Introduction to Micro-Hydro

http://www.youtube.com/watch?v=rnP EWQtmGQ
Sun, Wind, Water

- Solar Electricity
  - Simple
  - Reliable
  - No moving parts
  - Low maintenance
  - Resource is available to most people

- Wind Electricity
  - Requires tall towers
  - Requires regular maintenance
  - Complements PV
  - Resource available to few people

- Hydro Electricity
  - Most cost effective
  - Reasonable maintenance
  - Constant output
  - Resource available to fewest people
http://www.youtube.com/watch?v=shwGBLYR2dM
Hydro Power

• Full Scale Hydro (> 10 MW)
  - Large towns and extensive grid supplies

• Mini-Hydro (300 kW to 10 MW)

• Micro-Hydro (50 W – 300 kW)
  - ideal for remote areas away from the grid
  - group of houses to small factories (mini-grid)
  - AC or DC
  - Cost ranging between $2,000 - $10,000

• Pico-Hydro (< 50 W)
Micro-Hydro

• Advantages
  - uses portion of stream flow
  - environmentally benign
  - AC or DC
  - Flow as low as 5 gpm, head as low as 2 ft
  - No fuel required
  - Available energy is predictable
  - Available to meet continual demand
  - Low maintenance and operating costs
  - Long lasting and reliable
  - Can be connected to the utility grid
Micro-Hydro

• Disadvantages
  - certain flow, head and output characteristics are required
  - very site specific
  - seasonal variations in flow
  - Lack of knowledge and skills to sustain technology
  - Not all sites where there is potential energy available will allow micro-hydro to be developed in a cost effective fashion. Fixed costs
Energy released by a falling body of water of mass, \( m \), over a height, \( h \) (static head)

\[
E = mgh = \rho Vgh \text{ (Joules)}
\]

Power associated with falling body of water

\[
P = \frac{dE}{dt} = \rho ghV/dt = \rho ghQ \text{ (Watts)}
\]

where \( Q \) flow rate in \( m^3/s \) entering the turbine

Include friction losses in penstocks and channel, etc..

\[
P_{\text{net}} = e_0 P = e_0 \rho ghQ \text{ (Watts)}
\]

Since \( \rho g = 10 \text{ kN/m}^3 \) for water, a quick estimate of \( P_{\text{net}} \) can be determined by taking \( e_0 = 0.5 \). Thus,

\[
P_{\text{net}} = e_0 P = 0.5 \times 10 \times h \times Q \text{ (kWatts)}
\]
Site Assessment

• **Flow**
  - The flow is the quantity of water available to the turbine
  - The design flow will be a percentage of measured stream flow
  - Design flow determines penstock size
  - Design flow determines nozzle size

• **Head**
  - Determines the turbine speed

• **Penstock** length, diameter and material characteristics

• **Intake and Power house** locations

• **Geological Study**

• **Loads** – required power, potential power
Measuring Head

Convert head into pressure: 1 psi = 2.31 ft of head for water. An accuracy of ± 3% is required.

- Topographic map
- Hose and Pressure gage
- Water-filled tube
- Level
- Inclinometer, sighting meters
- Altimeters
A stream profile measures the vertical drop and the distance over the ground that your pipeline might take.

Credit: Corri Loschuck.
Measuring Flow

- Bucket Method
- Float Method
- Weir Method
- Salt Dilution Method
- Flow meter

Fig 2.2.11 The annual hydrograph shows flow in a particular river or average flow in all rivers monitored in a region. The irrigation or industrial demand for water can be included on the hydrograph.
Float Method

Flow = Area x average velocity

Area = Stream Width x Average Depth
Weir Method

\[ Q = 1.8 \left( L - 0.2 \, h \right) h^{1.5} \, m^3/s \]

<table>
<thead>
<tr>
<th>Overflow height</th>
<th>Weir width L</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5 m</td>
</tr>
<tr>
<td>5 cm</td>
<td>10</td>
</tr>
<tr>
<td>10 cm</td>
<td>27</td>
</tr>
<tr>
<td>20 cm</td>
<td>74</td>
</tr>
</tbody>
</table>
Salt Dilution Method

\[ Q = \frac{M}{kA} \]

