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Extended CBA

Extended benefit-cost analysis: quantifying some environmental impacts in a hydropower project

Malik Ranasinghe

Traditionally, economic analyses were confined to inputs and outputs incurred or produced directly by the project. Now, many indirect costs are included in the economic analyses by means of environmental and/or non-market valuation. This process is called the extended benefit-cost analysis. A case study is presented for a hydropower project from Sri Lanka, for which an attempt was made to quantify and incorporate in monetary terms the cost of some environmental impacts to the economic feasibility, using valuation techniques based on the principles of environmental economics. It develops the financial, economic and extended benefit-cost analyses assuming the hydropower project to be demand driven.

Keywords: environmental cost; economic feasibility; benefit-cost analysis

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IN THE DEVELOPING COUNTRIES, the traditional decision criteria for investments in large engineering projects such as hydropower dams, highways and airports, have been the economic, financial and technical feasibility of the projects. Until recently, little attention was paid to immediate and long-term environmental impacts of these engineering projects.[1-8] The following factors identified by Katerere[9] as limiting the progress in the developing countries in relation to environmental issues are applicable to Sri Lanka:

- the need to export some 'environmental' resources such as timber;
- unwillingness to reform policies which govern resource allocation and distribution;
- lack of financial and technical resources;
- the influence of interest groups at home and abroad;
- lack of government commitment and investment; and
- inadequate administrative structures.

Two other factors that have been a hindrance in Sri Lanka are the difficulty of measuring environmental impacts in physical terms, and, even when this has been achieved, the difficulty of valuing them in monetary terms.[10]

For most large infrastructure projects, the governing criterion for investment is economic feasibility. The objective of economic analysis is to explore whether the project can be expected to

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The original study showed that the hydropower plant would generate 144MW, but 1600 hectares of cultivated land would be inundated and 9,500 people displaced: there was widespread opposition from the local population and environmental organisations

create more net benefits than any other, mutually exclusive alternative, including the option of not doing it.[6,10] In principle, the economic appraisal should take into account all benefits and costs of the project.[6,11-15]

Traditionally, economic analyses were confined to inputs and outputs incurred or produced directly by the project. Now, many indirect costs are included by means of environmental and/or non-market valuations.[16] This process is called the 'extended benefit-cost' analysis. Then shadow prices, rather than market prices, are used to reflect economic opportunity cost, including valuation of externalities whenever practical.[10] Therefore, including environmental impacts in monetary terms in the early economic appraisal, however approximately, would improve the quality of decisions made.

When defining the costs of environmental impacts it is necessary to make a distinction between what constitute normal engineering costs, and what constitute costs of environmental impacts. For example, in Sri Lanka, it is now routine for hydropower projects to include in the capital costs, the costs of resettlement and production forgone due to inundation of land: these were earlier considered as costs of environmental impacts.

Similarly, many aspects of pollution control for thermal-power generation have become routine costs of good engineering practice. This paper presents a case study of an extended benefit-cost analysis for a hydropower project in Sri Lanka for which an attempt was made to quantify, and incorporate in monetary terms, the cost of some environmental impacts to the economic feasibility, using valuation techniques based on the principles of environmental economics.

The paper is structured as follows. First, the case study is introduced, by describing the background of the Kukule Ganga (River) hydropower project, the results of the economic feasibility that was carried out using the least-cost approach, and the environmental impacts of the project that were identified in the environmental impact assessment (EIA) report.

Then the extended benefit-cost analysis is developed. This analysis looks at the project as being demand-driven, as opposed to power-generation analysis being supply-driven, as assumed by the least-cost approach.[6] The environmental benefits and costs that are not included as normal engineering practice, are now included into the economic feasibility as the extended benefit-cost analysis. Finally, the lessons that are learned from the case study are highlighted.

Case study

Background

The focus of our case study is the Kukule Ganga (River) hydropower project located in central Sri Lanka on a tributary of Kalu Ganga which is the second longest river in the country. The river-bed level of the Kukule Ganga at the proposed site is around 190 metres above mean sea level (masl). The river slope upstream is flat, while the river bed gets relatively steep towards the power outfall downstream, dropping to around 16 masl in a distance of about 7.5 km along the proposed waterway.

