What is the range of costs?

Oliver Froend

Costs and Revenues are considered separately for the implementation phase and for the operation phase

### Implementation

**Costs**
- Direct Costs
- Indirect Costs

Possible Revenues:
- Subsidies & grants (mostly MHP)
- CDM upfront payment (usually SHP, LHP)

### Operation

**Costs**
- Operation and maintenance
- Administrative costs
- Possibly transmission fees
- Taxes
- Replacement costs
- Debt servicing of borrowed capital

**Revenues**
- Tariff payments
- Ancillary service / capacity fee (for peak power, if available in market)
- CDM and subsidies

What is the range of costs?

- Types of costs / expenses and revenues
  - Indicative costs for project preparation and implementation (project planning and preparation, civil works, electrical and mechanical equipment; transmission / distribution)
  - Generation costs
  - Indicative economic / financial assessment
  - Cost-Effectiveness to other renewable and non-renewable energy solutions

Costs and revenues - Timeline

Typical positions in a Bill of Quantities (BoQ) for Direct Costs

- Site installation: preparatory works, site office, camp, workshops, plants, spoil areas, etc.
- Access roads (permanent and semi-permanent) to site and within project area, including upgrading of existing roads and construction of new roads
- Main civil works of all permanent structures
- Hydro-mechanical equipment (e.g. gates, lifting equipment, stoplogs, trash racks)
- Penstock, erection, incl. bends, stiffeners, bifurcation, and all installation measures, incl. corrosion protection
- Generating equipment (e.g. turbines, generators, control equipment, transformers and switchgear)
- Transmission line from HPP switchyard to substation / point of interconnection.

Typical positions in a Bill of Quantities (BoQ) for Indirect Costs

- Technical Management or pre-construction costs: All project development costs up to start of construction works
- Land acquisition (incl. cost related to measures according to the Environmental and Social Impact Assessment (ESIA): Costs for purchase of land, relocation, preparation of agricultural land for compensation, mitigation measures
- Insurances
- Project administration (Client)
- Engineering: Detailed engineering (by contractor), owners engineering (by owner’s engineer), site supervision
- Other non billed items and expenses
- Taxes (VAT), custom’s fees for imported equipment
- Interest during construction (IDC)

Costs and revenues - Timeline

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**Micro-Hydropower Projects**

**Rural Electrification Indonesia**

- **Breakdown of costs for off-grid rural electrification MHP**
  - The stated cost / kW (installed) include distribution and project development (engineering, supervision, admin, etc.)
  - Cost for transmission and distribution can vary vastly, depending on characteristics of settlements.
  - ‘Economy of scale’ applies mainly to pre-construction cost (studies, engineering), but also to civil works and E/M equipment.

### 30 kW off-grid isolated

- ~2 500 USD/kW
- Costs include:
  - Civil Works: 600 USD/kW
  - E/M-Equipment: 600 USD/kW
  - LV-Distribution: 600 USD/kW
  - Engineering: 600 USD/kW
  - Others / Contingencies: 600 USD/kW

### 60 kW off-grid isolated

- ~3 000 USD/kW
- Costs include:
  - Civil Works: 1 500 USD/kW
  - E/M-Equipment: 1 000 USD/kW
  - LV-Distribution: 500 USD/kW
  - Engineering: 500 USD/kW
  - Others / Contingencies: 500 USD/kW

**Investment costs for on-grid small hydropower plants are usually within an approximate range**

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil works</td>
<td>1 500 to 3 000 USD/kW</td>
</tr>
<tr>
<td>Electro-mechanical equipment</td>
<td>400 to 1 300 USD/kW</td>
</tr>
<tr>
<td>Transmission lines, transformation, grid connection</td>
<td>50 to 200 USD/kW</td>
</tr>
<tr>
<td>Project planning and design, site supervision, project management</td>
<td>50 to 500 USD/kW</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2 000 to 5 000 USD/kW</strong></td>
</tr>
</tbody>
</table>

**Large Hydropower (>10MW)**

**On-grid Planned (Desk Level), Indonesia**

- Source: Master Plan Study of Hydropower Development in Indonesia, Nippon Koei / JICA, 2011
Breakdown of costs for a 42 MW on-grid HPP

What is the range of costs?

