20 ANNEX 14: Workshop Presentations and Photos

see attached on the following pages
Regional ECREEE Workshop on the ECOWAS Scale-Up Programme for Small Hydro Power

Address

By

Mr. Mahama Kappiah
Executive Director
ECOWAS Regional Centre for Renewable Energy and Energy Efficiency
(ECREEE)

Monrovia, 16th April 2012
Excellencies,  
Distinguished Guests,  
Ladies and Gentlemen,

I am delighted to be here today for the Regional ECREEE workshop on the ECOWAS Scale-Up Programme for Small Hydro Power. It is indeed a great honour and true pleasure for me to address so many distinguished guests on this important occasion.

I would like to start by expressing my appreciation and thanks to the Government of Liberia, the Energy Sector Management Assistance Programme (ESMAP) and the United Nations Industrial Development Organization (UNIDO), for their kind collaboration in organising this workshop. I would like to welcome also the UNIDO Regional Centre for Small Hydro Power, based in Abuja, Nigeria.

I am very encouraged to see so many high level experts gathered together here to discuss the potential benefits that Small Hydropower can unleash in our quest to ensure energy access for the ECOWAS region. Hydropower can contribute significantly to meet the electricity needs of urban areas as well as isolated rural areas.

Hydropower is one of the most advanced and flexible sources of renewable energy. It is considered as tested, reliable, low cost and is independent of the energy price volatility associated with plants using fossil fuels. Hydropower plants have usually a life time more than fifty years without major replacements. Grid-connected large
hydropower can improve energy security through the reduction of fossil fuel import dependency, diversification of the energy mix and reduction of electricity shortages. It can help to meet the rapid growth of electricity demand in urban centers and industry.

Small-scale hydro (SHP) can be connected to a central grid, to a rural isolated grid or can be connected to a dedicated power load (e.g. cement factory, lodges, mines). It can range from pico (1KW – 10KW), micro (10KW – 100KW), mini (100KW – 1 MW) to small (1MW – 30MW): SHP can serve the priority needs of the rural poor and boost local development, productive uses (e.g. processing and conservation of agricultural products, water pumping and desalination) and basic social services (e.g. health care, education).

West Africa accounts for one quarter of Africa’s total exploited hydropower potential. The hydroelectricity potential of the ECOWAS region is estimated at 25,000 MW, out of which up to now, only 16% are developed and utilized.

However, so far the ECOWAS countries do not take full advantage of their technical and economic feasible hydro potential. This is particularly true in the case of small-scale hydropower. The challenges that SHP developers are facing are many and most of them are part of the larger picture of general barriers for the uptake of renewable energy. In this context, the workshop aims at achieving the following results:
• to take stock of the progress of small scale hydro power (SHP) development and to assess the individual support needs of the participating ECOWAS countries

• to validate the proposal for the ECOWAS Up-Scale Programme for Small-Scale Hydropower and attract interest of possible financiers

• to gather country information on resources, institutional set-ups and policies in the SHP sector

• to compile an inventory of SHP investment projects to be presented to financiers and investors

• to initiate a regional information network of national SHP focal points and experts

• to provide training on key aspects of SHP project development for ECOWAS experts and facilitate cross-border exchange of experiences and lessons learned

• to create awareness among invited policy makers that SHP is a tool for poverty reduction and sustainable development in peri-urban and rural areas

During the first three days the event will feature a training seminar on small scale hydro project development. Experts from Austria, India
and Switzerland will share lessons learned and case studies. I encourage you to take advantage of the presence of the industry specialists participating in this workshop to share experiences and build knowledge so that together, we can implement a successful small hydropower programme.

The remaining two days we would like to invite you to validate the draft project proposal for the ECOWAS Up-Scale Programme for Small Scale Hydropower. The programme provides a comprehensive support framework to stimulate investments and business development in the sector during the next five years. After this workshop the final project document for the 3 million Euro programme will be submitted for approval to the ECOWAS Energy Ministers. The programme is considered as crucial step to achieve universal access to modern energy services to all in the ECOWAS region.

thank you for honouring our invitation to participate in this workshop and very much look forward to your valuable contributions.

Merci beaucoup!!! Muito obrigado!!!
ESMAP/Africa Energy Group of the World Bank Speech

Regional ECREEE Workshop on the ECOWAS Scale-Up Programme for Small-Scale Hydro Power, 16th to 20th of April 2012, Golden Gate Hotel, Monrovia, Liberia

Excellencies,
Distinguished Guests,
Ladies and Gentlemen,

Let me begin by expressing my congratulations to the organizers of this regional workshop on behalf of the Energy Sector Management Assistance Program (ESMAP) and the Africa Energy Group of the World Bank. I would like to mention particularly, the ECOWAS Regional Centre for Renewable Energy and Energy Efficiency (ECREEE), the United Nations Industrial Development Organization (UNIDO) and the Government of Liberia represented by the Rural and Renewable Energy Agency.

The date and theme of the workshop are well chosen, right in the forefront of the Rio+20 and the 2012 Year for Sustainable Energy for All. I am convinced that the outcome of this workshop will stimulate the forthcoming discussions on the future modalities to boost universal access to energy services by 2030.

The ECOWAS initiative to launch a Scale-up Program for Small Scale Hydro Power is very timely and has the potential to address the energy challenges of the peri-urban and rural areas in West Africa in a sustainable manner. The framework conditions are promising since some of the ECOWAS countries have a good small hydro potential and the technology is a proven and cost-effective technology alternative to conventional and other renewable energy solutions. However, much has to be done to mitigate the existing barriers for the deployment of the small hydro technologies in the ECOWAS region.
In this context, I would like to mention that the World Bank has been active in the large hydro power sector throughout the developing world for many decades. In recent years, small hydro power projects have also been included into the scope of eligible investments. Bundling small hydro projects of a pipeline into a portfolio with a representative size to be attractive to private investors is of particular interest to the World Bank since this could help reduce the transaction costs. PPAs, permits and licenses, environmental studies and other assessments could be negotiated and processed as a whole thus reducing the cost per MW installed. KfW has done some interesting work in Uganda which we can learn from. In the regard, it is exciting to hear the ECREEEE plans to establish a pipeline of projects in cooperation with the national Ministries of Energy in ECOWAS.

Also, ESMAP, through its AFREA program has been supporting two universities in the ECOWAS region, the Kwame Nkrumah University of Science and Technology (KNUST) in Ghana and the International Institute for Water and Environmental Engineering (2IE) in Burkina Faso to upgrade their capabilities to deliver to plan, deliver and evaluate “hands-on” training to transfer know-how on renewable energy technology (Solar PV, CSP and Wind) assessment and project implementation to policy makers, utilities, university students etc within the sub region. These two universities are already partnering ECREEE in a number of areas. One area ESMAP and the Africa Energy Group is considering further cooperation with ECREEE, KNUST and 2IE is to conduct an analysis of the gap in professional competencies in and to propose what can be done to fill the gaps in the sub region for the efficient implementation of renewable energy programs. I am pleased to note that as part of this workshop, ECREEE is conducting an SHP capacity needs assessment to identify the training needs of different stakeholder and to define appropriate modalities to best meet such needs.
For close to 30 years, ESMAP has supported over 800 energy-sector activities that help reduce poverty, foster economic growth and protect the climate. Our aim is to continue to assist the ECOWAS region in developing technical and institutional capacity to achieve environmentally sustainable energy solutions for poverty reduction and economic growth. Today, ESMAP is here to support yet another energy-sector programme, small-scale hydro power, for a better tomorrow for the ECOWAS populace.

Thank you.
What are we talking about?

Overview on „small-scale hydropower“ SHP

Martin Bölli
Content of the presentation

- Main components of a hydropower plant
- Various classifications of hydropower plants
- Crucial differences between micro, mini and small hydro
- Some words about costs
Main components of a (runoff river) hydropower plant

- Channel for diverted water
- Forebay tank
- Diversion weir and intake
- Pressure pipe feeding turbine (penstock)
- Turbine
Main components, plan view

- Flood spillway
- Weir
- Regulating gates
- Spillway drain
- Intake
- Wing walls
- Silt basin
- Channel crossing
- Channel
- Powerhouse
- Anchor
- Penstock
- Penstock support
- Forebay tank with silt basin and spillway
- Tailrace
### Classification applied in the current context

<table>
<thead>
<tr>
<th>Term</th>
<th>Power output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pico hydropower</td>
<td>&lt; 5 kW</td>
</tr>
<tr>
<td>Micro hydropower</td>
<td>5 - 100 kW</td>
</tr>
<tr>
<td>Mini hydropower (MHP)</td>
<td>100 – 1 000 kW (=1 MW)</td>
</tr>
<tr>
<td>Small hydropower (normally “SHP”)</td>
<td>1 MW - 30 MW (!)</td>
</tr>
<tr>
<td>Full scale (large) hydropower</td>
<td>&gt; 30 MW</td>
</tr>
</tbody>
</table>
Estimation of the power potential (simplified)

\[ P = Q \times h \times 7 \]

- \( P \): electric Power [kW]
- \( Q \): Available flow \([\text{m}^3/\text{s}]\)
- \( h \): Available head [m]
- \( 7 \): constant \([\text{m/s}^2]\), based on the gravity constant and the efficiencies of the equipment
Classification by design head

Most literature recommends the following general limits:

- low-head plants \( H < 15 \text{ m} \)
- medium-head plants \( H = 15 \text{ to } 50 \text{ m} \)
- high-head plants \( H > 50 \text{ m} \)
What are we talking about

Low head
High head
Classification by design type

- run-of-the river schemes
- storage schemes
Run-of-the-river

- Most common type in the context of mini and micro hydropower
- Diversion weir installed in the river causes a minimum impact to the river as it has no impact on the seasonal flow pattern downstream of this structure.
- In some cases enlarged forebay serves as daily storage to cover daily peak demands. These schemes also count to the run-of-river-type.
Storage system

- Not commonly used in the context of mini and micro (complex design and expensive to implement, more frequent for small and large hydro)
- Causes large accumulation of water by flooding the valley upstream of it → large impact on the river ecology
- Seasonal storage and flood prevention (regulation of river flow).
- Common problem with large dams is accumulation of silt.
- Disruption of river flow renders shipping, rafting of timber and fish migration impossible
Multipurpose plants

Use of hydropower potential in:

- drinking water supply systems
- irrigation systems
- Waste water systems

often economically viable!
Classification by grid type / destination of supply

- **off-grid** / captive generation
  - The SHP supplies an island / isolated grid, not interconnected with the national grid
  - Hybrid-operation is also possible (supply from various sources to the micro-grid)

- **on-grid**
  - The SHP directly supplies electricity to (usually) the national utility.
Crucial differences between pico, micro, mini and small hydro

The “order of magnitude” has an impact on:

- Required components and their technical standards
- (specific) investment and O&M costs
- Potential project owners and managers
- Environmental (and social) impact
What are we talking about

**Pico hydropower (≤ 5 kW)**

- Power supply for single or few households
- Cost start at about 200 US$ per unit
- Only suitable for isolated operation
- Depending on type of installation usually very maintenance intense and less cost efficient than larger community-based systems
- Productive use not possible
Pico hydropower (< 5 kW)

- normally owned and operated by private individuals or small communities
- Technical standards mainly to protect the users
- Almost no civil works required
- Can be installed by local population (with some external support)
- Normally no negative environmental and social impact
Micro hydropower (5 - 100 kW)

- Power supply for up to several hundred households
- Cost start at about 2,000 US$ per kW installed capacity
- Mostly used for isolated micro grids in the context of rural electrification
- Grid connection possible
- Normally no or no significant negative environmental & social impact
Micro hydropower (5 - 20 kW)

- Can be owned and operated by community or private individual
- Certain technical standards increase lifetime and reduce O&M cost
- Components can be cheap and simple → high local content (earth channel, manual control, one-phase generator etc.)
- Productive use often with “direct drive”
- High community contribution increases feeling of ownership
Micro hydropower (20 - 100 kW)

- Can be owned and operated by community or private individual
- Bigger size / higher investment often only justified in combination with productive use / factory etc.
- Higher technical standards (civil works and EM equipment, control system etc.) are obligatory for long lifetime
Micro hydropower (20 - 100 kW)

- Often transformation to medium voltage required (customers more widespread)
Design mistakes or inaccurate hydrological analysis can already have serious consequences!
Mini hydropower (100 – 1000 kW)

- Since several thousand households are required to justify investment, normally difficult as purely “community based scheme” → would need more support for institutional set-up for proper management
- Promising potential on smaller rivers
- Normally grid-connected to achieve reasonable load factor!
- Can substantially contribute to stabilization of grid, especially at end-points
What are we talking about

Mini hydropower *(100 – 1000 kW)*

- Larger-scale productive use possible (e.g. tea factories, ice factory...)
- Technical standards obligatory (safety regulations!)
- Requires involvement of experienced designers and construction companies
- Environmental and social impact have to be considered
Small hydropower (1 - 30 MW)

- Power supply for up to several ten thousand households → always grid-connected!
- Due to economies of scale, specific investment per kW often lower
- Much more profitable than isolated smaller plants → interesting for commercial investment / independent power producers → requires suitable legal framework (feed-in rules…)

What are we talking about
What are we talking about

Small hydropower (1 - 30 MW)

- Promising potential on medium sized rivers
- Can contribute to stabilization of grid
- Has to fulfill international technical standards and requires very professional planning and implementation
- Detailed hydrological analysis required!
- Detailed assessment of environmental and social impact required → mitigation measures
Large hydropower (> 30 MW)

- Power supply for municipalities of large cities and supply to national grids
- Is not considered in the present workshop context
Some words about the costs…

- Economy of scale: The larger a power plant, the lower the specific costs (Investment costs per kW installed)
- For large, high head hydropower plants starting from about USD 2,000 per kW
- For low head micro hydrosystems USD 15,000 per kW or even more!
- Strong dependence on local costs and head
Some words about the costs...

The graph shows the cost share in percentage for different categories as a function of head in meters. The categories shown are:
- Civil
- e/m equipment
- Penstock
- Electrical equipment

The cost share decreases as the head increases for all categories.
Possible conflicts of interest

- Fishery
- Irrigation
- Shipping
- Environmental Impacts
- Aquatic Wildlife
- Water use for human activities, like washing, bathing, sport, ...
Thank you!
The special challenge in W-Africa

Oliver Froend
entec AG / PT entec Indonesia

Comparison Low Head vs. High Head

Generic Projects

The basic layout of a hydro power plant is decided based primarily on topography and on the designated demand

Example: Run-of-River with Diversion Channel

High Head vs. Low Head

Example 1:

- $H_{net} = 100$ m
- $Q_d = 2.6$ m$^3$/s
- $P_{el} = 2.0$ MW

Example 2:

- $H_{net} = 10$ m
- $Q_d = 27$ m$^3$/s
- $P_{el} = 2.0$ MW
**NB: plant gradient**

(unit: %)

The quotient of the **difference in altitude** between the water level at the intake and the water level at the turbine outlet **divided by** the total length of the water conveyance structures from intake to the end of the tailrace channel. Common indicator for the attractiveness of a project. Projects with > 6% are very favourable, < 2% indicates low attractiveness.

\[
\text{Plant Gradient} = \frac{H}{L} \times 100 \text{ [%]} 
\]

**Examples: Intake**

<table>
<thead>
<tr>
<th>2-3 m³/s</th>
<th>25-30 m³/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usually smaller rivers with less destructive floods</td>
<td>Usually large rivers with high flood levels</td>
</tr>
<tr>
<td>→ less complex design and construction</td>
<td>→ complex design and construction</td>
</tr>
<tr>
<td>Long term gauging data for smaller streams rarely available.</td>
<td>Long term gauging data available for many rivers, analyses can be related to similar basins.</td>
</tr>
<tr>
<td>→ Own gauging required, analysis to be based on empiric approaches.</td>
<td>→ Frequently faster and more reliable analysis possible</td>
</tr>
</tbody>
</table>

**Example: Channel**

<table>
<thead>
<tr>
<th>2-3 m³/s</th>
<th>25-30 m³/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relatively small cross section, but long channel</td>
<td>Relatively large cross section, but short length</td>
</tr>
</tbody>
</table>

**Penstock: Economic diameter**

Computation of the most economic penstock diameter usually is a time consuming task. Additionally, many of the required economic and technical parameters may not yet been known at a certain stage of project development.

→ **use rule of thumb (empiric formula):**

\[
D_{opt} = \frac{1}{2} H^{1/3} \left( \frac{P_{hydr}}{H} \right)^{1/5}
\]

where:

- \( D_{opt} \) = optimum diameter (in m)
- \( H \) = gross head of the hydro power plant (m)
- \( P_{hydr} \) = hydraulic power = \( \rho \times g \times Q \times H \) (kW)
Examples: Penstock
Optimum Diameter

<table>
<thead>
<tr>
<th>2.6 m³/s</th>
<th>27.0 m³/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usually long pipe, but small diameter.</td>
<td>Usually short pipe, but very large diameter.</td>
</tr>
<tr>
<td>$D_{\text{opt}} \approx 1.0 \text{ m}$</td>
<td>$D_{\text{opt}} \approx 4.0 \text{ m}$</td>
</tr>
<tr>
<td>$(v \approx 3.3 \text{ m/s})$</td>
<td>$(v \approx 2.2 \text{ m/s})$</td>
</tr>
<tr>
<td>$L \approx 350 \text{ m}$</td>
<td>$L \approx 40 \text{ m}$</td>
</tr>
<tr>
<td>total weight $\approx 9 \text{ tons}$</td>
<td>total weight $\approx 3 \text{ tons}$</td>
</tr>
</tbody>
</table>

Examples: Powerhouse and Turbine

<table>
<thead>
<tr>
<th>2-3 m³/s</th>
<th>25-30 m³/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Madland HPP, Norway</td>
<td>Gstatterboden HPP, Austria</td>
</tr>
<tr>
<td>1 Francis, $D_r = 572 \text{ mm}$</td>
<td>1 Axial Bulb, $D_1 = 1 950 \text{ mm}$</td>
</tr>
<tr>
<td>$P = 1.9 \text{ MW}, H = 84 \text{ m}$</td>
<td>$P = 2.0 \text{ MW}, H = 9.4 \text{ m}$</td>
</tr>
<tr>
<td>Photo: Gugler</td>
<td>Photo: Andritz Hydro</td>
</tr>
</tbody>
</table>

Specific Types of HPP

Hydropower Barrage
Hydropower Dam
Run-of-River (ROR) and Reservoir (RES) HPPs have different electricity supply characteristics

Run-of-River (ROR) HPP
- These schemes usually supply base load.
- Seasonal variations in generation may occur (i.e. below design capacity operation in dry season).
- Flow available for power generation limited to the actual river flow, no storage capacity.

Reservoir (RES) HPP
- These schemes can supply peak load.
- River flow, as energy source, can be stored and released through the turbine during times of high demand (e.g. ‘evening peak’).
- Very large reservoirs may provide seasonal storage capability.

River Barrage
- Low head and large flow usually result in large structures and turbines, and correspondingly in high costs per installed capacity.
- In large hydro these schemes are often built as cascades, frequently with a large ‘head reservoir’ upstream.
- May have substantial environmental and social impact if large upstream areas are converted to reservoir.
- As it usually blocks off large rivers which are required for navigation. Adequate measures have to be implemented (expensive in implementation and operation!)
- In some countries (if environmental legislation permits) these schemes are operated to provide balancing load, resulting in fluctuating water levels.

Hydropower Dams
- Common only above 10 MW (large hydro)
- Usually medium to high head
- Frequently hydropower dams have substantial strategic value for a utility as they provide peak/balancing capacity.
- Seasonal storages allow increased hydropower generation during dry seasons and impact on the operation of downstream hydropower plants.
- Multi-purpose projects: Dam might serve for various purposes with different priorities (drinking water, irrigation, river control, etc.)
- Such projects are generally expensive!
- Power market does not provide adequate tariffs in most countries for IPPs.

