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A Comparative Cost -Benefit Analysis of Hydropower Options for Developing Countries : The Sustainable Approaches

KEYWORDS

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ABSTRACT *The present paper discusses the comparative cost- benefit analysis of hydropower options for the developing countries. The study observed different sustainable approaches of the hydropower options. The gainers and loosers were identified to show the impacts of the projects. The revenue of cost and benefits in the form of cash flow were studied. The research illustrates the strengths and weaknesses of each of the hydro options studied, suggesting where each is most applicable, based on the best evidence available. It shows that micro and pico hydro can be cost effective for supply of rural electricity, even where population densities are sparse. It also shows that large-scale hydro may be cost effective, even where the major costs of environmental mitigation are included. However, as a means of achieving rural electrification in developing countries, small hydro schemes may not be cost effective*

Introduction Hydropower produces almost a fifth of the world's electricity and supplies 87% of electricity derived from renewable sources, yet only a third of the world's realistic hydro potential has so far been developed. This is particularly surprising as there is great scope for it in countries where the need for electric power is greatest. Sustainable hydropower is a renewable, safe, clean and reliable source of energy. It already supplies energy to 161 countries, and its development is most advanced in some of the richest and most environmentally aware nations.It can become one of the international community's key tools in the struggle to raise the living standards of the poorest. Continued exploitation of this resource is likely as a response to the world demand for energy. Environmental legislation such as the Kyoto Protocol is increasing pressure on all governments to generate 'clean' energy or energy from sustainable sources. Hydropower produces little CO2, but in other respects may not be truly sustainable.

Hydropower schemes range from the massive to the very small. The biggest schemes involve damming huge rivers, and supply large urban population centres with electricity. A dam built across a river valley creates an artificial storage reservoir and an increase in hydrostatic head (height through which water will fall). A powerhouse containing turbines and generators is built at the foot of the reservoir. The storage capacity of the dam reduces the effects of seasonal changes in river flows and allows regulation of releases through the turbines. These hydro-schemes will usually be grid connected, although smaller projects may serve localized users, particularly in rural areas.

Run-of-river systems do not rely on a reservoir. Generation capacity can vary significantly depending on seasonal river flows. These schemes often utilise existing weir technology.

Run-of-river schemes can vary in size significantly but many are relatively small and so often not grid connected. Micro and Pico systems typically utilise the high heads and small flows often found in upland regions. Their small generating capacity makes them suitable for isolated off-grid locations to provide power to small rural communities. They are typically run-of-river, although small storage tanks may be required to hold a small amount of water to ensure that, even at times of low flow, generation can be guaranteed for at least a short period every day.

Large dams on rivers are now well understood to be far from environmentally benign, and such schemes have suffered much criticism in recent years. It is generally accepted in the literature on hydropower pitfalls that, the larger the hydropower scheme, the greater the adverse effects are to riverine wildlife, riverside communities and river ecology. These effects are mainly a result of water storage in the river valley and disturbed downstream flows..

Table 1.

Classification	Power Output
Large	> 100MW
Medium	10 - 100MW
Small	1 - 10MW
Mini	100kW - 1MW
Micro	5 – 100kW
Pico	< 5kW

.. The 10MW outer boundary for a 'small' project is subject to alteration in different countries or by different organisations, the value shown here is as defined in the EU.

Project Definition

In a hypothetical scenario, the government of a developing country is considering tapping the hydropower resource of a particular region by building a 100MW hydropower dam on the region's main river. The intention of the government is to further the economic development of the country through increased access to electricity, particularly for the many rural inhabitants of the region who currently rely on wood and car batteries for power. They intend to connect 100,000 rural households to supplies of around 75W each and it is hoped that this action will improve the quality of life of very poor people and encourage industrial end uses of the electricity.

This scenario was addressed through economic assessment using CBA style techniques and decision making to decide the relative balance of costs and benefits for three discernible hydropower schemes utilising different scales of hydro technology:

Option A 'Single Large': A large dam on the region's main river with A considerable storage reservoir can continuously supply 100MW of electricity. In order to connect rural communities, a significant grid extension program will be required. Generating capacity in excess of that required to electrify rural communities will be used for urban centres, large industry or export. Option B 'Several Small': There are several smaller river basins and tributaries to the region's main river which could be used for a series of small hydropower projects in the region of 5MW each. Power stations will be dispersed throughout the region but a significant new distribution network will be required.

Option C 'Micro & Pico': Fast flowing streams pass close to or through many of the target communities, which lend themselves to Micro or Pico hydro schemes.