- Types of costs / expenses and revenues
- Indicative costs for project preparation and implementation (project planning and preparation, civil works, electrical and mechanical equipment, transmission / distribution)

Generation costs

- Indicative economic / financial assessment
- Cost-Effectiveness to other renewable and non-renewable energy solutions

Components of Generation Cost

Fixed Costs

- Capital cost / Loan servicing
- Operation & maintenance (details on next slide)
- Insurances

Variable Costs

- Expenses for service and maintenance, which depend on operating times
- Taxes (depend on generation / sales)

Fixed Operation and Maintenance Costs

<table>
<thead>
<tr>
<th>Cost item</th>
<th>Description</th>
<th>Annual O&amp;M cost (% of capital cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel</td>
<td>Operators, linemen, revenue collectors (if applicable)</td>
<td>according to local salary levels</td>
</tr>
<tr>
<td>Administration</td>
<td>Insurance, customer service costs, land rent, taxes, water fees, other duties</td>
<td>according to local rules and regulations</td>
</tr>
<tr>
<td>Maintenance of civil works</td>
<td>materials (paint, cement, etc.) and local manpower</td>
<td>0.2 to 1 % of capital costs of the civil works</td>
</tr>
<tr>
<td>and access roads</td>
<td>supports, salaries of local fitters, electricians</td>
<td>1 to 3 % of capital costs of E/M equipment of MHP</td>
</tr>
<tr>
<td>Maintenance of E/M equipment</td>
<td>spare parts and salaries of local fitters, electricians</td>
<td>1 to 3 % of capital costs of E/M equipment of MHP</td>
</tr>
<tr>
<td>Maintenance of transmission &amp;</td>
<td>bush cutting, fuses, insulators, cross-arms, poles</td>
<td>1 to 3 % of capital costs of T&amp;D</td>
</tr>
<tr>
<td>distribution works</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What is the range of costs?

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### Economics of Hydro Power

<table>
<thead>
<tr>
<th>Installed Capacity</th>
<th>1,000 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Investment Cost MHP Scheme</td>
<td>3,000 USD/kW</td>
</tr>
<tr>
<td>Total Investment Cost MHP Scheme</td>
<td>3,000,000 USD</td>
</tr>
<tr>
<td>Average Annual Inflation rate</td>
<td>0 %</td>
</tr>
<tr>
<td>Average Interest/Discount Rate</td>
<td>10 %</td>
</tr>
<tr>
<td>Inflation Corrected Interest Rate</td>
<td>10 %</td>
</tr>
<tr>
<td>Service Life MHP Scheme</td>
<td>25 years</td>
</tr>
<tr>
<td>Annuity of Investment</td>
<td>330,504 USD</td>
</tr>
<tr>
<td>Annual Cost Operation &amp; Maintenance</td>
<td>90,000 USD</td>
</tr>
<tr>
<td>Plant Availability</td>
<td>95 %</td>
</tr>
<tr>
<td>Average Plant Factor</td>
<td>65 %</td>
</tr>
<tr>
<td>Average Annual Energy Production</td>
<td>5,403,300 kWh</td>
</tr>
<tr>
<td>Average Energy Production Cost</td>
<td>7.77 US¢/kWh</td>
</tr>
</tbody>
</table>

### Objectives of Economic Analysis

To **compare costs and benefits of a project** during its service life, and to determine which among alternative projects (e.g. hydro versus diesel options) have an acceptable return on investment, or which one is the **least cost option** to supply electricity to an area or a station.

- The **economic analysis** estimates returns to society / the national economy as a whole.
- The **financial analysis** estimates returns to an individual project participant, usually the developer.