The last study on the Kukule Ganga basin was carried out in 1989 as a part of the pre-feasibility study for the Kalu Ganga Multipurpose Project.[17] It studied various development scenarios such as flood protection, hydropower, irrigation and multipurpose developments. As a result, it was recommended that the feasibility of a single-purpose development for hydropower, with a 50m high dam located on Kukule Ganga, should be explored.

Of the available locations for future hydropower generation in Sri Lanka this proposal had the highest expected capacity of 144MW. However, it was also identified that the resulting reservoir (20.8km^2) would cause a relatively large amount of inundation of cultivated land (1600ha) and displacement of a population of approximately 9,500 persons from 1,900 households. There was widespread opposition from both the local population and the environmental organisations.

The current study for Kukule Ganga hydropower project[18] aimed to select an economically optimal alternative for power generation, within the limits of 'acceptable impacts' to the environment, by examining the layout of major structures, scale of storage and power plant. After a preliminary screening of the information in the pre-feasibility study, possible waterway systems, adduction of water from other basins to Kukule, and topographical effects on the area of the reservoir, 42 alternatives for economic and financial analyses and six alternatives for environmental assessment were selected as shown in Table 1.

The primary planning objective for power generation in Sri Lanka has been to meet the anticipated need for electrical energy at the least cost. The least-cost approach assumes that the

Table 1. Alternatives for economic and evnironmental feasibility

Criteria	Key	Economic	Environment
Waterways		2	2
Intake - Kukule; outfall-Kukule	K-K		
Intake-Kukule; outfall-Peleng	K-P		
Full supply level	FSL	3	3
Run of River - 206 masl	ROR		
Low Dam - 230 masl	LD		
High Dam - 242 masl	HD		
Capacity factors		7	-
Total		42	6

benefits from a hydropower project are the costs of generating equivalent electrical energy by an alternative resource — in Sri Lanka, the comparison is with thermal energy (see Figure 1).

In other words, if the Kukule Ganga hydropower project is not implemented, the system would still have to produce 317GWh of electric energy per annum to meet its projected demand.[19] This would have to be generated from a more expensive thermal source, such as diesel, coal or gas. This assumes that the analysis for power generation is supply-driven. The least-cost technique is called the cost-effectiveness approach,[20] as opposed to the benefit-cost approach in which the analysis is demand-driven.

Economic feasibility

The 42 alternatives derived from the two waterway configurations (three full supply levels (FSL), and seven installed capacity factors (ratio between plant discharge and average inflow)) were considered in the optimisation analysis. The alternatives were eliminated step by step to find the economically best alternative. From economic analyses based on preliminary benefit and cost estimates and intangibles (social and environmental) it was concluded that the preferred alternative was a run of river configuration with intake and outfall of water at the Kukule Ganga (K-K ROR) with an installed capacity factor of 1.5 (70MW), to be commissioned in 1999.[18]

The estimated construction period was 4.5 years. In other words, if the civil works are started in the second half of 1994, the project can be commissioned at the beginning of the year 1999. The economic analysis assumed such a construction schedule.

The total economic cost of the project was estimated at US$133.139 million. The economic cost of the project was calculated by adjusting only the annual local cost component with a standard conversion factor of 0.9 for shadow pricing. The foreign currency portion was US$112.908 million, while the local cost was US$22.479 million. Taxes and duties were excluded. A discount rate of 10% was used for the economic analysis in accordance with the requirement of the World Bank.[18]

The economic analysis assumed that the economic benefits from Kukule hydropower project were equal to the costs of generating equivalent usable energy from the best capacity-expansion plan, which is shown in Table 2. It reported an economic internal rate of return (EIRR) of 14.56.[18] However, there was no comparison of the economic costs and benefits of Kukule hydropower project alone.

