HYDROPOWER AFRICA 2011

Workshop
on
Developing Small Hydropower Projects
Sandton City Convention Center,
Jo’ burg, South Africa
September 21, 2011
Presentation Outline

• Hydropower General Aspects
• Fundamentals of small hydropower technologies
  • Site selection and feasibility evaluation
  • Project evaluation (IHA protocols) and Feasibility Design
• Civil engineering works
• Electromechanical equipment
• New developments in turbine technologies
• Environmental considerations
• Economical considerations and evaluation
• Financing for Hydropower Projects + Project Cases
• Construction of Hydropower Plants: Selecting the right contractors
• Tariff design and Power Purchase Agreements
Hydropower in General Aspects – How Hydropower Works

- Water constantly moves through a vast global cycle, evaporating from lakes and oceans, forming clouds, precipitating as rain or snow, then flowing back down to the ocean.
- Hydropower is using water to power machinery & make electricity.
- Hydropower uses water as fuel that is not reduced or used up in the process. Because the water cycle is an endless, constantly recharging system, hydropower is considered a renewable energy.
The power potential of the water flowing in a river is determined by the flow rate \( Q \) & the head \( H \) through which the water can be made to fall.

The **flow rate** = quantity of water flowing past a point in a given time measured in l/s or m\(^3\)/s. The **head** = vertical height, in m

Theoretical power \( P = \rho g Q H \) Where \( Q \) is in m\(^3\)/s, \( H \) in m, \( g = 9.81 \) m/s\(^2\)) and \( \rho \) = water specific density
Types of Hydropower Facilities

- Impoundment:
  - Transmission lines - conduct electricity, ultimately to homes and businesses
  - Dam - stores water
  - Penstock - carries water to the turbines
  - Generators - rotated by the turbines to generate electricity
  - Turbines - turned by the force of the water on their blades

- Run of River Projects:

- Diversion projects:

- Pumped storage:
  - Reversible Pump-turbine
  - Main Transformers
  - Waterflow When Generating
  - Penstocks: Large Strand Ties
  - Gantry Crane
  - Waterflow When Pumping
  - Powerhouse
  - Reservoir
  - Lake
Benefits from Hydropower

- Hydro power is a clean, indigenous and renewable source of energy.
- Almost no greenhouse gases or other air pollution.

- Hydropower leaves no waste.
- Unlike in fossil fuel, Water is not polluted during the production of electricity – it can be reused for other purposes.
- In addition to clean electricity production, more benefits:
  i. reservoirs offer a variety of recreational opportunities like fishing, swimming, and boating.
  ii. water supply and flood control.
Cost factor in Hydropower

Average Power Production Expense per KWh

- Fossil-Fueled Steam
- Nuclear
- Hydroelectric
- Gas Turbine

- Fuel
- Maintenance
- Operation
Disadvantages of Hydropower

- **Fish populations** can be impacted by restricting movement to spawning grounds or if they can’t migrate d/s to the ocean. Mitigations are fish ladders or elevators, or by trapping and hauling the fish upstream by truck.
- **Hydropower** can impact **water quality** and **flow**. They can cause low dissolved oxygen levels in the water, which can be remedied by various aeration techniques, which oxygenate the water. Other remedies can be by maintaining a minimum/compensation flow.
- **Hydropower plants** themselves can be impacted by drought. When water is not available, the hydropower plants can't produce electricity!!. What is the remedy for this? Subject for discussion for all!!
PART II. Basic Design and General Aspects of SHP