Only village distribution networks are required or short transmission lines to distribute Micro-hydro power to several small villages.

The options have been chosen so that the most difficult to quantify benefit, economic growth due to electrification, will be the same for each as the same number of households are to be electrified. The level of service may be slightly different (i.e. Pico may not be able to generate electricity all of the time) but this discrepancy can be accounted for through the final analysis. Estimation of the benefits obtained through rural electrification has been attempted.

Identification of Gainers and Losers
Identification of the populations of gainers and losers is an important step in a CBA because it sets boundaries and focuses attention on specific groups. It is also identifies who loses and who gains from a particular course of action, which is important if the focus is on poverty reduction. For instance, if the impact of an action provides a benefit for group A, but a cost of equal but opposite value for group B the resultant cost/benefit is zero. However, if group B are poor and group A are wealthy then this course of action is less justifiable in social and political terms.

All potential groups of losers and gainers are now listed:

One : The rural populations targeted for new permanent electricity supplies: These people typically have limited or no access to electricity, many will be users of rechargeable car batteries and dry cell batteries for lighting, radio and possibly television. Cooking will be done over stoves fuelled by locally collected wood or any other suitable materials available locally. These people will typically work the land and/or fish to feed themselves and possibly to trade.

Two : Rural populations negatively affected by development: Those displaced by the creation of reservoirs who may suffer loss of livelihood, cultural identity, social support network etc.

Three: Urban householders: Residing in the region's most densely populated towns and cities, these people have some or total access to electricity. Their lifestyles and increasing wealth lead them to purchase gradually more consumer electrical goods.

Fourth: Industry: Major users of electricity, industrial companies are drawn to developing ountries by cheap labour, raw materials and emerging markets.

Fifth : The government: In this scenario, they are the hydropower investors – and they have a vested interest in the economic prosperity of the region and the standard of living of its inhabitants.

Sixth : The world at large: People with an interest in the sustainability of the planet.

Identification of Project Impacts
This stage identifies all possible impacts of the three project options. It is also necessary at this stage to identify which of these impacts are economically relevant.

- Potentially all the negative environmental and ecological effects associated with large dams such as greenhouse gas emissions, obstruction to fish migration, reduced delivery of sediment to the sea, loss of diverse ecosystems etc.
- Negative sociological effects of large dam installations, such as population displacement and resettlement.
- Reliable supply of electricity to rural communities.
- Alteration of rural landscapes due to power lines.
- For the 'Single Large' option, electricity will be generated in excess of that required for the identified rural population. This will result in more electricity being available for urban households and/or industry – and the impact could manifest itself as cheaper electricity, or a more stable supply for these users. If the excess is exported then this will help with the investor's balance of payments.
- For the 'Micro & Pico' option, employment opportunities for inhabitants of rural communities in the construction and operation of multiple localised generating stations.

Costs and Benefits
Conversion of this list of possible impacts into a set of costs or benefits requires some initial decision making. The detrimental effects of hydro schemes will differ in their severity from country to country and from project to project. A good example of this is the difference in GHG emissions recorded from reservoirs in tropical and in boreal regions. Ideally, this comparison is intended to estimate costs and benefits for a general case. For items that are difficult to evaluate, this analysis attempts to find innovative routes to achieving realistic estimates.

The following costs and their respective time scales have been identified to include in the analysis, alongside a list of benefits.

Costs Costs time scale

Plant construction (i)	8-10 years (large/ small); 10-12 years (micro/ pico)
Transmission	As above
Distribution	Towards the end of plant construction period
Pre-inundation clearing(ii)	Immediately before flooding.
Operation & maintenance	Once plant is completed
Resettlement (iii)	Before flooding
Loss of agricultural land	As long as river is dammed
Damage to ecosystems	Infinite and irreversible

Benefits
Income from sale of electricity.,time savings for household chores, Improved productivity for home businesses, less expensive/more use of lighting/radio,reduced deforestation.

Cheaper/reliable electricity for industry/urban consumers,contribution to economic growth, additional-purpose benefits of reservoirs i.e. irrigation, flood control, fisheries.

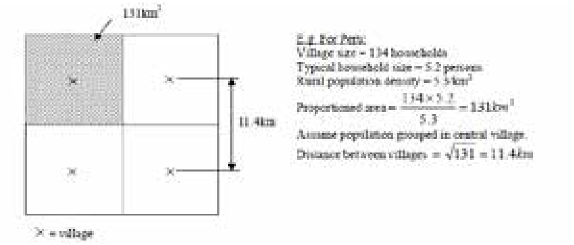
Thus is not an exhaustive list of costs and benefits in terms of detail, as certain types of effects have been grouped together under single headings to aid handling.