Comparison On-Grid vs. Off-Grid
Optimisation criteria for on-grid and off-grid HPPs are very different

**On-grid**
- Aim is to maximise the economic attractiveness of the project
- Adjustment of the capacity to maximise the rate of return on the investment
  (NB: Limited validity non-commercial projects)

**Off-grid**
- Aim is to ensure provision of peak demand throughout the year
- Provision of the ‘least cost option’ for electricity supply

Summary and comparison of different types of HPP plants

There are 3 main types of MHP commonly found:

<table>
<thead>
<tr>
<th>Grid Connected</th>
<th>Captive</th>
<th>Stand Alone</th>
</tr>
</thead>
<tbody>
<tr>
<td>on-grid</td>
<td>commercial projects</td>
<td>off-grid</td>
</tr>
<tr>
<td>usually commercial projects</td>
<td>private sector</td>
<td>usually rural electrification</td>
</tr>
<tr>
<td>• Private sector or utility financed</td>
<td>• Alway been implemented on a fully commercial basis</td>
<td>• Normally grant financed</td>
</tr>
<tr>
<td>• Mostly implemented on a fully commercial basis (government run utilities might follow other objectives as well)</td>
<td>• Medium / High level technology adopted</td>
<td>• Usually not viable on a fully commercial basis</td>
</tr>
<tr>
<td>• Medium / High level technology adopted</td>
<td>• Mostly viable from relatively small size ranges</td>
<td>• Low to medium level technology adopted</td>
</tr>
<tr>
<td>• Only viable from a certain size (economy of scale)</td>
<td>• Operated &amp; Managed by the industry owning the scheme</td>
<td>• Small size ranges</td>
</tr>
<tr>
<td>• Operated &amp; Managed by professionals staff</td>
<td>• Often combined with electrification for staff</td>
<td>• Usually official procedures relatively uncomplicated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Locally managed by community</td>
</tr>
</tbody>
</table>

Diagram showing different types of HPP plants and their characteristics.
Most potential issues and challenges are primarily attributed to commercial schemes

Mainly related to grid connected commercial schemes but also applicable to some extent to off grid and captive schemes

<table>
<thead>
<tr>
<th>Item</th>
<th>on-grid</th>
<th>captive</th>
<th>Isolated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulatory and Promotional Issues</td>
<td>++</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Project Identification and Definition</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Project Risks</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Power Purchase Agreement</td>
<td>++</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Financing Constraints</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Project Implementation Structuring</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Example on-grid vs. off-grid: indicative design flow for a run-of-river HPP

- The on-grid HPP uses a much larger design flow than the off-grid HPP.
- The installed capacity (directly related to the flow), would be much bigger for the on-grid scheme.
- The on-grid scheme can run on full capacity only during 30% of the time, the off-grid HPP can generate the full capacity during 95% of the time.

Thank you for your attention!

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The Francis Turbine
Medium head ROR with moderate flow fluctuation

• The Francis turbine is the oldest and probably the best-known reaction turbine.
• The runner consists of a row of curved blades which form channels through which the water is accelerated and redirected.
• Regulation of flow is accomplished by a row of adjustable blades, the so-called wicket-gates or guide vanes, which are arranged concentrically around the runner.
• For very low head applications (< 10 m), Francis turbines come in the form of open flume or pit-type machines. For higher heads up to 200 m, spiral casings are used.
### The Pelton Turbine

**High head schemes with relatively small discharges**

- Turbine consists of a runner with a number of buckets on which one or more water jets impinge.
- Flow and hence power output is typically adjusted by a spear valve which can increase or decrease the nozzle opening.
- For higher flows the number of jets can be increased.
- Highly efficient turbine also for part-flow operation down to 10% of design flow.
- By installing a jet deflector the pressure surge in the penstock can be avoided.

### The Crossflow Turbine

**'Robust working horse' in MHP for low to medium head**

- Cross-flow turbines are very robust and relatively simple machines and are therefore highly recommended for small scale rural electrification where operators might be limited in availability of skills and maintenance support.
- The efficiency of cross-flow turbines (up to 80%) is lower compared to other turbine types.

### Propeller-Type Turbines

- Propeller turbines are reaction turbines. Flow passes through the runner in axial direction with little to no inward deflection.
- The oldest propeller type turbine is the Kaplan turbine (see next slide) with a scroll or spiral casing and radial wicket gate configuration for flow regulation similar to the Francis.
- Propeller turbines are also available in the form of tube, bulb and S-turbines.
- Propeller turbines with non-adjustable runner blades (different from the Kaplan-principle) have a less good part-flow efficiency.

### The Kaplan Turbine

**Low Head Run-of-River Plants with High Discharge**

- The classic Kaplan turbine has both adjustable blades and adjustable wicket gates which gives best efficiencies over a wide range of flow rates.
- The axial-flow Kaplan turbine was invented by Viktor Kaplan in 1912.
- This type of turbine is perfectly suited for HPPs with high discharges and relatively low heads (run-of-river).
Example: SHP Kaplan Turbine

Example: S-Type Propeller Turbine

Part-Flow Efficiencies for Different Turbines

Examples: Intake

| 2-3 m³/s | 25-30 m³/s |
What is the range of costs?

Oliver Froend

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 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)

details on following slides

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

details on following slides

Costs and revenues - Timeline

Scrap value
Deconstruction

Amortization

Operation Time

Abandon
Alternative: reinvest and continue operation

Implementation

Total Investment

Land acquisition

Revenues

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

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
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

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Cost Range (USD/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 kW off-grid isolated</td>
<td>~2 500 USD/kW</td>
</tr>
<tr>
<td>60 kW off-grid isolated</td>
<td>~3 000 USD/kW</td>
</tr>
</tbody>
</table>

Civil works 1 500 to 3 000 USD/kW
Electro-mechanical equipment 400 to 1 300 USD/kW
Transmission lines, transformation, grid connection 50 to 200 USD/kW
Project planning and design, site supervision, project management 50 to 500 USD/kW
Total: 2 000 to 5 000 USD/kW

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

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

New Built HPP in Indonesia
FS-Level Cost Estimate

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Annual O&amp;M cost (% of capital cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital cost / Loan servicing</td>
<td>Expenses for service and maintenance, which depend on operating times</td>
<td></td>
</tr>
<tr>
<td>Operation &amp; maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insurances</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxes (depend on generation / sales)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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
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

### 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/AW</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>3.0 % of Investment</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?

- 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
**Graph 1:**

**Generation costs of different power plant types**

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

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Hours per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear energy</td>
<td>7,500</td>
</tr>
<tr>
<td>Lignite</td>
<td>6,000</td>
</tr>
<tr>
<td>Hard coal</td>
<td>5,500</td>
</tr>
<tr>
<td>Natural gas</td>
<td>5,000</td>
</tr>
<tr>
<td>HYDRO</td>
<td>4,500</td>
</tr>
<tr>
<td>Wind</td>
<td>4,000</td>
</tr>
<tr>
<td>Photo-voltacs</td>
<td>3,500</td>
</tr>
<tr>
<td>Natural gas GCC</td>
<td>3,000</td>
</tr>
<tr>
<td>Lignite GCC</td>
<td>2,500</td>
</tr>
<tr>
<td>Hard coal GCC</td>
<td>2,000</td>
</tr>
<tr>
<td>HYDRO GCC</td>
<td>1,500</td>
</tr>
<tr>
<td>Nuclear energy GCC</td>
<td>1,000</td>
</tr>
<tr>
<td>MIX</td>
<td>0.500</td>
</tr>
</tbody>
</table>

**Graph 2:**

**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

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Operating Costs</th>
<th>Fuel Costs</th>
<th>Capital Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>2.00</td>
<td>1.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Pumped storage</td>
<td>3.20</td>
<td>2.80</td>
<td>1.00</td>
</tr>
<tr>
<td>Wind</td>
<td>4.00</td>
<td>3.50</td>
<td>1.50</td>
</tr>
<tr>
<td>Solid Biomass</td>
<td>5.00</td>
<td>4.50</td>
<td>2.00</td>
</tr>
<tr>
<td>Biogas</td>
<td>6.00</td>
<td>5.50</td>
<td>2.50</td>
</tr>
<tr>
<td>Natural gas GCC</td>
<td>7.00</td>
<td>6.50</td>
<td>3.00</td>
</tr>
<tr>
<td>Lignite GCC</td>
<td>8.00</td>
<td>7.50</td>
<td>3.50</td>
</tr>
<tr>
<td>Hard coal GCC</td>
<td>9.00</td>
<td>8.50</td>
<td>4.00</td>
</tr>
<tr>
<td>HYDRO GCC</td>
<td>10.00</td>
<td>9.50</td>
<td>4.50</td>
</tr>
<tr>
<td>Nuclear energy GCC</td>
<td>11.00</td>
<td>10.50</td>
<td>5.00</td>
</tr>
<tr>
<td>MIX</td>
<td>12.00</td>
<td>11.50</td>
<td>5.50</td>
</tr>
</tbody>
</table>

**Graph 3:**

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

- Tidal/Wave energy: 0.10 – 0.25 €cent/kWh
- Geothermal: 0.30 – 0.40 €cent/kWh
- Solar thermal: 0.40 – 0.50 €cent/kWh
- PV: 0.50 – 0.60 €cent/kWh
- Biogas: 0.60 – 0.70 €cent/kWh
- Solid Biomass: 0.70 – 0.80 €cent/kWh
- Wind offshore: 0.80 – 0.90 €cent/kWh
- Wind onshore: 0.90 – 1.00 €cent/kWh
- Hydro Power: 1.00 – 1.10 €cent/kWh

**Graph 4:**

**Thank you for your attention!**

Oliver Froend

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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% => 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.

Real interest/discount rate: $i^* = \frac{i+1}{(1+a)+1}-1$

- $i$ = nominal interest or discount rate (absolute, not in %)
- $a$ = inflation rate (absolute, not in %)
Grid-Connected vs. Isolated Systems

Martin Bölli, Skat Consulting Ltd, Switzerland
Content of the presentation

- Grid-connected systems:
  - Characteristics of the grid
  - Dimensioning and technical Requirements
  - Production costs
  - Advantages of decentralised energy production

- Isolated systems
  - Characteristics of an isolated system
  - Technical requirements
  - Dimensioning, Production Costs

- Summary
Characteristics of the grid

- The grid can absorb all produced energy and make it available wherever it is required
  - The SHP runs permanently at maximum possible capacity
- Voltage and Frequency are defined by the grid and cannot be influenced by the SHP
  - The SHP needs to “form” its produced energy in a way that it is possible to feed it into the grid
- Faulty equipment can cause black outs of large extend
  - Higher requirements to the installed equipment
  - Application of Standards
Technical Requirements (I)

- Dimensioning according to the flow duration curve
  - Design flow at about 60 to 80 exceedance days
    → Plant factor typically 0.5 to 0.6 (limited by flow)
  - Some days not operational because of little flow
    → maintenance!

![Graph showing flow duration curve with Design Flow and Minimum Flow indicators.](chart.png)
Technical Requirements (II)

- Synchronisation
  - Adaptation of the produced energy to the grid
  - Connect the generator with the grid
Technical Requirements (II)

- Synchronisation
  - Adaptation of the produced energy to the grid
  - Connect the generator with the grid
Technical Requirements (II)

- Synchronisation
  - Adaptation of the produced energy to the grid
  - Connect the generator with the grid
Technical Requirements (II)

- Synchronisation
  - Adaptation of the produced energy to the grid
  - Connect the generator with the grid
Technical Requirements (III)

- **Control**
  - Maximum production depending on the available flow
  - → Water level control (constant water level at the intake / forebay)
Advantages of Decentralised Power Production

- Reduction of transmission losses in the national grid
- Backing up the voltage level in remote areas
- Reduced dependency on single large power plants (shutdowns because of maintenance, failure, …)
Isolated systems (off grid)

- Small remote villages, far from national grid
  - High costs for grid extension
  - Low consumer density
  - Low electricity consumption
  - → grid connection: hardly cost-effective

- But: Often high opportunity costs for other energy sources like candles, kerosene, diesel, etc.

- Isolated systems may produce energy at lower costs and allow for additional income possibilities
  - Energy for productive use (agro processing: milling, threshing, hulling etc.), water pumping, etc.
  - Fridges for food conservation and safekeeping of pharmaceuticals
Characteristics of isolated systems

- Electricity production should cover the demand (at any time)
  - **Forecast** of the demand and its development over the next years
  - In case of insufficient hydropower potential
    - load management
    - demand side management
    - back-up solutions (genset)
  - **Stabilise** the isolated system within the required technical limits
- **Revenues** (and thus also the cash flow) depend on electricity consumption
  - Importance of regular electricity consumption (and not only in the morning and the evening)
Technical Requirements

- Dimensioning: Cover the demand at any time
  - Maximum design flow at about 350 to 365 exceedance days
    - Depending from peak demand → Demand forecast!
  - The available hydropower potential is not being fully utilised

![Design Flow and Minimum Flow](chart.png)
Demand Forecast

- **domestic consumption**
  - Light, TV, Radio, fridge…

- **consumption of social infrastructure**
  - (public and service consumption):
    - schools, health centers, mosques, churches, street lighting, administration etc.

- **productive use**
  - milling and other agricultural processing, kiosks, welding and carpentry workshops etc.)
## Power demand of some devices

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Wattage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mill (rice, coffee, cassava etc.)</td>
<td>2-4 kW</td>
</tr>
<tr>
<td>Grain thresher (rice, wheat, etc.)</td>
<td>3-4 kW</td>
</tr>
<tr>
<td>Huller (rice, coffee)</td>
<td>3-5 kW</td>
</tr>
<tr>
<td>Oil expeller</td>
<td>5-8 kW</td>
</tr>
<tr>
<td>Kapok mill (50 kg/hr)</td>
<td>2.3 kW</td>
</tr>
<tr>
<td>Planer</td>
<td>0.5-0.75 kW</td>
</tr>
<tr>
<td>Angle grinder</td>
<td>0.5 kW</td>
</tr>
<tr>
<td>Drilling machine</td>
<td>≤ 0.5 kW</td>
</tr>
<tr>
<td>Circular saw (200 mm diameter)</td>
<td>0.75 kW</td>
</tr>
<tr>
<td>Band saw wheel (300 mm diameter)</td>
<td>0.75 kW</td>
</tr>
<tr>
<td>Centre lathe (medium duty, 160 mm)</td>
<td>0.3-0.4 kW</td>
</tr>
<tr>
<td>Soldering iron (medium duty, 160 mm)</td>
<td>0.07 kW</td>
</tr>
<tr>
<td>Battery charging</td>
<td>0.1-2 kW</td>
</tr>
<tr>
<td>Electric oven (bread, cakes etc.)</td>
<td>1-25 kW</td>
</tr>
<tr>
<td>Blender / juicer</td>
<td>0.3-0.4 kW</td>
</tr>
<tr>
<td>Mixer</td>
<td>0.3-0.4 kW</td>
</tr>
<tr>
<td>Freezer / refrigerator</td>
<td>0.3-0.4 kW</td>
</tr>
<tr>
<td>Ironing</td>
<td>0.3-0.8 kW</td>
</tr>
<tr>
<td>Incandescent bulb (25-100 W)</td>
<td>0.025-0.1 kW</td>
</tr>
<tr>
<td>Energy efficient lamp (brightness of a 100 W bulb)</td>
<td>0.012 kW</td>
</tr>
</tbody>
</table>
Isolated vs. grid-connected SHP systems

Forecast

- How many appliances of which type are switched on simultaneously?
- Which appliances are switched on for how long?

Load forecast
- Peak load in kW
- Plant design

Demand forecast
- Demand in kWh
- Revenues

For both consider the development over the lifetime of the MHP system:
- Population growth in the village
- Increase of individual consumption
- Increase of productive end use
- Additional social infrastructure
### Demand estimate for a typical representative household

<table>
<thead>
<tr>
<th>Capacity (W)</th>
<th>No</th>
<th>Penetration Rate</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorescent lamp 1</td>
<td>12</td>
<td>1</td>
<td>100%</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<td>1.00</td>
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</tr>
<tr>
<td>Fluorescent lamp 2</td>
<td>12</td>
<td>1</td>
<td>80%</td>
<td>1.00</td>
<td>1.00</td>
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<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Bulb 1</td>
<td>100</td>
<td>1</td>
<td>100%</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
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<td>0.50</td>
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<td>0.50</td>
</tr>
<tr>
<td>Bulb 2</td>
<td>60</td>
<td>1</td>
<td>100%</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
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<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Bulb 3</td>
<td>60</td>
<td>1</td>
<td>20%</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>Electric plate</td>
<td>1500</td>
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<td>10%</td>
<td>0.50</td>
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<td>Kettle</td>
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<td>20%</td>
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<td>0.50</td>
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</tr>
<tr>
<td>Iron</td>
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</tr>
<tr>
<td>Satellite antenna</td>
<td>40</td>
<td>1</td>
<td>5%</td>
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<tr>
<td>Sewing machine</td>
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<td>10%</td>
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</tr>
<tr>
<td>Washing machine</td>
<td>400</td>
<td>1</td>
<td>1%</td>
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</tr>
</tbody>
</table>

Average connected capacity: 1,032 W
### Total demand – daily load curve

#### consumption [kWh] during every hour of the day

<table>
<thead>
<tr>
<th>Time [h]</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic use</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
<td>3.4</td>
<td>29.5</td>
<td>13.1</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>4.7</td>
<td>27.6</td>
<td>4.5</td>
<td>2.3</td>
<td>1.2</td>
<td>1.2</td>
<td>21.2</td>
<td>17.3</td>
<td>27.4</td>
<td>19.6</td>
<td>16.4</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Social Infrastructure</td>
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<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.3</td>
<td>0.4</td>
<td>0.4</td>
<td>0.8</td>
<td>0.3</td>
<td>0.3</td>
<td>1.2</td>
<td>1.0</td>
<td>0.4</td>
<td>0.4</td>
<td>0.2</td>
<td>0.6</td>
<td>0.7</td>
<td>0.5</td>
<td>0.5</td>
<td>0.4</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Productive use</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.2</td>
<td>0.2</td>
<td>11.5</td>
<td>11.5</td>
<td>9.8</td>
<td>2.8</td>
<td>0.0</td>
<td>0.8</td>
<td>10.0</td>
<td>10.0</td>
<td>9.3</td>
<td>0.0</td>
<td>0.2</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

#### demand [kWh]

<table>
<thead>
<tr>
<th>Time</th>
<th>daily</th>
<th>monthly</th>
<th>yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>208</td>
<td>6,253</td>
<td>75,032</td>
</tr>
</tbody>
</table>

#### Typical load curve over the day

- **Productive use**
- **Social Infrastructure**
- **Domestic use**
# Projection of demand growth

| Year of operation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Domestic use     |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Growth rate demand per household | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% |
| Demand per household | 750 | 765 | 781 | 796 | 812 | 828 | 845 | 862 | 879 | 897 | 915 | 933 | 952 | 971 | 990 | 1,010 | 1,030 | 1,051 | 1,072 | 1,093 kWh |
| Growth rate number of households | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| Number of households | 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 112 | 113 | 114 | 115 | 117 | 118 | 120 | 121 HH |
| Demand growth domestic use | 75,032 | 77,298 | 78,632 | 80,037 | 81,515 | 83,067 | 84,697 | 86,408 | 88,296 | 90,354 | 92,580 | 94,973 | 97,532 | 100,254 | 103,136 | 106,173 | 109,361 | 112,694 | 116,171 | 119,800 kWh |
| Social infrastructure |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Growth rate social infrastructure | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% |
| Productive and use |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Growth rate productive use | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% |
| Peak demand     |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Growth rate     | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% |
| Peak demand growth | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 kW |

![Graph showing demand growth over time]

- **Demand growth**
  - **Productive use**
  - **Social infrastructure**
  - **Domestic use**

![Graph showing peak demand over time]
## Summary on the forecast

<table>
<thead>
<tr>
<th></th>
<th>year 1</th>
<th>year 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of hh's</td>
<td>100</td>
<td>121</td>
</tr>
<tr>
<td>monthly hh consumption [kWh/month]</td>
<td>63</td>
<td>91</td>
</tr>
<tr>
<td>total monthly demand of all hh [kWh/month]</td>
<td>6,253</td>
<td>11,005</td>
</tr>
<tr>
<td>monthly consumption of social infrastructure [kWh/month]</td>
<td>279</td>
<td>489</td>
</tr>
<tr>
<td>monthly productive consumption [kWh/month]</td>
<td>1,989</td>
<td>3,256</td>
</tr>
<tr>
<td>total peak load [kW]</td>
<td>30</td>
<td>38</td>
</tr>
</tbody>
</table>

- **Revenues** → cash flow
- **System design**
Load and demand side management

Reduce peaks and/or demand by:
- sensitising consumers / awareness raising (energy saving bulbs, promotion of productive end use etc.)
- creating special tariff system, e.g. combined with installation of current limiters...
- Load shedding

More continuous demand:
- Promotion of productive use during at morning / afternoon
- For example water pumping / irrigation at night
Full control of the grid

- Operation of the grid according to the electrical standards (voltage, frequency)
- Influences on the power production from
  - Available flow
    - Only critically during dry season
    - Operator must ensure that the penstock never empties
      - Closing main valve → reduced capacity of the power plant
  - Demand side
    - Fast variations, depending on the electricity users → need automatic control, by
      - Fly wheel (inertia, mechanical energy)
      - Activation of electric ballasts
      - Flow control
      - Load shedding
Comparison

Grid connected
- Maximum utilisation of the available hydropower potential
- Plant factor limited by the available flow (about 0.5 to 0.6)
- Low generation costs
- Tariff agreed with utility

Isolated system
- Low utilisation of the available potential, continuous power capacity
  (some few percent of the production of a grid connected system at the same place)
- Plant factor limited by the demand (typically 0.15 ... 0.3)
- Higher generation costs
- Tariff depends on the acceptance of the end users
- Can rarely be implemented on a commercial basis
  → often grant financed
- Can become a “cash cow” for the community if later on connected to national grid (feed-in)
Comparison – Specific components

**Grid connected**
- Synchronisation Equipment
- Transmission line to connect to the grid
- → High technical requirements, approved by utility

**Isolated system**
- Components to enable the reaction on fast demand variations (flywheel, electric ballasts, load shedding)
- Distribution grid and household connections
- Utilisation of simpler technology possible
  - Without cutting back on safety aspects!
Comparison – Operations and maintenance

**Grid connected**
- **Operation**
  - (usually) full automatic control, often managed by an investor
  - Billing to utility (1 costumer)
  - When grid is down: no possibility to sell the produced energy
- **Maintenance**
  - In dry season
  - Power plant downtime: consumers still have electricity (from the grid)

**Isolated system**
- **Operation**
  - Manually operated (operator), often managed by a community
  - Billing to various end users (meter reading required)
- **Maintenance**
  - Power plant downtime: Consumers do have no electricity
  - Includes the maintenance of the distribution grid and the end user connections
Thank you for your attention!

