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Incorporating socio-environmental considerations into project assessment models using multi-criteria analysis: A case study of Sri Lankan hydropower projects

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HIGHLIGHTS

- This study provides an effective hydropower project evaluation method using the MCA.
- The proposed tool shows the quantitative relationship explicitly.
- Marginal trade-offs between sustainability objectives are presented.

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ABSTRACT

Before commissioning any energy projects, conducting robust assessments of different options in terms of their economic and socio-environmental impacts is important for successful project implementation. Yet, there is currently a lack of tools that simultaneously assess sustainability impacts; instead, they are often investigated separately, which gives decision makers somehow disintegrated information. Thus the main objective of this study is to examine how to incorporate socio-environmental considerations into project assessment models. The multi-criteria analysis is applied to the case study of Sri Lankan hydropower projects as an illustrative example. The estimated quantitative relationship between economic, environmental and social impacts of hydropower development is presented in this study. Such estimation, using sustainability indicators of hydropower projects, enables us to understand marginal trade-offs among economic, environmental and social objectives of hydropower development. Hence, this would provide an overview of potential impacts of different scenarios that are designed to be implemented and indicate an optimum mix of hydropower generation.

1. Introduction

Approximately 16% of electricity worldwide is produced by hydropower and global hydropower production increased more than 5% in 2010 (IHA, 2010). The countries with large installed hydropower capacity are China, Brazil, the United States, Canada, and Russia, accounting for 52% of global total installed capacity (World Energy Council, 2010; IEA, 2010). Many countries in Africa (e.g., Ethiopia, Malawi, Zambia, Mozambique, and Democratic Republic of Congo) as well as Norway produce almost 100% of their grid-based electricity with hydropower. Today, Asia and Latin America are the two major regions for new hydropower development: e.g., 2.4 GW Son La in Vietnam, 1.1 GW Nam Theun 2 in Laos, 0.9 GW Foz de Chapeco in Brazil, 2.4 GW Jin'anqiao in China, and 0.5 GW Beles in Ethiopia. Small-scale hydropower is also popular worldwide, with many schemes under construction or in the planning stages.

Dams not only generate energy, but also provide water and protection from floods. However, environmental degradation (e.g., changes of ecosystems, reduced water quality) and social destruction (e.g., displacement of rural communities) due to ineffectively planned hydropower projects have been witnessed worldwide. For example, the proposed Belo Monte dam in Brazil, which will be the third largest dam in the world, is expected to submerge around 400,000 ha (e.g., deforestation problem) and could displace an estimated 20,000 people including a large number of indigenous population (*Guardian* 8 *April* 2012). Another prime example is the world's largest hydropower, the Three Gorges Dam that has attracted numerous criticisms. The Chinese government has admitted the problems related to living conditions for 1.4 million relocated people, the surrounding environment, and geological disasters, such as landslides and a dam-induced earthquake (BBC

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19 May 2011). A much smaller but still controversial project is the Ilisu dam in Turkey, which would devastate the area's environmental and cultural heritage, as well as displace more than 50,000 people (*BBC* 5 *August* 2006). Although hydropower is considered to be clean renewable energy, reservoirs emit high emissions of CO_2 and methane (its warming effect is 25 times stronger than CO_2), because of decaying matter underwater (*Guardian* 8 *April* 2012).

The main objective of this study is to demonstrate how to incorporate socio-environmental considerations into project assessments using multi-criteria analysis (MCA). This would enable decision makers to identify a sustainable balance between economic growth facilitated by hydropower and socio-environmental objectives attached to sustainable energy development. The proposed assessment tool in this paper explicitly illustrates the quantitative relationship between economic, environmental and social impacts of hydropower development. Such an estimation, using sustainability indicators for hydropower projects, enables us to understand marginal trade-offs among economic, environmental and social objectives of hydropower development. Hence, this would provide an overview of potential impacts of different scenarios that are designed to be implemented and present an optimum mix of hydropower generation. The proposed approach is applied to the case study of Sri Lankan hydropower projects as an illustrative example.

The paper consists of the following four sections: the next section describes the case study of hydropower projects in Sri Lanka. Section 3 explains the methodology applied in this study, i.e., MCA. Section 4 presents the findings followed by the conclusion.

2. Case study: hydropower projects in Sri Lanka

Sri Lanka is an island of 21.28 million people located in the Indian Ocean. The GDP in Sri Lanka was US$165.5 billion with its annual GDP growth rate of 9.1% in 2010 (CIA, 2011). According to CIA (2011), their service sector consists of 57.6% of the economy, followed by industry (29.8%) and agriculture (12.6%). Per capita electricity consumption in Sri Lanka in 2009 was 418 kWh (IEA, 2009), while the demand for electricity is estimated to rise at an annual rate of 8%–10% (MP&E, 2008). The national electrification rate improved significantly from 10.9% to 76.7% over the period of 1986–2005 (ADB, 2007). Approximately 82% of the population is connected to the national grid, serviced by the Ceylon Electricity Board, the largest government-owned electricity company in Sri Lanka, and the another 2% uses off-grid systems (SLSEA, 2009).