- 50 MW
- 9.5 MW
- 1.5 MW
- 0.1 MW
## Small Hydro Classification

Classification based on **power output** varies from country to country

<table>
<thead>
<tr>
<th>Country</th>
<th>Pico (kW)</th>
<th>Micro (kW)</th>
<th>Mini Hydro (kW)</th>
<th>Small (kW)</th>
<th>Medium/Large Hydro (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>&lt; 10</td>
<td></td>
<td></td>
<td>up to 50,000</td>
<td>&gt; 50,000</td>
</tr>
<tr>
<td>India</td>
<td>&lt; 10</td>
<td>10 - 100</td>
<td>101 – 2,000</td>
<td>2,001 - 25,000</td>
<td>&gt; 25,000</td>
</tr>
<tr>
<td>Italy</td>
<td>&lt; 10</td>
<td></td>
<td></td>
<td>Up to 3,000</td>
<td>&gt; 3,000</td>
</tr>
<tr>
<td>Tanzania</td>
<td>&lt; 10</td>
<td>10 - 100</td>
<td>101 – 1,000</td>
<td>1,000 - 10,000</td>
<td>&gt; 10,000</td>
</tr>
<tr>
<td>Kenya</td>
<td>&lt; 10</td>
<td>10 - 100</td>
<td>101 – 1,000</td>
<td>1,000 - 10,000</td>
<td>&gt; 10,000</td>
</tr>
<tr>
<td>Uganda</td>
<td>&lt; 10</td>
<td>10 - 100</td>
<td>101 – 1,000</td>
<td>1,001 - 10,000</td>
<td>&gt; 10,000</td>
</tr>
<tr>
<td>Rwanda (process to agree and establish “classification” in the initial stages)</td>
<td>&lt; 10</td>
<td>10 - 100</td>
<td>101 - 1000</td>
<td>1,001 – 10,000</td>
<td>&gt; 10,000</td>
</tr>
<tr>
<td>UK</td>
<td></td>
<td></td>
<td></td>
<td>Up to 20,000</td>
<td>&gt; 20,000</td>
</tr>
<tr>
<td>USA</td>
<td></td>
<td></td>
<td></td>
<td>Up to 30,000</td>
<td>&gt; 30,000</td>
</tr>
<tr>
<td>ESHA/EC/UNIPEDE (Portugal, Spain, Ireland, Greece and Belgium)</td>
<td></td>
<td></td>
<td></td>
<td>Up to 10,000</td>
<td>&gt; 10,000</td>
</tr>
<tr>
<td>Philippines</td>
<td>&lt; 10</td>
<td>10 - 100</td>
<td>101 – 10,000</td>
<td>10,000 - 50,000</td>
<td>&gt; 50,000</td>
</tr>
<tr>
<td>UNIDO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt; 10,000</td>
</tr>
</tbody>
</table>

*Source: ESHA 2004 + Author’s notes  
UNIPEDE: International Union of Producers and Distributors of Electricity*
# Small Hydro Classification

Based on **Head**

<table>
<thead>
<tr>
<th>Ultra Low Head</th>
<th>Below 3 metres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low head</td>
<td>3 to 10 metres</td>
</tr>
<tr>
<td>Medium Head</td>
<td>10 to 50 metres</td>
</tr>
<tr>
<td>High Head</td>
<td>Above 50 metres</td>
</tr>
</tbody>
</table>

Based on **Mode of Operation**

<table>
<thead>
<tr>
<th>Run of River Plant</th>
<th>Output depends on water flow in the river</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage Plant</td>
<td>Water can be accumulated during low power demand and released during the peak</td>
</tr>
</tbody>
</table>

Based on **Power Supply**

<table>
<thead>
<tr>
<th>Stand alone or isolated</th>
<th>Supply an independent load center without being connected to other generating plants of bigger capacities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid Connected</td>
<td>Supply power to national, regional grid which are operated by other power plants of bigger capacities</td>
</tr>
</tbody>
</table>
The Protocol has been developed primarily to assist IHA members in assessing performance against criteria described in the IHA Sustainability Guidelines. The protocol document is in three sections:

- **“A”** – gives guidance on sustainability issues used when assessing new (Greenfields) energy supply projects. This section describes each of the 20 selected sustainability aspects and lists key considerations and assessment requirements for each aspect. It can be used as part of a preliminary due diligence review of proposed new energy projects. It is useful for policy and decision makers when developing energy policies and assessing future energy options requirements.