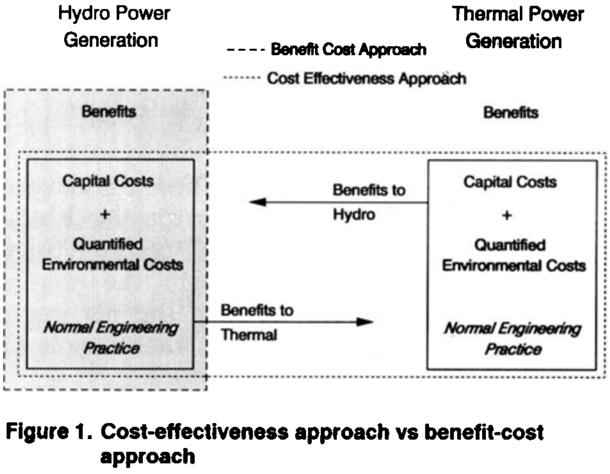

Figure 1. Cost-effectiveness approach vs benefit-cost approach

Environmental impact assessment

An extensive environmental impact assessment was carried out, in which the six alternatives derived from the two waterway configurations and the three FSLs were considered. That Report[21] observed the impacts of the economically preferred option, K-K ROR with a 1.5 capacity factor, on the environment as follows:

1. The main impact of K-K ROR will be that caused by the weir, which reduces the water flow between the weir and the water outfall, and interrupts the migration route of fish and other migratory aquatic animals.
2. On the natural terrestrial habitats — vegetation and fauna — the impact is almost negligible, as the area to be flooded does not contain any forest land or important habitats.
3. Due to the quick turnover of the water in the small regulation pond, the danger of eutrophication is small. As excess water will be released from the weir during the wet season, the effects of the water quality downstream of the weir will be less noticeable than with a dam.
4. As the reservoir is small, only a small area (about 70 ha) of land will be lost due to inun-

dation. Therefore, only a small number of people (approximately 100) will have to be resettled.
5. No cultural or archaeological sites will be affected by K-K ROR.
6. The risk of creating higher incidence of malaria and other water-related diseases is relatively small.

The Report concluded that the K-K ROR option was the most environmentally friendly alternative when compared to others in the set of 'development options'. When K-K Low Dam is considered, which is the next preferred alternative, there is a magnification of the environmental impacts. In addition to those impacts mentioned for K-K ROR, the following were identified as significant:

1. Loss of more than 80ha of forest due to submersion. These forests are important habitat for the indigenous fauna.
2. High risk of eutrophication of the water due to changing a stretch of river into a lake.
3. Loss of densely populated and intensively cultivated land and, therefore, resettlement of large number of people.
4. Submersion of roads and places of gem mining.
5. Inundation of two temples, which are cultural sites of local importance.
6. Higher risk of increase of malaria and other water-related diseases. Higher health risks as a large number of people have to be resettled.

Extended benefit-cost analysis

The objective of the extended benefit-cost analysis is to analyse and quantify two important issues that were ignored in the feasibility study for the Kukule Ganga hydropower project.

Firstly, the economic feasibility was analysed using only the costs and benefits forecasted in the feasibility study. In other words, the project was considered from a demand-driven (benefit-cost) approach as opposed to the supply-driven (cost-effectiveness) approach that is generally assumed in the traditional power-generation analysis. The demand-driven approach involves the use of power tariffs to value benefits. Since Kukule will be developed as a pure hydropower project, the quantified benefits are those from the sale of electrical energy through the national grid.

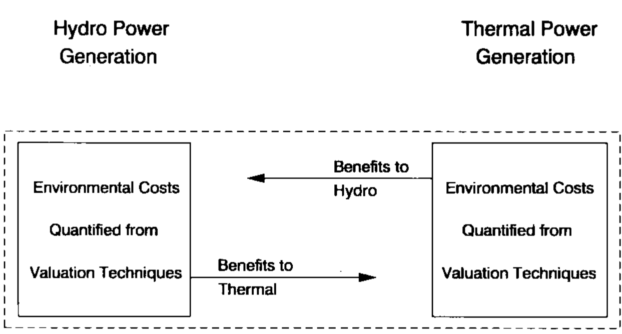

Figure 2. Environmental impacts for extended benefit-cost analysis

Table 2. Best capacity thermal expansion plan at 10%

	Diesel	Coal	Gas	Total
Thermal-energy generation	168	89	60	317

This approach is reasonable because the power supply from the Kukule Ganga hydropower project is incremental to the national grid. The implementation of this project will not affect the prices of electricity, as the amount of electricity generated is relatively small compared to the total national supply. The pricing policy for electricity is based on the costs of the total supply to the national grid.[19]

The second consideration was the environmental impacts of the Kukule Ganga hydropower project that are not quantified as normal engineering practice. Meier and Munasinghe[22] state that the first step in carrying out environmentally sound economic analyses is to determine the environmental and natural resource impacts of the energy project in question. As in any project appraisal, the physical impacts are determined by comparing the 'with project' and 'without project' scenarios.

