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Assessment of the environmental impacts associated with hydropower

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ABSTRACT

The production of electricity from hydropower results in several environmental impacts that, in only some instances, have been analysed from an economic valuation approach. Moreover, as environmental impacts largely depend on the specific characteristics of the case study, benefit transfer techniques are inadequate for valuation. The present paper demonstrates through the review of valuation studies on the environmental impacts of this technology, and the analysis of the different environmental impacts associated with hydropower for specific case studies that in fact benefit transfer should not be applied as each hydropower plant has specific and different impacts. The paper demonstrates the importance of a case study approach, for defining priorities with respect to alternative hydropower production facilities. Finally, the paper demonstrates that choice experiments are particularly suited for valuing the identified environmental impacts, being relevant for policy planning purposes.

1. Introduction

In recent years, within available renewable energy sources (RES) hydropower has acquired an increasingly significant role, currently representing the largest contributor of its kind to power generation in Europe [1] and starting to capture a substantial amount of attention from developing counties. This energy alternative, due to its specificities has become a key player helping to face global energy challenges, in keeping with sustainability goals. Recognizing underlying resource finitude and depletion, it constitutes an opportunity not only to answer continuous energy demands associated with economic and population growth while meeting environmental standards (especially considering greenhouse gas (GHG) emissions, global warming and climate change issues) and simultaneously improving social wellbeing through power supply to underdeveloped and isolated regions (see [2–6]). Notwithstanding in order to fulfill these objectives, encompassing environmental, social and economic pillars, it is necessary to identify and "internalize" potential impacts (both benefits and costs) resulting from hydropower project deployment.

Several authors (see [2,5,7–9]) have already pointed out the need for accountability based on public consent and relationships between different stakeholders including project developers, local populations, national, regional and local authorities, Non-Profit Organizations, among others, in order to develop a comprehensive and sustainable approach. Although impact assessment has recently undergone a series of changes towards becoming a more open process encouraging participatory approaches in order to gain public acceptance, adoption of steps leading to its field implementation is still currently a challenge. However, effectively the increase of awareness and knowledge has contributed to shift existing policies and assessment procedures towards an increasingly environmentally and socially inclusive process with hydropower being currently considered one of the most sensitive energy sources regarding these issues (see [7,10]).

Despite hydropower being considered a "tool for economic development" essentially because of its multifunctional nature, presenting environmental advantages when compared to more conventional energy sources, its impacts cannot be neglected ([11]. Whilst [4,12] stress the urgency of integrating equity in impact assessment and policies to minimize adverse impacts, [9,13,14] have suggested a more widespread and inclusive approach, integrating Social Impact Assessment (SIA) and Environmental Impact Assessment (EIA). Evidencing, according to this latter author, how potentially affected environmental aspects, such as "water quality, biodiversity, passage of aquatic species, pest species, erosion and sedimentation", have reper-

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cussions at social and economic level potentially generating enduring problems, if not previously assessed. Furthermore, by being undertaken along with EIA, SIA improves understanding of social repercussions of prospective projects (see [9]), aiming to identify potential impacts and ensure that local communities' effectively affected by hydropower deployment are fairly compensated, making sensitive issues like involuntary resettlement an opportunity to improve prior livelihood, reducing the risk of impoverishment.

The economic valuation of environmental impacts of renewable energy sources (RES) has become an important issue in economics, especially because of the evident and increasing need to value damages caused by human activity either for awarding compensation or for planning purposes. It is also recognized the importance of the economic valuation of environmental impacts as an important requirement of cost–benefit analysis (CBA), which plays an important role in the public decision process. Economic valuation methods provide monetary estimations of environmental, health, and social impacts, so that they can be incorporated into CBA.

This paper aims to present a critical analysis of the literature addressing the environmental impacts of hydropower deployment and its economic valuation. The contribution of this study is twofold: firstly the most common environmental impacts from hydropower are classified in categories and methodologies used to value these impacts are critically analysed; secondly hydropower cases studies in Portugal are reviewed confirming not only the relevance of the previously identified impacts but also the importance of addressing environmental specificities of each project for which choice experiments methods are particularly well suited. Section two summarizes the environmental impacts identified in the literature. Section three discusses the methodologies used to value the impacts. Section four, analyses four reports of three case studies of hydroelectric power plants planned or under implementation in Portugal. Finally, section five presents some concluding remarks.