- **“B”** – for Assessment associated with specific New Hydro Projects

- **“C”** – for Operating Hydropower Facilities, rely on objective evidence to support a sustainability score against each of twenty sustainability aspects. These sustainability aspects have been selected to give appropriate coverage to relevant economic, social, and environmental issues. Assessment is scored from 0 to 5, and looks at both process and performance against each aspect or criteria.
## Summary of Aspects and Scores to consider for New Hydro Projects

<table>
<thead>
<tr>
<th>No.</th>
<th>Aspect</th>
<th>Score</th>
<th>No.</th>
<th>Aspect</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>Political risk and regulatory approval</td>
<td></td>
<td>B11</td>
<td>Safety</td>
<td></td>
</tr>
<tr>
<td>B2</td>
<td>Economic viability</td>
<td></td>
<td>B12</td>
<td>Cultural heritage</td>
<td></td>
</tr>
<tr>
<td>B3</td>
<td>Additional benefits</td>
<td></td>
<td>B13</td>
<td>Environmental impact assessment and management plan</td>
<td></td>
</tr>
<tr>
<td>B4</td>
<td>Planned operational efficiency and reliability</td>
<td></td>
<td>B14</td>
<td>Threshold and cumulative environmental or social impacts</td>
<td></td>
</tr>
<tr>
<td>B5</td>
<td>Project management plan</td>
<td></td>
<td>B15</td>
<td>Construction and associated infrastructure impacts</td>
<td></td>
</tr>
<tr>
<td>B6</td>
<td>Site selection and design optimisation</td>
<td></td>
<td>B16</td>
<td>Land management and rehabilitation</td>
<td></td>
</tr>
<tr>
<td>B7</td>
<td>Community and stakeholder consultation and support</td>
<td></td>
<td>B17</td>
<td>Aquatic biodiversity</td>
<td></td>
</tr>
<tr>
<td>B8</td>
<td>Social impact assessment and management plan</td>
<td></td>
<td>B18</td>
<td>Environmental flows and reservoir management</td>
<td></td>
</tr>
<tr>
<td>B9</td>
<td>Predicted extent and severity of economic and social impacts on directly affected stakeholders</td>
<td></td>
<td>B19</td>
<td>Reservoir and downstream sedimentation and erosion risks</td>
<td></td>
</tr>
<tr>
<td>B10</td>
<td>Enhancement of public health and minimization of public health risks</td>
<td></td>
<td>B20</td>
<td>Water quality</td>
<td></td>
</tr>
</tbody>
</table>
SHP Development Process

Basic elements that should be covered in the Development Process:

- The water resources and its potential (Hydrology & Energy Generation)
- Civil Engineering Aspects
- Electro-Mechanical Equipment
- Economical Considerations & Evaluation
- EIA
The Water Resources and its Potential

- **Hydrological Survey:**

  Organizing Qs: One way of doing this is to plot them sequentially in the form of a hydrograph, which shows discharge against time, in chronological order.

  Another way of organizing discharge data is by plotting a flow duration curve (FDC). An FDC shows the proportion of time during which the discharge equals or exceeds certain values. It can be obtained from the hydrograph by organizing the data by magnitude instead of chronologically. E.g., individual daily flows for one year are organized in categories as shown below:

  - Flows of 8.0 m³/s and greater: 41, 11.23
  - Flows of 7.0 m³/s and greater: 54, 14.9
  - Flows of 6.5 m³/s and greater: 61, 16.8
  - Flows of 5.5 m³/s and greater: 80, 21.8
  - Flows of 5.0 m³/s and greater: 90, 24.66
  - Flows of 4.5 m³/s and greater: 100, 27.5
  - Flows of 3.0 m³/s and greater: 142, 39
  - Flows of 2.0 m³/s and greater: 183, 50
  - Flows of 1.5 m³/s and greater: 215, 58.9
  - Flows of 1.0 m³/s and greater: 256, 70
  - Flows of 0.35 m³/s and greater: 365, 100
The Water Resources and its Potential

Sizing a power plant:

- FDC provides means of determining quickly how much of the available water resources can be used by turbines of different sizes.
- Power from flow varies with time since Q is varying & is given by $P = QH\eta$ where Q is discharge, H is net head, $\gamma$ is specific weight of water (9.81 kN/m$^3$), $\eta$ is overall efficiency (may initially est. to be 0.8).

