# Viability Measurement of Hydropower Projects

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## Abstract

*Evaluating the viability of hydropower projects involves a comprehensive examination of costs and benefits. Economic analysis extends to broader impacts, such as fuel diversification, market advantages, production cost savings, job creation, and improved reliability. Benefit-cost analysis compares monetary costs and benefits, including direct and indirect community effects. This study has used literature survey method to provide insights into projected and actual outcomes, supported by guidelines from institutions like ADB, UNIDO, and the World Bank. Financial benefits of hydropower projects involve optimizing energy output and revenue from Power Purchase Agreements. Economic benefits include fuel diversification, market impacts, navigation, tourism, water supply, and tax revenues. Costs related to physical properties, structures, and resettlement are evaluated using the Price Quantity (PQ) method, while rental income and business losses are assessed through opportunity cost analysis. The loss of crops and trees is evaluated based on expected yields. This approach ensures a thorough understanding of both financial viability and broader economic impacts.*

***Key words:*** *hydropower, cost, benefit, economic, analysis.*

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## Introduction

Economic analysis, in recent decades, is one of the most extensively used methods, and mandatory in assessing the benefits and costs of hydropower projects developed both by the public and private sectors in order to appraise the feasibility of investment made on such projects. In financial analysis, a detailed examination of projected costs and benefits within a project's cash flows is crucial. This involves using standard financial tools such as the Financial Internal Rate of Return (FIRR), Net Present Value (NPV), and Payback analysis to gauge the project's viability. Economic analysis, however, goes further by evaluating factors beyond financial costs and benefits, including fuel diversification, market advantages, production cost savings, job creation, economic activity benefits, tax revenues, and improved reliability. This comprehensive approach provides a deeper understanding of the project's broader economic impact. Benefit-cost analysis (CBA) is widely used to evaluate future investment projects. It compares costs and benefits in monetary terms, with costs being easier to predict than benefits. Benefits must be assessed both directly and indirectly, considering community-wide effects. There are two types of CBA: ex-ante (before the project) and ex-post (after the project), with comparative CBA comparing predictions to outcomes. Economic analysis, essential for assessing project sustainability, incorporates financial, environmental, and social factors, including risk and sensitivity analysis.

The challenge of CBA lies in monetizing benefits and costs, particularly externalities, which are difficult to identify and quantify. Accurate benefit identification involves comparing the current scenario with the projected improvements post-implementation. This analysis often references guidelines from organizations like ADB, UNIDO, and the World Bank. This study aims to get the variables on viability measurement of hydropower projects while taking investment decision in investment project.

## Methods

In this study, a survey research design was employed. The literature review involved a systematic selection, reading, and synthesis of relevant works, adhering to established research norms. Purposive sampling was utilized to collect essential textual materials, with an emphasis on reliable and authentic sources, such as reference books, research-based articles, and papers. Grey literature was excluded from the review. Key databases and e-libraries, including HINARY, JSTOR, ProQuest, Academia, and the World Bank Library, as well as the ADB guidelines for project evaluation, were primarily accessed. Additionally, other resources such as Academia, NDLI, ResearchGate, Elsevier, Google Scholar, and various search engines were consulted.

Five significant search terms, such as "cost variables" and "benefit variables," were employed to retrieve relevant texts. The search parameters included "content I can access" for access type, "articles, books, and research reports" for academic content, "no boundary" for publication date, "economics" for the subject area, and "relevance" for sorting results. The materials were selected based on three criteria: (1) quantitative analysis of costs and benefits, (2) social cost and benefit, and (3) environmental cost and benefit variables. Thirteen research articles, guidelines, and books met these criteria and were reviewed accordingly. The search did not impose limitations on date and time, as the study's objective was to review theoretical literature rather than empirical data, making both historical and contemporary sources equally valuable.

### Benefit measurement

Hydropower project benefits include financial aspects like optimizing energy and revenue from power purchase agreements (PPA). Economic benefits cover fuel diversification, market impacts (e.g., GDP growth, employment), navigation, tourism, water supply, taxes, cost savings, social and ecological gains, carbon reduction, and downstream benefits like irrigation and flood control.

