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Inequalities and externalities of power sector: A case of Broadlands hydropower project in Sri Lanka

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ABSTRACT

The objective of the paper is to estimate environmental externalities related to a run of river project in Sri Lanka and to investigate inequity in distribution of impacts among different social groups. Diversion of the river resulted in loss of water sports (for high-income groups both local and remote), loss of historical monuments (for remote high-income groups) and recreation losses (for local poor). Removal of forest cover leads to loss of non-timber products (for local poor) and carbon storage (for remote high- and low-income groups). Loss of home garden productivity was borne by local poor groups. Benefit of the project, generation of 145 GWh annually, was a gain for the grid connected groups. The impacts were valued using various valuation methods. The base case of the cost benefit analysis resulted in NPV of US$ 11,335,730. When distributional weights are applied for different income groups, both the sign and magnitude of net benefits change. In order to be viable, the project needs diversion of at least 9% of generated electricity to the poorest households in the country. Implications for energy policy towards reducing externality and inequality impacts are also discussed.

1. Introduction

The use of renewable energy resources is assuming increasing importance both in developed and developing countries. Since the oil crisis in the early 1970s, developments of renewable energy systems have been expanded due to their low cost and local availability (Bugaje, 2006). The recent emphasis on renewables in the developed countries however, is due to the comparatively less environmental impacts (Kaldellis et al., 2005) and climate change concerns (Batley et al., 2001; Dincer, 2000) and in the case of developing countries their role in enhancing rural economies, poverty alleviation (Martinot, 2001), self-reliance in supply (Biswas et al., 2001), carbon trading potential (Ghosh et al., 2002) and their ability to provide decentralised power. In addition, renewable energy technologies have the lowest operating costs, are speedily constructed (Bugaje, 2006) and are more flexible than the conventional energy sources.

Most developed countries have set their own targets on the proportion of renewables in their energy production based on the Kyoto agreements and in addition renewable energy generation has been enhanced by other new market mechanisms (Batley et al., 2001). International donor agencies have provided support for renewable energy programs in developing countries (Lipp, 2001; Wijayatunga et al., 2004). Both cooperative (Biswas et al., 2001) and market mechanisms (Bandaranaike, 2000) seem to operate successfully in renewable energy generation and marketing in developing countries.

Although renewable energy sources are considered to be cleaner than conventional sources, their improper location could lead to significant negative impacts. Energy externalities in Sri Lanka are often either ignored or undervalued in decision making and distributional aspects are largely neglected in analysing projects. This study, therefore, makes a particular emphasis on identification and valuation of externalities associated with a run of river hydro project. Different social groups affected by externalities are identified and distributional weights are applied within the cost benefit framework in order to address the equity concerns.

The paper is organised as follows. The following section provides a brief overview of energy sector of Sri Lanka with emphasis on inequalities and externalities of renewable energies followed by an overview of decision making frameworks. The next section of the introduction discusses the distributional aspects of power sector projects. Introduction is followed by methodology and results, discussion and conclusions of the study.

2. Energy sector of Sri Lanka

In year 2007, total energy demand of the country was supplied by a combination of biomass (48%), petroleum (42.5%) and hydropower (9.5%) making renewable share 57.5%. The highest

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Table 1
Generating capacity of grid and off-grid renewable resources.
Source: Adapted from Sri Lanka Sustainable Energy Authority, 2007.

Facility	Capacity	Percentage
Grid		
Major hydro	1187 MW	88.99
Small hydro	133.38 MW	10
Wind	3 MW	0.22
Subtotal grid	**1323.38 MW**	**99.21**
Off grid		
Small hydro, industrial	3226.2 kW	0.26
Small hydro, household	1506.2 kW	0.06
Solar photovoltaic, household	5806.0 kW	0.17
Wind energy, household	8.2 kW	0
Subtotal Off-Grid	**10,340.6 kW**	**0.5**
Total	**1333.93 MW**	**100**

energy consumption was from the household commercial and other sectors (48.5%) while industrial sector and transport sector were consuming 25.6% and 25.9%, respectively.

Sri Lankan power sector is faced with a rapid increase in electricity demand. Ceylon Electricity Board (CEB) under the Ministry of Power and Energy is the main entity responsible for generating, transmitting and distributing electricity in the country. CEB presently generates about 60% of electrical energy supplied through the national grid, while the balance is generated by private power plants. CEB directly serves 90% of electricity consumers in the country and meets its peak demand from its own power plants, several private thermal power plants and 74 MW mini hydropower plants owned by the private sector (Sri Lanka Sustainable Energy Authority, 2006, 2007).