In the cost-effectiveness approach it is assumed that the alternative best-capacity generation plan is the 'without project' scenario. A benefit-cost approach will also have to assume such a scenario to quantify the environmental benefits and costs (see Figure 2). In other words, it assumes that the hydropower project will replace alternative thermal plants and avoid the costs of their environmental impacts. While this may seem inconsistent with the demand-driven approach, there is no reason why they cannot be included as benefits due to avoided costs.

In the following analysis, the costs of unquantified environmental impacts of the best capacity thermal expansion plan at a discount rate of 10% given in Table 2 are compared to the costs of environmental impacts of the hydropower project that are not quantified for the economic feasibility.

Financial and economic analyses

Table 3 shows the market price (financial) analysis for the K-K ROR alternative for the Kukule Ganga hydropower project at 1992 constant prices. The benefits are derived from the sale of 270.6GWh of electrical energy, the net energy generated by the project after transmission and distribution losses.

When it is assumed that the annual estimated costs occur at the middle of the calendar year and

Table 3. Financial analysis in 1992 market prices (US$ '000)

	Constant dollar cost			Annual	O&M	Net
	Local	Foreign	Total	revenue	cost	benefits
Conversion factor	1.0	1.0		1.0	1.0	
1994	2646	5566	8212			
1995	6212	26045	32257			
1996	3275	16102	19377			
1997	5494	34252	39746			
1998	4852	30943	35795			
1999				15462.857	131	15331.857
...				...	...	...
2048				15462.857	131	15331.857
Total	22479	112908	135387			

net annual benefits at the end of the calendar year for discounting, the rate of return is 9.28% indicating that the project does not meet the rate of 10% required for investment in infrastructure projects. For a discount rate of 10%, the net present value is US$-6.986 million at 1992 constant prices and the benefit cost ratio is 0.92.

Table 4 shows the economic analysis of the K-K ROR alternative. The shadow prices for the economic analysis were evaluated as suggested in the report for the National Planning Department (NPD)[23] for projects in Sri Lanka. As recommended, three conversion factors were used to convert the market prices to economic prices.

The local cost component of the capital costs was converted by the investment conversion factor of 0.9. This same conversion factor was used for the least-cost analysis performed in the Kukule Ganga feasibility study report.[18] The electricity prices were converted by the factor of 1.572. The annual operation and maintenance cost was converted by 0.785, the average conversion factor, which was used because a detailed breakdown of the cost components was not available in the feasibility study, and the conversion factors for the main inputs to operation and maintenance costs, scarce labour, surplus labour and machinery and equipment are 0.785, 0.722 and 0.776, respectively.

The EIRR is 13.77%, when it is assumed that the annual estimated costs occur at the middle of the calendar year and the net annual benefits at the end of the calendar year for discounting. The net present value at a discount rate of 10% is US$39.611 million and the benefit-cost ratio is 1.47. It meets the rate of return of 10% required for investment in infrastructure projects.

When the feasibility analysis is from a benefit-cost approach, that is, assuming that the project should be demand-driven, the K-K ROR alternative for the Kukule Ganga hydropower project is not feasible at market prices. However, economically it is feasible and it is the most environmentally friendly option.[21]

Environmental benefits and costs

Since electrical power generation in Sri Lanka at present is predominantly hydro-based, the main

Table 4. Economic analysis in 1992 prices (US$ '000)

	Constant dollar cost			Annual	O&M	Net
	Local	Foreign	Total	revenue	cost	benefits
Conversion factor	0.9	1.0		1.572	0.785	
1994	2381.4	5566	7947.4			
1995	5590.8	26045	31635.8			
1996	2947.5	16102	19049.5			
1997	4944.6	34252	39196.6			
1998	4366.8	30943	35309.8			
1999				24307.611	102.835	24204.776
...				...	...	...
2048				24307.611	102.835	24204.776
Total	20231.1	112908	133139.1			