Annual energy production:

- Can be estimated to a 1st approximation by measuring the usable area under the FDC, converting to an actual qty of water in m$^3$ in a specific time, multiplying that by 9.8 and the net head (averaged) and mean efficiency (estimated). The result is annual energy in kJ which is converted to kWh by dividing by 3600.
- Or $E = P*t = QH\eta*t$ (hrs in a year)*plant factor
Different Site layouts

- Canal and Penstock
- Penstock Only
- Mill Leat
  - Turbines are on the exit flow from water-treatment plants or sewage works.
- Barrage
  - The turbine(s) are constructed as part of the weir so that almost no approach canal or pipe-work is required.
**Dams/Weirs:** has functions:
- To increase the available head
- To create a reservoir to store water

**Intakes:** have the following functions:
- To conduct water into the penstock or power canal/tunnel (waterways)
- To minimise the amount of debris and sediment carried by the incoming water.

**Waterways:**
- Power Tunnels/Canals: these convey water either directly or via penstock to the turbines
- Forebay: designed to provide only enough storage to provide extra volume needed during the turbine start-up
- Penstocks: these are pressure pipes conveying water to the turbines

**Powerhouse:** location for turbines, generators, etc.
Electromechanical Equipment

Hydraulic Turbines: They convert potential energy to mechanical energy. 3 types of conventional turbines:

- Kaplan & Propeller turbines: these are axial flow reaction turbines used for low head.
- Francis turbines: these are radial flow reaction turbines with fixed runner blades and adjustable guide vanes used for medium heads.
- Pelton turbines: these are impulse turbines with single or multiple jets, each jet issuing thru a nozzle with a needle to control the flow. They are used for both medium and high heads.
Principal Turbine Types

- Pelton
- Turgo
- Open-Flume Francis
- Spiral-Case Francis
- Crossflow
- Propeller
Classification of Turbine types

Turbine types based on Head and Discharges

<table>
<thead>
<tr>
<th>Turbine</th>
<th>Head Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High (&gt;50m)</td>
</tr>
<tr>
<td></td>
<td>Medium (10-50m)</td>
</tr>
<tr>
<td></td>
<td>Low (&lt;10m)</td>
</tr>
</tbody>
</table>

Impulse

- Pelton
- Turgo
- Multi-jet Pelton
- Crossflow
- Turgo
- Multi-jet Pelton
- Crossflow (Banki)

Reaction

- Francis (spiral case)
- Francis (open-flume)
- Propeller
- Kaplan
**Electromechanical Equipment-cont.**

**Generators:** These transform mechanical energy to electrical energy. There are two choices: Synchronous alternators equipped with a DC excitation system and Asynchronous Generator which draws excitation from the grid.

**Control equipment:**

- **Governors** can be mechanical or electrical
- **Switchgear panel and protection**
- **Automatic control**
- **Powerstation auxiliary electrical equipment:**
  - Station service transformer
  - DC control power supply
  - Outdoor substation
Economical Considerations

Main parameters influencing costs and revenues:

- Type of turbine e.g cross-flow<francis; Propeller <Kaplan
- Number of Units; turbines with multiple runners or multiple nozzles
- Speed of rotation; Higher specific speed turbine => smaller turbine dimensions hence higher speed generators
- Turbine setting: -ve aspect of high specific speeds, requiring a deeper setting to avoid cavitation, should be included in the assessment:
  - Additional foundation excavation, Extra dewatering costs, Higher costs of draft tube gate because of higher tailwater head etc
- Control equipment. Kaplan vs. Pelton
- Size of powerhouse
- Sale of electricity (Tarrif): \( R = 9.81 \times Q \times Hn \times n \times Ta \) where
  - \( Q \) is discharge in m\(^3\)/s
  - \( Hn \) is net head in m
  - \( n \) is overall efficiency of the system = running time
  - \( Ta \) is electricity tariff
New developments in turbine technologies
Jetpro Floating Hydro Power

Comparison of Hydro Power

<table>
<thead>
<tr>
<th>Type</th>
<th>Traditional: Hydro Power Dam</th>
<th>Traditional: Underwater Turbine</th>
<th>Floating Type Hydro Turbine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photos</td>
<td><img src="image1.png" alt="Dam" /> <img src="image2.png" alt="Turbine" /> <img src="image3.png" alt="Turbine blade" /></td>
<td><img src="image2.png" alt="Turbine" /> <img src="image3.png" alt="Turbine blade" /> <img src="image3.png" alt="Turbine blade" /></td>
<td><img src="image2.png" alt="Turbine" /> <img src="image3.png" alt="Turbine blade" /> <img src="image3.png" alt="Turbine blade" /></td>
</tr>
</tbody>
</table>
Jetpro Floating Hydro Power