2.1. Renewables in Sri Lanka

In 2007, 49% of the total installed capacity of the national grid was hydroelectric, both large and small. Other non-conventional sources such as small scale hydropower, solar photovoltaic and wind energy systems serve off-grid loads of both industries and households. Table 1 summarises the grid and off-grid generating capacity and energy from renewable resources.

3. Inequalities in the power sector of Sri Lanka

Inequalities of the Sri Lankan power sector could be discussed from two related aspects; CEB's policy on electrification and market failures in the power sector, which lead to inequalities.

3.1. Inequalities resulting from CEB's policy on the electrification

Electricity generation and distribution of CEB has its main focus on grid connected consumers. About 78% of the households are presently connected to the grid (Sri Lanka Sustainable Energy Authority, 2006). Although rural electrification has been accelerated, due to technical and financial limitations, extension of the main grid will hardly be feasible for 20% of the households in the country. Targets for electrification of households as proposed by the National Energy Policy and Strategies of Sri Lanka (2008) are given in Table 2.

Almost all households that are without electricity use kerosene lamps for lighting. This has lead to a higher percentage of household accidents due to burns from unsafe kerosene bottle lamps (Laloë, 2002), emission of green house gases and indoor air pollution (Biswas et al., 2001; Goldemberg, 1996; Wijayatunga and Attalage, 2002).

Table 2
Targets for electrification though grid and off-grid electrification of households.

Year	Total households to be provided access to the grid	Total households using off-grid electricity systems
2003	65% (actual)	2% (actual)
2006	75%	4%
2010	80%	6%

Off-grid power plants would be the only option for such rural areas (Nagendran, 2001; Ravindranath and Hall, 1995). In addition, self-generation by end users (off-grid generation) has several important features from the environmental point of view, for example, lesser transmission and distribution losses (Martinot, 2001; Ravindranath and Hall, 1995). However, off-grid renewable power generation is not a high priority for the CEB. Thus, off-grid communities are penalised in two ways: lack of grid supplied energy due to financial concerns and lack of access to other forms of off-grid power.

The generated power at present is also consumed extremely unequally. Electricity consumption of the Western province alone is 60% and the lowest shares are consumed by Northern (2%) and North Central (3%) Provinces (Central Bank of Sri Lanka, 2006). Any additions to the national grid would be used by the high consumption groups, further widening the existing consumption gaps.

3.2. Inequalities due to externalities of renewable power

An externality denotes the inefficiencies that arise when some of the benefits or costs of an action are external to the decision maker's calculations; that is, some of the benefits accrue to, or some of the costs are imposed on, individuals who play no part in the decision (Pearce and Turner, 1990).

Valuation studies on external costs and benefits of renewable energy include hydropower (De Almeida et al., 2005; Egre and Milewski, 2002; Kaldellis et al., 2005; Udayakumara and Gunawardena, 2002), dendro-thermal (Chaturika and Gunawardena, 2005), PV and wind (El-Kordy et al., 2002).

Environmental impacts of different renewable energy sources could be significant (Abbasi and Abbasi, 2000; Oud, 2000). Often, large hydropower projects have been heavily criticised for their often irreversible environmental impacts. Although micro hydro systems are considered to be having lesser impacts (Edinger and Kaul, 2000), dispersed systems of small hydropower generation could incur equally serious impacts on the environment as centralised large systems when per unit costs are considered. Goldemberg (1996) suggests that power produced per hectare could be considered as an indicator of the impact of a hydroelectric scheme. Micro hydro systems have been recognised as the most cost effective form of renewable power due to lesser impacts on social and ecological systems.

Costs of energy projects are however, unequally born by minorities, low-income groups or unknown future generations (Farrow, 1998; Zerbe et al., 2005) and wealthier groups usually suffer little loss (Torras, 1999). For example, Mahaweli Development Programme of Sri Lanka aimed to provide water to the dry zone and to generate hydropower. The project required inundation of considerable agricultural land (5400 ha) and displacement of 14,000 rural families. It would be the wealthy urban groups that are benefited mostly due to the inequality generated by the rural electrification policy of CEB. Low-income groups are affected in several ways: loss of traditional land in the affected areas and loss of opportunity to develop off-grid power since the limited funds are being devoted to the large grid connected projects in preference to off-grid projects.