When the project is analysed from a benefit-cost approach (demand-driven) it is not feasible in a strict financial analysis at market prices: however, an economic analysis shows it to be feasible and it is the most environmentally friendly option

environmental issues that the power sector has had to deal with have been those due to inundation of land, such as resettlement of people and opportunity cost of lost production. As the system shifts towards the generation of thermal energy in the future, major environmental issues will also shift towards those associated with thermal plants. These will be of quite a different nature to those associated with hydro projects.[22]

The objective of this section is to explore whether the conclusions of the economic analysis from the benefit-cost approach would change if the costs of environmental externalities are included. This exercise is influenced by the guidelines developed by Meier and Munasinghe.[22]

While estimating the costs associated with pollution control is relatively easy, estimating the cost of environmental damage associated with a specific pollutant is much more difficult. The main reason for this is the absence of markets for environmental services, which means that prices, normally the best indicator of society's willingness to pay, are not available. The difficulties of economic valuation of environmental impacts are nowhere better illustrated than in the health costs of air pollution and the related issues of the valuation of human life.

The second step in considering the environmental effects involves valuing the physical impacts and relationships. An environmental impact can result in a measurable change in production and/or in environmental quality.[22] The environmental impacts of hydropower that can be quantified, such as resettlement costs and opportunity costs of production forgone, are now included in the capital costs as normal engineering practice.[18]

Environmental impact valuation

This section identifies some of the environmental degradations caused by thermal and hydropower generation that have not been quantified in the economic analysis, and, where possible, quantifies in monetary terms their costs for inclusion in the extended economic feasibility.

The loss of sequestration of carbon dioxide (CO_2) from the 70ha land inundated directly or indirectly by the K-K ROR alternative, and the economic value of river fish that will be affected by the weir, are two environmental impacts from the hydropower generation not included in the economic analysis. The main such impact from thermal-power generation is on air pollution. Discharging heated cooling water to the sea by coal-powered plants, and the waste that will be accumulated by the three best capacity thermal plants, are two others that can be significant.

Due to lack of information on the sequestration rate of different varieties of crops such as tea, rubber and rice, the environmental cost of CO_2 was not quantified. Similarly, the environmental impacts of discharging heated cooling water to the sea and the accumulated waste from the best capacity thermal plants, were not quantified due to lack of information. The economic cost of fish affected by the construction of the weir was not valued for two reasons: river fish in general have very small economic value in Sri Lanka; and fishing in the project area is not an established economic activity for measuring before and after productivity.

However, it is assumed that the two unquantified environmental costs of hydropower generation are offset by those of thermal plants, which are much larger in magnitude.[24] Therefore, the environmental cost of air pollution caused when generating 317GWh from the best capacity thermal plants is assumed to be the equivalent environmental benefit to Kukule Ganga hydropower project, due to the cleanness of hydropower generation (see Figure 2).

The first step in approximating the environ-

Table 5. Emission coefficients

Resource	Heat rate (kCal/kWh)	SO_2 (kg/kWh)	NO_x	Particulate (kg/kCal*10^6)	CO_2
Diesel	2134	0.0149	3.141	0.042	300
Diesel + NO_x	2134	0.0149	0.314	0.042	300
Coal (Mawella)	2269	0.0068	1.802	1.802	376
Coal + FGD (M)	2382	0.0014	1.802	1.802	376
Coal (Trinco)	2232	0.0067	1.802	1.802	376
Coal + FGD (T)	2344	0.0014	1.802	1.802	376
Gas turbine	2908	0.0029	0.897	0.065	290

Source: Meier and Munasinghe (1992)

There is considerable debate over the appropriateness of putting a value on human life, but it must be remembered that in most of the decisions we make in our day-to-day lives we implicitly give life a value

mental cost of air pollution is to define appropriate emission coefficients for the main thermal-power pollutants of sulphur dioxide (SO_2), nitrous oxides (NO_x), CO_2 and particulates. After an extensive review of the literature, Meier and Munasinghe[22] suggested emission coefficients applicable to the main air pollutants in Sri Lanka. To derive these they converted values suggested in different units in various studies to a common unit of kg/kCal*10^6 for comparison. Those emission coefficients given in Table 5 were used for this case study.