Contact

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Vadianstrasse 42, CH – 9000 St. Gallen / Switzerland
+41 71 228 54 54 – martin.boelli@skat.ch – www.skat.ch
Experiences of the Private Sector Participation in Micro-Hydro Power (PSP Hydro) project in Rwanda

16 - 20 April 2012, Monrovia, Liberia
ECOWAS Regional Workshop on Small-Scale Hydro Power

Benjamin Attigah
Programme Manager
GIZ / Energising Development (EnDev) Rwanda
a. Background & baseline
b. Activities
c. Results
d. Conclusion
Dutch–German Energy Partnership
‘Energising Development’” (EnDev)

18 countries (10 Africa, 4 Latin America, 4 Asia)
Background: GIZ PSP Hydro project

- **PSP Hydro** project is part of the global Dutch–German Energy Partnership ‘Energising Development’ (EnDev) which is implemented by GIZ
- PSP Hydro project is the **first attempt** in Rwanda to attract private commercial participation in micro-hydro power
- **Project duration**: 2006-2013
- **Objectives**:
  - to provide more people with electricity (through MHP projects)
  - to create a self-sustaining private sector micro hydropower capable of designing, building and operating MHPs after the closure of PSP Hydro (sector development)
- **Partner**: Ministry of Infrastructure (MININFRA); since 2011 Energy Water Sanitation Authority (EWSA)
Baseline: situation in 2006

- Growing electricity demand, very low generation capacity, limited national grid network

- **Prevailing approach**: 100% publicly financed MHP plants + community owned schemes (since 2005, by UNIDO)

- **No private companies** working in renewable energy in 2006
  - Low capacities (managerial, technical) of potential private developers and sub-contractors
  - lack of own funds/collateral

- **No political and legal framework** for private investments:
  - No regulatory procedures, no Electricity law, etc.

- **Zero experience of local banks** in MHP / renewable energy
  - concerned about unknown sector, lack of expertise, insufficient collateral of applicants to cover high guarantee requirements
a. Background & baseline
b. Activities
c. Results
d. Conclusion
Project activities

Support to SMEs

- Technical Engineering Assistance*
- Business Plan Development*
- Financial support: subsidies of *below 50% of investment costs*
  - just enough to make project profitable (**viability gap funding**)
  - precondition: min. 15% equity & commercial loan (35 - 60%)

Sector Development / Regulatory framework

- Political support and institutional guidance
- Establishment of regulatory processes
- Assistance for sector consolidation
- Improve cooperation between stakeholders in the sector

* through local contractors
Tendering

- **Stage 1**: Submission of *Expression of Interest* by the developers:
  - Detailed description of the site to be developed
  - Preliminary MoU with district authorities
  - Estimation of customer potential
  - References of project developers
  - Proof of equity and likelihood of obtaining financial closure
  - Rough cost estimate and indications of likely IRR

  Evaluation of proposals by PSP Hydro and award of grant of € 5000 for complete Business Plan development

- **Stage 2**: Submission of complete *Business Plan* and obtaining of *financial closure*

- **Stage 3**: Provision of *limited co-financing* (max 50%, mostly 20-30%)
## Financing Mechanism

<table>
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<tr>
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<th>Suggested contribution</th>
<th>REPRO (96 kW)</th>
<th>ENNY (500 kW)</th>
<th>SOGEMR (438 kW)</th>
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<tr>
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<td>1,415,113</td>
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<td><strong>EnDev Grant</strong></td>
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<tr>
<td><strong>Equity</strong></td>
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<td>41.5%</td>
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<tr>
<td><strong>Loan</strong></td>
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<td>18.8%</td>
<td>46.9%</td>
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Tendering II

- Call for Proposals from private sector in 2005, 2007 and 2009

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<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2009: Call 3</td>
<td>10</td>
<td>7 (+ 3)*</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

* Old sites from Call 1
Murunda Hydropower Plant (96kW)

- Operating since March 2010 without problems
- First ever privately owned and operated MHP plant in Rwanda
Mazimeru Hydropower Plant (500kW)

- Connected to grid April 2012
- First “wheeling” arrangement in Rwanda (SSA): sell to local tea factory by using national grid operated by EWSA
Musarara Hydropower Plant (438 kW)
Project activities II: Privatisation of MHPPs

- MININFRA/EWSA are now interested in privatisation of all publicly funded MHP plants below 2.500 kW
  - EWSA not interested in management of smaller plants
  - Community managed plants not working efficiently

- PSP hydro studies:

<table>
<thead>
<tr>
<th>Name</th>
<th>Sponsor</th>
<th>Connection</th>
<th>Management</th>
<th>Capacity (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agatobwe</td>
<td>GoR, UNIDO</td>
<td>Off-grid</td>
<td>Community</td>
<td>200</td>
</tr>
<tr>
<td>Mutobo</td>
<td>GoR, UNIDO</td>
<td>Off-grid</td>
<td>Community</td>
<td>200</td>
</tr>
<tr>
<td>Nyamyotsi I</td>
<td>GoR, UNIDO</td>
<td>Off-grid</td>
<td>Community</td>
<td>100</td>
</tr>
<tr>
<td>Nyamyotsi II</td>
<td>GoR, UNIDO</td>
<td>Off-grid</td>
<td>Community</td>
<td>100</td>
</tr>
<tr>
<td>Rugezi</td>
<td>GoR</td>
<td>On-grid</td>
<td>EWSA</td>
<td>2.200</td>
</tr>
</tbody>
</table>
To be privatised MHP plants

- Rugezi
- Agatobwe
- Mutobo
- Nyamotsi I
- Nyamotsi II
Privatisation of MHPPs (continued)

- **Findings** of ‘Privatisation Assessment report’
  - No cost information/design drawings provided by (Asian) constructor
  - Very poor operational records
  - low load factors (esp. comm managed) > insufficient management capacity
  - Nyamyotsi I&II in poor physical condition, others mostly in good condition
  - Potential capacity not always what is developed (Mutobo, Nyamotsi)

- **Recommendations**
  - Lease gives higher returns to GoR than sale
  - Rehabilitation is attractive
  - Isolated grid not attractive, 100% feed-in/mix more attractive

- **Government** now wants to **privatise all MHP plants** in Rwanda
  - First step: Government ‘Steering committee’, then prepare tender
  - Govt has started to **actively invite** private companies (Energy Investor Forum, February 2012), first proposals already coming in
a. Background & baseline
b. Activities
c. Results
d. Conclusion
Results: implementation level

- Completion of the **first privately owned and operated micro hydro power plant** (96 kW) in Rwanda in 2010
- 2 additional MHPPs (438 + 500 kW) to be completed soon; more MHPPs in planning stages
- First **wheeling arrangement** (MHPP selling to private Tea factory through EWSA grid) in Rwanda (Sub Saharan Africa?)
- Developers already working on **2nd and 3rd sites**
  - Original idea of creating a new private MHP sector
- **International investors** and other donors providing finance
- Rwandan **banks** have given first commercial loans to MHP projects
  - MHPs developed with **limited public subsidies**
## Current Status of PSP Hydro Projects

<table>
<thead>
<tr>
<th>Company</th>
<th>Direct PSP support</th>
<th>Indirect support / spin-offs</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Site</td>
<td>kW</td>
<td>Site</td>
</tr>
<tr>
<td>ENNY</td>
<td>Mazimeru</td>
<td>500</td>
<td>Maruruma</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rukarara 2</td>
</tr>
<tr>
<td>CALIMAX</td>
<td>Gasumo</td>
<td>80</td>
<td>Rubagabaga</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Yungwe</td>
</tr>
<tr>
<td>SOGEMR</td>
<td>Musarara</td>
<td>438</td>
<td>Mukungwa 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Giciye 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>+ 5 others</td>
</tr>
<tr>
<td>REGREPOWER</td>
<td>Kavumu</td>
<td>285</td>
<td>Mukungwa 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mugambazi</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nshili 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Umunywanzuki</td>
</tr>
<tr>
<td>RED/REPRO</td>
<td>Mashyiga</td>
<td>140</td>
<td>n.a</td>
</tr>
<tr>
<td>REPRO</td>
<td>Murunda</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td><strong>1,539</strong></td>
<td></td>
</tr>
</tbody>
</table>

* preliminary, early estimation based on MoUs with MININFRA/districts, pre/feasibility studies
Results: policy & legal framework

- Guidance and support for the establishment of a regulatory framework has led to **standardized procedures**:
  - Clear process for **license** from regulator established
  - Process for Memorandum of Understanding (**MoU**) with Ministry
  - Existence of **environmental regulations**
  - Establishment of standardized **PPAs** (utilised e.g. by solar firms)
  - Establishment of a **feed-in tariff** negotiated – in Feb 2012 general REFIT programme introduced (see Annex)

- Government committed to **private sector driven approach**, neglect of 100% public / community managed approach

- **Privatization** of publicly owned MHP plants initiated

- Approach taken up by other **donor agencies** (e.g. World Bank)
a. Background & baseline
b. Activities
c. Results
d. Conclusion
Private sector vs. public / community approach

- Private sector approach – advantages:
  - Reduces amount of public subsidies
  - Leveraging of private sector capital (already contributing 75% of investment costs)
  - More efficient and sustainable operation & maintenance
  - More utilisation and building of local capacity
  - Private companies able to build additional sites on their own with their own resources
  - **Upscaling** possible (not the case for community managed)
  - In general, expansion of private sector strengthens industrial structure of the country; employment creation
Thank you for your attention!

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Renewable Energy Feed-in Tariffs

- Feed-in tariff applicable to hydropower and mini-hydropower was issued in February 2012
- Calculated on cost plus return basis
- Differentiated by size
- Applicable to project sizes between 50 kW and 10 MW, program cap of 50 MW
- Reviewed after 3 years

Examples from Rwandan REFIT Tariff Schedule

<table>
<thead>
<tr>
<th>Tariff per kWh (in $ US)</th>
<th>Plants installed capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.6 cents</td>
<td>50 kW</td>
</tr>
<tr>
<td>12.9 cents</td>
<td>500 kW</td>
</tr>
<tr>
<td>7.2 cents</td>
<td>5 MW</td>
</tr>
<tr>
<td>6.7 cents</td>
<td>10 MW</td>
</tr>
</tbody>
</table>
More information

PSP Hydro project:

- Fact sheet: www.giz.de/themen/de/17218.htm


Renewable Energy Feed-in Tariffs (REFIT) for Rwanda:

- RURA website:
  www.rura.gov.rw/.../REGULATIONS_ON_FEED_TARIFFS_HYDROPOWER_PLANTS.pdf
Policy and legal framework

Martin Bölli

Capacity Building Workshop on SHP Project Development, 17 April 2012, Monrovia / Liberia
Overview

- **Regulatory issues**
- **Policy issues**
  1. Decentralised power feed-in and IPPs
  2. Expectations of different players
  3. Policy framework to attract SHP investors
  4. Feed-in tariff systems
  5. (Standardised) Power Purchase Agreements
  6. Connection agreement (Grid Code)
Regulatory Issues

**Key Challenge:** definition of a regulatory framework which is conducive to SHP development, but which does not distort market conditions of the power sector.

a) Water use rights and water use fee  
b) Grid connection policy  
c) Environmental clearances  
d) Implementation agreement  
e) Land acquisition and resettlement policy  
f) Import policy for electro-mechanical equipment
a) Water Use Rights and Water Use Fee

**Challenge:** Conflicting interests between optimal use of water resources for various purposes and SHP development.

- SHP developers should pay water use fee
- Revenues from this fee should be administered **locally**
- Pico and micro hydro should be exempted from fee
- If larger project of national interest requires water or head of SHP plant → revocation of water use right and compensation of developer
- > 1MW compensation very expensive → avoid such conflicts by establishing a master plan before granting water rights
b) Grid Connection Policy

**Challenge:** SHP plants are usually only attractive for the private sector, if investor can make use of the available water flow and produce electricity irrespective of the power demand in the grid.

- **Effective policy** required to oblige grid operators to accept at all times the generated power from small hydro producers.
c) Environmental Clearances

**Challenge**: SHP projects normally have very limited environmental impact (compared to large hydro and especially storage schemes).

- **Specific regulation** for small-scale run-of river hydropower required
- **residual flow** is most crucial issue to be defined based on the environmental and social requirements
- Costly, full-scale environmental impact assessment not required for SHP
- < 50 kW can be exempted from environmental clearances
d) Implementation Agreement

**Challenge:** It has to be ensured that a project developer has the resources to see a project through and does not leave the site with a half-finished plant which may become a threat to other water users and the environment.

- documentation of the developer’s background, information of the sources of funds
- signing of an implementation agreement (with security fees or bonds)
- Exemption from these rules for < 50 kW (?)
- Successful SHP mostly based on BOO (Build-Own-Operate) concept, i.e., no transfer of the asset to the State at the end of a specified contract period or water use concession.
e) Land Acquisition and Resettlement Policy

**Challenge**: Even without the existence of a reservoir or pond, SHP facilities may require acquisition of considerable plots of land and displacement of a few individual families.

- **Assistance by the Government** (e.g. via one-stop-shop) to reduce costs and shorten negotiation process.
- **Application of standard Government land prices** (or long-term lease fees) and compensation fees for crops.
f) Import Policy for Electromechanical Equipment

**Challenge:** In the absence of specific rules, duties and fees on import of electromechanical equipment often are very high compared to the overall project cost → disincentive for SHP development.

→ If equipment is not available in the country: Grant duty-free import of electro-mechanical equipment to SHP developers
Nepal
- project successfully supported IPPs
- almost NO impact on rural electrification
- Attempt for improvement with „Split PPA

India / Himachal Pradesh
- Royalty payment in the form of „free energy to the state“ (up to 30 %)
- 1 % free power to be provided to Local Area Development Fund (income generation, welfare schemes, additional infrastructure, common facilities etc.)
- 1-1.5 % of investment for Local Area Development Committee
- ensure employment to the people of Himachal → minimum 70 % of total employees / officers / executives are to be engaged in the region

Switzerland (1800-1900)
- isolated hydropower stations for domestic and industrial supply emerged (bound to vicinity of riversides); later included into integrated network
- Due to negative experiences with the private sector, “Community Utilities” started as (public) owners and directors of electricity infrastructure
- cantons as conferrer of concessions in favourable position
- Water royalty and other hydropower-related “profits” were and still are a crucial economic factor for development
- mountainous cantons receive ~ 765 million USD of revenues per year due to water royalty, taxes, compensations, investments and salaries
- < 1 MW schemes are exempted from royalty!
Overview

- Regulatory issues

- **Policy issues**
  1) Decentralised power feed-in and IPPs
  2) Expectations of different players
  3) Policy framework to attract SHP investors
  4) Feed-in tariff systems
  5) (Standardised) Power Purchase Agreements
  6) Connection agreement (Grid Code)
1) Decentralised power feed-in and IPPs

- Technical advantages
  - Reduction of transmission losses in the national grid
  - Backing up the voltage level in remote areas
  - Reduced dependency on single large power plants (shutdowns because of maintenance, failure, ...)

- Economic and supply advantages
  - Presence of IPPs boosts the uprating of the capacity of the national power plants
  - IPPs realise power plants at pre-defined tariffs without risks to the utility
  - Synergies with rural electrification possible in case IPPs are (legally) obliged to connect nearby villages to the grid
2a) Expectations / fears of utilities

- **Lower plant factor**
  The presence of IPPs may lower the plant factor of the utilities’ power plants → higher generation costs

- **Stability of the grid**
  Limited influence on the third party SHP (quality of selected equipment, operational modes)
  - The larger the capacity of a power plant, the more it influences the grid.
  - Demand side variations require a regulation of the production park
2b) Expectations of IPPs

- IPPs invest if feed-in tariff is higher than production costs per kWh plus a competitive profit margin

- Predictable risks
  - Transparent permission procedures
  - Tariff guarantee
  - Grid access: quality and availability (to be able to sell the produced energy)
  - Warranty of the issued licences
Conclusions

- **Small Power Plants:**
  - Negligible risks for the utility, as long as technical standards are followed (Grid Code)
  - Standardised PPA
  - Defined Tariffs, Net metering, …
  - Administrative burden should be reduced to a minimum → simple procedures to obtain permits, water usage rights…

- **Larger Power Plants:**
  - Impact on the stability of the grid → national utility must have option to intervene!
  - Individual PPA, tariffs, etc.
3) Policy Framework to attract SHP investors

a) Feed-In law
b) Tariff Regime
c) Equity
d) Independent regulator (tariffs, dispute)
e) One-stop-shop
f) Incentives
g) Clear definition of exemptions
a) Feed-In Law
- Fair, clear and transparent
- Defines the feed-In tariff system and a set of standardised technical and legal documents (SPPA, Grid Code)

b) Reasonable Feed-In Tariff
- Motivate developers & investors
- Consider the impact on the buyer (utility, end consumer)
- Transparent and simple; needs to be published (internet, brochures, …)
c) Equity:
- All (potential) developers are treated equally
- Guarantee that the total production can be sold
- Symmetry in risk sharing

d) **Independent** regulator required to supervise and control:
- Transparent and equal frame conditions for utilities and IPPs
- Tariff setting
- (optimal) electricity production to satisfy consumers’ demand
- Optimisation of the production cost
- Rules and regulations for demand side management
policy and legal framework

e) „One-stop-shop“ which provides

- Clear information and promotion
- All required documents
- Support the compliance with environmental standards

f) Incentives, like

- Exemptions from custom charges for equipment which is not available in the respective country
- Tax exemptions (Sales / Income tax)
- Subsidies on investment (?)
- Access to low interest, long-term loans
g) Clear definition of exemptions:

**Pico and micro power plants (< about 50 kW)**

- Can be regarded as „negative loads“
- Negligible impact on the management of the grid:
  - no need for detailed schedules
  - normally run-of-river (no storage possibilities)
- Comparable with household and small industries connections
  - apply same technical standards (only meter for consumption and production to enable net metering)

  ⇒ **Simplified administrative procedures !**

**Large power plants**

- Large impacts on the whole grid
- Detailed production schedules required
- Buyer must be able to control the power

  ⇒ **Individual agreements required !**
**Isolated grids shall be promoted**

- Electrification of remote villages
- not interacting with national grid, technical requirements mainly for safety and sustainability reasons
- The area of supply (licence area) shall be protected
- As long as isolated: system owner is free to define tariff

→ If the national grid arrives, the system owner has the choice to connect or not (if not, microgrid stays isolated)
4) Feed-in tariff systems: based on production costs

- Producer perspective → his costs are covered

- If production costs exceed market price → expensive energy for the utility. Who pays for additional costs?