3.3. Decision making frameworks and their ability to incorporate externality and equality concerns

The literature reveals several analytical tools (both single disciplinary and pluralistic) available for analysis of renewable energies ranging from economic models (Batley et al., 2001; Bergmann et al., 2006; Venetsanos et al., 2002) and techno-economic models (Kaldellis et al., 2005) to integrated models (Biswas et al., 2001). Other tools such as life cycle assessment (Pehnt, 2006; Sarigiannis and Triacchini, 2000), strategic environmental assessments (Finnveden et al., 2003), sustainability assessments (Reddy et al., 2006) and multi-impact evaluation (De Almeida et al., 2005) have also been employed successfully. Hanley and Craig (1991) applied Krutilla Fisher algorithm for peat bog exploitation and the multi-attribute theory has been applied for main power projects in Sri Lanka (Meier and Munasinghe, 1994). Studies that have incorporated equity aspects are summarised in Table 3 while mechanisms for internalisation of energy externalities are summarised in Table 4.

Integration of externalities into energy prices has been questioned by many (Daly and Cobb, 1990; Norton, 1987; Sagoff, 1988) on the basis that the ultimate goal should be achieving equity or social fairness. Stirling (1997) highlights the range of uncertainties from physical–chemical to political and ethical aspects that affect the choice of the discount rate. In addition, externality estimates are being questioned on both ethical and methodological grounds (Soderholm and Sundqvist, 2003). In response, alternative methodologies have been recommended (Nyborg, 2000; Pillet, 2004; Soderholm and Sundqvist, 2003).

Cost benefit analysis (CBA) is the classical tool for evaluating public projects. Although CBA could easily deliver a judgement on efficiency of the project, equity aspects are hardly ever considered, except where a social cost benefit approach is adopted. Thus, Kaldor–Hicks criterion has been widely criticised for ignoring equity (Zerbe et al., 2005). CBA also fails to take account of the potential for risk pooling across projects (Smith, 1979).

The problems of relying on CBA to guide environmental policy is widely discussed (Hanley and Shogren, 2005). Acceptance of current distribution of income and exclusion of all other values than utilitarian values are often highlighted. CBA deals with expressions of money values, which depend on individual's ability to pay, which in turn is a function of income and wealth. Application of the value judgement that individual preferences should count and the ensuing proposition that a decision that reflects individual's preferences is a good decision are not always legitimate. Use of other numeraire such as emission load has been proposed by Brekke (1997) in order to overcome such biases. Learning from other disciplines has also been suggested.

Alternative frameworks suggested for CBA such as safe minimum standards (Ciriacy-Wantrup, 1968) and Krutilla Fisher Algorithm do not have explicit treatment of intra-generational (spatial) inequity but they deal with temporal dimensions of (inter-generational) inequity (Pearce and Turner, 1990; Hanley and Craig, 1991). Social cost benefit analysis with distributional weights is the only mechanism capable of addressing both spatial inequalities and externalities.

However, externalities and equity issues are largely neglected in decision making in the power sector of Sri Lanka. Generation plans of CEB are usually analysed from the financial point of view. The prioritised plans are then queued for implementation. According to the National Environmental Act of Sri Lanka, Environmental Impact Assessments (EIAs) are a mandatory requirement for power plants. EIA is the only decision making tool that incorporates environmental values into the decision making through an extended cost benefit analysis (ECBA). However, externalities are not incorporated into the analysis in a systematic manner. Under the present EIA of Sri Lanka, if there are significant disproportionate environmental impacts on low-income groups they need to be identified and evaluated. However, identifying disproportionate impacts to low-income groups does not necessarily preclude an agency from going ahead with the development of the project. Hence, concerns of distributional issues are rarely incorporated into projects.

Table 3
Mechanisms to address equity concerns in power projects.

Study	Equity concerns addressed	Mechanisms
Hanley and Craig (1991)	Inter-generational equity	Adjustments to discount rates with Krutilla Fisher algorithm
Reddy et al. (2006)	Intra-generational equity	Enhancement of social, natural capital with off-grid small hydels
Trussart et al (2002)	Intra-generational equity	Social and environmental mitigation measures—shadow projects and compensation funds
Biswas et al (2001)	Intra-generational-Gender equity	Improving productivity (savings in firewood collection time), mobility, security and health (lesser indoor pollution) of women with provision of biogas/hydropower to rural areas
Farrow (1998)	Intra-generational equity	Actual compensation to identified groups

Table 4
Internalisation mechanisms for energy externalities.