The second step is to estimate damage costs related to the pollutants associated with the thermal-power generation sector in Sri Lanka. Unfortunately there are no known studies in Sri Lanka. The lack of epidemiological studies that might provide evidence of a relationship between air pollution and health effects is hardly surprising given the lack of data on ambient air quality.[22] We therefore have to look for studies done elsewhere.

The extensive review by the Pace University Study (PUS) by Ottinger *et al*,[25] based largely on values from the United States is used as a guide to this study. Most of the damage cost estimates in this study are attributable to mortality, morbidity effects and the degradation of visibility. Therefore, the loss of earnings (human capital) approach can be adopted to quantify the possible future health impacts of pollutants SO_2, NO_x and particulates in Sri Lanka.

Respiratory diseases, such as bronchitis, are a significant health issue in Sri Lanka, as they account for 8% of the hospital deaths and 9% of all hospitalisation cases. The link between the cause and effect is generally given by the dose response function, which is interpreted as the probability that an individual will contract bronchitis in any one year if exposed to a unit per volume of particulates for the entire year.[22]

To overcome the lack of epidemiological data to develop a dose response function, we can make a reverse calculation and find out what would be the valuation of human life, or per case cost per illness, to estimate the damage cost.[22] There is considerable debate regarding the appropriateness of valuing human life. While the ethics of such a valuation is beyond the scope of this paper, it must be remembered that in most of the decisions we make in our day-to-day lives we implicitly put a value on human life.

The damage costs of the PUS study are based on a valuation of US$4 million per death and US$400,000 per non-fatal but disabling illness. Meier and Munasinghe valued a non-fatal but disabling illness of a Sri Lankan at US$50,000, as a result of a survey of their study-team members and an approximation to the ratio of US per capita GNP (gross national product) to that of Sri Lanka. They recommended 10% of the PUS damage costs for pollutants SO_2, NO_x and particulates in Sri Lanka (see Table 6).

A more realistic estimate of the value of a non-fatal but disabling illness of a Sri Lankan can be obtained by assuming the average salary of a Sri Lankan to be approximately SLR (Sri Lankan rupees) 100,000 (1US$ = 50SLRs) per annum over 45 years at a discount rate of 10%. Then the value of a non-fatal but disabling illness of a Sri Lankan is approximately US$20,000. Therefore, the use of 5% of the PUS damage cost estimates for pollutants SO_2, NO_x and particulates as shown in Table 7 is more reasonable. However, this is still a lower bound of the damage costs, because we have con-

Table 6. Damage cost of air pollution due to thermal-power generation

	SO_2	NO_x	Particulate	CO_2		Total	
Damage cost (US$/ton)	446.6	180.4	261.8	15.0			
Resource	USCts per KWh					GWh	US$
Diesel	0.666	0.121	0.002	0.960	1.750		
Diesel + NO_x	0.666	0.012	0.002	0.960	1.641	168	2756434
Coal (Mawella)	0.304	0.074	0.107	1.280	1.765		
Coal + FGD (M)	0.064	0.077	0.112	1.343	1.597		
Coal (Trinco)	0.299	0.073	0.105	1.259	1.736		
Coal + FGD (T)	0.063	0.076	0.111	1.322	1.572	89	1398899
Gas turbine	0.130	0.047	0.005	1.265	1.447	60	868191
Total annual environmental benefit for hydropower project							5023524

Source: Meier and Munasinghe (1992)

Table 7. Damage cost of air pollution due to thermal-power generation

	SO_2	NO_x	Particulate	CO_2		Total	
Damage cost (US$) / Ton	223.3	90.2	130.9	10.0			
Resource	USCts per KWh					GWh	US$
Diesel	0.333	0.060	0.001	0.640	1.035		
Diesel + NO_x	0.333	0.006	0.001	0.640	0.980	168	1647101
Coal (Mawella)	0.152	0.037	0.054	0.853	1.096		
Coal + FGD (M)	0.032	0.039	0.056	0.896	1.023		
Coal (Trinco)	0.150	0.036	0.053	0.839	1.078		
Coal + FGD (T)	0.032	0.038	0.055	0.881	1.007	89	895993
Gas turbine	0.065	0.024	0.002	0.843	0.934	60	560594
Total annual environmental benefit for hydropower project							3103688

Source: This case study

sidered only the morbidity effects. The mortality effects would increase the damage costs.