- Allows the promotion of specific technology types (Renewable Energy)
4) **Feed-in tariff systems:** based on **avoided costs**

- Perspective of utility (buyer)
  - No negative financial impact on the buyer
  - Only the most profitable projects will be developed

- Tariffs change regularly and are defined and published every year by the regulator → **no investment security**

- Tariff definition complex:
  - End consumer tariffs?
    → often different prices for different customers, or even subsidised
  - Include transmission costs?
  - Based on long-term marginal costs
    → Calculation difficult and allows flexible interpretation of the associated costs
To share the risk, the „avoided cost“ system can be combined with a lower and upper threshold:

- Guarantee to the investor a minimum tariff of 90% of the avoided cost of the first year
- Guarantee to the utility a maximum tariff of 110% of the avoided cost of the first year
4) **Feed-in tariff systems:** based on *quota system*

- The amounts of required energy are tendered:
  - The supplier with the best offer will obtain a licence to supply a certain amount of energy
  - Requires transparent allocation procedure
  - Difficult to hold the supplier liable for his offer (no guarantee if he goes bankrupt)
- No (negative) financial impact on the buyer
- No certainty for the investor
- Low incentive for investors and project developers because of high risks
- Investor takes the risk to bear the cost for preparatory works (e.g. feasibility study), even if he does not win
## Comparison of different feed-in tariff systems

<table>
<thead>
<tr>
<th></th>
<th>Avoided costs</th>
<th>Producer costs</th>
<th>Quota system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economically efficient</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Certainty of revenue stream</td>
<td>Yes (?)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Transparency</td>
<td>Yes (???)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Financial impact on buyer</td>
<td>None (by definition)</td>
<td>Negative (&gt; avoided cost)</td>
<td>None (by definition)</td>
</tr>
<tr>
<td>Equitable</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Regulatory burden</td>
<td>Medium</td>
<td>Highest</td>
<td>Lowest</td>
</tr>
<tr>
<td>Consistency with market principles</td>
<td>Good</td>
<td>Poor</td>
<td>Best</td>
</tr>
</tbody>
</table>
## Country Overview (selection)

<table>
<thead>
<tr>
<th>Tariff based on costs of the:</th>
<th>Producer(seller)</th>
<th>Buyer (&quot;avoided cost tariffs&quot;)</th>
<th>Quota systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Published</td>
<td>Most European countries (&quot;Feed-in tariffs&quot;); Ontario; Sri Lanka 2007</td>
<td>Sri Lanka (until 2006); Indonesia; Hungary; most American States; Serbia (proposed)</td>
<td></td>
</tr>
</tbody>
</table>

| Market price + fixed premium  | Spain             | Czech Republic                   |                |
| Set by market (tradable green certificates, quotas) |                |                                | Romania; many Latin American countries |
| Individually Negotiated       | Vietnam (present) |                                |                |
## Feed-In Tariff overview (selection)

<table>
<thead>
<tr>
<th>Country</th>
<th>Capacity limit</th>
<th>Tariff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nepal</td>
<td>100 kW to 10 MW</td>
<td>US¢ 5.9/kWh (wet season)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US¢ 4.2/kWh (dry season)</td>
</tr>
<tr>
<td>Indonesia</td>
<td>&lt; 1 MW</td>
<td>US¢ 4.1/kWh (low voltage)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US¢ 5.2/kWh (medium voltage)</td>
</tr>
<tr>
<td>Philippines</td>
<td>100 kW to 10 MW</td>
<td>US¢ 3.4/kWh (typical rate, to be agreed upon by both parties)</td>
</tr>
<tr>
<td>Himachal Pradesh</td>
<td>&lt; 5 MW</td>
<td>US¢ 5.5/kWh</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>10 MW</td>
<td>US¢ 5.2/kWh (wet season)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US¢ 5.4/kWh (dry season)</td>
</tr>
</tbody>
</table>
5) Standardised Power Purchase Agreement (SPPA)

**Key Challenge:**
Tariff regime and sales conditions are crucial for investments in SHP

- Agreement between project developer/investor and buyer / utility
- Robust legal agreement, **not** negotiable
  - No ad hoc negotiations
  - Reduction of transaction costs (for buyer and seller)
  - 1 PPA for all!
  - Transparent
- Tied to a published tariff
5) Standardised Power Purchase Agreement (SPPA)

- Definition of details on interconnection point, measuring point, …
- Force majeure
- Eligibility
  - Upper / lower capacity threshold
  - Contract term
- Should be published (internet)
- Lower / upper limit of the original agreed tariff (avoided cost; shared risk of investor / buyer)
6) Connection agreement (Grid Code)

- Contains technical requirements and standards for a connection to the national grid
Thank you for your attention!

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Assessment of hydropower resources

Oliver Froend
entec AG, Switzerland
PT entec Indonesia
Assessment of hydropower resources

- Relevance of surveys, data assessment and analyses to the success of the project.
- Required data and field survey.
- Key element: hydrological data.
  Data gathering, analyses, relevance for project.
Why?
Mitigating project risks through sound assessment and analysis.

**Key Challenge:** (Small) hydro power development involves a number of **risks** which deter developers and investors.

- Hydrological Risk
- Construction Risk
- Risk of Design Flaws
- Social and Environmental Risks
- Political Risks

Detailed site assessment, appropriate analysis and project preparation leads to a vast mitigation of these risks.

Most risks can be identified and their potential impact can be quantified in risk and sensitivity analyses.
When?
Right timing reduces the risk of needless cost and conflict.

Site Surveying and Data Collection
- should be conducted, if an Initial Technical Project Assessment (‘Desk Study’) comes to the conclusion that a site is potentially attractive.
- should only be conducted, if there is a realistic chance that a potential project can be funded and implemented (Particularly for rural electrification projects: Avoid raising expectations among local population that can not possibly be fulfilled later!)
- should be conducted during times with potentially lowest stream flows
Assessment of hydropower resources

• Relevance of surveys, data assessment and analyses to the success of the project.

• Required data and field survey.

• Key element: hydrological data.
  Data gathering, analyses, relevance for project.
During site investigations data is collected which is very critical for successful technical and financial planning.

| Hydrological Analysis                      | • flow duration (➔ project optimisation, design flow)  
|                                           | • flood flows (technical safety of project components) |
| Topographical Mapping                     | • head available for power generation  
|                                           | • optimum positions and alignment for structures  
|                                           | • distances for transmission  
|                                           | • accessibility |
| Geological Analysis                       | • stability of structures  
|                                           | (the degree to which these investigations are conducted depends on type and dimension of structures) |
| Social and Environmental Studies          | • identify demand (off-grid electrification)  
|                                           | • to identify potential risks / conflicts and means for mitigation  
|                                           | • feasibility to fulfil obligations of legislation, donors and lenders |

Neglect in any of these assessments leads to flaws in optimisation and design, eventually reflected in the project’s feasibility.
Very critical information during project planning and optimisation are the available flow and head

\[ P_{el} = \rho \cdot g \cdot Q_d \cdot H_n \cdot \eta \]

**Design Discharge \( Q_d \)**
Very critical value, based on complex hydrological analysis.
- **too high \( Q_d \):** HPP oversized, expected annual generation not achieved, revenue stream smaller than required, financial viability critical
- **too low \( Q_d \):** HPP dimensioned too small, more attractive development solution possible
- **wrong \( Q_d \):** not matching peak efficiency point of installed turbine

**Net Head \( H_n \)**
Very critical value, but relatively easy to determine with topographic survey.
- **wrong \( H_n \):** leads to mismatch of turbine (strong impact)
Very critical information during project planning and optimisation are the available flow and head

\[ P_{el} = \rho \cdot g \cdot \eta \cdot Q_d \cdot H_n \]

\[ = 7 \cdot Q_d \cdot H_n \]

**Design Discharge** $Q_d$

Very critical value, based on hydrological analysis.

- **too high** $Q_d$: HPP oversized, expected annual generation not achieved, revenue stream smaller than required, financial viability critical

- **too low** $Q_d$: HPP dimensioned too small, more attractive development solution possible

- **wrong** $Q_d$: not matching peak efficiency point of installed turbine

**Net Head** $H_n$

Very critical value, but relatively easy to determine with topographic survey.

- **wrong** $H_n$: leads to mismatch of turbine (strong impact)
The HPP planning from initial assessment to detailed engineering design should follow a proven approach

Project development should be conducted in a stepwise approach:

1. Desk study
2. Initial site assessment / Reconnaissance visit
3. Pre-feasibility study
4. Feasibility study
5. Detailed engineering design & Tender documents
6. Implementation (Tendering, Contracting, Construction, Testing & commissioning, Operation and Maintenance)

→ described in more detail in session “Project cycle and planning tools”
## Suitable methods for head measurement and topographic survey

<table>
<thead>
<tr>
<th>Site Reconnaissance</th>
<th>pre-Feasibility &amp; Feasibility</th>
<th>Detailed design</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Altimeter</td>
<td>• Theodolite, total station</td>
<td>• Additional topographic survey of specific areas, if required</td>
</tr>
<tr>
<td>• Hypsometer</td>
<td>• Stereoscopic aerials, triangulation and control point survey</td>
<td></td>
</tr>
</tbody>
</table>

**only Micro Hydro**
- • Clinometer / hypsometer and compass

---

ECOWAS Regional Centre for Renewable Energy and Energy Efficiency
Regional Workshop on Small Scale Hydropower
Assessment of hydropower resources

- Relevance of surveys, data assessment and analyses to the success of the project.
- Required data and field survey.
  - Key element: hydrological data.
  
Data gathering, analyses, relevance for project.
The Water Cycle

Water storage in ice and snow

Water in the atmosphere

Condensation

Evaporation

Evapotranspiration

Surface runoff

Streamflow

Infiltration

Snowmelt runoff to streams

Freshwater storage

Ocean

Ground-water storage

Spring

U.S. Department of the Interior
U.S. Geological Survey
http://ga.water.usgs.gov/edu/watercycle.html

entec AG, Switzerland
PT entec Indonesia
Catchment hydrology

Entec AG, Switzerland
PT Entec Indonesia
Why is a hydrological assessment indispensable?

The hydrological study is the basis for the design of the project

- determination of capacity to be installed
  (design of civil structures & electromechanical equipment)
- calculation of yearly energy production
- statement about the profitability of the plant

Ultimately the economic and overall viability of the project depend on the hydrological analysis.

If predicted flow is not available, less than planned electricity will be generated.
How to obtain runoff data?
Permanent gauging station

Register water level / stage in regular intervals.

Options

a) data logger (automatic recording)

b) staff gauge (manual reading)

➔ It is absolutely required to take discharge measurements to relate water level [cm] to runoff [m³/s].
Important aspects for gauging stations

- easy access during low and high river levels
- far from confluences (avoid tailback)
- straight section of the river, no curves or eddies (parallel streamlines)
- well-defined cross section / river bed which does not change in time (no sedimentation, no erosion)
- stage-discharge relation (= rating curve) must be clear and well-defined over the whole measuring range (from low to high runoff!), no lateral overflowing etc.
Flow measurements are required to establish the rating curve

- Any collected water level (stage) data is completely useless if the relationship between flow and stage is not known!
  - The established relationship is used to transform the observed stages into the corresponding discharges.
A large number of different flows must be measured to establish a reliable rating curve.
The most common methods to measure stream flow are the use of a current meter and the salt dilution method.

**Current meter** (velocity-area-method)
- Can be applied from small to large rivers
- Accurate, if measured with appropriate care

**Salt dilution method** (tracer method)
- Small to medium streams
- Using a tracer (commonly salt) to calculate the stream flow as function of the dilution over time
Stage measurements in combination with measuring weirs are a good option, particularly for small streams

- Very accurate flow calculation as (empiric) formulas are available for common weir shapes.
- Only a very limited number of flow measurements are required for check results.
- Recommended mainly for small streams (<0.5 m3/s).
- Possible also in medium size streams but installation difficult.
Further methods to measure stream flow might be applied if their limitations are considered

**float method**
- During initial site assessments only due to very limited accuracy!
- Measurements can be corrected with factors for different types of river beds.

**bucket method**
- Accurate, but suitable for very small streams only (<20l/s).
Recap: Procedure to establish a flow duration curve (FDC)

Continuous water level registration + Rating curve

Hydrograph

Flow Duration Curve (FDC)
A number of methods with different pros and cons are possible

<table>
<thead>
<tr>
<th>Method</th>
<th>Accuracy</th>
<th>Time</th>
<th>~ Price</th>
<th>Mobility</th>
<th>Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RECOMMENDED:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current meter</td>
<td>good</td>
<td>1-3 hrs</td>
<td>&gt; 1500 $</td>
<td>good *</td>
<td>only steady streams with smooth bed</td>
</tr>
<tr>
<td>Salt dilution</td>
<td>good</td>
<td>½ hr</td>
<td>&gt; 400 $</td>
<td>very good</td>
<td>good for rough mountain streams</td>
</tr>
<tr>
<td>Measuring weir</td>
<td>good</td>
<td>dpd. site cond.</td>
<td>-</td>
<td></td>
<td>&gt; 0.5 m³/s difficult, suitable location</td>
</tr>
<tr>
<td><strong>OTHER METHODS:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bucket / Drum</td>
<td>good</td>
<td>1 hr</td>
<td>5 $</td>
<td>+/-</td>
<td>only small streams</td>
</tr>
<tr>
<td>Float</td>
<td>low **</td>
<td>1 hr</td>
<td>-</td>
<td>++</td>
<td>steady streams with smooth bed</td>
</tr>
</tbody>
</table>

* For wading set-up. Suspended measurements require additional installation and specific equipment.
** Medium, if correction of results with appropriate factors for morphology.
Results should be verified by correlation of flows in similar catchment areas

This method provides a good option to relate to long term (decades long) flow data from gauged streams with similar catchment areas.

**Important!**

This method is not suitable as ‘stand alone’ method to determine the FDC for a site!
Flow data available from other sources: FDCs based on monthly averages tend to provide higher flows than available for power generation
Specific hydrological problems in W-Africa ‘in a Nutshell’

• Small rivers with high gradients tend to have very low to zero flow during the dry season
• Large rivers with reliable flow (and possibly existing flow data) have usually very low gradients and hence low hydropower potential
Example: FDC for an on-grid HPP, considering residual flow

- Flow available for power generation for a maximum turbine capacity of \((2.25 - 0.60 =) 1.65 \text{ m}^3/\text{s}\) (104 kW)
- Residual flow for aquatic life = 0.60 m³/s
Results of the hydrological analysis

- Average flow duration curve → for optimum design discharge
- Residual flow → for yearly energy production
- Flow duration curve of the driest year
  → Economic sensitivity analysis
- Flood events and water depths
  → Design of civil structures (e.g. intake, power house)
Thank you for your attention!

Oliver Froend
entec AG / PT entec Indonesia
oliver.froend@entec.ch
Technical characteristics of promising projects

A hydro power site is more likely to be technically attractive the more of the following criteria are fulfilled:

1. **Overall slope of the water conveyance system** is 8% or more
2. **Pressure head** of more than 40m
3. **Technical risks** and degree of difficulty is low.
4. **Distance** from powerhouse to load centre / grid connection point is less than 1 km per 100 kW installed capacity.
5. (off-grid) **Flow**: firm capacity is more than demand estimate
6. (off-grid) **Consumer density** is greater than 30 connections per 1km of transmission and distribution lines.
General Characteristics of Promising Projects

Note: Technically attractive projects are not necessarily promising projects!

- Economic, financial, social, political and institutional aspects are equally important as purely technical aspects!

→ Broad perspective required to identify promising projects
Clinometer

Measurement of vertical angle and distance required

\[ H = D \cdot \tan \alpha \quad \text{or} \quad H = D_s \cdot \sin \alpha \]

provided that \( a_1 = a_2 \) (instrument height = target height)
backup hydrology
Matching Power Supply and Demand
Load Predictions

Daily Load on Tea Estate (Indonesia)
Stand-alone Electricity Generation

• The objective of stand-alone schemes is to **meet the peak demand of the load centre all year round**.

• Using the flow duration curve established in the previous chapter a design flow can be determined which should be available on 365 days per year.