Study	Internalisation mechanism
Carlson (2002)	Consideration of external costs in the planning stage
Soderholm and Sundqvist (2003)	Adjusting the existing incentive or tax structures to reflect the efficient social choices
De Almeida et al. (2005), Gulli (2006), Roth and Ambs (2004)	Using external costs to rank alternative energy and to select least costly options
Kim (2007)	Integration of external cost to energy pricing
Spalding-Fecher and Matibe (2003)	Taxation, tradable permits and integrated resource planning
Markandya and Tamborra (2002) cited in Krewitt (2002)	Integration into green national accounts

4. Application of distributional weights in CBA

Use of distributional weights is one of the most controversial aspects of CBA. Distributional weights are important in achieving intra-generational equity while the use of social discount rate deals with the inter-generational distribution. Weights can be attached either to income changes (benefits or costs) of the groups affected by the project (Stewart, 1978) or to the good that is being provided (Brent, 1996). In the latter, distributional weights become a part of the determination of shadow prices. Distribution weights can be estimated by two methods. The first method involves specifying a parameter that applies to the whole income distribution that reflects society's aversion to inequality. It could be an explicit or implicit weighting function. The second method uses revealed preference method to estimate the distribution weights. The first method determines distribution weights specifying reasonable assumptions. These include, firstly, assumption on similar utility functions of individuals and secondly, diminishing marginal utility of individuals with respect to income. The social marginal utility of any group i is given by

$$a_i = Y_i^{-\eta}$$

where η is a positive constant signifying the elasticity of the social marginal utility function. The final assumption is to specify a value for η. When η is 0, it means every group's weight must be equal to 1, which is assumed by the traditional CBA. When η is ∞, (infinity), it implies effect only on the worst-off individuals in society matters. This is in line with the maximin principle associated with Rawls (1971). When η is set between 0 and ∞, distribution weights are determined by the inverse of the group's income. This can be expressed relative to a group at average income level of $\acute{Y}$, which means

$$a_i/\tilde{a} = \acute{Y}/Y_i$$

It can be shown that the relative weight $a_i/\tilde{a}$ is a smoothly declining function of relative income $\acute{Y}/Y_i$.

There are many arguments for not using distributional weights in CBA. The most common one is that CBA is to be used for efficiency test, leaving distributional issues for tax transfer systems. Brent (1996) and Nyborg (2000) suggest that unweighted CBA can be defended only if the status quo income distribution is socially optimal. It is also argued that use of explicit distributional weights may be problematic when there are normative disagreements. Nyborg (2000) and Somanathan (2006) suggest use of several sets of weights for such situations.

However, rational decision makers will have to take distributional consequences into account in the project evaluation itself, not just as *ex post* transfers. CBA itself is not free of distributional value judgments. For example, price data of a CBA are dependent on the prevailing income distribution. The disparity associated with estimated costs and benefits is therefore unavoidable. The literature suggests alternatives for income distributional weights, for example use of physical unit based indicators along with decision maker's judgment on welfare effects of environmental quality changes. Such indicators would have the added advantage of not having to value the environment and the associated bias of the present income disparities. However, judgements on the weight attached by decision maker to the changes in environmental quality are unavoidable (Nyborg, 2000).

Income inequalities are widening in Sri Lanka. In 1990s, it was amongst the countries that had the worst income disparity. Incorporation of externalities has been very rare in Sri Lanka and use of distributional weights has never been attempted for development projects of the country. Therefore, the study sought to estimate costs and benefits of a mini hydropower plant in Sri Lanka, to investigate how these benefits and costs are perceived by different groups that are affected by the project and how they need to be appropriated in a better framework to derive more socially desirable outcomes.

5. Methodology and results

5.1. Study site

Broadlands hydropower project is located in the west of central highlands of Sri Lanka in the Kelani river basin, about 65 km away from Colombo. Table 5 provides details related to the project.

The project lies in two provinces of Sri Lanka. The proposed dam and the weir are located in Nuwaraeliya district under Central Province and the proposed powerhouse is located in Kegalle district in Sabaragamuwa Province. The proposed project site is close to Kitulgala, which is a small village but a popular tourist destination. It was the main location for the 1957 Oscar-winning film, 'Bridge on the River Kwai'. Though there is no bridge remaining, it is still a popular place among foreign visitors. Starting upriver outside of Kitulgala there is a 7-km stretch used by the white-water rafting recreationists, both local and foreign. The area has a hilly terrain, which is covered by secondary forests, creating a scenic landscape.

Table 5
Characteristics of the power plant.
Source: EIA, 2003.

Item	Description
Dam	Height—24 m Length—100 m
Effective storage capacity	$0.24 \times 10^6\,m^3$
Operation	Run-of-river type
Installed capacity	40 MW
Expected annual energy	145.23 GWh

The surrounding communities are characterised by low-income people with heavy dependence on their natural resource base for water, food and fuel wood. Only 67% of the households have electricity supply. This location has been identified in the provincial tourism plan in which it has been proposed to develop tourism attractions based on the 'Bridge on the River Kwai' film site.

5.2. Valuation of environmental impacts of the project

Impacts of the project were subjected to valuation based on significance of the impact and data availability. A set of direct and indirect use values that are lost due to the project was identified, quantified and valued. Data collection was carried out in 2003. There were three main impact categories: diversion of river flow, loss of forest land and loss of home gardens.