According to SLSEA (2008), in terms of energy supply, biomass accounts for 47.39%, followed by petroleum (43.05%), hydro (9.51%) and non-conventional renewable energy (0.04%). At present, hydropower is the most exploited renewable in power generation, though it also displays seasonal variations as most of the hydropower installations are run-of-the-river schemes (Deheragoda, 2009). Since the commissioning of the first hydroelectric power plant in 1950, the largest share of electricity generation historically came from hydropower projects until the mid-1990s (Siyambalapitiya, 2005; Wickramasinghe, 2009). Yet, despite several hydropower capacity additions, the share of hydropower has shown a reducing trend since the mid-90s due to the non-availability of new sites that are economically feasible (ECF, 2004). Gradually, thermal power has been replacing hydropower for meeting the growing electricity demand. There are also about 350 villages in Sri Lanka electrified by village micro hydro schemes, 100 houses obtain electricity from small wind turbines, 10 villages benefit from dendro power[1] and 30 houses use electricity generated by biogas (Ferdinando and Gunawardana, 2008). Socio-economic benefits of rural electrification such as poverty eradication are widely discussed, and the Sri Lankan government envisages reaching a 100% target in electrification by 2016 (e.g., ESMAP, 2002; Yang and Yu, 2004).

The exponential growth of non-conventional renewable energy is increasingly attributed to the small hydropower sector whose capacities are less than 10 MW (Deheragoda, 2009). The economically feasible small hydro potential in Sri Lanka is estimated to be 400 MW,[2] and there are plans to add extra 350 MW to the national grid by 2020 (*Asian Tribune* 28 *Feb* 2011). Moreover, the government currently intends to develop renewable energy resources (mini hydro, biomass and wind) to reach 10% of total electricity by 2016, as illustrated in Fig. 1. It is clear that other than the planned coal power generation (the commission of the first coal power station was delayed to 2011), the actual generation figure for 2010 is fairly similar to the planned figure for 2010 depicted in Fig. 1.

3. Methodology

3.1. MCA

There are various approaches to assess project viability, such as Environmental Impact Assessment (EIA), Social Impact Assessment (SIA), Multi-Criteria Analysis (MCA), and Cost Benefit Analysis (CBA). Sovacool and Bulan (2011) argue that including findings from not only quantitative studies, but also from qualitative analysis is useful for effectively assessing broader impacts of projects. Moreover, the importance of equity concerns when conducting project assessments, taking into account of distribution of benefits/costs among different stakeholders, is often discussed (e.g., Gunawardena, 2010). Additionally, considering both inter-generational and intra-generational equity during project assessments is crucial (Gunawardena, 2010).

CBA is widely used as one of the most common tools for hydropower project analysis worldwide (see e.g., Little and Mirrlees, 1974; Squire and Van der Tak, 1975; World Commission of Dams, 2000). The World Bank and other multilateral financial institutions have been applying CBA in order to improve decisions by evaluating project feasibility using decision criteria (i.e., net present value, internal rate of return, benefit cost ratio). CBA aims to maximise the margin between revenue and costs (EC, 2000). Limitations and difficulties surrounding CBA have been widely discussed, such as valuation of impacts over time, exclusion of externality, equity & distribution issues (e.g., World Commission of Dams, 2000). In order to include externalities, some studies evaluate socio-environmental impacts in monetary terms and incorporate them into conventional CBA (e.g., see some applications of CBAs with socio-environmental considerations in Morimoto and Hope, 2004a, 2004b; Morimoto, 2007; Gunawardena, 2010).

EIA has become widely used as a tool for project analysis since it was introduced in the United States in 1969 (See e.g., ADB, 2004, EEPCO, 2009). While many countries have introduced legislation that requires EIAs for certain categories of development, bilateral and multilateral donors have introduced procedures, manuals and guidelines for the environmental assessment of projects. In Sri Lanka, the concept of EIA was introduced in the early 1980s, and became mandatory for power projects under the *National Environmental* (*Amendment*) *Act of Sri Lanka no.* 56 1988. The EIA process in Sri Lanka has changed over time for hydropower projects as a result of higher consumer demand (Kodituwakku and Wattage,

[1] Fuel wood biomass with fast growing species and short rotational periodic cutting and pruning.

[2] SLSEA: ⟨http://www.energy.gov.lk/sub_pgs/energy_renewable_hydro_potential.html⟩ retrieved on 20 June 2012.