• Note: The design flow should be below the minimum flow on the flow duration curve for the following reasons:
  – Residual flow should be maintained for ecological reasons
  – Minimum flow might be overestimated
If the minimum stream flow is not sufficient to cover the demand:

- Storage ponds or basins can be designed to store water during periods of low power demand.
- Non-hydropower energy sources can be used as a back-up to the hydro during the dry season such as diesel generating sets (hybrid systems).
- Load management can be envisaged, whereby base loads such as refrigerators, boilers or water pumps are cut out during the (evening) peak hours to make the necessary power available for other appliances such lighting, radios and TV sets.
Main methods to calculate residual flows  
(‘ecological flow’ remaining in the river during operation)

1. Methods based on hydrological or statistics values
   – Referring to the average flow rate (MQ)  
     (e.g. 10% of MQ)
   – Referring to the minimum mean flow (MNQ)  
     (e.g. 33% of MNQ)
   – Referring to prefixed values on the Flow Duration Curve (FDC)  
     (e.g. in Switzerland the residual flow depends on Q347)

2. Methods based on physiographic principles
   – Catchment area with catchment-specific coefficients
   – Constant specific residual flow  
     (e.g. depending on geological conditions)
   – Formulas based on velocity and water depth

3. Methods based on ‘multi-objective planning’ taking into consideration ecological parameters

An overview of common methods can be downloaded on the web site of ESHA:  
Capacity Building Workshop on Small Hydro Power Project Development

April 17, 2012
Monrovia (Liberia)

Assessment of Micro Hydro Potential in Sub-Saharan Africa Countries: Mali, Togo & Benin

M’Gbrea N’Guessan
VP Africa, Econoler
Small Hydro Project Analysis Using RETScreen

Small Hydro Site: Akloa (Togo)

Photo Credit: M’Gbra N’Guessan, Econoler
RETScreen® Small Hydro Project Model

Worldwide analysis of energy production, life-cycle costs and greenhouse gas (GHG) emission reductions

- Central-grid and isolated-grid
- Single turbine micro hydro to multi-turbine small hydro
- “Formula” costing method

\[ \text{Power in kW} \approx 7 \times \text{Head} \times \text{Flow} \]
<table>
<thead>
<tr>
<th>Language</th>
<th>Code</th>
<th>Language</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arabic</td>
<td>العربية</td>
<td>Bulgarian</td>
<td>Български</td>
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<tr>
<td>Bangla</td>
<td>বাংলা</td>
<td>Chinese</td>
<td>中文</td>
</tr>
<tr>
<td>Danish</td>
<td>Dansk</td>
<td>Croatian</td>
<td>Hrvatski</td>
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<td>Nederlands</td>
<td>Czech</td>
<td>Čeština</td>
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<td>हिंदी</td>
<td>Farsi</td>
<td>فارسی</td>
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<tr>
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<td>Polski</td>
<td>Filipino</td>
<td>Tagalog</td>
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<td>Português</td>
<td>Romanian</td>
<td>Română</td>
</tr>
<tr>
<td>Russian</td>
<td>Русский</td>
<td>Serbian</td>
<td>Srpski</td>
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<tr>
<td>Swahili</td>
<td>Swahili</td>
<td>Swedish</td>
<td>Svenska</td>
</tr>
<tr>
<td>Tamil</td>
<td>தமிழ்</td>
<td>Tagalog</td>
<td>Tagalog</td>
</tr>
<tr>
<td>Ukrainian</td>
<td>українська мова</td>
<td>Vietnamese</td>
<td>tiếng Việt</td>
</tr>
</tbody>
</table>

Image: RETScreen International website with a selection of languages.
SUB-SAHARAN AFRICA REGIONAL MINI/MICRO HYDRO PROJECT

- A regional project initiated by UNDP with the support of 11 SSA Governments
- Funding Source: Global Environment Facility

Sub-Saharan Africa divided into 3 clusters:
- **Cluster 1**: West Africa (Benin, Mali and Togo)
- **Cluster 2**: Central Africa (Cameroon, Central African Republic, Equatorial Guinea, and Gabon)
- **Cluster 3**: Eastern Africa (Burundi, Congo; DR Congo; Rwanda)
PURPOSE OF PROJECT BRIEFS

3 Project Briefs (1 per cluster) have been prepared for submission to UNDP-GEF for project funding.

Each Project Brief lays out:

› Energy policies and rural electrification strategy of each country
› Legal and institutional framework
› Government strategy for micro/mini hydro power system development
› Baseline activity and GEF alternative course of action
› Proposed project financing and incremental costs
OVERALL PROJECT SCHEDULE

- Approval for Pipeline Entry by GEF Secretariat
- Preparatory Assistance Phase
- Project Briefs Validation
- 1st Steering Committee Meeting in Douala
- 2nd Steering Committee Meeting in Vienna
- Project Briefs Submitted for Review by GEF
- GEF Approval of Full-Size Project

- April 2004
- May 2004 – February 2005
- April 2005
- July-Nov 2005
- End of 2005
FULL-SIZE PROJECT COMPONENTS

1. Identification of mini/micro hydro sites
2. Identification and removal of barriers to the adoption of micro/mini hydropower technologies
3. Capacity building and technical assistance for the deployment of micro hydroelectric plants
4. Dissemination of project outcomes
5. Project monitoring and evaluation (M&E)
6. Deployment of micro/mini hydropower plants on a turnkey basis
7. Systems management/financing schemes/ownership structure and plant operation
FINDINGS OF CONSULTANT REPORTS

1. Improved rural access to electricity is a means of improving quality of life and socio-economic development.
2. Participating countries are at various stages of introducing legal and regulatory reforms to liberalize the energy sector.
3. Some countries have gone further in formulating rural electrification policies and strategies that clearly identify actions to be taken to attract much needed investments.
4. All countries offer good to strong candidates for micro hydro deployment, but the technical, financial and/or managerial resources are often lacking.
5. National institutional partners and NGOs/multilateral donors, can provide much needed capacity building and leverage investment capital for identified projects.
• Benin and Mali have both made progress in introducing sectoral reforms and establishing dedicated rural electrification agencies.
• Mali has been the most proactive in developing incentive mechanisms to attract investors, but the financial resource remain limited.
• Given the uneven water situation in Cluster 1 countries, the technical team conducted detailed technical and financial analysis for each site.
## Proposed Micro-Hydro Configurations

<table>
<thead>
<tr>
<th>Cluster 1 Configurations</th>
<th>Benin</th>
<th>Mali</th>
<th>Togo</th>
<th>Total 3 Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-75 kW (cost US$300,000)</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>100-150 kW (cost US$400,000)</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>200-400 kW (cost US$600,000)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td><strong>TOTAL # Systems</strong></td>
<td><strong>6</strong></td>
<td><strong>8</strong></td>
<td><strong>5</strong></td>
<td><strong>19</strong></td>
</tr>
<tr>
<td><strong>TOTAL kW</strong></td>
<td>750 kW</td>
<td>850 kW</td>
<td>650 kW</td>
<td>2,250 kW</td>
</tr>
<tr>
<td><strong>TOTAL COST</strong></td>
<td>US$2.7 million</td>
<td>US$3.3 million</td>
<td>US$2.3 million</td>
<td>US$8.3 million</td>
</tr>
</tbody>
</table>
SMALL HYDRO PRE-FEASIBILITY

We used RETScreen Model for Cost Analysis

High initial costs

› But civil works and equipment can last >50 years

Very low operating and maintenance costs

› One part-time operator is usually sufficient
› Periodic maintenance of major equipment requires outside contractor

High head developments tend to be less costly

Typical range: US$1,000 to US$5,000 per installed kW
SMALL HYDRO PROJECT ANALYSIS

Four phases for engineering work:

› Reconnaissance surveys/hydrology studies

› Pre-feasibility study

› Feasibility study

› System planning and project engineering
See e-Textbook
Renewable Energy Project Analysis: RETScreen® Engineering and Cases
Small Hydro Project Analysis (Chapter 3)
USING RETSCREEN MODEL FOR A CASE STUDY

RETScreen® International
Clean Energy Project Analysis Software

Small Hydro Project Model

Click Here to Start
- Description & Flow Chart
- Colour Coding
- Online Manual

Worksheets
- Energy Model
- Hydrology & Load
- Equipment Data
- Cost Analysis
- Greenhouse Gas Analysis
- Financial Summary

Features
- Product Data
- Weather Data
- Cost Data
- Unit Options
- Currency Options
- CDM / JI Project Analysis
- Sensitivity Analysis

Clean Energy
Decision Support Centre
www.retscreen.net

Training & Support
- Internet Forums
- Marketplace
- Case Studies
- e-Textbook

Partners

Version 3.0 © Minister of Natural Resources Canada 1997-2004.
## DEFINITION OF ENERGY MODEL

**RETScreen® Energy Model - Small Hydro Project**

**Units:** Metric

### Site Conditions

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Notes/Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project name</strong></td>
<td>Wonougba</td>
</tr>
<tr>
<td><strong>Project location</strong></td>
<td>Rivière Sio, région Kpalimé, Togo</td>
</tr>
<tr>
<td>Latitude of project location</td>
<td>N 6.91</td>
</tr>
<tr>
<td>Longitude of project location</td>
<td>E 6.76</td>
</tr>
<tr>
<td>Gross head</td>
<td>m 8.00</td>
</tr>
<tr>
<td>Maximum tailwater effect</td>
<td>m 0.80</td>
</tr>
<tr>
<td>Residual flow</td>
<td>m³/s 0.20</td>
</tr>
<tr>
<td>Firm flow</td>
<td>m³/s 0.51</td>
</tr>
<tr>
<td>Peak load</td>
<td>kW 55</td>
</tr>
<tr>
<td>Energy demand</td>
<td>MWh 332</td>
</tr>
</tbody>
</table>

### System Characteristics

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Notes/Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid type</td>
<td>Isolated-grid</td>
</tr>
<tr>
<td>Design flow</td>
<td>m³/s 1,000</td>
</tr>
<tr>
<td>Turbine type</td>
<td>Kaplan</td>
</tr>
<tr>
<td>Number of turbines</td>
<td>turbine 1</td>
</tr>
<tr>
<td>Turbine peak efficiency</td>
<td>% 87.6%</td>
</tr>
<tr>
<td>Turbine efficiency at design flow</td>
<td>% 87.2%</td>
</tr>
<tr>
<td>Maximum hydraulic losses</td>
<td>% 7%</td>
</tr>
<tr>
<td>Generator efficiency</td>
<td>% 93%</td>
</tr>
<tr>
<td>Transformer losses</td>
<td>% 1%</td>
</tr>
<tr>
<td>Parasitic electricity losses</td>
<td>% 2%</td>
</tr>
<tr>
<td>Annual downtime losses</td>
<td>% 4%</td>
</tr>
</tbody>
</table>

---

See Online Manual

Complete Hydrology & Load sheet

Complete Equipment Data sheet

---

ECONOLER
Hydrology Analysis and Load Calculation - Small Hydro Project

**Project type:** Run-of-river

**Hydrology method:** User-defined

**Hydrology Parameters**
- Residual flow: 0.2 m³/s
- Percent time firm flow available: 50%
- Firm flow: 0.51 m³/s

**Flow-Duration Curve Data**

<table>
<thead>
<tr>
<th>Time (%)</th>
<th>Flow (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>11.07</td>
</tr>
<tr>
<td>5%</td>
<td>9.57</td>
</tr>
<tr>
<td>10%</td>
<td>7.94</td>
</tr>
<tr>
<td>15%</td>
<td>5.97</td>
</tr>
<tr>
<td>20%</td>
<td>4.33</td>
</tr>
<tr>
<td>25%</td>
<td>2.82</td>
</tr>
<tr>
<td>30%</td>
<td>2.70</td>
</tr>
<tr>
<td>35%</td>
<td>2.39</td>
</tr>
<tr>
<td>40%</td>
<td>1.48</td>
</tr>
<tr>
<td>45%</td>
<td>1.03</td>
</tr>
<tr>
<td>50%</td>
<td>0.71</td>
</tr>
<tr>
<td>55%</td>
<td>0.65</td>
</tr>
<tr>
<td>60%</td>
<td>0.54</td>
</tr>
<tr>
<td>65%</td>
<td>0.42</td>
</tr>
<tr>
<td>70%</td>
<td>0.35</td>
</tr>
<tr>
<td>75%</td>
<td>0.31</td>
</tr>
<tr>
<td>80%</td>
<td>0.28</td>
</tr>
<tr>
<td>85%</td>
<td>0.27</td>
</tr>
<tr>
<td>90%</td>
<td>0.24</td>
</tr>
<tr>
<td>95%</td>
<td>0.20</td>
</tr>
<tr>
<td>100%</td>
<td>0.15</td>
</tr>
</tbody>
</table>
# ESTIMATE LOAD CHARACTERISTICS

**Grid type**
- Isolated-grid

**Load Conditions**
- Load-duration curve: User-defined

**Peak load kW**
- 55

## Load-Duration Curve Data

<table>
<thead>
<tr>
<th>Time (%)</th>
<th>Load (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>55</td>
</tr>
<tr>
<td>5%</td>
<td>47</td>
</tr>
<tr>
<td>10%</td>
<td>46</td>
</tr>
<tr>
<td>15%</td>
<td>45</td>
</tr>
<tr>
<td>20%</td>
<td>45</td>
</tr>
<tr>
<td>25%</td>
<td>44</td>
</tr>
<tr>
<td>30%</td>
<td>43</td>
</tr>
<tr>
<td>35%</td>
<td>42</td>
</tr>
<tr>
<td>40%</td>
<td>40</td>
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<tr>
<td>45%</td>
<td>39</td>
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<td>60%</td>
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</tr>
<tr>
<td>95%</td>
<td>28</td>
</tr>
<tr>
<td>100%</td>
<td>23</td>
</tr>
</tbody>
</table>

**Energy demand MWh**
- 332

**Average load factor %**
- 69%

**Annual**
- 0,9

**Daily**
- 69%
### Annual Energy Production

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Notes/Range</th>
</tr>
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<tbody>
<tr>
<td>Small hydro plant capacity</td>
<td>kW</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>MW</td>
<td>0.057</td>
</tr>
<tr>
<td>Small hydro plant firm capacity</td>
<td>kW</td>
<td>31</td>
</tr>
<tr>
<td>Available flow adjustment factor</td>
<td>-</td>
<td>1.00</td>
</tr>
<tr>
<td>Small hydro plant capacity factor</td>
<td>%</td>
<td>51%</td>
</tr>
<tr>
<td>Renewable energy available</td>
<td>MWh</td>
<td>257</td>
</tr>
<tr>
<td>Renewable energy delivered</td>
<td>MWh</td>
<td>187</td>
</tr>
<tr>
<td>Excess RE available</td>
<td>GJ</td>
<td>673</td>
</tr>
<tr>
<td></td>
<td>MWh</td>
<td>70</td>
</tr>
</tbody>
</table>

### Flow-Duration and Power Curves

- **Available Flow**
- **Flow Used**
- **Available Power**

---

**Complete Cost Analysis sheet**

---

**ECONOLER**
Turbine efficiency
› Compared with manufacturer’s data for an installed 6 MW GEC Alstom Francis turbine

Plant capacity & output
› Compared with HydrA for a Scottish site
› All results within 6.5%

• Formula costing method
  › Compared with RETScreen®, with 11% of a detailed cost estimate for a 6 MW project in Newfoundland
Small Hydro Turbine Characteristics

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Notes/Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross head m</td>
<td>8.00</td>
</tr>
<tr>
<td>Design flow m³/s</td>
<td>1.000</td>
</tr>
<tr>
<td>Turbine type</td>
<td>Kaplan</td>
</tr>
<tr>
<td>Turbine efficiency curve data source</td>
<td>Standard</td>
</tr>
<tr>
<td>Number of turbines</td>
<td>1</td>
</tr>
<tr>
<td>Small hydro turbine manufacturer</td>
<td>ABC ltée</td>
</tr>
<tr>
<td>Small hydro turbine model</td>
<td>modèle XYZ</td>
</tr>
<tr>
<td>Turbine manufacture/design coefficient</td>
<td>4.5</td>
</tr>
<tr>
<td>Efficiency adjustment %</td>
<td>0% to 5%</td>
</tr>
<tr>
<td>Turbine peak efficiency %</td>
<td>87.6%</td>
</tr>
<tr>
<td>Flow at peak efficiency m³/s</td>
<td>0.8</td>
</tr>
<tr>
<td>Turbine efficiency at design flow %</td>
<td>87.2%</td>
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</table>

Turbine Efficiency Curve Data

<table>
<thead>
<tr>
<th>Efficiency (%)</th>
<th>Turbine efficiency</th>
<th>Turbines running</th>
<th>Combined turbine efficiency</th>
</tr>
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<tbody>
<tr>
<td>0%</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>5%</td>
<td>0.00</td>
<td>1</td>
<td>0.00</td>
</tr>
<tr>
<td>10%</td>
<td>0.00</td>
<td>1</td>
<td>0.00</td>
</tr>
<tr>
<td>15%</td>
<td>0.07</td>
<td>1</td>
<td>0.07</td>
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<tr>
<td>20%</td>
<td>0.40</td>
<td>1</td>
<td>0.40</td>
</tr>
<tr>
<td>25%</td>
<td>0.61</td>
<td>1</td>
<td>0.61</td>
</tr>
<tr>
<td>30%</td>
<td>0.73</td>
<td>1</td>
<td>0.73</td>
</tr>
<tr>
<td>35%</td>
<td>0.81</td>
<td>1</td>
<td>0.81</td>
</tr>
<tr>
<td>40%</td>
<td>0.84</td>
<td>1</td>
<td>0.84</td>
</tr>
<tr>
<td>45%</td>
<td>0.86</td>
<td>1</td>
<td>0.86</td>
</tr>
<tr>
<td>50%</td>
<td>0.87</td>
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<td>0.87</td>
</tr>
<tr>
<td>55%</td>
<td>0.87</td>
<td>1</td>
<td>0.87</td>
</tr>
<tr>
<td>60%</td>
<td>0.88</td>
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<td>0.88</td>
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<tr>
<td>65%</td>
<td>0.88</td>
<td>1</td>
<td>0.88</td>
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<tr>
<td>70%</td>
<td>0.88</td>
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<td>0.88</td>
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<tr>
<td>75%</td>
<td>0.88</td>
<td>1</td>
<td>0.88</td>
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<tr>
<td>80%</td>
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<tr>
<td>85%</td>
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<td>0.88</td>
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<tr>
<td>90%</td>
<td>0.88</td>
<td>1</td>
<td>0.88</td>
</tr>
<tr>
<td>95%</td>
<td>0.87</td>
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<td>0.87</td>
</tr>
<tr>
<td>100%</td>
<td>0.87</td>
<td>1</td>
<td>0.87</td>
</tr>
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</table>

Efficiency Curve - 1 Turbine(s)
## COST ESTIMATE – INPUT PARAMETERS

**RETScreen® Cost Analysis - Small Hydro Project**

<table>
<thead>
<tr>
<th>Formula Costing Method</th>
<th>Notes/Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Parameters</td>
<td></td>
</tr>
<tr>
<td><strong>Project country</strong></td>
<td>Togo</td>
</tr>
<tr>
<td>Local vs. Canadian equipment costs ratio</td>
<td>1.10</td>
</tr>
<tr>
<td>Local vs. Canadian fuel costs ratio</td>
<td>1.25</td>
</tr>
<tr>
<td>Local vs. Canadian labour costs ratio</td>
<td>0.50</td>
</tr>
<tr>
<td>Equipment manufacture cost coefficient</td>
<td>0.50</td>
</tr>
<tr>
<td>Exchange rate</td>
<td>XOF/CAD 400.00</td>
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<tr>
<td>Cold climate?</td>
<td>yes/no No</td>
</tr>
<tr>
<td>Number of turbines</td>
<td>turbine 1</td>
</tr>
<tr>
<td>Flow per turbine</td>
<td>m³/s 1.0</td>
</tr>
<tr>
<td>Approx. turbine runner diameter (per unit)</td>
<td>m 0.5</td>
</tr>
<tr>
<td>Project classification:</td>
<td></td>
</tr>
<tr>
<td>Suggested classification</td>
<td>- Mini</td>
</tr>
<tr>
<td>Selected classification</td>
<td>- Micro</td>
</tr>
<tr>
<td>Existing dam?</td>
<td>yes/no No</td>
</tr>
<tr>
<td>New dam crest length</td>
<td>m 10.0</td>
</tr>
<tr>
<td>Maximum hydraulic losses</td>
<td>% 7%</td>
</tr>
<tr>
<td>Intake and miscellaneous losses</td>
<td>% 1% 1% to 5%</td>
</tr>
<tr>
<td>Access road required?</td>
<td>yes/no Yes</td>
</tr>
<tr>
<td>Length</td>
<td>km 3.0</td>
</tr>
<tr>
<td>Tote road only?</td>
<td>yes/no Yes</td>
</tr>
<tr>
<td>Difficulty of terrain</td>
<td>- 1.0 1.0 to 6.0</td>
</tr>
<tr>
<td>Canal required?</td>
<td>yes/no Yes</td>
</tr>
<tr>
<td>Length in rock</td>
<td>m 280</td>
</tr>
<tr>
<td>Terrain side slope in rock (average)</td>
<td>° 20 Max. 45°</td>
</tr>
<tr>
<td>Length in impervious soil</td>
<td>m 0</td>
</tr>
<tr>
<td>Terrain side slope in soil (average)</td>
<td>° 0 Max. 15°</td>
</tr>
<tr>
<td>Total canal headloss</td>
<td>m 0.28</td>
</tr>
<tr>
<td>Penstock required?</td>
<td>yes/no Yes</td>
</tr>
<tr>
<td>Length</td>
<td>m 70.0</td>
</tr>
<tr>
<td>Number of identical penstocks</td>
<td>penstock 1</td>
</tr>
<tr>
<td>Allowable penstock headloss factor</td>
<td>% 3.0% 1.0% to 4.0%</td>
</tr>
<tr>
<td>Pipe diameter</td>
<td>m 0.84</td>
</tr>
<tr>
<td>Average pipe wall thickness</td>
<td>mm 6.8</td>
</tr>
<tr>
<td>Transmission line</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>km 1.5</td>
</tr>
<tr>
<td>Difficulty of terrain</td>
<td>- 1.0 1.0 to 2.0</td>
</tr>
<tr>
<td>Voltage</td>
<td>kV 25.0</td>
</tr>
<tr>
<td>Interest rate</td>
<td>% 0.5%</td>
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</tbody>
</table>
### Initial Costs / Annual Costs Estimate