5.2.1. Impacts due to the diversion of river flow

5.2.1.1. Impact on historical monuments landscapes and sites. The proposed location for access roads to powerhouse site and the bridge is situated along the access to film site location, which is frequently visited by considerable number of tourists. Hence, during the construction stage, tourists who intend to visit this site may face difficulties (EIA, 2003). Valuation was done using the contingent valuation method. A survey was carried out among randomly selected 100 visitors within the site. An open ended question format was used. The contingent valuation scenario is given in Appendix.

The affected population is mainly foreign visitors from countries ranging from UK, Italy, The Netherlands, Germany, Switzerland, etc. Most of the visitors were tourists who selected this particular route when travelling to central highlands. According to results of the CVM survey, the mean WTP value for preventing the loss of river flow for perpetuity is Rs 425.00. There were 20 protest bids. The bid function was significant with R^2 of 26.5. Variables age, income and household number positively contributed to the WTP value. According to observations, the visitation is about 25 visitors per day. Aggregated value of the cost of lost scenic value is therefore Rs 3,187,500. This represents an infinite stream of lost benefits and its annual equivalent is Rs 318,750 (US$ 2998) taking social time preference rate of 10%.

The values are comparable with estimates of Bedate et al. (2004) for values derived from visits to heritage assets in Spain using zonal travel cost method. The consumer surplus per visit ranged from Euro 3.80 (Rs 300) to Euro 2.10 (Rs 166) (1 Euro=Rs

Table 6
Lost benefits of water sports due to the project.

Water rafting company	Average visitation (per month)	Rates (per person)		Total value per year (Rs)
		Foreign	Local[a]	
1	150	1800	1300	3,150,000
2	100	2000	1500	2,340,000
Total				**5,490,000**

[a] It has been assumed that local visitors represent only 10% of the total visitation.

79 in 1998—year of data). Similar values are reported from Beltran and Rojas (1996), who valued visits (US$ 4–6 or Rs 216–324) and preservation ($ 1–4.60 or Rs 54–248) of archaeological sites in Mexico (US$ 1=Rs 54 in 1996). WTP values of £3.70 (Rs 451) to £6.40 (Rs 781) for conservation of collections at Upton House, Warwickshire, are reported from UK (Brown, 2004 cited in Provins et al., 2008).

5.2.1.2. Cost of lost recreational activities/water sports. The location of the proposed bridge at powerhouse site is situated on the river stretch used for white-water rafting adventure sport activity. Hence, this adventure sports activity cannot be operated, as there will be physical barriers. Market prices were used to estimate lost benefits of the water sports. Average visitation rates for the site were obtained from field observations and average fees for the water sport were obtained from a survey carried out among the main rafting companies (Table 6). Operation of the project will result in an annual loss of Rs 5.49 million (US$ 51,632).

These market prices are compared with consumer surplus estimates available elsewhere. According to Hynes and Hanley (2006), white-water recreation values range from Euro 24.01 (Rs 2473) to Euro 131.90 (Rs 13,585) per trip, which clearly indicate that the market prices are lower bound estimates of consumer surpluses (1Euro=Rs 103 in 2003).

5.2.1.3. Loss of scenic view of the river. The lost stretch of river has been a scenic view for the residents in the powerhouse area. This is considered a significant impact as the views capture natural forest in its background and residents have experienced this view on average for 30 years. Valuation of impact of the loss of river flow for local residents was done using a contingent valuation survey of 33% of affected households randomly selected using an open ended survey instrument. The mean for preventing the loss of river flow for perpetuity per person is Rs 890. The bid equation was significant with adjusted R^2 of 74.7%. Education and income positively and significantly contributed to the WTP value. About 60 households will experience the loss. The number of economically active people in the household is assumed to be 3 and the aggregated value of Rs 160,200 represents an infinite stream of lost benefits. Its annual equivalent is Rs 16,020. This loss is expected to be experienced by affected households for the entire project period.

The mean annual value of Rs 89 per person is comparable with the WTP for recreational value of small tanks for rural communities in Sri Lanka (annual per person values range from Rs 131 to 389 in 2003 prices; Dayananda and Gunawardena, 2006).

5.2.2. Costs of lost forest cover

All facilities (permanent and temporary) of the proposed powerhouse site and a part of the access road to the powerhouse from the highway are to be located within the boundary of the forest, which contains disturbed secondary vegetation. The total forest area that is lost will be 25 ha and an area of 10 ha will be restored. For the remaining 15 ha, in the absence of an afforestation programme under the proposed project, it may take several decades to regain its current state, causing long-term impact with permanent loss of associated resource utilizations (EIA, 2003). The following two impacts were valued.