The above list includes the development benefits to rural populations that are inherent in the structure of each of the three options and so will apply to all and in equal measure. On this basis they can be excluded from the economic analysis but consideration of their effects will be included in the final discussion. The convenience of not needing to value certain benefits because they are the same for all options is not uncommon in CBA, and is sometimes described as Least-Cost Analysis.

In order to calculate the likely total length of transmission infrastructure required, it was necessary to consider population density, and the distribution of villages within the region.

Peru and Pakistan were selected as transmission case studies as they have similar hydropower development potential but very different population densities. From Bongaarts the average number of people per household was taken as Figure 2. This was used together with the population density information to calculate the typical distances between villages and households in the two countries, as shown in Figure 1.

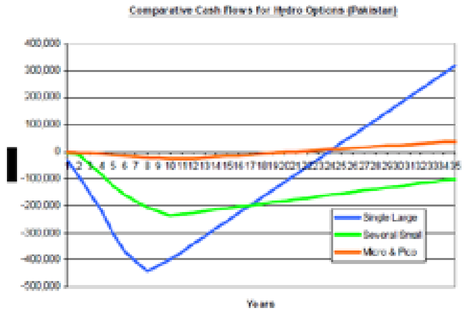
Figure 1 - Example of village spacing model.



As three different village sizes are used in the model, there are three different grids for each country.

Revenue and cost-benefit cash flow

The revenue collected from the sale of electricity was based on published data on electricity costs from The Energy Information Administration , which gives average values of $0.101/kWh for domestic $0.062/kWh for industrial power. For domestic power use, a very basic model was assumed. Except for the micro & pico hydro option, it was assumed that there would be demand from industry for any excess power for an average of 12 hours per day. These revenue values were then offset against the costs of each project option. The resulting financial position after each year of the project was then plotted to compare the performance of each option.



The graphs show that for Option A where a single large dam is built, the costs are considerable, but the benefits obtained are similarly large to result in a good eventual inflow of benefits. With the Micro & pico option (C) where very small isolated schemes are used, there are considerably fewer costs, but the benefits are relatively good and the overall payback is the fastest. The option of several small schemes (B) falls between the other two, with moderate costs; but its desirability is questionable because the scant inflow of benefits results in a very lengthy payback duration. The results for Peru and Pakistan are similar, although the costs are higher for Peru.

Limitations of cost benefit analysis

As discussed in the section entitled investing in hydropower, there are some costs and benefits of the schemes that cannot be reliably evaluated financially. These are:

- Those adverse effects of reservoirs that cannot be mitigated against i.e. the loss of unique habitats, species and ecosystems. This is a cost in option A and option B and affects the world at large.
- Direct benefits of electricity for users i.e. time savings for household chores, improved productivity for home business and less expensive use of lighting/radio. This is applicable equally in options A, B and C and affects rural populations.
- Cheaper/reliable electricity for industry/urban populations. There is an element of this in both options A and B.
- Contribution to economic growth of the country through increased industrial activity in rural areas and the potential to use electricity supply to improve schools and healthcare facilities in rural areas (i.e. a 'trickle down' effect). This applies equally to A, B and C.
- Reduced deforestation is relevant in all options and affects the world at large.
- Additional-purpose benefits of reservoirs i.e. irrigation, flood control, fisheries. Relevant to option A and option B; those living near to the reservoir and in some downstream areas will benefit.

Conclusion

The research presented illustrates the strengths and weaknesses of each of the hydro options studied, suggesting where each is most applicable, based on the best evidence available. It shows that micro and pico hydro can be cost effective for supply of rural electricity, even where population densities are sparse. It also shows that large-scale hydro may be cost effective, even where the major costs of environmental mitigation are included. However, as a means of achieving rural electrification in developing countries, small hydro schemes may not be cost effective because the cost of transmission systems and the cost of environmental mitigation cannot be covered by the relatively small income from rural consumers and local industries.

The research does not provide a firm conclusion, i.e. there is no 'best option'. Instead, the relative usefulness of the three options depends upon several factors (as discussed in the conclusion) and there is some inherent uncertainty. Some of these uncertainties stem from the difficulties commonly found with CBA. Specific measures were taken to include project externalities such as environmental and social impacts, although there is scope for finding new ways of valuing some of these factors. Another area of concern in CBA is the issue of equity and distribution. The micro and pico hydro option might score well from this point of view as there would be few 'losers' from the implementation of the technology. This option would also have more potential for active participation of the beneficiaries in the process of rural electrification.

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