#### Initial Costs (Formula Method) (local currency) Factor (local currency) Relative Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Initial Cost</th>
<th>Factor</th>
<th>Local Cost</th>
<th>Relative Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feasibility Study</td>
<td>XOF 6,800,000</td>
<td>1.00</td>
<td>XOF 6,800,000</td>
<td>3.2%</td>
</tr>
<tr>
<td>Development</td>
<td>XOF 7,600,000</td>
<td>1.00</td>
<td>XOF 7,600,000</td>
<td>3.5%</td>
</tr>
<tr>
<td>Land rights</td>
<td></td>
<td></td>
<td>XOF</td>
<td>0.0%</td>
</tr>
<tr>
<td><strong>Development Sub-total:</strong></td>
<td></td>
<td></td>
<td>XOF 7,600,000</td>
<td>3.5%</td>
</tr>
<tr>
<td>Engineering</td>
<td>XOF 1,600,000</td>
<td>1.00</td>
<td>XOF 1,600,000</td>
<td>0.7%</td>
</tr>
<tr>
<td>Energy Equipment</td>
<td>XOF 66,400,000</td>
<td>1.00</td>
<td>XOF 66,400,000</td>
<td>30.9%</td>
</tr>
<tr>
<td><strong>Balance of Plant:</strong></td>
<td></td>
<td></td>
<td>XOF 7,600,000</td>
<td>3.5%</td>
</tr>
<tr>
<td>Access road</td>
<td>XOF 5,200,000</td>
<td>1.00</td>
<td>XOF 5,200,000</td>
<td>2.4%</td>
</tr>
<tr>
<td>Transmission line</td>
<td>XOF 9,600,000</td>
<td>1.00</td>
<td>XOF 9,600,000</td>
<td>4.5%</td>
</tr>
<tr>
<td>Substation and transformer</td>
<td>XOF 400,000</td>
<td>12.00</td>
<td>XOF 4,800,000</td>
<td>2.2%</td>
</tr>
<tr>
<td>Penstock</td>
<td>XOF 13,600,000</td>
<td>1.00</td>
<td>XOF 13,600,000</td>
<td>6.3%</td>
</tr>
<tr>
<td>Canal</td>
<td>XOF 32,400,000</td>
<td>1.00</td>
<td>XOF 32,400,000</td>
<td>15.1%</td>
</tr>
<tr>
<td>Tunnel</td>
<td>XOF -</td>
<td>1.00</td>
<td>XOF -</td>
<td>0.0%</td>
</tr>
<tr>
<td>Civil works (other)</td>
<td>XOF 57,200,000</td>
<td>1.00</td>
<td>XOF 57,200,000</td>
<td>26.6%</td>
</tr>
<tr>
<td><strong>Balance of Plant Sub-total:</strong></td>
<td>XOF 118,400,000</td>
<td>0.50</td>
<td>XOF 9,800,000</td>
<td>4.6%</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>XOF 19,600,000</td>
<td>0,50</td>
<td>XOF -</td>
<td>-</td>
</tr>
<tr>
<td>GHG baseline study and MP</td>
<td>XOF -</td>
<td>-</td>
<td>XOF -</td>
<td>-</td>
</tr>
<tr>
<td>GHG validation and registration</td>
<td>XOF -</td>
<td>-</td>
<td>XOF -</td>
<td>-</td>
</tr>
<tr>
<td><strong>Miscellaneous Sub-total:</strong></td>
<td>XOF 9,800,000</td>
<td>0,50</td>
<td>XOF 9,800,000</td>
<td>4.6%</td>
</tr>
<tr>
<td><strong>Initial Costs - Total (Formula Method):</strong></td>
<td>XOF 220,400,000</td>
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<td>XOF 215,000,000</td>
<td>100.0%</td>
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</table>

#### Annual Costs (Credits)

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit Cost</th>
<th>Amount</th>
<th>Relative Costs</th>
<th>Quantity Range</th>
<th>Unit Cost Range</th>
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</thead>
<tbody>
<tr>
<td>O&amp;M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land lease</td>
<td>XOF</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property taxes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water rental</td>
<td></td>
<td></td>
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<td>Insurance premium</td>
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<td>Transmission line maintenance</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Spare parts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O&amp;M labour</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GHG monitoring and verification</td>
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<td></td>
</tr>
<tr>
<td>Travel and accommodation</td>
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<td></td>
</tr>
<tr>
<td>General and administrative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other - O&amp;M</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contingencies</td>
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<tr>
<td><strong>Annual Costs - Total:</strong></td>
<td>XOF 11,440,000</td>
<td>100.0%</td>
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</table>

#### Periodic Costs (Credits)

<table>
<thead>
<tr>
<th>Description</th>
<th>Period</th>
<th>Unit Cost</th>
<th>Amount</th>
<th>Interval Range</th>
<th>Unit Cost Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine overhaul</td>
<td>Cost</td>
<td>XOF 10,000,000</td>
<td>XOF 10,000,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>End of project life</td>
<td>Credit</td>
<td>XOF -</td>
<td>XOF -</td>
<td></td>
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</tr>
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</table>

---

Econoler / Cabinet EATP Abidjan

Go to GHG Analysis sheet
FINANCIAL ANALYSIS
# RETScreen® SMALL HYDRO PROJECT MODEL – FINANCIAL SUMMARY

## Financial Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Energy Production Credit</td>
<td>XOF/kWh</td>
<td>120,000</td>
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<tr>
<td>DE production credit</td>
<td>XOF/kWh</td>
<td>100,000</td>
</tr>
<tr>
<td>GHG Emission Reduction Credit</td>
<td>XOF/tCO₂</td>
<td>120,000</td>
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</table>

## Project Costs and Savings

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feasibility Study</td>
<td>XOF</td>
<td>3%</td>
</tr>
<tr>
<td>Development</td>
<td>XOF</td>
<td>35%</td>
</tr>
<tr>
<td>Engineering</td>
<td>XOF</td>
<td>0.7%</td>
</tr>
<tr>
<td>Balance of Plant</td>
<td>XOF</td>
<td>57.1%</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>XOF</td>
<td>4.6%</td>
</tr>
<tr>
<td>Initial Costs</td>
<td>XOF</td>
<td>215,000,000</td>
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</table>

## Financial Feasibility

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-tax IRR and ROI</td>
<td>%</td>
<td>22.3%</td>
</tr>
<tr>
<td>After-tax IRR and ROI</td>
<td>%</td>
<td>22.3%</td>
</tr>
<tr>
<td>Capacity Savings/Income</td>
<td>XOF</td>
<td>22,424,713</td>
</tr>
<tr>
<td>Pre-tax energy production cost</td>
<td>XOF</td>
<td>92,539,614</td>
</tr>
<tr>
<td>GHG emission reduction cost</td>
<td>XOF</td>
<td>148,267</td>
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<tr>
<td>Project equity</td>
<td>XOF</td>
<td>250,000</td>
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<tr>
<td>Debt service coverage</td>
<td></td>
<td>1.13</td>
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</table>

## Yearly Cash Flows

<table>
<thead>
<tr>
<th>Year</th>
<th>Pre-tax XOF</th>
<th>After-tax XOF</th>
<th>Cumulative XOF</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>21,500,000</td>
<td>21,500,000</td>
<td>21,500,000</td>
</tr>
<tr>
<td>1</td>
<td>21,966,976</td>
<td>21,966,976</td>
<td>43,470,947</td>
</tr>
<tr>
<td>2</td>
<td>22,066,551</td>
<td>22,066,551</td>
<td>65,537,508</td>
</tr>
<tr>
<td>3</td>
<td>22,166,127</td>
<td>22,166,127</td>
<td>87,603,625</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
SMALL HYDRO PROJECT MODEL – PROJECT CASH FLOWS

Small Hydro Project Cumulative Cash Flows
Wonougba, rivière Sio, région Kpalimé, Togo

Renewable energy delivered (MWh/yr): 187
Total Initial Costs: XOF 215 000 000
Net average GHG reduction (t CO₂/yr): 168

Cumulative Cash Flows

- IRR and ROI: 22.3%
- Year-to-positive cash flow: 6.8 yr
- Net Present Value: XOF 73 156 745

Econoler / Cabinet EATP Abidjan
RETSCELSCREEN® SMALL HYDRO PROJECT MODEL – GHG CALCULATION
## Base Case Electricity System (Baseline)

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Fuel mix</th>
<th>CO₂ emission factor (%)</th>
<th>CH₄ emission factor (kg/GJ)</th>
<th>N₂O emission factor (kg/GJ)</th>
<th>Fuel conversion efficiency (%)</th>
<th>T &amp; D losses (%)</th>
<th>GHG emission factor (tCO₂/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel (#2 oil)</td>
<td>100.0%</td>
<td>100% 74.1</td>
<td>0.0020</td>
<td>0.0020</td>
<td>30.0%</td>
<td>17.0%</td>
<td>1.081</td>
</tr>
<tr>
<td>Electricity mix</td>
<td>100%</td>
<td>297.6</td>
<td>0.0080</td>
<td>0.0080</td>
<td>17.0%</td>
<td>1.081</td>
<td>1.081</td>
</tr>
</tbody>
</table>

Does baseline change during project life? No

## Proposed Case Electricity System (Small Hydro Project)

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Fuel mix</th>
<th>CO₂ emission factor (%)</th>
<th>CH₂ emission factor (kg/GJ)</th>
<th>N₂O emission factor (kg/GJ)</th>
<th>Fuel conversion efficiency (%)</th>
<th>T &amp; D losses (%)</th>
<th>GHG emission factor (tCO₂/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity system</td>
<td>Small hydro</td>
<td>100.0%</td>
<td>0.0</td>
<td>0.0000</td>
<td>100.0%</td>
<td>8.0%</td>
<td>0.000</td>
</tr>
</tbody>
</table>

## GHG Emission Reduction Summary

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Base case GHG emission factor (tCO₂/MWh)</th>
<th>Proposed case GHG emission factor (tCO₂/MWh)</th>
<th>End-use annual energy delivered (MWh)</th>
<th>Gross annual GHG emission reduction (tCO₂)</th>
<th>GHG credits transaction fee (%)</th>
<th>Net annual GHG emission reduction (tCO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity system</td>
<td>1.081</td>
<td>0.000</td>
<td>172</td>
<td>186</td>
<td>0.0%</td>
<td>186</td>
</tr>
</tbody>
</table>
## SUMMARY OF PREFEASIBILITY STUDY

**BENIN**

### Mini/Micro Hydro Project – Republic of Benin – Project cost

<table>
<thead>
<tr>
<th>Micro hydro site name</th>
<th>Country</th>
<th>River</th>
<th>Project location</th>
<th>Cost have been extrapolated</th>
<th>Transmission line for first village - Length (m)</th>
<th>Small hydro plant capacity (kW)</th>
<th>Transmission system cost (US$)</th>
<th>Electromechanical cost (US$)</th>
<th>Civil works and penstock cost (US$)</th>
<th>Basic cost for the micro hydro plant (US$)</th>
<th>Contingencies 10% of basic cost (US$)</th>
<th>Control and work supervision cost (US$)</th>
<th>Inflation rate 5% of control cost (US$)</th>
<th>Project total cost (US$)</th>
<th>Investment cost/WW (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apanouga</td>
<td>Benin</td>
<td>Zoumè</td>
<td>Lomé</td>
<td>No</td>
<td>2,0</td>
<td>40</td>
<td>67,075</td>
<td>117,302</td>
<td>130,613</td>
<td>285,079</td>
<td>29,507</td>
<td>14,253</td>
<td>713</td>
<td>328,543</td>
<td>3,029</td>
</tr>
<tr>
<td>Glozomoum</td>
<td>Benin</td>
<td>Agoudi</td>
<td>Sahousamou</td>
<td>No</td>
<td>2,0</td>
<td>176</td>
<td>213,040</td>
<td>460,320</td>
<td>394,560</td>
<td>1,117,020</td>
<td>111,792</td>
<td>55,836</td>
<td>2,796</td>
<td>1,299,403</td>
<td>15,016</td>
</tr>
<tr>
<td>Kounagou</td>
<td>Benin</td>
<td>Kounagou</td>
<td>Koudé</td>
<td>No</td>
<td>1,5</td>
<td>192</td>
<td>96,200</td>
<td>171,860</td>
<td>147,300</td>
<td>417,850</td>
<td>41,700</td>
<td>20,000</td>
<td>1,043</td>
<td>489,966</td>
<td>2,545</td>
</tr>
<tr>
<td>Koupengou</td>
<td>Benin</td>
<td>Kounagou</td>
<td>Sahousamou</td>
<td>No</td>
<td>2,0</td>
<td>204</td>
<td>315,648</td>
<td>552,384</td>
<td>473,472</td>
<td>1,341,554</td>
<td>134,150</td>
<td>67,675</td>
<td>3,354</td>
<td>1,546,083</td>
<td>18,020</td>
</tr>
<tr>
<td>Sinaozi</td>
<td>Benin</td>
<td>Chitase</td>
<td>Sahousamou</td>
<td>No</td>
<td>2,0</td>
<td>185</td>
<td>236,736</td>
<td>414,268</td>
<td>345,104</td>
<td>1,061,128</td>
<td>106,813</td>
<td>50,306</td>
<td>2,515</td>
<td>1,159,563</td>
<td>13,515</td>
</tr>
<tr>
<td>Awaui</td>
<td>Benin</td>
<td>Hans</td>
<td>Awaui</td>
<td>No</td>
<td>2,0</td>
<td>134</td>
<td>144,000</td>
<td>253,400</td>
<td>217,200</td>
<td>415,400</td>
<td>61,540</td>
<td>30,770</td>
<td>1,539</td>
<td>769,246</td>
<td>5,541</td>
</tr>
<tr>
<td>Kota</td>
<td>Benin</td>
<td>Chitare de Kola</td>
<td>Koba</td>
<td>No</td>
<td>3,0</td>
<td>80</td>
<td>111,000</td>
<td>195,560</td>
<td>167,700</td>
<td>475,150</td>
<td>47,515</td>
<td>23,756</td>
<td>1,186</td>
<td>547,916</td>
<td>6,642</td>
</tr>
<tr>
<td>Pemba</td>
<td>Benin</td>
<td>Pemba</td>
<td>Sahousamou</td>
<td>No</td>
<td>2,0</td>
<td>200</td>
<td>307,757</td>
<td>538,571</td>
<td>451,625</td>
<td>1,307,966</td>
<td>130,797</td>
<td>65,398</td>
<td>3,270</td>
<td>1,567,431</td>
<td>17,569</td>
</tr>
</tbody>
</table>
### SUMMARY OF PRE-FEASIBILITY STUDY MALI

**Mini Micro Hydro Project – Republic of Mali – Project cost**

<table>
<thead>
<tr>
<th>Micro hydro project name</th>
<th>Country</th>
<th>River</th>
<th>Project location</th>
<th>Cost have been extrapolated</th>
<th>Transmission line for first village length (km)</th>
<th>Small hydropower capacity (kW)</th>
<th>Transmission system cost (US$)</th>
<th>Elettromechanical cost (US$)</th>
<th>Cost water and powerlock cost (US$)</th>
<th>Basic cost for the microhydro plant (US$)</th>
<th>Contingencies 5% of basic cost (US$)</th>
<th>Control and work supervision cost (US$)</th>
<th>Inflation rate 2% of control cost (US$)</th>
<th>Project total cost (US$)</th>
<th>Investment cost (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fanako1</td>
<td>Mali</td>
<td>Fanako</td>
<td>Ville de Fanako,</td>
<td>No</td>
<td>2</td>
<td>52</td>
<td>31,817</td>
<td>196,589</td>
<td>235,570</td>
<td>43,804</td>
<td>21,902</td>
<td>1,055</td>
<td>504,836</td>
<td>9,738</td>
<td></td>
</tr>
<tr>
<td>Fanako2</td>
<td>Mali</td>
<td>Keha</td>
<td>Commune de Keha,</td>
<td>No</td>
<td>1</td>
<td>26</td>
<td>14,794</td>
<td>53,971</td>
<td>262,996</td>
<td>35,157</td>
<td>17,254</td>
<td>888</td>
<td>409,329</td>
<td>14,115</td>
<td></td>
</tr>
<tr>
<td>Doundji</td>
<td>Mali</td>
<td>Doundji</td>
<td>Commune de Doundji</td>
<td>No</td>
<td>4</td>
<td>117</td>
<td>62,154</td>
<td>50,215</td>
<td>227,517</td>
<td>33,926</td>
<td>16,811</td>
<td>849</td>
<td>391,419</td>
<td>3,345</td>
<td></td>
</tr>
<tr>
<td>Nounkougou</td>
<td>Mali</td>
<td>Nounkougou</td>
<td>region de Nounkougou</td>
<td>No</td>
<td>4</td>
<td>52</td>
<td>51,985</td>
<td>96,410</td>
<td>285,920</td>
<td>44,544</td>
<td>22,272</td>
<td>1,114</td>
<td>513,365</td>
<td>9,872</td>
<td></td>
</tr>
<tr>
<td>Serekkoure</td>
<td>Mali</td>
<td>Serekkoure</td>
<td>region de Serekkoure</td>
<td>No</td>
<td>1</td>
<td>30</td>
<td>30,718</td>
<td>93,971</td>
<td>253,315</td>
<td>38,704</td>
<td>18,290</td>
<td>918</td>
<td>422,972</td>
<td>14,099</td>
<td></td>
</tr>
<tr>
<td>Wonek1</td>
<td>Mali</td>
<td>Wonek1</td>
<td>village Wonek,</td>
<td>No</td>
<td>3</td>
<td>72</td>
<td>25,278</td>
<td>100,630</td>
<td>318,836</td>
<td>47,281</td>
<td>23,641</td>
<td>1,182</td>
<td>544,917</td>
<td>8,789</td>
<td></td>
</tr>
<tr>
<td>Wonek2</td>
<td>Mali</td>
<td>Wonek2</td>
<td>village Wonek,</td>
<td>No</td>
<td>4</td>
<td>62</td>
<td>33,275</td>
<td>100,830</td>
<td>318,836</td>
<td>47,281</td>
<td>23,641</td>
<td>1,182</td>
<td>544,917</td>
<td>8,789</td>
<td></td>
</tr>
</tbody>
</table>

**Total**

| 18                         | 414                         | 279,594                        | 645,956                        | 1,991,922                               | 2,913,822                      | 251,383                        | 145,552                        | 7,705                               | 3,358,191                          | 8,112                         |
# SUMMARY OF PRE-FEASIBILITY STUDY TOGO

## Mini/Micro Hydro Project – Republic of Togo – Project cost

### Project cost details – Togo – West Africa

<table>
<thead>
<tr>
<th>Micro Hydro Site name</th>
<th>Country</th>
<th>River</th>
<th>Region/River</th>
<th>Cost have been extrapolated</th>
<th>Transmission line for first village - Length (km)</th>
<th>Small hydro plant capacity (kW)</th>
<th>Transmission system cost (US$)</th>
<th>Electromechanics cost (US$)</th>
<th>Civil works and prestock cost (US$)</th>
<th>Basic cost for the microhydro plant (US$)</th>
<th>Contingencies 10% of basic cost (US$)</th>
<th>Control and work supervision cost (US$)</th>
<th>Inflation rate 5% of control cost (US$)</th>
<th>Project total cost (US$)</th>
<th>Investment cost (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ataka I</td>
<td>Togo</td>
<td>Domi</td>
<td>Région d’Alagome</td>
<td>No</td>
<td>10.0</td>
<td>100</td>
<td>123 989</td>
<td>116 465</td>
<td>224 086</td>
<td>468 846</td>
<td>46 836</td>
<td>23 582</td>
<td>1 715</td>
<td>534 369</td>
<td>5 344</td>
</tr>
<tr>
<td>Wonouga</td>
<td>Togo</td>
<td>Slo</td>
<td>région Apalimé</td>
<td>No</td>
<td>1.5</td>
<td>57</td>
<td>26 524</td>
<td>122 362</td>
<td>199 750</td>
<td>348 868</td>
<td>34 866</td>
<td>17 433</td>
<td>872</td>
<td>401 829</td>
<td>7 950</td>
</tr>
<tr>
<td>Aojoegbé</td>
<td>Togo</td>
<td>Slo</td>
<td>ville de Talévé</td>
<td>No</td>
<td>1.0</td>
<td>43</td>
<td>20 629</td>
<td>118 677</td>
<td>197 227</td>
<td>396 942</td>
<td>30 064</td>
<td>15 332</td>
<td>767</td>
<td>352 460</td>
<td>6 219</td>
</tr>
<tr>
<td>Langa Pouzenda</td>
<td>Togo</td>
<td>Kara</td>
<td>localité de Kansou, région de Kara</td>
<td>No</td>
<td>3.0</td>
<td>75</td>
<td>42 016</td>
<td>145 950</td>
<td>248 199</td>
<td>434 166</td>
<td>43 416</td>
<td>21 760</td>
<td>1 085</td>
<td>503 315</td>
<td>6 504</td>
</tr>
<tr>
<td>Legouasarethi</td>
<td>Togo</td>
<td>n/a</td>
<td>Sokodé</td>
<td>Yes</td>
<td>3.0</td>
<td>100</td>
<td>65 978</td>
<td>262 482</td>
<td>293 734</td>
<td>562 174</td>
<td>56 217</td>
<td>29 109</td>
<td>1 405</td>
<td>647 985</td>
<td>6 478</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19</td>
<td>376</td>
<td>270 269</td>
<td>765 916</td>
<td>1 071 104</td>
<td>2 115 289</td>
<td>211 529</td>
<td>165 764</td>
<td>5 288</td>
<td>2 437 870</td>
<td>6 484</td>
</tr>
</tbody>
</table>
CONCLUSION

• RETScreen was used to estimate capacity, output and costs based on site characteristics such as flow duration curve and head.