5.2.2.1. Cost of lost carbon storage. The avoided global damage cost approach was used to value one forest function—carbon sequestration value. A closed secondary forest could contain (biomass and soil) 152–237 tons of carbon per ha (Bundestag, 1990; Houghton et al., 1987). Destruction of 15 ha of the forest imposes a global damage cost due to release of carbon. Taking a value of $ 10 as the global damage cost of a ton of carbon released to the atmosphere (Pearce et al., 1989) results in a cost of Rs 136,800 per year per ha, which gives total cost of Rs 2,052,000 (US$ 19,298).

5.2.2.2. Cost due to the lost forest product collection. The community in the powerhouse area depends on the forest for fuel wood, medicinal herbs and edible foods such as leafy vegetables and tubers for their day to day needs. The construction and operation of powerhouse facilities will terminate community interaction with this part of the forest (EIA, 2003). Information on the lost forest use was obtained from a social survey carried out among the affected households. The survey gathered information from randomly selected 229 households and market prices were used to derive the values. Table 7 presents the economic value of different forest products that would be lost due to the project.

The above estimates have been based on the assumption that the collection of forest products would not be compensated by any other area. The estimated per household fuel wood values (Rs 4098.25 or $ 45.5) could be compared with the value of $ 43.5 per household per year (2003 prices) of Shyamsundar and Kramer (1996) for communities surrounding the Mantadia National Park in Madagascar. Further, Gunatilake et al. (1993) report firewood value of $ 59.5 (2003 prices) for peripheral communities of Knuckles Wilderness area in Sri Lanka.

5.2.3. Cost of lost home garden productivity

Constructions of access road at the powerhouse site, the culvert and road between the dam and the head race tunnel utilize homesteads along a stretch of about 1.7 km. Based on the field survey it was estimated that a total extent of 15.87 ha is considered to be out of production due to the project. This loss is expected to be experienced by the affected households for the entire project period. The benefit transfer method was used to estimate the cost. An annual home garden productivity value of Rs 535,929 per ha (Gunawardena, 2003) was used to derive the annual total value of lost production of the home garden, which is Rs 8,506,265.

Table 7
Lost forest product collection due to the project.

Forest product	Annual economic value[a] (Rs)	Per household value (Rs)
Fuel wood	938,500	4098.25
Timber	6000	26.20
Fish tail palm (Kitul) products	16,000	69.87
Medicinal plants	300	1.31
Total	**960,800**	**4195.63**

[a] These values have not considered the costs of collecting the products and therefore will be an overestimation of the true value.

5.2.4. Environmental benefits of the project: benefits of avoided coal power generation

Operation of the present hydropower project will avoid the need for any other alternative means of power generation, especially thermal power generation. The avoided release of carbon dioxide to the atmosphere due to the present project has been estimated and valued. Table 8 presents emissions of carbon dioxide from different electric power generation sources.

Power generation from coal emits 1051.6 additional tons of carbon. The average annual power generation for the proposed project is 145 GWh. Therefore, the project avoids the cost of 152,482 tons of carbon released into the atmosphere. When $ 10 is taken as the avoided global damage cost (Pearce et al., 1989), a benefit of Rs 137,233,800 per year results.

Table 9 provides a summary of the results along with the main social groups affected and possible compensation mechanisms. Most of the costs mentioned here are unpaid; however, a closer look reveals that remote high-income groups and local high-income groups are both gainers as well as losers of the project. However, local and remote low-income groups are only losers due to the project.

It was assumed that the cost of global warming damage is incurred by the global community who are of low income since the low-income groups have the least potential to mitigate and face vulnerabilities of the climate change. The benefits of avoided global warming damage however, are assumed to be enjoyed mainly by the high-income groups of the global communities due to their ability to pay for the benefits they gain.

There are two main inequality issues emanating from the above. The first is related to the costs, the highest cost being borne by the local low-income groups (US$ 879,000). The second inequality issue is that additional energy supplied to the main grid will not be necessarily used to supply power for the people who are without electricity at present. Main beneficiaries of the project are the grid connected people and the global communities, who receive carbon benefits.

5.3. Cost benefit analysis

The estimated costs and benefits along with other project costs such as construction, replacement and operation costs were analysed within the CBA framework (Table 10). CBA justifies the project with a NPV of 11,335,729 (at 10% discount rate) and with an internal rate of return of 11.52%.

In order to reflect concerns of people of different incomes, the estimated costs and benefits are recalculated applying distribution weights.