### Economic vs. Financial Analysis

**Economic Analysis – rural electrification MHP**

- Taxes, duties and subsidies are not considered in least-cost analysis of e.g. rural electrification projects.
- Adjustment to market prices in economic analysis is called **shadow pricing** and can be a very important but also difficult aspect in the analysis.

**Financial Analysis – commercial on-grid HPP**

- In the financial analysis market prices are used when estimating project costs.
- Subsidies (e.g. CDM) are considered as revenue.
- Cash-flow is calculated based on real costs / revenues to the developer.
The Internal Rate of Return (IRR) is a key indicator in economic and financial analysis.

The net present value or cost of a project does not say anything about the value of the project as compared to other project options.

Simplified, the IRR on an investment is equivalent to the interest rate received for capital based on the payments and income that occur at regular periods.

Funding agencies, Governments and developers use the IRR as a selection criterion. They could accept all projects with an IRR greater than the cut-off rate, or compare several project options on the basis of the IRR.

Generation cost as indicator in economic analyses

Sensitivity analysis

- Increase of generation costs vs. increasing specific investment cost
- Increase of generation costs vs. service life of project

What is the range of costs?

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**Generation costs of different power plant types**

**Annual full-capacity hours of utility operated power plants**

- Nuclear energy
- Lignite
- Hard coal
- Natural gas
- Pumped storage hydro
- Wind
- Photovoltaics
- Mineral oil

![Graph showing hours per year for different power plant types.]

**Split generation costs of different power plant types operated by a utility**

- Operating costs in ct/kWh
- Fuel costs in ct/kWh
- Capital costs ct/kWh

![Graph showing split generation costs for different power plant types.]

**Range of generation costs of different power plant types**

- Tidal/Wave energy
- Geothermal
- Solar thermal
- Photovoltaics
- Biogas
- Solid biomass
- Wind offshore
- Wind onshore
- Hydro Power

![Graph showing range of generation costs for different power plant types.]

**Thank you for your attention!**

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The Time Value of Money - Discounting

Costs and benefits can have very different values for society or for the developer depending on when they occur. Present values are better than the same values in the future, and early returns are better than later returns. In other words, we need less money in our pocket today if the investment is due next year as compared with the same investment payable now.

In order to take account of these facts in our economic and financial analysis the concept of discounting project worth is used.

Discount Factor

\[
\text{Discount Factor} = \frac{1}{(1 + i)^n}
\]

- \( i \) = discount rate, must be absolute, not in % (i.e., 10% \( \Rightarrow 0.1 \))
- \( n \) = number of periods (years) from the present (year 0) to year \( n \) when the value occurs (end of that year)

Methods of Economic Analysis

Static methods look at a project and the associated costs and benefits independent of time. They do not consider the time value of money.

Dynamic methods on the other hand treat costs and benefits which occur at different points in time of a project with different values.

Static methods should not be used to analyze the economics of a power project. Thanks to computer models (spread sheets), economic analysis using dynamic methods is no longer a time consuming affair.
**Payback period:** Time in years from the beginning of the project until the time when the sum of the revenues from electricity sales (and other income) equals the capital invested for the project.

**Break-even point:** The break-even point is usually taken as the minimum tariff level required at which annual revenues from electricity sales exceed the cost of production. For a given tariff, the break-even point can also mean the year when due to increasing electricity sales the annual revenue exceeds annual costs.

**Annuity:** An annuity is an amount paid or received annually. With the annuity method, all costs and revenues (benefits) are expressed in equal annual amounts. This allows quick calculation of unit production costs, pay-back period and break-even point.

In order to simplify economic analysis, inflation-free values should be used, i.e., costs and benefits should be stated at current prices and interest / discount rates should be inflation corrected.

Inflation corrected interest rates are called real as opposed to nominal rates which include inflation.

\[
\text{real interest / discount rate } i^* = \frac{i + 1}{a + 1} - 1
\]

- \(i\) = nominal interest or discount rate (absolute, not in %)
- \(a\) = inflation rate (absolute, not in %)