2. Environmental impacts of hydropower deployment

Despite the increasing role played by hydropower as a much needed renewable alternative in global energy scenario, like any other energy source it entails both benefits and costs at an environmental as well as at a socio-economic level. The nature and extent of the impact is highly dependent of site specific characteristics as well as on the type and dimension of hydropower plant [15]. This implies that impacts affecting local communities must be assessed "on a case-to case basis" [7] and, as such, it becomes an increasingly complex task to identify the most meaningful impacts. Therefore, in order to achieve this purpose a cross-referenced comparative approach is suggested and the literature on the economic valuation of hydropower environmental impacts can also be organized by the type of environmental impacts considered, and methodology used.

Renewable energy compared to conventional energy sources, i.e., sources of non-renewable energy from fossil fuels (oil derivatives, coal and natural gas) are considered to have a lower impact on the environment. In this context, Ferreira et al. [16] has emphasized, mitigation of greenhouse gas (GHG) emissions through low carbon power generation as a key contribution of small hydroelectric projects (SHP) towards sustainability. However, RES also have some environmental effects themselves that should not be overlooked. For hydropower, environmental impacts reported in the literature are frequently associated to biodiversity limitation, impacts on fauna and flora, landscape intrusion, water resource impacts, destruction of historical relics and visual impacts ([4,17–26] among others). As such, the various studies have pointed environmental impacts associated with hydropower activity which can be summarized in four important categories: fauna, flora, landscape and historical remains [23]. In Table 1 we summarize the previous studies by counting the number of times (papers) that an impact is considered in the analysis.

Table 1
Environmental impacts summarized by the number of studies that are considered.

Environmental impacts associated with hydropower	Number of studies	References
Fauna	9	[17,20–24,27,29,30]
Flora	11	[4,17–21,23,24,27,29,30]
Landscape	8	[4,20,22,25–27,29,30]
Remains	4	[4,23,29,30]

Only four studies [4,23,29,30] consider historical remains as environmental impacts (possibly because in many circumstances these are not the most prominent impact). The flora is the attribute more frequently mentioned, since eleven studies using this attribute in their analyses. This is due in large part by direct damage caused by the impact of constructing dams on flora as agricultural losses, forestry losses, erosion and vegetation, referred to by [4,17–21,23,24,27,29,30]. Next we focus on the methodologies used to value these identified impacts and the results obtained.

3. Valuation of environmental impacts

Determining the economic value of the environmental impacts is a process far from being simple, since there are no markets for the environmental goods and services impacted and, therefore, prices are not available. Nevertheless, the inexistence of prices for these environmental impacts does not necessarily mean they have no value. This type of resources are called non-market goods and their value may be estimated through two main types of valuation methods: (i) revealed preferences (RP), through which the goods' value is inferred based on the observation of consumers' behaviour, and (ii) stated preferences (SP), where the goods' value depends on the individuals' statements when asked how they would behave when faced with a certain scenario regarding non-market goods. These two types of methodologies have advantages and drawbacks. One major advantage of SP over RP techniques is the fact that they allow the elicitation of the total economic value (including use and non-use values) of the goods and services; and is applicable ex-ante and ex-post. RP requires the existence of a market context where the behaviour of the consumer is observed and preferences over the environmental good inferred, thus its application is only possible ex-post and it only allows the elicitation of the value attributed by users [33].

Due to its advantages and applicability, the analysis focus on SP methods: the contingent valuation method (CVM) and the choice experiments (CE). The CVM is a direct survey approach to estimate consumers` preference [33–37]. Through an appropriately designed questionnaire, respondents are asked to express their maximum willingness to pay (WTP) or minimum willingness to accept (WTA) compensation for a hypothetical change in the level of provision of the good or service. In fact, a hypothetical market situation is specified and the respondent is asked how he would behave (*buying* (wtp) or *selling* (wta)) in that situation. This methodology is most commonly used to value environmental changes [38] and is essential for CBA of environmental projects [39]. The CVM is in addition the methodology recommended by the NOAA (National Oceanographic and Atmospheric