5.4. Application of distributional weights

Distribution weights were calculated based on average income of the different groups affected by the project. Table 11 provides details related to calculation of the distribution weights for the estimated environmental costs and project benefits.

Table 12 shows the percentage of costs and benefits after applying the distribution weights. When the distribution weights are applied, percentages of costs incurred by different groups changed significantly. Cost of the local low-income people increased to 85% while that of remote high-income groups becomes very small. When the Rawlsian principle is used, local and remote low-income groups' costs add to 100% and the application of distributional weights would result in cost distribution closer to the Rawlsian principle.

In addition to the project's negative impacts, there are benefits that are distributed differently among different income groups. With the distributional weights, local benefit share becomes 98% and this is also closer to the reforms suggested by Rawls (1971).

When distributional weights are applied for different income groups, the project resulted in a different NPV (Table 13). Different scenarios of electricity consumption are tested in order to identify the most just system. Maximum social benefits are obtained when all the electricity benefits are diverted to the lowest

Table 8
Emissions of pollutants from electric power generation: the total fuel cycle.
Source: FAO (1997).

Energy source	Carbon dioxide (tons per GWhr)
Conventional coal	1058.2
Fluidised bed coal	1057.1
Hydropower	6.6

Table 10
Results of the cost benefit analysis.

Criteria	Value
Net present value (@ 10%)	US$ 11,335,730
Net present value (@5%)	US$ 98,107,978
Internal rate of return	11.52%

Table 9
Costs, benefits and different social groups affected by the project.

Impact	Present value (US$ × 1000) @ 10%, 53 yr	Main social group affected	Possible internalisation mechanisms
Costs			
Impacts due to diversion of river flow			
C_1: Lost recreation monuments	33	Remote high-income visitors	Alternative sites
C_{2a}: Lost recreation water sports (remote)	510.7	Remote high-income visitors and local high-income visitors	
C_{2b}: Lost recreation water sports (local)	56.7		Alternative sites
C_3: Loss of scenic view of the river	1.7	Local low income	None
Impacts due to lost forest cover			
C_4: Lost forest land (global warming damage)	175	Remote low-income non-visitors	Alternative sites
C_5: Lost forest produce collection	99	Local low income	Alternative sites
C_6:Lost home garden productivity	879	Local low income	Compensation or alternative sites
Benefits			
B_1: Avoided coal power generation (avoided global damage)	12,550	Remote high-income non-visitors	Alternative projects
B_2: Power and energy[a]	82,924	Grid connected, mostly high income	Alternative projects

[a] The issue of to what extent this benefit could become an externality (consumption of an unequal share) was not analysed here.

income groups. Maintaining the present electricity distribution and consumption pattern means any additional supply provided to the grid would be consumed by the urban high-income groups. This would not however yield an economically efficient outcome when distributional weights are applied. In order to be viable, the project needs diversion of at least 9.3% of its electricity generated for low-income households in the country.

6. Discussion and conclusions

Estimated values of externalities were comparable with the estimates available worldwide. However, the cost figures could be underestimations, especially where market values were used. The magnitude of values that were not estimated however could also be significant. Indirect use and option values are examples. The study assumed carbon trading to be a reality, where both forest and hydropower carbons are traded equally at similar rates. However, the possibility of a 'free ride' from developed countries cannot be ignored, adding further dimension of inequality.

The only impact that was difficult to compensate due to the project was the local peoples' loss of scenic view of the river. A possible pareto-based solution is to allow environmental flow during the day time to maintain the lost services. Most of the other river associated lost benefits could be recovered from another river site but lost forest benefits may need compensation payments for the affected communities. This suggests that although CBA assumes weak sustainability, strong sustainability approach would be needed to address some of the equity aspects.

Internalisation of externalities needs proper consideration in any development plan if the ultimate objective is to achieve sustainability. If internalisation mechanisms for individual projects are difficult to apply, the next step is to look for broader approaches. Decisions based purely on economic grounds have been subjected to much criticism on ethical grounds (Sagoff, 1988; Stirling, 1997) and the need for public discourses in making decisions has been emphasised (Soderholm and Sundqvist, 2003). Pearce et al. (1989) suggested that extended CBA needs sustainability to be integrated through a sustainability constraint. That is, for a group of projects undertaken by a decision maker, environmental damage should be zero or negative. This framework could be further extended to incorporate an equity constraint. That is, for a group of projects there should be a net improvement of income of lowest income groups of the society. The potential imbalance between costs arising at the local level and benefits accruing at the national and global levels should be neutralised by appropriate transfer mechanisms.