The 'shadow project' approach was used for the valuation of the damage cost of CO_2 pollution. The PUS estimate of US$15/ton of CO_2 is based on the cost of reforestation of an area with the equivalent sequestration of CO_2. The same value is suggested by Meier and Munasinghe for Sri Lanka (see Table 6). We suggest that a lower value of US$10/ton of CO_2 is more applicable, in line with the suggested carbon sequestration rate of 1.81-2.26 tons/acre/year.[26] This value is still likely to be conservative for two reasons: the cost of forestry programmes in Sri Lanka is likely to be lower and growth rates in the tropical forests are likely to be faster than in the temperate forests of the United States.

With these assumptions we can now explicitly value the environmental cost of air pollution caused by thermal plants in Sri Lanka for two scenarios: first, using the damage costs recommended by Meier and Munasinghe; and, second, using those argued by this case study to be more applicable for Sri Lanka. The annual pollution cost from diesel for example, is calculated by multiplying the energy generated from diesel (168GWh) by the total pollution costs per kWh (1.641) (see Table 6). The total pollution cost per kWh was evaluated by summing the multiplications of the damage costs per ton by the emission coefficients of individual pollutants and by the heat rate of the generation plant where applicable.

The annual pollution costs of diesel, coal and gas turbine are summed to obtain the annual environmental cost of air pollution. For the first scenario, the annual environmental cost of air pollution is approximately US$5 million (see Table 6), and for the second it is approximately US$3 million (see Table 7).

The environmental cost of air pollution in generating 317GWh of thermal energy per annum from the best capacity expansion is added as environmental benefit to the economic analysis of Kukule hydropower project given in Table 4. Then, the extended net present value of the project with environmental benefits at 10% discount rate are US$65.17 million and US$55.4 million and the extended benefit-cost ratios are 1.78 and 1.66, respectively, for the two scenarios. The extended EIRR is 15.95% and 15.14%, respectively, clearly satisfying the discount rate of 10% required for investment in infrastructure projects in Sri Lanka.

These values will be underestimates if the environmental costs of thermal energy that were not quantified, the costs from discharging heated cooling water to the sea and the waste that will be accumulated by the best capacity thermal plants, are greater than those from hydro, those due to the loss of sequestration of CO_2 from the 70ha affected by inundation and the loss of fish that will be affected by the weir.

As a result of the extended economic analysis the client can now state with confidence that from both the cost-effectiveness approach, which is the supply-driven analysis, and the more robust benefit-cost approach, which is demand-driven, the Run of River option proposed by the Kukule Ganga hydropower feasibility study is a worthwhile alternative for investment from both an economic and an environmental point of view.

Summary

We have used a case study to illustrate the concept of extended benefit-cost analysis. The starting point was the assumption that the project should be analysed as demand-driven. The analysis at market prices showed that the project is not feasible. Using some of the aggregate and sectoral conversion factors recommended for Sri Lanka,[23] the market-price analysis was converted to an economic analysis. At economic prices the project was feasible.

Some of the main environmental impacts not quantified under normal engineering practice were identified under the extended benefit-cost analysis. The costs of environmental impacts due to the hydropower project are included as extended costs, while the avoided costs of environmental impacts of equivalent thermal-power generation are included as extended benefits to the project. The extended benefit-cost analysis confirmed the conclusion of the Kukule Ganga feasibility report[18] that the K-K ROR alternative is feasible from an economic and environmental viewpoint.

The extended benefit-cost analysis goes beyond the traditional benefit-cost analysis as it explicitly quantifies as many environmental impacts as possible in monetary terms for the economic feasibility. It provides the link between the EIA report, which is generally a technical document, and the economic feasibility analysis. Including environmental impacts in monetary terms in the economic appraisal, however approximately, would therefore improve the quality of decision-making.

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