In cost-benefit analysis, revenue from the power purchase agreement (PPA) is the primary variable, derived from optimizing the power and energy output of a hydropower project.

### Optimization of power and energy

For hydroelectric projects, key benefits are electricity generated and revenue from the power purchase agreement (PPA). Benefit calculation involves multiplying power generated (N) by the feed-in tariff (PG). Optimizing power/energy is crucial, requiring efficient use of water resources to maximize potential and minimize costs.

### Revenues from the sale of power

A Power Purchase Agreement (PPA) is a bilateral contract between an electricity generator (seller) and a buyer, defining terms such as operation start dates, delivery schedules, penalties, payment terms, and termination clauses. The PPA is crucial for shaping revenue and credit outlooks, making it vital for project financing. PPAs vary in duration from 5 to 20 years and may include energy, capacity, or ancillary services. They ensure consistent cash flow and may have different rates for various periods, such as dry or rainy seasons. Larger hydroelectric projects typically operate under PPAs or wholesale market rates, providing essential base power with low marginal costs. Hydropower plants often use feed-in-tariff (FiT) programs for fixed pricing, protecting against market fluctuations. Plants without FiTs, like merchant plants, sell power at market risk. Financial analysis must account for cash flow and pricing structures, especially in deregulated markets.

### Fuel diversification from the power

Fuel diversification, or fuel cost savings, is a key benefit in analyzing hydroelectric projects. For electricity-deficit countries like Nepal, which relies heavily on imported petroleum for thermal power, hydropower can significantly reduce costs. By providing reliable electricity, hydropower saves money otherwise spent on heavy fuel oil (HFO) and reduces the reliance on expensive thermal generation.

### Value of lost load

The Value of Lost Load (VoLL) quantifies how much consumers value avoiding energy supply disruptions and is crucial for cost-benefit analyses of grid improvements. It helps align security benefits with financial costs, reflecting customer responses to outages through metrics like the Customer Damage Function (CDF), which assesses blackout impacts based on duration. VoLL informs infrastructure investments by normalizing outage costs and ensuring reliability. Though its application is limited and lacks uniformity, standardizing VoLL calculations could improve grid investments and business planning. VoLL measurement varies between households and businesses, using techniques like macroeconomic metrics and surveys to assess economic output losses from power outages (Billinton et al., 2001).

Using top-down structures like Leontief production functions links electricity as an input affecting economic output, aiding in assessing output losses in sectors during power outages (Wenzel et al., 2013; Sullivan & Keane, 1995).

### Conventional cost of production savings

Hydropower remains the cheapest form of electricity and hence the energy. Traditional costing aids the average overhead rate to the direct costs of manufacturing products and is best used when a company's overhead is low in comparison with direct production costs. Activity-based costing identifies all specific overhead operations pertaining to each product's manufacture. This benefit includes expected savings on production costs as a result of the reliable and relatively cheap supply of electricity derived.

### Local economic benefits

Hydropower offers several advantages, categorized by the International Finance Corporation into local and public economic benefits. Locally, it provides low-cost electricity, job creation, skill training, and improvements in water supply, education, and healthcare. It also boosts local GDP through enhanced infrastructure and commercial opportunities. Publicly, hydropower projects can improve tourism and hospitality, along with direct benefits like jobs and social services, and indirect benefits such as better access roads.

### Tourism opportunities

Many hydropower projects provide public access to reservoirs, enhancing recreational activities such as fishing, swimming, and boating. River releases support kayaking and white-water rafting. The reservoir area attracts tourists with its scenic beauty and cultural heritage, adding aesthetic and cultural value. Tourism potential depends on accessible roads to the dam and reservoir, which can improve transportation routes, create job opportunities in transport services, and boost local sales of food, products, and souvenirs.

### Employment and wage benefit

To quantify job creation benefits, economic analysis calculates the average number of workers and their annual salaries during construction. The total benefit (TB) is determined by multiplying the number of staff (NS) by their monthly salary (MS) and the number of months. Wage benefits are measured using the shadow wage rate (SWR), which considers factors like labor opportunity costs and income changes. Estimating SWR is crucial for each labor type in the economic analysis of hydropower projects.