- **M**: mass of salt (g)
- **A**: area under curve \( (\Omega^{-1}s) \)
- **k**: Conversion factor \( (\text{g}\Omega/l) \)

Distance 20 to 70 metres

- **Bucket of salt water**
- **Conductivity meter**
- **Probe**
Geography

- A penstock route must be considered
- Identify possible sites for intake and powerhouse when measuring head
- Note soil/rock types, erosion, geologic conditions
- Consider future changes in river pattern
Intake and Powerhouse

- Flood conditions must be planned for
- Composition and nature of stream bed determines erosion and future path changes
- Natural features can protect civil works
- Location to avoid competing with other users
- Access for construction and maintenance
Locating the Intake

• Choose a site with a stable streambed (constant flow stream, bedrock, small gradient)
• The inside of bends accumulate sediment
• The outside of bends are subject to erosion and flood damage
• Place intake along straight section
Locating the Powerhouse

• Must be above flood height
• To maximize head, place the turbine below the powerhouse floor
• Locate powerhouse on inside of bends
• Use natural features for protection
• Tailrace oriented downstream
• May be some distance from the stream
\[ P = \eta (\rho g) h Q \]

- **SI Units**: \( h \) (m), \( Q \) (m\(^3\)/s), \( \rho g = 10 \) kN/m\(^3\)

**Rule of Thumb**

\[ P \text{ (kW)} = F_c \times \text{Head (m)} \times \text{Flow (m}^3\text{/s)} \]

with

- \( F_c = 4.9 \) for a 50\% overall efficiency
- \( F_c = 3.9 \) for a 40\% overall efficiency
\[ P = \eta \rho ghQ \ (\text{Watts}) \]

- **Imperial Units:** \( h \ (\text{ft}) \), \( Q \ (\text{ft}^3/\text{min}) \), \( \rho g = 62.4 \ \text{lb/ft}^3 \)

**Rule of Thumb**

\[ P \ (\text{Watts}) = \text{Head (ft)} \times \text{Flow (gpm)} / F_c \]

with

- \( F_c = 9 \) for a 59% overall efficiency
- \( F_c = 10 \) for a 53% overall efficiency
- \( F_c = 13 \) for a 41% overall efficiency
Civil Works

Fig 3.1.2 The components of a micro-hydro scheme
System Layout
Intake structures

Sediment build-up downstream of this side intake can be removed manually instead during low flow periods when access is feasible. In many sites the side intake will remain clear of blockage by acting in the same way as a direct intake, that is, sucking all sediments through to the silt basin.

A direct intake will automatically stay clear of blockage by encouraging the debris to flow through the intake rather than collect at the intake mouth.

Fig 3.3.12 Trench Intake. Fast flowing mountain streams are often laden with excessive silt loads and larger debris such as stones, grasses and branches. The Intake rack shown here allows these objects to flow over it, the water velocity itself acting to keep the rack clean. Any debris which collects on the rack during low flow periods will be washed off in high flow periods. If such intakes are designed carefully, with correct mesh size, slope angle, evenness of slope, width, etc, they can operate in difficult conditions for years on end without attention.
Penstocks

Fig 3.7.1 Components of penstock assembly. Penstocks must be laid in such a way as to prevent airlocks forming inside them. These airlocks act as obstructions in the penstock and cause a pressure drop across them. If a danger of airlocks exists because the ground rises and the penstock cannot be cut in, an air bleed valve must be fitted as shown. Similarly water drain valves may be needed. Always avoid the use of valves since after some years they can become unreliable.
Penstocks

a Static conditions

Water in penstock static
Turbine not rotating

$h_{gross}$

b Normal operating conditions

Water in penstock moving
Turbine rotating

$h_{net}$

$h_{friction}les$ Note that the power available to the turbine is given by

$P_{net}(kW) = \text{Flow (m}^3/\text{s}) \times h_{net}(m) \times 10.$

$h_{surge}$

$h_{gross}$

$h_{total}$

High pressure wave or 'surge'

Valve suddenly blocked by foreign bodies (or closed too fast)
Videos

• http://www.youtube.com/watch?v=shwGBLYR2dM
• http://www.youtube.com/watch?v=CG95NnnzPYo