• RETScreen allowed the Technical Team to achieve preliminary feasibility study and cost assessment.

• Run-of-river projects:
  • Lower cost & lower environmental impacts
  • But need back-up power on isolated grid
  • Initial costs high and 75% site specific
Questions?
Project cycle and planning tools

Oliver Froend

Project cycle and planning tools

• Course of planning and implementing
  • Timelines (examples) for different types of hydropower projects.
  • Relevance of common tools for analyses and planning.
  • Presentation of planning/appraisal tools such as RETScreen, HOMER

The ‘classic approach’ for project preparation and implementation hydropower projects

<table>
<thead>
<tr>
<th>Project Preparation</th>
<th>Project Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Desk study</td>
<td>1. Tendering</td>
</tr>
<tr>
<td>2. Initial site assessment /</td>
<td>2. Contracting</td>
</tr>
<tr>
<td>Reconnaissance visit</td>
<td>3. Construction &amp; installation</td>
</tr>
<tr>
<td>3. Pre-feasibility study</td>
<td>4. Testing &amp; commissioning</td>
</tr>
<tr>
<td>4. Feasibility study</td>
<td>5. Normal operation</td>
</tr>
<tr>
<td>5. Detailed design</td>
<td>(Operation and Maintenance)</td>
</tr>
</tbody>
</table>

Pre-Feasibility and Feasibility Study

Purpose

Pre-feasibility Study

• Defines and compares several options for development / layout
  – ease of construction
  – costs
  – operational aspects
  – environmental impact
  – etc.
• Detailed description of the rationale for selection of the most attractive option.

Feasibility Study

• Detailed analysis of the most attractive option.
• Detailed design, allowing accurate cost estimates (BoQ) (not yet construction design / site drawings)
  → Allows final decision for developer
  → ‘Bankable’ document
Typical structure / scope of works for a feasibility study for large HPP

The expected accuracy of cost estimates depends on the stage of development

<table>
<thead>
<tr>
<th>Level</th>
<th>Usual assumed error</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desk Study</td>
<td>approx. 30%</td>
<td>Based on cost for similar projects</td>
</tr>
<tr>
<td>Initial Site Assessment</td>
<td></td>
<td>Detailed BoQ based on preliminary design.</td>
</tr>
<tr>
<td>Pre-Feasibility Study</td>
<td>better than 20%</td>
<td>Detailed BoQ based on FS-level design.</td>
</tr>
<tr>
<td>Feasibility Study</td>
<td>better than 10%</td>
<td></td>
</tr>
</tbody>
</table>

Project cycle and planning tools (15 min)

- Course of planning and implementing
- Timelines (examples) for different types of hydropower projects.
- Relevance of common tools for analyses and planning.
- Presentation of planning/appraisal tools such as RETScreen, HOMER
**Generic timeline for project development (vs. expenses)**

- **Project Realisation**
  - Construction
  - Installation
  - Test Runs
- **Operation**

**Tools**

- In engineering (and analysis) a tool is usually a **specialised software** to fulfil or ease certain tasks.
- Such tools **work well for clearly defined tasks or standardised processes**. In the context of hydropower planning this applies to a number of 'sub-tasks', such as hydraulic calculations, planning / design of the transmission, or financial analysis.
- Most planners and engineers use a large number of **self-programmed tools** (primarily in MS excel) in their work.
“Common” public domain tools

What should be considered, what should be avoided

In many (TA) projects tools were developed and some became available to the public (sometimes intentionally, sometimes not). Also a number of ‘tools’ of unknown source are circulated and exchanged.

Such tools should be handled with great caution as they

– often do not provide suitable plausibility checks (therefore may only be used by experienced professionals able to judge the plausibility of results and output and are able to draw appropriate conclusions (i.e. results are generated from any input -> "rubbish in – rubbish out")),

– sometimes were developed for a very specific context and lack of the flexibility to adjust factors or assumptions to suit other environments.

– are often poorly documented (-> a good reason not to use a tool is if calculations can not be retraced or comprehended).

– not supported by any organisation or company.

Project cycle and planning tools

- Course of planning and implementing
- Timelines (examples) for different types of hydropower projects.
- Relevance of common tools for analyses and planning.

- Presentation of planning/appraisal tools such as RETScreen, HOMER

RETScreen Software Hydro Power Model can be used to cover many aspects up to pre-FS level

This software is well established (since more than 10 years), is very well documented and supported, and can be downloaded for free.

The small hydropower module can be applied for
- micro to small hydropower
- run-of-river and reservoir schemes
- projects worldwide
- on-grid and off-grid projects

It computes primarily
- energy production and emission reductions
- cost estimates, financial viability and risk (i.e. sensitivity)
Limitations!
The user enters
• hydrological data (flow-duration curve)
• size and the layout of the required civil structures (basis for cost estimates)
→ reliable results can only be expected if input is correct

Available for download at
http://www.retscreen.net/
It is highly recommended to also download and study the
e-Textbook for “Small Hydro Project Analysis”
http://www.retscreen.net/ang/textbook_hydro.html

Tool for designing and analysing hybrid power systems, which contain a mix of conventional generators, combined heat and power, wind turbines, solar photovoltaics, batteries, fuel cells, hydropower, biomass and other inputs.
• on-grid and off-grid
• simulations of energy systems
• projection of their capital and operating expenses
• optimisation and economic feasibility of hybrid systems
→ Detailed entry of data of specific systems required to allow simulation and optimisation of the ideal mix between various power sources.

Thank you for your attention!

Oliver Froend
entec AG / PT entec Indonesia
oliver.froend@entec.ch
Desk study

- The purpose is to become familiar with the physical, hydrologic and socio-economic profile of the project area without visiting the site by using maps, hydrological data etc.
- In many cases potential sites can already be preliminary identified and make the subsequent reconnaissance visit much more efficient.
- The desk study may also reveal the absence of a good hydropower potential and time and expenditures for traveling to the proposed site can be saved.
- The accuracy of preliminary cost estimates should be in the range of ±30%.

Reconnaissance site visit

- Short (one-day) visit to the proposed site to verify the findings of the desk study:
  - existing hydropower potential?
  - approximate power demand?

Initial Project Assessment (1)

Usual steps / scope of works

1. Obtain maps (scale 1:50 000 or more detailed) of the project area and locate potential site
2. Know whether the HPP will be grid-connected or off-grid
3. Measure the catchment area upstream of the selected water intake point.
4. Obtain hydrologic data (e.g. flow gauging data) and estimate available stream flow.
5. Calculate minimum and average power output of the selected site.
6. Investigate closest point for interconnection and feasibility of connection.
6. Calculate approximate power demand of the prospective electricity consumers.
### Initial Project Assessment

**Usual steps / scope of works**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td>Estimate the flow available or exceeded during 100 days per year (or Q_{100} or Q_{300})</td>
</tr>
<tr>
<td>7.</td>
<td>Calculate the minimum capacity of the site (based on minimum flow)</td>
</tr>
<tr>
<td>8.</td>
<td>Calculate the capacity of the site based on this flow.</td>
</tr>
<tr>
<td>8.</td>
<td>Compare power demand with minimum electrical power output</td>
</tr>
<tr>
<td>9.</td>
<td>n/a</td>
</tr>
<tr>
<td>9.</td>
<td>Investigate alternative sources of electricity supply</td>
</tr>
<tr>
<td>10.</td>
<td>Calculate energy production cost</td>
</tr>
<tr>
<td>11.</td>
<td>Sketch the retained solution of the power supply system</td>
</tr>
<tr>
<td>12.</td>
<td>Estimate project implementation cost</td>
</tr>
<tr>
<td>13.</td>
<td>Outline project objective and concept</td>
</tr>
</tbody>
</table>

### pre-Feasibility study

- A pre-FS will usually be conducted to determine which of several proposed projects, sites or technical options are most attractive for MHP development.
- Preliminary assessments are reviewed and worked out with more detail. Development options are worked out and conclusions and recommendations are made in view to which of these options should be further taken to FS-level.
- The accuracy of preliminary cost estimates should be in the range of ±20-25%.

### Feasibility study

- Assessment whether the implementation of the proposed scheme is desirable or not.
- On the basis of the FS the final decision for or against the project will be taken by the developer and the document shall allow him to present the project to potential lending institutions with sufficiently sound analyses and details.
- The accuracy of preliminary cost estimates should be in the range of ±10-15%.

### Detailed design

- Preparation of the detailed layout of the scheme, the canal and structure drawings in final detail.
- The detailed design usually includes the preparation of the required tender documents.
Project Finance in Africa
AfDB Role in Hydro Sector

Richard Claudet
Infrastructure Department
African Development Bank

Capacity Building Workshop on Hydro Projects
Monrovia, Liberia – April 2012
Two lending windows: Public and Private

AfDB’s lending operations

Public window

- Governments or state owned enterprises
- Concessionary terms

Private window

- Privately owned enterprises
- "Financially strong" govt. owned enterprises
- Non sovereign
- Commercial terms
Private Sector operations strategy

- Assist African governments to improve the enabling environment for the private sector:
  - Improve essential physical infrastructure
  - Improve “soft infrastructure” (regulatory and legal frameworks, financial sector, trade liberalization, BDS)

- Create catalytic and demonstration effects by assisting entrepreneurs with specific transactions:
  - Infrastructure (power, transportation, telecoms, water)
  - Industries and Services (mining, O&G, cement, agribus, hotels)
  - Financial Intermediation (banks, MFIs, insurance, leasing)
Non-sovereign financing eligibility

- An enterprise/project must be located and incorporated in the Regional Member Countries (RMCs) of the Bank, whether promoted by African or non-African investors.
- An enterprise/project must be majority-owned (51%+) by private-sector investors, or publicly owned with strong financial standing and proven managerial autonomy.
- Projects for the establishment, expansion, diversification and modernization of productive enterprises (i.e., CAPEX). No direct financing of trade.
- AfBD can provide up to 1/3 of Project Cost as Debt
Financial Products

- Senior Loans, USD, Euro etc., Local Currency Possible
  - Project Loans, Corporate Loans, Lines of Credit to banks
- Subordinated / Mezzanine Loans
- Direct Equity or through PE Funds
- A / B Loan - Commercial Bank Syndications
- Partial Risk Guarantees (PRGs)
- Arranger Role – Assistance in Mobilizing Funds
- PPPs in Collaboration with Public Sector Window
- Close collaboration with other multilaterals
- Technical Assistance Grants and concessional funding
Technical Assistance Grants and Seed Capital

- **Sustainable Energy Fund for Africa (SEFA)**
  - Established in 2011 with Danish support with two objectives
    - Project preparation grants for projects up to US$ 70 m
    - Seed capital for projects up to US$35 m before they are bankable.
  - For RE and EE projects
  - First round of projects is being considered for grants now
  - Seed capital will flow through a fund manager not directly from AfDB

- **Fund for African Private Sector Assistance (FAPA)**
  - Created in 2006 with Japanese support
  - Technical assistance grants up to US $1 million
  - US $30 m from Japan and US$10 m from AfDB so far
Bankability

- Hydrology
- Technical feasibility and design
- Environmental and Social
- Legal
- Insurance
- Commercial
- Economic
- Financial
- Procurement
AfDB Procurement Rules

- If the concession or PPA was awarded under international competitive bidding – No need for further competitive process
- If the concession or PPA was negotiated or awarded through an unsolicited bid, some or all of the project contracts (EPC etc.) must be competitively bid.
- In exceptional cases with proprietary technology and limited choices, these conditions can be waived
**Recent / Current Hydro Projects**

- Bujagali – Uganda - 250 MW – USD 800 m
- Sahanivotry – Mozambique – 14 MW – EUR 14 m
- Buzeruka – Uganda – 9 MW – EUR
- Coder – Gabon – 86 MW – EUR 200 m.
- Itezhi-Tezhi – Zambia – 120 MW – USD 248 m
Sahanivotry

- 14 MW Run of River Project in Madagascar
- Scope included: access road, bridge, power house, penstock, water retention pond, switchyard and 63 KV t-line connection
- Project Cost - EUR 14 million
- AfDB Loan – EUR 6 million (43%) – (Normal guidelines 33%)
- Consortium of local banks led by BFV- SG – Eur 3.6 m in local currency (27%)
- Equity EUR 4.4 m (31%)
- Borrower: Hydelec Madagascar S.A. (HMSA)
- Offtaker – JIRAMA (Government Agency for Energy and Water)
- 30 Year concession
- First CDM project and first PPP in Madagascar’s energy sector
- AfDB Board Approval – July 2007
- Plant commissioned in October 2008 – within budget – slight delay due to political situation in the country
Buzeruka

Buzeruka Mini Hydro Power Project is a “Renewable Energy project” located in Uganda, 270KM from Kampala, on River Wambabya-Buseruka sub-county in Hoima district – Western Uganda.

The project site has a catchment area of 745 sq. Km. and is a run of river 9 MW project.

The power generated is to be fed directly to the Grid and fed into the proposed distribution network along the transmission line for the rural communities.

The US$38.4M project is intended to promote Rural Electrification and Poverty Reduction for Rural communities along shores of lake Albert.
Project site before development
Project Progress Photos

Penstock Works
## Financing structure

<table>
<thead>
<tr>
<th>Slno</th>
<th>Source</th>
<th>Amount-USD</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Developer's Equity</td>
<td>12,804,500</td>
<td>33</td>
</tr>
<tr>
<td>2</td>
<td>African Development Bank</td>
<td>9,000,000</td>
<td>23</td>
</tr>
<tr>
<td>3</td>
<td>Eastern and Southern African Trade and Development Bank (PTA)</td>
<td>10,000,000</td>
<td>26</td>
</tr>
<tr>
<td>4</td>
<td>Sub-ordinated Loans - subsidiary</td>
<td>3,000,000</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>African Development Bank</td>
<td>4,000,000</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>38,804,500</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
Buzeruka

- Consequent to increase in Project cost due to Geological surprises during the implementation of the project which made the project unviable at this stage the AfDB team acted on behalf of the developer and skillfully convinced the authorities (UETCL and ERA) to revise the Tariff and concession period which salvaged the project to a viable state.

- Consideration for an additional financing for the project and convincing the Government in granting the transmission line to evacuate the power to the grid.
Coder

- 96 MW Run-of-river project in Gabon
- Two Sites, two concessions and two PPAs in one Project Finance SPV
- Chutes D’Imperatricie 60 MW expandable to 86 MW
- Chutes de FE2 36 MW
- Total cost – about EUR 216 m
- AfDB Co-arranger Role with other DFIs and Commercial banks
- Financial close expected Q1 2012
- Two to three year construction period
- T-line of 450 km in parallel, with sovereign financing
- EPCM Contracting Approach!
EPCM Pros and Cons

- Under EPCM approach, sponsor manages a suite of contracts instead of having one EPC contractor
- Saves costs – perhaps 20% cheaper than EPC
- You know what you are getting (unbundling)
- One underperforming contractor may be easier to fire
- But - much higher interface risk
- Harder to project manage
- A small contractor may obstruct a larger one and may not post a large enough performance bond
- Less certainty on project cost
- Harder to finance since banks don’t like the completion risk and cost overrun risk
Agenda

1. Market Overview
2. SHP in Austria
3. Operator Models
4. SHP vs. Diesel
   BREAK
6. Business Plan
7. Case Study:
   “Cost effective analysis“
General overview of the Austrian electricity market
Hydro power plays the major role in Austria’s production mix for electricity

Gross electricity production vs. consumption in Austria (1945 – 2010)

Source: E-Control Austria (2011)
Austria generates 7 % of its gross electricity production with the help of small hydro power plants (2010)

Gross electricity production in Austria 2010
by technology

- Hydro Power: 51.5%
- Thermal Power (fossil): 32.1%
- Thermal Power (biogene): 6.4%
- Wind: 2.9%
- Others: 0.1%

Source: E-Control Austria (2011), Analysis PwC
Overview of SHP in Austria
SHPPs play a vital role in supplying Austria’s private households with electricity

around

3,381 SHPPs

producing

~ 5,000 GWh

supplying

1.7 mn households

(50 % of Austrian households)

Source: Verein Kleinwasserkraft Österreich
A brief History of hydro power in Austria

Up to 18th century
Water wheels as a source of mechanical energy in mills

1947 2nd Electricity Nationalization Act
Act for the nationalization of hydro power plants in AUT

1987
Partial privatization, modification of the 2nd Electricity Nationalization Act

1998
ELWOG

2001
Electricity market liberalized, also for private households

Turn of century 18th /19th
Existing wheels transformed for electricity production

Between 60’s until 90’s
Intensive development phase of large-scale HPP’s

End of 90’s until today
Extension and rejuvenation of SHPPs, pump storage HPPs

Today

2010
Turnover of EUR 1.2 bn and 7,500 direct employees in HP

Source: BMLFUW, Erneuerbare Energien in Zahlen 2010
Relative to its size, Austria already has a large amount of SHPP installed – with potential for extension

Installed capacity of SHP in Austria vs. EU states + additional potential for SHPPs through upgrading and constructing (2004)

Source: European Small Hydropower Association (2005), Pelikan (2010), Analysis PwC
SHPPs (smaller than 10 MW) receive investment grants; in addition they can apply for a feed-in tariff

### Investment grants for SHHPs

<table>
<thead>
<tr>
<th>Capacity of SHPP</th>
<th>Grant for total costs</th>
<th>Max. Grant in EUR/kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.5 MW</td>
<td>30%</td>
<td>1,500 EUR/kW</td>
</tr>
<tr>
<td>0.5 to 2 MW</td>
<td>20%</td>
<td>1,000 EUR/kW</td>
</tr>
<tr>
<td>2 to 10 MW</td>
<td>10%</td>
<td>400 EUR/kW</td>
</tr>
</tbody>
</table>

### Specific programs of Austria’s provinces

- Direct subsidies
- Consultancy programs

### Feed-in Tariffs

<table>
<thead>
<tr>
<th>Source: E-Control, Ökostrombericht 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas</td>
</tr>
<tr>
<td>Solid Biomass</td>
</tr>
<tr>
<td>Wind</td>
</tr>
<tr>
<td>SHP</td>
</tr>
<tr>
<td>Market price</td>
</tr>
</tbody>
</table>

Small Hydro Power in Austria
Austrian companies have a leading position in producing, installing and servicing system components