#### *Benefits from fish capture*

A significant advantage of multipurpose hydropower projects is the benefit of fish capture. Its value can be estimated by multiplying the total volume of fish caught by the current market price, as demonstrated by Nhiakao et al. (2022).

*Benefits of carbon-dioxide reduction*

Global energy demand is rising due to industrialization and economic growth, increasing CO2 emissions and climate change risks. Prioritizing renewable energy (RES) is essential for sustainable development. RES, including hydropower, enhances economic performance, ensures energy security, and reduces reliance on fossil fuels, offering a low-cost, low-emission solution to climate challenges. Hydropower's adaptability is crucial for reliable grid operations, unlike less predictable renewable sources (Sun et al., 2021). It can meet energy needs while greatly reducing CO2 emissions compared to coal-fired power plants (IEA, 2015), leading to its rapid global development. The social cost of carbon (SCC) measures the annual monetary impact of each ton of CO2 emissions. By multiplying the amount of carbon reduced by the SCC, the benefits of carbon reduction can be quantified (Sun et al., 2021).

### Tax and royalty benefits to the government

The tax and royalty benefits to the government are assessed using the ‘With and Without Project’ approach in cost-benefit analysis (CBA). This includes anticipated tax benefits from hydropower project construction, such as expected income tax, indirect taxes (e.g., VAT, excise duties), and direct taxes (e.g., social security tax) based on estimated rates.

### Navigation benefit

Hydropower development creates waterways that facilitate transportation, making the movement of goods and people faster and cheaper. To measure these benefits, we compare the cost of using hydropower-managed waterways (such as rivers or canals) with other routes, known as the equal alternative program. The net benefit is calculated by finding the cost difference between using the waterways and the cheapest alternative route, revealing the savings from using hydropower infrastructure.

### Ecological benefits

Compensating for river flow from reservoir outflow helps nature, but quantifying the benefits of increased river runoff is tricky. There's a basic formula to estimate these benefits by comparing river flow to its average monthly rate, multiplied by a benefit coefficient. This calculation is done over 12 months. The Tennant method suggests that a certain percentage of average flow is needed to protect aquatic life (Tennant, 1976). Biologists can help rate the importance of river flow at different times and levels. Each river discharge gets a time and level score based on when and how much water flows. These scores, multiplied by river discharge, give possible ecological benefits. Experts use a similar method to calculate the benefit coefficient. One major concern is improving water quality. If water discharge is managed properly, it can support ecological flow in dry seasons and help enhance water quality.

### Downstream benefits

The benefits to downstream communities from hydropower projects primarily include irrigation, municipal water supply, and flood control. These projects have a wide-ranging impact on downstream populations, contributing to flood management, irrigation infrastructure, soil conservation, a stable supply of drinking water, job creation, social services, infrastructure development, tourism, hospitality management, municipal services, navigation, industrial cooling, and environmental protection.

Boadway (1974) emphasized that the primary benefit of flood control is the avoidance of flood-related losses. These benefits can be both direct and indirect. Direct benefits include the prevention of damage to properties and assets, such as crops and livestock, as well as minimizing harm to production and safeguarding human life and property. Indirect benefits involve the prevention of disruptions to business communication and economic activities, the underutilization of land, and the reduction of initial expenditures associated with these damages.

### Irrigation benefit

Irrigation benefit can be measured by the profit gained from increased grain yield under varied irrigation settings (Moghaddasi et al., 2013). This benefit can be measured by taking the difference of output before and after the project.

### Municipal water supply benefit

Water supply benefits can be derived from the supply quantity for household use and industry, multiplied by the unit price of water.

### Flood control benefit

Dams serve flood control by storing excess water and releasing it in a controlled manner. Pumped storage allows storing extra water for later electricity production, preventing disasters and benefiting energy storage. Flood benefits quantify economic losses prevented by reservoir regulation in flood control systems. Basin areas are divided into units, totaling flood benefits per unit using specific equations. To evaluate flood control benefits, the reduction in projected losses to buildings, contents, and land in flood-prone areas is assessed. Damages avoided due to flood protection are estimated based on flood severity and asset value. Agencies conduct studies to link flood stages to damages, assessing the saved costs. Estimating damaged land hectares from compensation costs helps calculate net benefits, converted to monetary values. The reduction in property losses determines flood control value. Overall benefits sum up all benefits over time, including residual values of flood control facilities at the study's end. These evaluations aid in understanding flood control's economic impact, guiding future decisions regarding flood prevention and management.