Renewable energy could incur significant environmental costs at local, national and global levels and distributional inequalities when they are placed in inappropriate locations. The study estimated costs and benefits related to a run of river project in Sri Lanka and identified different social groups related to the project. CBA implies that undertaking the project is worthwhile. However, if the local low-income groups are the main cost bearers while local as well as remote affluent groups are the main beneficiaries, the traditional approach seems to result in an unfair decision. With application of distribution weights, the

Table 11
Distribution weights for different income groups affected by the project.

Income group	Mean monthly income (US$)	Distribution weight w[a]
Cost bearers		
Remote high income (visitors, C_1, C_{2b})	2444[b]	0.07
Remote low income (non-visitors, C_4)	75.4[c]	2.27
Local high income (visitors, C_{2b})	533[b]	0.32
Local middle income (C_5)	136[b]	1.26
Local low income (C_3, C_6)	60[b]	2.85
Beneficiaries		
Remote high income (non-visitors, B_1)	926[c]	0.15
Local average income (B_2)	171	1
Local people of the lowest income quintile (mostly off-grid community, B_2)	22[d]	7.96
Local people of highest income quintile (mostly grid connected) (B_2)	588[d]	0.29

[a] w=average income/groups income.
[b] Based on the survey data.
[c] World Bank (2008).
[d] Central bank of Sri Lanka (2005).

Table 13
Efficiency of different electricity consumption scenarios among different income groups (with distributional weights).

Electricity consumption scenario	NPV @10% (US$)
All electricity benefits are provided for the lowest income quintile of the rural	524,925,856
When all electricity benefits are provided for the highest income quintile of the urban	−53,084,155
When electricity benefits are equally shared by the highest income quintile of the urban and the lowest income quintile of the rural	235,920,850
Electricity benefits are shared by the highest income quintile (90.7%) of the urban and the lowest income quintile (9.3%) of the rural	0

Table 12
Percentage of costs and benefits with and without distributional weights.

Income group	Percentage of cost/benefit without distribution weights (when $\eta=0$)	Percentage of cost/benefit with distribution weights (when 1<$\eta>0$)	Percentage of cost/benefit (when $\eta=1$)
Cost bearers			
Remote high income (visitors)	30.9	1.2	0
Remote low income (non-visitors)	9.9	12.88	20
Local high income (visitors)	3.2	0.58	0
Local low income (living close to the project site)	55.8	85.2	80
Total	100	100	100
Beneficiaries			
Remote high income (non-visitors)	13.2	2.2	0
Local average income	86.8	97.8	100

project NPV changes and suggests that at least 9.3% of benefits be reserved to the low-income groups for the project to pass the efficiency test.

The main implication for the government is that while implementing redistributive programs in general, it is essential to have special programs to address inequities at the sectoral level. If incomes of the lowest income groups, who are presently without electricity, are considered in the analysis, it may recommend an even higher percentage of electricity benefits to be allocated for such groups.

Continuity of off-grid schemes with suitable renewable technologies that are capable of providing multiple benefits to the low-income communities will be a strong proposition in the backdrop of near impossibility of the national grid to reach certain rural areas. Intervention by the government to create a mechanism to sustain these projects is a strongly felt need. Other concerns will be the possibility of minimising environmental impacts associated with power through energy efficiency. Investments should be directed to programs to minimise life-threatening burns associated with the use of kerosene lamps by off-grid communities.

The paper raises two key questions: how best to internalise externalities and how to integrate inequality into decision making? Demonstration of the use of distributional weights will have only little practical importance in the present decision making context in Sri Lanka since even the extended versions of CBA have been unable to bring a significant shift in decisions. Therefore, promoting equity in all projects related to natural resources and incorporating equity in all stages of project analysis would be an immediate need along with proposals for incorporating an equity assessment into the existing EIA procedures.

Appendix. Contingent valuation scenario

You mentioned that it is very important/important that the flow of water be there for the experience you intend to enjoy.

The stretch of the river with the filming location of the 'Bridge on the River Kwai' will be used for a development project activity in the near future. The river will be completely dried since the water is planned to be diverted for hydropower generation. Your answer to this question is very important. Government wants to learn how much it is worth to people like you to avoid the loss of river flow. Your answer will help them make decisions about measures to continue the river flow.

You will be losing the scene you used to enjoy. Those who have not yet visited will lose the chance of seeing this location in the original situation. This benefit will be lost forever if the project is implemented.

Imagine that a special programme is going to be operated for the maintenance of the river flow during daytime. The programme will ensure the normal natural flow to be there during daytime. However, the programme could be operational only if it receives individual support. Think carefully, if the individual support is not there, the programme will not be implemented. Would you be willing to support such a programme? If yes, what is the maximum amount of money you are willing to pay for such programme?

(When you state your amount, remember that when you pay this you have less money to use for other goods and services.)

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