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Applicability of multicriteria decision aid to sustainable hydropower

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HIGHLIGHTS

- Selected 23 environmental criteria to be evaluated for sustainable hydropower.
- Valuation methodology for all selected criteria is proposed.
- VIKOR method is introduced into decision making process on sustainable hydropower.
- Inclusion of "Do Nothing" alternative is discussed.
- Applicability of multicriteria decision aid to sustainable hydropower is tested.

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ABSTRACT

EU directives RESD (2001/77/EC) and WFD (2000/60/EC) can be considered as partially conflicting. Achieving a good qualitative and quantitative status of waters, what presumes "non-deterioration principle" of the existing ecological status in line with WFD, is conflicting with the construction of new hydropower plants that are promoting renewable energies, what is in line with RESD.

Several projects have been developed in order to minimize conflicts between the two Directives, often providing a list of key criteria to be taken into consideration when deciding on the impact minimization of new ones or certification to existing plants. One example is CH2OICE, aiming at developing a technically and economically feasible certification procedure for hydropower generation facilities of high environmental standard.

This paper aims to evaluate applicability of multicriteria decision aid to decision makers during the design process, decisions on site selection and plant technical and operational parameters, based on both economic and environmental criteria selected.

1. Introduction

The two EU directives, namely WFD (2000/60/EC) and EC RESD (2001/77/EC), have own objectives that could be considered as conflicting. While the first one requests achieving a good qualitative and quantitative status of waters, presuming "non-deterioration principle" of the existing ecological status, the other asks for increasing energy consumption of renewable resources, what includes considering construction of hydropower plants.

Paper objective is to assess applicability potentials of a specific multicriteria decision support method to sustainable hydropower design, aiming thus finding a compromise between the two directives. This objective is in line with the principles promoted by the special issue of Energy Journal on Energy Solutions for a Sustainable World, which contains a collection of papers on this theme with five main topics, including the topic on Energy, Environment and Sustainable Development [1].

1.1. Background on RESD and WFD directives

European leaders signed up in March 2007 to a binding EU-wide target to source 20% of their energy needs from renewable sources, including hydropower plants (HPPs) by 2020. To meet this objective the EU leaders agreed on a new Directive on promoting renewable energies, the Directive on Electricity Production from Renewable Energy Sources, officially named 2001/77/EC [2] and widely known as the RES Directive (RESD). European Parliament and the Council agreed upon the RES Directive (2009/28/EC) in December 2008, and it entered into force in June 2009 [2].

RES Directive requires each Member State (MS) to adopt a national renewable energy action plan. These plans are to set out the MS national targets for the share of energy from renewable sources consumed in transport, electricity and heating and cooling in 2020 and adequate measures to achieve these targets.

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Article 2 of RES Directive in definitions writes that "energy from renewable sources means renewable non-fossil energy sources: wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases".

Article 5 (on calculations of the share of energy from renewable sources) writes that "the electricity generated by hydropower shall be accounted for in accordance with the normalization rule in Annex II", what actually refers to the following formula:

$$Q_N = C_N * \left[\sum_{i=N-14}^{N} \frac{Q_i}{C_i} \right] \bigg/ 15 \quad (1)$$

where N relates to the reference year; Q_N is normalized electricity generated by all hydropower plants of the MS in year N, for accounting purposes; Q_i is the quantity of electricity actually generated in year i by all plants of the MS measured in GW h and C_i is the total installed capacity of all the plants of the MS in year i, measured in MW. This formula intends to smooth the effects of interyearly climatic variation in calculating the contribution of hydropower.

Thus the RES Directive stimulates the Member States to increase hydropower production and usage, in order to achieve the set goal of meeting 20% of the energy needs from renewable sources.

At the same time, the EU adopted in October 23, 2000 the Water Framework Directive – WFD (2000/60/EC) [3], which is establishing a framework for Community action in the field of water policy. The Directive defines status of a body of surface water as determined by the poorer of its ecological status and its chemical status, where ecological status refers to the quality of the structure and functioning of aquatic ecosystems of the surface waters. The Water Framework Directive expands the scope of water protection to all waters and sets clear objectives that a "good (qualitative and quantitative) status" must be achieved for all European waters by 2015 and that water use must be sustainable throughout Europe.