Features

- Multi-national patented floating hydro turbine for river, irrigation channel and ocean current power generation.
- Shrouded Design: Converged inlet and diverged outlet for optimal output.
- Floating Platform: Turbine blades submerged in water while generator and control installed above water surface, safe for operation and maintenance.
- Simple Anchor: Adjustable height with water levels.
- Cascaded Format: For larger output.
- Turbine Net: installed at inlet to avoid fish or grass entering turbine.
- Warning Signal: Flashing lights to avoid boat collision.
- Rudder: For stability and direction adjustment.
### General Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>HT60</th>
<th>HT100</th>
<th>HT200</th>
<th>HT60-5</th>
<th>HT100-5</th>
<th>HT200-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shrouded Design</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Rated Power (KW)</td>
<td>1</td>
<td>3</td>
<td>12</td>
<td>3</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td>Voltage Output (Vdc)</td>
<td>150</td>
<td>220</td>
<td>220</td>
<td>220</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>Rotor Diameter (m)</td>
<td>0.6</td>
<td>1.0</td>
<td>2.0</td>
<td>0.6</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Length Diameter (m)</td>
<td>1.5</td>
<td>2.0</td>
<td>2.5</td>
<td>1.5</td>
<td>2.0</td>
<td>2.5</td>
</tr>
<tr>
<td>Number of Blades</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Start-up Water Speed (m/s)</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Rated Water Speed (m/s)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>50</td>
<td>80</td>
<td>130</td>
<td>60</td>
<td>110</td>
<td>400</td>
</tr>
</tbody>
</table>

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Environmental Impact Assessment

Environmental assessment is essential when it comes to applying for permission and environmental licenses.

Impact on the environment must be accompanied by an Environmental Statement/Report. It provides an assessment of the project’s likely environmental effects, together with any design, construction, operational and decommissioning measures that are to be taken to minimise them.
PART III
Financing of Hydropower Projects
Issues & Challenges related to financing of Hydropower Projects in Developing World

The financing of Greenfield Infrastructure on a limited-recourse basis in developing countries faces certain common issues (difficulty of accessing long-term international finance, concerns over currency exposure & undeveloped state of local capital markets) irrespective of the type of project.

However, hydropower faces additional difficulties caused by:

- the site-specific nature of projects,
- high construction risk and long construction periods,
- their capital-intensive nature with a high proportion of local costs,
- unpredictable output subject to river flows and broader water management constraints,
- complex concession process to achieve transparency in the award and
- pricing of output, and environmental sensitivities.
- General
- Equity Financing
- Debt Financing
- Support of the Public Sector (Official Assistance)
General Issues in Financing Arrangements

The difficulty of accessing long-term international finance is proving to be a serious obstacle in raising debt for privately funded hydro projects. This is exacerbated by concerns over currency exposure and the relatively undeveloped state of local capital markets in many countries with good hydro potential.

In contrast there appears to be no serious shortage of equity for good projects, although equity holders' expectations on returns (20 to 25 percent a year) are often in variance with those of the host utilities.

There is wide diversity of approaches to financing, ranging from a heavy dependence on public sector institutions to projects almost completely financed in the private sector. The reliance on public support is most evident in the low income countries where there is no domestic financial market to draw upon and where both the legal and regulatory environment, as well as the credit standing of the country, is perceived to be less than adequate by international financiers.
Equity Financing

Projects are financed through locally incorporated special purpose companies in which the equity is held by the sponsors and, in some cases, the host utility.

The amount of equity that a developer has to put into a project is largely determined by the lender's perception of the risk. This is reflected among the projects where the higher gearings (that is, lower equity proportions) were achieved on projects where most of the risk has been deflected away from the project company, as for Birecik and San Roque; or where there was no longer a serious exposure to construction risk, as in Ita.
Debt Financing

Involves direct lending and guarantees from a number of sources:

- **Export Credit Agencies (ECAs)**, which provided both direct loans and guarantees in support of bank lending under terms regulated and administered by the appropriate government agencies in the principal exporting countries.

