surface water will take a higher priority in civil infrastructures planning.