During an economic evaluation, residual values are discounted to prices. The residual values of a flood control facility at the end of the economic evaluation period should be determined. Alternatively, using a replacement approach, the flood control benefit can be calculated based on the loss of property caused by flooding (Moghaddasi et al., 2013). The benefit was calculated by multiplying the hectares of damaged land by the compensation amount.

## Cost variables

The costs and variables associated with hydropower projects vary by location and country. Some of the primary cost variables are presented below:

### Design and study costs

Total cost incurred from quantity invoices, including all resource expenditures. This covers a site assessment and resource analysis, analysis and modeling, results, financial analysis and recommendations, and full feasibility pricing for hydropower projects. An important component is the appraisal of the location for a hydropower feasibility study. This is a critical component of a hydropower feasibility study that benefits greatly from years of hydropower system design and development expertise. Cost estimates must be realistic and based on strong costing concepts. This is a critical component of a hydropower feasibility study, and it benefits greatly from years of practical experience planning and building hydropower projects.

Because the cost estimate is an important factor in deciding whether or not to proceed with the project, it must be realistic and founded on sound costing principles. To get appropriate estimates of hardware and civil engineering expenses, as well as consenting and design fees for the next project stages, data from actual projects and recognized construction industry price recommendations should be employed.

### Construction costs

The total costs of hydropower projects include construction expenses for resources, feasibility studies, planning, design, civil engineering, and infrastructure development. Hydropower is capital-intensive, requiring significant time and investment. Major costs include civil works, electro-mechanical and hydro-mechanical equipment, land acquisition, and technology installations. Additional costs cover environmental mitigation, skilled labor, and operational training. Investment costs can be reported per installed capacity or per kilometer of power lines. Preparatory work costs, office facilities, and environmental mitigation vary by project type. Electro-mechanical equipment costs are lump-sum, with transmission line expenses calculated by length. Administration, engineering, and contingency costs are estimated at 15 percent of total expenses. Interest rates are influenced by local currency exchange rates (IRENA, 2012).

### Resettlement and rehabilitation costs

Displacement due to forced relocation, particularly from large dams, is a significant global issue affecting millions annually. About 4 million people are displaced each year by big dams alone, with urban development and transportation, including hydropower projects, adding up to 6 million more, totaling 10 million annually (World Bank, 1994). Hydropower projects must include clear plans for land acquisition, resettlement, and compensation, adhering to international and governmental policies. Effective Land Acquisition, Resettlement, and Rehabilitation Action Plans (LARRAP), along with Livelihood Restoration Plans (LRP), are crucial to minimize adverse effects and ensure fair compensation and support for affected individuals, including those without formal property titles. Estimated expenses encompass costs related to land and building acquisition, loss of crops and trees, business income loss, support for vulnerable indigenous communities, and compensation for lost common property resources and access.

### Operation and maintenance costs

Project supervision costs, typically 4 to 7 percent of total construction expenses, decrease with project size and do not include procurement of goods. Supervision involves assessing material quality, usage, and waste, and ensuring compliance with construction standards. Operating and maintenance (O&M) costs cover all expenses for running and maintaining a service, including labor, repair resources, raw materials, energy, and administrative costs. O&M costs are divided into fixed (e.g., insurance, labor) and variable categories (e.g., fuel, utilities). For hydropower projects, annual O&M costs are about 1 to 4 percent of the annual investment cost per kW, with large-scale projects generally having lower costs. Refurbishment expenses are also included, with large-scale projects costing around USD 45/kW/year and small-scale projects about USD 52/kW/year (IRENA, 2012).