- **Multilateral Development Banks (MDBs)** like the World Bank Group, the Inter-American Development Bank (LADB), African Development Bank (AfDB) and the Asian Development Bank (ADB). These public institutions have played an important role in the provision of debt financing in many countries. The other increasingly important aspect of MDB participation is guarantees and insurance facilities (for example, the guarantee programs of the WB and political risk insurance of MIGA).

- **Co financing through bilateral funds generally in the form of soft loans to the project company, or grants to the government to cover related social and environmental costs. This is a relatively minor source of financing but, like multilateral funds, it is important as a catalyst for mobilizing other sources of debt.**

- **Commercial banks have provided substantial sums under the umbrella of the ECAs**, and a much smaller amount of pure commercial debt. In many markets commercial debt is severely limited in volume, and short maturities combined with high prices make it unattractive. Debt denominated in local currency often carries very high interest rates. As international commercial debt is often raised on the back of ECA funding, the relatively low proportion of the ECA eligible component in hydro projects also adversely affects the prospects for commercial loans.

- **Bond issues for hydro schemes are still relatively rare.**
Support of the Public Sector (Official Assistance)

The support of the public sector, in one form or another, has been crucial to the financing of all of the projects, even where public funds have not been directly involved.

The most obvious support has been the provision of guarantees by the host government, particularly in respect of payment obligations of the utility, and the provision of funding and guarantees by the MDBs. A significant role has also been played by the ECAs of a number of governments.
## Financing Plan for Selected Projects

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Project Cost in MUSD</th>
<th>Equity Portion</th>
<th>Project Debt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Equity</td>
<td>Debt</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td>Casecnan</td>
<td>495</td>
<td>139</td>
<td>356</td>
</tr>
<tr>
<td>San Roqueb</td>
<td>580</td>
<td>134</td>
<td>446</td>
</tr>
<tr>
<td>Bakun, Philippines</td>
<td>147</td>
<td>44</td>
<td>103</td>
</tr>
<tr>
<td>Theun Hinboun</td>
<td>317</td>
<td>126</td>
<td>190</td>
</tr>
<tr>
<td>Nam Theun 11</td>
<td>1227</td>
<td>368</td>
<td>859</td>
</tr>
<tr>
<td>Khimti I</td>
<td>139</td>
<td>43</td>
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<td>267</td>
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<td>Guilman-Amorin</td>
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<td>118</td>
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<td>Giciye</td>
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<td>4</td>
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<tr>
<td>Rukarara IV</td>
<td>12</td>
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<td>11.4</td>
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<tr>
<td>Nyabarongo I</td>
<td>97.7</td>
<td>17.7</td>
<td>80</td>
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<tr>
<td>Rukarara I</td>
<td>23.5</td>
<td>23.5</td>
<td>-</td>
</tr>
</tbody>
</table>
Trending Average among the Selected Project

World Bank archive data 2000

- Equity: 25%
- Debt: 75%

Total Project Cost: 100%

Sampled Projects in Rwanda 2011

- Equity: 36%
- Debt: 64%

Total Project Cost: 100%
Recommendation/Suggestions (1)

1. The need for longer-term financing to better suit hydropower characteristics

2. Conducive Regulatory framework to enable investment environment: Establish good conducive Investment climate. Clearly mandated, independent institutions such as Regulatory Authorities, Utilities, Rural Energy Agencies, etc with adequate technical and managerial capabilities are very necessary.