Austrian turbine-producers

Besides turbine-production other Austrian companies work in the fields of designing, constructing, electrically engineering and operating HPPs

Source: Verein Kleinwasserkraft Österreich
Operator models
Operator models for HPP’s mainly differ by grid connection and utilisation of produced electricity

<table>
<thead>
<tr>
<th>Utility with/ without own grid or connected with public grid</th>
<th>Industrial plant</th>
<th>Isolated application</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Own distribution grid (y/n)</td>
<td>• Own consumption (balance of electricity production and own consumption)</td>
<td>• Production plant not connected to grid</td>
</tr>
<tr>
<td>• Supply of end customers (y/n)</td>
<td>• Sale of SHPP-electricity to market (higher selling price with proof of origin)</td>
<td>• Outage = black out – Back-up needed (e.g. diesel generator, PV or battery-system)</td>
</tr>
<tr>
<td>• Own production facility (y/n)</td>
<td>• Own grid, industrial use</td>
<td>• Appropriate for African rural areas</td>
</tr>
<tr>
<td>• Only SHPP or IPP (Independent power producer)</td>
<td>➔ no grid charges</td>
<td>• AUT: Only used in detached houses (e.g. alpine cabins)</td>
</tr>
</tbody>
</table>
Cost analysis
Comparison between SHP and Diesel
**SHP is both economically and ecologically smarter**

### General assumptions

<table>
<thead>
<tr>
<th>kW</th>
<th>Full-load hours/year</th>
<th>Time period</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>4,000</td>
<td>60</td>
</tr>
</tbody>
</table>

### SHPP

- Capital expenditure: EUR 3,000/kW (once)
- Life cycle: 60 years
- Operation and maintenance costs: 0.025 EUR/kWh (vary between 0.015 and 0.025 EUR/kWh)
- CO$_2$-emissions/kWh: 0.040 kg

### Diesel-electricity generator

- Capital expenditure: EUR 250/kW (exchange of generator: two times)
- Life cycle: 20 years
- Diesel consumption: 0.28 l/kWh ~ 0.305 EUR/kWh
- Cost of Diesel 1.09 EUR/l
- CO$_2$-emissions/kWh: 0.734 kg
- No maintenance costs included

### Total costs (60 years)

<table>
<thead>
<tr>
<th></th>
<th>SHPP</th>
<th>Diesel generator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital expenditure</td>
<td>EUR 300,000</td>
<td>EUR 75,000</td>
</tr>
<tr>
<td>Operational expenditure</td>
<td>EUR 600,000</td>
<td>EUR 7,332,000</td>
</tr>
<tr>
<td><strong>Total costs (EUR)</strong></td>
<td><strong>EUR 900,000</strong></td>
<td><strong>EUR 7,407,000</strong></td>
</tr>
<tr>
<td>CO$_2$-emissions [t]</td>
<td>960</td>
<td>17,591</td>
</tr>
</tbody>
</table>

Source: European Small Hydropower Association, PwC Analysis

- Lower CO$_2$-emissions
- Local economic development (construction, rejuvenation, local manufacturers)
- Strengthens national economy and reduces the dependence from others (no import of fossil fuel needed)
- Multi-purpose planning: power generation, drinking water supply, flood protection, irrigation
After 2.5 years the SHP is more profitable than a diesel electricity generator – not to mention the CO₂-emission.

Break Even analysis of SHPP and diesel electricity generator

Cumulated costs SHPP
Cumulated costs diesel electricity generator
Business plan
The business plan needs to reflect all financial and technical aspects in order to inform potential investors

General information

Corporate structure, Human Resources (staff,...), IT (hardware/software)

Technical information

• Location, plan of site, property
• Planning and authorisations (permits, operating license, etc.)
• Technical data of all components
• Hydrology/geology of HPP and catchment area
• Precipitation stations in the area
• Projected full load hours and annual electricity production

Financial information

• EPC (Engineering, Procurement, Construction) and any sub-contracts
• Feed-in tariffs, contracts regarding sale of electricity, projected prices and quantities
• Projected Capital Expenditure, Operation and Maintenance costs per year (costs of small and large audits)
• Taxation
• Bancable financial model with projected Profit and Loss statement, Balance Sheet, Cash flow
Cost effective analysis / feasibility study (case study, financial model)
“Project Finance is financing the development or exploitation of a right, natural resource or other asset where bulk of the financing is not to be provided by any form of share capital and is to be repaid principally out of revenues produced by the project in question.”

Financial Modelling is the basis for Project finance

### Financial Modelling – Goals

- Illustrate complex projects in a structured manner
- Determine KPIs/ target figures for the valuation of the project
- Provide insight of effects of changed framework conditions
- Understand cause-and-effect
- Assess certainty of planned result
- Decision and controlling support
- Evaluation of the economic viability of projects
- Analysis of risks / opportunities

### Characteristics of project finance

- Establishment of an independent project company („SPV“)
- Off-balance-sheet financing (newly established SPV acts as a debitor)
- Cash-flow-related lending (future cash flows affect financing)
- Risk sharing (risk allocation reduces individual risks)
- Non-recourse vs. limited-recourse (no or limited liability of investors)
- Inexistence of payment guarantees (Sovereign, banks, corporation)
Different Project Structures require different Financing Plans

**Corporate Finance Model**
- Financing partner provides funding to the corporate/consortium (promoter)
- Provision of funds to the Corporate
- Exposure to credit risk of the corporate

**Project Finance Model**
- Project is realised and financed by a legally and financially stand-alone entity
- The company/consortium contribute equity as “sponsors”

![Diagram showing the flow of funds for Corporate and Project Finance Models](image)
Typical process of project finance transactions

Development stage

- Project analysis, negotiation of project contracts
- Financial modelling, structuring
- Funding competition
- Negotiations with financiers

- Technical feasibility
- Market feasibility
- Financial feasibility
- Bank terms/conditions
- Mandate/lead group
- Syndication
- Documentation
- Financial Close
**Project assessment process and development of the Financial Model**

**Step 1: Market Analysis & Qualitative Risk assessment**
- Market analysis
- Business planning – cash flow modelling
- Quantitative risk assessment
- Financial structuring – covenants

**Cashflow**
- Calculation & waterfall
  - Total revenues
  - Interest income from cash balance
  - Total OPEX
  - Total revenue - operating cashflow

- Investments (incl. capitalized financing costs)
- Initial funding of DSRA
- Initial funding of MRA
  - Drawdown equity
  - Drawdown senior loan 1
  - Drawdown senior loan 2
  - Drawdown junior loan
  - Drawdown shareholder loan
- Taxes
  - Change in working capital
  - Cash from MRA
  - Change in liabilities for unpaid interest

**Result:**
- Pre feasibility
- Bankability

**Development of the project / timeline**

Small Hydro Power in Austria
Value Drivers, influencing the profitability of SHPPs

SHPP

- Project duration
- Costs of capital
- Costs of site construction, turbines
- Technical characteristics
  - Cost of capital per year
  - Operation and maintenance costs per year
- Site characteristics
  - Cost of site construction, turbines
  - Turbines
- Total costs per year
  - Annual energy production
- Profit / Loss
  - Feed-in tariff/Green Certificates
Case study
Definition Financial Model

„A financial model is a simplified illustration of reality that focuses on specific aspects and allows the analysis of different scenarios.“

BUT a Financial Model can not illustrate the reality 1:1!
The decision what shall be considered is crucial:

- Only various aspects of the reality and their consequences can be considered
- Too little inputs: Results are not representative
- Too many inputs: Model is too complex and vulnerable to errors

“A model is only as good as the assumption behind it.”
**Major inputs for deriving the profitability**

**PwC**

*Project Monrovia - Example SHPP in Austria*

**Inputs**

**General Information**

<table>
<thead>
<tr>
<th>Input</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Project name</td>
<td>Monrovia</td>
</tr>
<tr>
<td>Country</td>
<td>Austria</td>
</tr>
<tr>
<td>Currency (of financing)</td>
<td>EURk</td>
</tr>
<tr>
<td>Corporate Tax Rate</td>
<td>25.00%</td>
</tr>
</tbody>
</table>

**Project key dates**

<table>
<thead>
<tr>
<th>Input</th>
<th>Start</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model timing</td>
<td>2012</td>
<td>2072</td>
</tr>
<tr>
<td>Construction period</td>
<td>2011</td>
<td>2012</td>
</tr>
<tr>
<td>Operational period</td>
<td>2012</td>
<td>2072</td>
</tr>
<tr>
<td>Duration of operation</td>
<td>60</td>
<td></td>
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<tr>
<td>Installed capacity MW</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Annual production/MW MWh</td>
<td>4,000</td>
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<tr>
<td>Total annual reference p/MWh</td>
<td>8,000</td>
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<tr>
<td>Investment cost for 1MW kEUR/MW</td>
<td>2,300</td>
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<tr>
<td>Investment grant (20% for &lt;2MW) kEUR/MW</td>
<td>460</td>
<td></td>
</tr>
<tr>
<td><strong>Total Investment cost</strong> kEUR</td>
<td>3,680</td>
<td></td>
</tr>
<tr>
<td>Electricity price EUR/MWh</td>
<td>51.3</td>
<td></td>
</tr>
<tr>
<td>Cost of Debt</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>Equity Share</td>
<td>40%</td>
<td></td>
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<tr>
<td>Debt Share</td>
<td>60%</td>
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<tr>
<td>Operational expenditure ct/kWh</td>
<td>2.5</td>
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<tr>
<td>Operational expenditure kEUR/MW</td>
<td>0.0250</td>
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</table>
The Financial Model calculates the NPV and the IRR for the investment depending on the inputs.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Annual production MWh</td>
<td>8,000</td>
<td>8,000</td>
<td>8,000</td>
<td>8,000</td>
<td>8,000</td>
<td>8,000</td>
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<tr>
<td>Electricity price EUR/MWh</td>
<td>51.3</td>
<td>51.3</td>
<td>51.2</td>
<td>51.5</td>
<td>53.1</td>
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<td>Revenues kEUR</td>
<td>410.4</td>
<td>410.4</td>
<td>409.6</td>
<td>412.0</td>
<td>425.0</td>
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<tr>
<td>- OPEX kEUR</td>
<td>(200)</td>
<td>(200)</td>
<td>(200)</td>
<td>(200)</td>
<td>(200)</td>
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</tr>
<tr>
<td>EBITDA kEUR</td>
<td>210.4</td>
<td>210.4</td>
<td>209.6</td>
<td>212.0</td>
<td>225.0</td>
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<tr>
<td>EBITDA margin</td>
<td>51.27%</td>
<td>51.27%</td>
<td>51.17%</td>
<td>51.46%</td>
<td>52.94%</td>
<td></td>
</tr>
<tr>
<td>- Depreciation kEUR</td>
<td>(61)</td>
<td>(61)</td>
<td>(61)</td>
<td>(61)</td>
<td>(61)</td>
<td></td>
</tr>
<tr>
<td>EBIT kEUR</td>
<td>149.1</td>
<td>149.1</td>
<td>148.3</td>
<td>150.7</td>
<td>163.6</td>
<td></td>
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<tr>
<td>EBIT Margin</td>
<td>36.32%</td>
<td>36.32%</td>
<td>36.20%</td>
<td>36.57%</td>
<td>38.50%</td>
<td></td>
</tr>
<tr>
<td>- Adjusted taxes kEUR</td>
<td>(37.3)</td>
<td>(37.3)</td>
<td>(37.1)</td>
<td>(37.7)</td>
<td>(40.9)</td>
<td></td>
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<tr>
<td>NOPLAT kEUR</td>
<td>111.8</td>
<td>111.8</td>
<td>111.2</td>
<td>113.0</td>
<td>122.7</td>
<td></td>
</tr>
<tr>
<td>- Interest Expenses kEUR</td>
<td>(75.7)</td>
<td>(72.6)</td>
<td>(69.6)</td>
<td>(66.5)</td>
<td>(63.4)</td>
<td></td>
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<tr>
<td>- Repayment kEUR</td>
<td>(88.3)</td>
<td>(88.3)</td>
<td>(88.3)</td>
<td>(88.3)</td>
<td>(88.3)</td>
<td></td>
</tr>
<tr>
<td>+ Depreciation kEUR</td>
<td>61.3</td>
<td>61.3</td>
<td>61.3</td>
<td>61.3</td>
<td>61.3</td>
<td></td>
</tr>
<tr>
<td>- Investments kEUR</td>
<td>(3,680.0)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Net Cash Flow kEUR</td>
<td>(3,680)</td>
<td>9.1</td>
<td>12.2</td>
<td>14.7</td>
<td>19.6</td>
<td>32.4</td>
</tr>
<tr>
<td>Discount rate</td>
<td>4.0%</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Discount factor</td>
<td>0.96</td>
<td>0.92</td>
<td>0.89</td>
<td>0.85</td>
<td>0.82</td>
<td></td>
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<tr>
<td>Net Present Value kEUR</td>
<td>5091.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRR</td>
<td>5.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**EBIT** Earnings before interest and taxes  
**EBITDA** Earnings before interest, taxes, depreciation and amortisation  
**OPEX** Operational expenditure  
**IRR** Internal rate of return  
**NOPLAT** Net operating profit less adjusted taxes  
**NPV** Net present value
Full load hours and investment costs are highly sensitive to the NPV.

**Sensitivity analysis - NPV vs full load hours**

- Full load hours and investment costs are highly sensitive to the NPV.

**Sensitivity analysis - NPV vs investment costs**

- +200% in NPV if 4% discount rate

- ~24% in NPV if 4% discount rate
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SMALL HYDROPOWER – SUCCESS & RISK FACTORS

Drona Upadhyay, Principal Consultant

SHP Regional Workshop, 16-20 April 2012, Monrovia, Liberia
Outline

➢ Small Hydropower Success Factors
➢ Some examples
➢ Conclusions
➢ Questions
Small Hydropower – Key Factors

Success and risk factors - broadly categorized into:

• Technical
• Financial
• Social
• Legal / Political
• Organisational

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Success and Risk Factors

• Success and risk factors - two sides of the same coin
• Can be pre or post installation
• Risks cannot be completely eliminated, but can be reduced
• Factors presented here not an exhaustive list
• Participants will be familiar with many of them and can contribute to this list
Technical Factors

- Resource assessment
- Resource Quality
- Site location
- Skilled Manpower
- Infrastructure
- Local repair / maintenance facilities
- Capacity Factor (Load Factor)
Example

• Micronesia – in the Pacific
• 2MW (2 turbines), run of river
• Resource assessment flaw
• Insufficient flow
• Now almost defunct
Financial Factors

- Tariff / Ability to pay
- Investment availability
- Financial Viability (cost/benefit)
- Subsidies (is a political factor too)
- Willingness to pay (is a social factor too)
- Cost of energy
- End Uses
Examples in the UK
Many of the schemes are low head – inherently higher cost / kW
Almost all the SHPs are grid connected
Many use existing infrastructure such as an old mill
Social Factors

Mostly applicable to community based schemes

- Awareness of the project
- Willingness to pay
- Feeling of ownership
- Community participation
- Alternative use of water
Example

- Ghandruk 50kW micro hydro scheme in Nepal
- Example of Social and Financial Success Factors
- Community mobilization – other community projects such as nature conservation already in place
- Steady income source from tourism
Organisational Factors

- Ownership structures
- Management Capacity
- Revenue Collection
- Community mobilization
- Capacity Building
- Demand Assessment

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Legal / Political Factors

- Environmental impact requirements
- Subsidies and incentives such as tax breaks
- Feed in Tariff
- Insurance schemes
- Political Influence
- Organisation registration
Conclusions

• Several Factors affect the success or failure of an SHP scheme
• Experience shows Organisational and Social factors are equally, if not more, important
• Efforts should be made to maximize success and minimize risk
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Thank you
merci beaucoup

• Questions, Clarifications & Contributions
Ground Realities

Village People

Burdened, uneducated
Ground Realities of Rural World

- Limited local employment avenues
- Uneconomical and fragmented agriculture land holdings.
- Agriculture - traditional with low yield - *de facto* organic.
- Cattle-agriculture-forest interlinked.
- Women spend most of the time on agriculture activities - drudgery.
- Acute shortage of skilled manpower
- Out-migration of youth
- Local manpower engaged in multifarious activities to earn a living
- Low per capita income, poverty.
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Hydropower Power

Ownership Model

- Complete Government Ownership
- Joint ownership, Government, Private and or community
- Complete community Ownership
Planning for Community Participation

Nature and extent of participation (wholly or partially)

• In manpower and labour
• In collection of revenue and tariff
• In sharing of resources (land and water)
• In complete post installation management
• In all aspects and all phase of development
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Role of Developer

• Identify community
• Identify the site having potential of power generation
• Verify rights of people on land and water
• Engage community for discussions and complete involvement
• Identify needs, and plan for livelihoods
• Prepare design, estimates and raise funds
• Identify leaders in the community for proactive role in implementation and set up an organization such as Village Energy Committee in the village
• Select at least two persons who would operate power house
• Initiate construction of power project with local involvement
• Procure equipment
• Install power house with the help of community
• Train and handhold for operation and maintenance
• Introduce livelihoods
• Regulate operations and oversee working
• Withdrawal but maintain contact with the community
Complete Community participation Projects

Community Participation in all phases-

- Pre construction,
- During construction
- Post construction

Best Practice

Do it yourself and be self reliant
Role of Community

• Participation from inception onwards
• Contribution in cash or kind
• **Form Core Group** and select trained person for operation and maintenance or select persons who can be trained
• Ownership for sustenance of the project
• Work for new livelihoods
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• Work for new livelihoods
Village formally applies
Before starting the project for hydropower

Problems and challenges

Identified after discussions at village

- Wheat - inadequate milling facility
- Rice - no milling facility
- Millet - Inadequate milling facility
- Mustard - no milling facility
- Wool - no mechanized processing
- Milk - no processing facility
- Aromatic Plants - no processing facility
- Fuel for cooking - scarce and difficult to obtain
- Irrigation facilities - limited, power required to lift water
- News and information - dependent on ‘word of mouth’
- Education in schools - poor quality as computer are not used, teachers do not like to stay in the village as the village is not electrified
Map preparation by Transect
Before starting the project for hydropower

Problems and challenges

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**Survey of Manpower**

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Comprehensive capacity building is key to the success of isolated Community microhydro
Training programme

Electro/mechanical tools

Training in wiring and instruments etc
Villagers measuring water discharge
## Community Participation

Nature of Participation and existing local capacity

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Community Owned And Managed Hydropower Schemes

1. Local Organization with a strong core group
2. Local Contribution
3. Appropriate Technology
4. Capacity Building
   🖋️ Construction
   🖋️ Maintenance
   🖋️ Management
   🖋️ Productive Application
5. Maximum Use Of Power For Improving Quality of life and Livelihoods
6. Sustainable Mechanism

© Yogeshwar Kumar
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Identifying Institutional Frame Work At Village

- Village Councils, Local Self Government
- Non Governmental Organization, Trusts
- Cooperative Society
- Producer Company
- Village Energy Committee
- Forest Council/Panchayats
Process of Community Mobilization

Regular Meetings in the village

Discussions at site
On spot guidance
Installation phase

- Material procurement
- Construction
- Fabrication work
- Installation
- Commissioning
- Setting up Transmission lines
- Wiring and metering
- Training
- Management
Channel and de-silting chamber built by community (Uttarakhand, India)

225 m long power channel

Desilting Chamber at Badiyarkuda
Transparency in community Hydropower structure is necessary to keep away disputes in areas such as local contribution, outside support, revenue, remunerations, purchase of material, election to office of core group.
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Grassroots Engineers Training Programme

Grassroots engineers engaged in construction programme and Learning equipment intricacies while fabricating and during construction

Use of power tools for minor fabrication/repair work

Grass engineers engaged in site clearance
Project installed by the local community (Ladakh, India)
Power House constructed by the Community (Kalahandi, Orissa, India)
Setting up Penstock

By Local Villagers under supervision
Equipment Installation by local community

Pangethi, India
Installation of Equipment

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