### Environmental impacts and costs:

Infrastructure development projects, such as building reservoirs and dams, significantly alter the environment and society, causing land loss, community displacement, and livelihood disruption. Environmental impact assessments must cover internal, external, and benefit-cost factors, including natural environments, resettlement, and water quality. Large-scale hydropower projects particularly face challenges, requiring detailed studies and costly mitigation measures to address issues like pollution, biodiversity loss, and infrastructure damage. These impacts vary by project size and location, necessitating comprehensive environmental and social evaluations to guide effective planning and restoration (Kaunda et al., 2012; WCD, 2000).

Expected environmental impacts range from spoil disposal, slope instability, landslides, soil erosion, obstruction of natural drainage, tree loss, and agricultural land issues to cultural and religious site disturbances. The comprehensive assessment of these impacts is crucial in planning and executing such projects (WCD, 2000). The impacts and their mitigation measures are slope instability, landslides and soil erosion, impacts of spoil disposal of excavated materials and other construction waste, drainage management including natural drainage, vegetation and wildlife, land and soil, dust and noise pollution, labor camp management and safety, extraction of quarry material for construction and safety of road users/pedestrians. All environmental costs are calculated using the conventional Price-Quantity (PQ) method, which involves multiplying the quantity of work by the standard price.

### Cost of carbon sequestration loss

The 'value of carbon' refers to the monetary cost of small changes in CO2 and other greenhouse gas emissions. New York State is required to establish this value, expressed in dollars per ton of CO2 equivalent (CO2e), by January 2021, as per the Climate Leadership and Community Protection Act (CLCPA). This involves evaluating reduced CO2 emissions using two primary methods: the social cost of carbon (SCC) and the marginal abatement cost (MAC). SCC measures the future environmental and societal impacts of a small increase in emissions against the economic benefits of reducing them. MAC estimates the cost of eliminating the final ton of CO2 to meet specific targets. These methods aid in policy discussions and regulatory assessments, helping determine the cost-effectiveness of emissions reduction strategies. The memo covers both SCC and MAC approaches, with estimates endorsed by the US federal government, states, and European nations. It highlights the importance of these methods in guiding policy and suggests calculating the societal cost of carbon sequestration from deforestation by estimating carbon released, considering flooding impacts, and multiplying forest size and CO2 emissions.

### Costs of ecological loss

The dam's construction has submerged forest and paddy areas, causing ecological damage. This cost is assessed based on ecosystem disturbance and previous damage estimates. The total ecological loss is calculated by multiplying the annual power generated (kWh/year) by the cost of ecological loss (USD/kWh

### Social impacts and costs

While hydropower projects offer significant benefits, they can also result in negative impacts after implementation. These include the destruction of both public and private lands and forests, damage to buildings, and rapid population growth. Other potential issues are financial losses, job reductions, social problems like trafficking, disruption of community cohesion, increased pollution, and higher waste levels. It is crucial to manage these impacts effectively through compensation for displaced communities, addressing issues such as loss of land, structures, rental income, crops, and businesses, and supporting affected river-dependent communities and vulnerable households. This also includes compensating for the loss of common property resources, community infrastructure, and irrigation and water supply systems.

## Conclusion

In financial and economic analysis, evaluating the viability of hydropower projects involves a comprehensive examination of projected costs and benefits. Financial tools like the Financial Internal Rate of Return (FIRR), Net Present Value (NPV), and Payback analysis assess the project's profitability. However, economic analysis extends beyond financial metrics to consider broader impacts, such as fuel diversification, market advantages, production cost savings, job creation, and improved reliability. Benefit-cost analysis (CBA) is essential for assessing future investments by comparing monetary costs and benefits, which include direct and indirect effects on the community. Both ex-ante (pre-project) and ex-post (post-project) CBAs provide insights into projected and actual outcomes, supported by guidelines from institutions like ADB, UNIDO, and the World Bank. For hydropower projects, financial benefits primarily involve optimizing energy output and revenue from Power Purchase Agreements (PPA). Economic benefits encompass fuel diversification, market impacts, navigation, tourism, water supply, and tax revenues. Costs related to physical properties, structures, and resettlement are evaluated using the Price Quantity (PQ) method, while losses such as rental income and business disruptions are assessed through opportunity cost analysis. The loss of crops and trees is evaluated based on expected yields throughout their lifecycles. This comprehensive approach ensures a thorough understanding of both the financial viability and broader economic impacts of hydropower projects.

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