3. Realistic public-private risk-sharing arrangements responsive to the requirements of hydropower projects, and

4. Careful preparation of projects by the public sector to enable their formulation on an adequate technical and contractual basis for development as a private
Recommendation/Suggestions (2)

- **Clear Tax breaks:** For developers, the government should consider to reduce VAT payable on hydro-electric plant machineries.
- **Tax Credit on Domestic Capital Equipment:** Intends to benefit & promote local manufactured machineries, equipment and spare parts w.r.t SHP.
- **Grants:** The Rural Energy Agencies and Funds can offer grants to domestic owners of mini-hydro plant e.g USD 500-1000.00 per customer connected in TZ is a form of incentive subsidy.
- **Offer attractive and an unambiguous tariff for grid connected as well off grid connections:** EWURA, ERC.
PART IV:

Construction of Hydropower Plants: Selecting the right contractors
Selection Methods

**Competitive tendering** from a shortlist of prequalified contractors was the preferred route for most of the developers

Direct **Contracting/Contract by Invitation**

**NB:** Selecting a contractor will significantly be influenced by the source of financing for the project as there are strings attached to the financing
# Real Project Cases

<table>
<thead>
<tr>
<th>Items</th>
<th>Nyabarongo I (28 MW)</th>
<th>Rukarara I (9.5 MW)</th>
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<td>Type of Contract</td>
<td>EPC</td>
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<td>Date Signature of Contract</td>
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<td>Nov 2006</td>
</tr>
<tr>
<td>Effective Date</td>
<td>May 20, 2009</td>
<td></td>
</tr>
<tr>
<td>Initial Completion Date</td>
<td>February 2013</td>
<td></td>
</tr>
<tr>
<td>Actual Operational Date</td>
<td>April 2014 (~30% time overrun)</td>
<td>Dec 2010 (&gt;30% time overrun)</td>
</tr>
</tbody>
</table>
| Main Causes                  | • variation in site conditions different from FS report which necessitated EM design works  
                                • Land unavailability for the works | • unexpected geological conditions variations  
                                • Extreme weather conditions  
                                • local administrative issues (umuganda, etc)  
                                • Design capacity for the Spillway design (under designed and hence required to make adjacent design to existing one) |
| Delays Consequences          | • late delivery of cheap hydropower energy  
                                • It will prolong the Gvt to continuous use of expensive rental thermal generation  
                                • Thermal generation will prolong CO2 emissions | • late delivery of cheap hydropower energy  
                                • It will prolong the Gvt to continuous use of expensive rental thermal generation  
                                • Thermal generation will prolong CO2 emissions |
| Who is Liable for the Delays | As an EPC contractor takes most of the blame for not conducting necessary site verification careful verifying accuracy of site data given inform of FS report, etc  
                                Employer takes some of the liabilities also | Both Contractor shared geological risk at 50:50  
                                Contractor incurring additional cost for a new spillway |

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www.leokassana.com  
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REFIT Tariff Design and PPAs (1)

Tariff Model used was to calculate an energy rate (the REFIT) to be paid per unit of generation in a given size range that will cover the costs and provide an acceptable return for a generation facility based on a given RE resource.

These costs include capital expenses (CAPEX) to build a facility and ongoing operating expenses (OPEX) to operate and maintain the facility.

The Model assumes that no government funds, subsidies, international grants, or other concessionary credits used for RE projects undertaken by IPPs, if they are to receive a REFIT tariff.

The Model also fixes a debt:equity ratio at 75:25 for all projects and seeks the REFIT required to produce the Revenue which achieves a selected target Post-tax ROE (Return on Equity) for the investor or, alternatively, a selected target Pre-tax IRR (Internal rate of Return) for the project’s cash flow, at the user’s preference.
REFIT Tariff Design and PPAs (2)

For each distinct RE base and project size, the Model derives REFITs for multiple CAPEX (3), OPEX (3), and Capacity Factor (3) scenarios, as follows:

- **CAPEX**: Base Cost, Base Cost +10%, Base Cost -10%
- **OPEX**: Base Cost, Base Cost +20, Base Cost -20%
- **Capacity Factor** (which vary depending on the type of RE base):

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<tr>
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<th>Geothermal</th>
<th>Solar</th>
<th>Wind</th>
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<td>0.90</td>
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<td>0.85</td>
<td>0.95</td>
<td>0.25</td>
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Summary of Draft REFiT/FiT proposals for RWANDA

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<tr>
<th>usd:rwf</th>
<th>usd</th>
<th>rwf</th>
<th>kW</th>
<th>category</th>
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<th>Avg tarrif in RWF</th>
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<td>0.167</td>
<td>100.2</td>
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<td>2</td>
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Thanks for your attention!