Article 1 of WFD clearly states that the purpose of this Directive is to establish a framework for the protection of inland surface waters, preventing further deterioration and protecting and enhancing the status of aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems.

Article 4 sets environmental objectives, specifically for surface waters, writing that Member States shall implement the necessary measures to prevent deterioration of the status of all bodies of surface water, and shall protect, enhance and restore all bodies of surface water (subject to the application of defined subparagraphs) also for artificial and heavily modified bodies of water, with the aim of achieving good ecological potential and good surface water chemical status, all at the latest 15 years from the date of entry into force of the Directive. And artificial and heavily modified water bodies include existing reservoirs for hydropower production, while preventing deterioration of the status of all bodies of surface water may relate to potential construction of the new hydropower plants.

Thus these objectives of the two Directives are conflicting. Achieving a good qualitative and quantitative status before any other objective presumes a "non-deterioration principle" of the existing ecological status, which requires an extremely careful environmental impact assessment of potential new infrastructure at river systems, especially those already having favorable status. Thus, if "precautionary principle" would be applied, the new water infrastructure construction, primarily hydropower plants, would rather be avoided then implemented – unless designed mitigation measures secure avoiding deterioration of the existing ecological status.

1.2. Examples of projects addressing sustainable hydropower

CH2OICE is a project funded by EC (www.ch2oice.eu) that aims at developing a technically and economically feasible certification procedure for hydropower generation facilities of high environmental standard, being explicitly coherent with the requirements of the Water Framework Directive, to be implemented in "green labelled" electricity products, and being integrated, as much as possible, with existing EU tools, such as Ecolabel, EMAS, Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA).

But CH2OICE project recognize the conflict and underlines that while increasing the production of renewable energy (often including hydropower) is a must in order to reduce CO_2 emissions, at the same time reducing river flow alteration and other hydromorphological pressures is a must to improve river ecosystems.

As a strategy to compromise such objectives, CH2OICE propose that the power companies need to reduce their impacts, innovate technologies and improve management of existing plants to increase the value of their production, so as to design new plants considering from the beginning environmental constraints and best management practices. Project thus proposes introducing certification procedure for the plants which comply with such conditions, advocating at the same time for higher prices for certified energy.

Yet another EC funded project recognized the inconsistency in the implementation of the two European Directives (WFD vs. RESD). Small Hydro Energy Efficient Promotion Campaign Action (SHERPA – www.esha.be/index.php?id=80) is a project in the framework of the Intelligent Energy for Europe Programme (IEE). SHERPA aims to make a significant contribution in reducing the barriers that are currently hindering the development of small hydropower, addressing the challenges and contributing to the uptake of small hydropower in the European Union. This project states that the European policy framework for renewable energy gives Member States a reason to look at small hydropower because it has the best track record of all renewable energy technologies, being a clean and very efficient renewable energy source. But still growth rates have not been high, among other reasons also for the common impression that hydro plants must adversely affect river ecosystems, what is one of the consequences of the inconsistency in the implementation of WFD and RESD.

2. Selection of criteria

2.1. Multi criteria selection

The necessity of considering the environment as an additional design factor arises due to increasing environmental conscience worldwide and stricter requirements to reduce the environmental impact of energy systems. That most often leads to introducing conflicting objectives, since environment friendly technologies are usually more expensive. There are technical options for sustainable and environment friendly energy supply systems, but minimization of both costs and environmental impacts are usually contradictory objectives, as it is often expensive to utilize environmentally friendly technologies. Environmental constraints are expected to play more and more important role in energy systems, besides the economic objective [4].

A number of studies use multi-objective optimization to analyze the optimal operating strategy, combining the minimization of energy cost, including thus minimizing construction and operational costs so as maximizing production capacity, with the minimization of environmental impact. Such environmental impact may be assessed in different terms – e.g. Ren and others in their paper assessed it in terms of CO emissions and the trade-off curve is obtained by using the compromise programming method [5].

One option for multi-objective optimization would be to summarize economic objectives into one function, and to do the same with environmental objectives. Such principle was applied by Ren