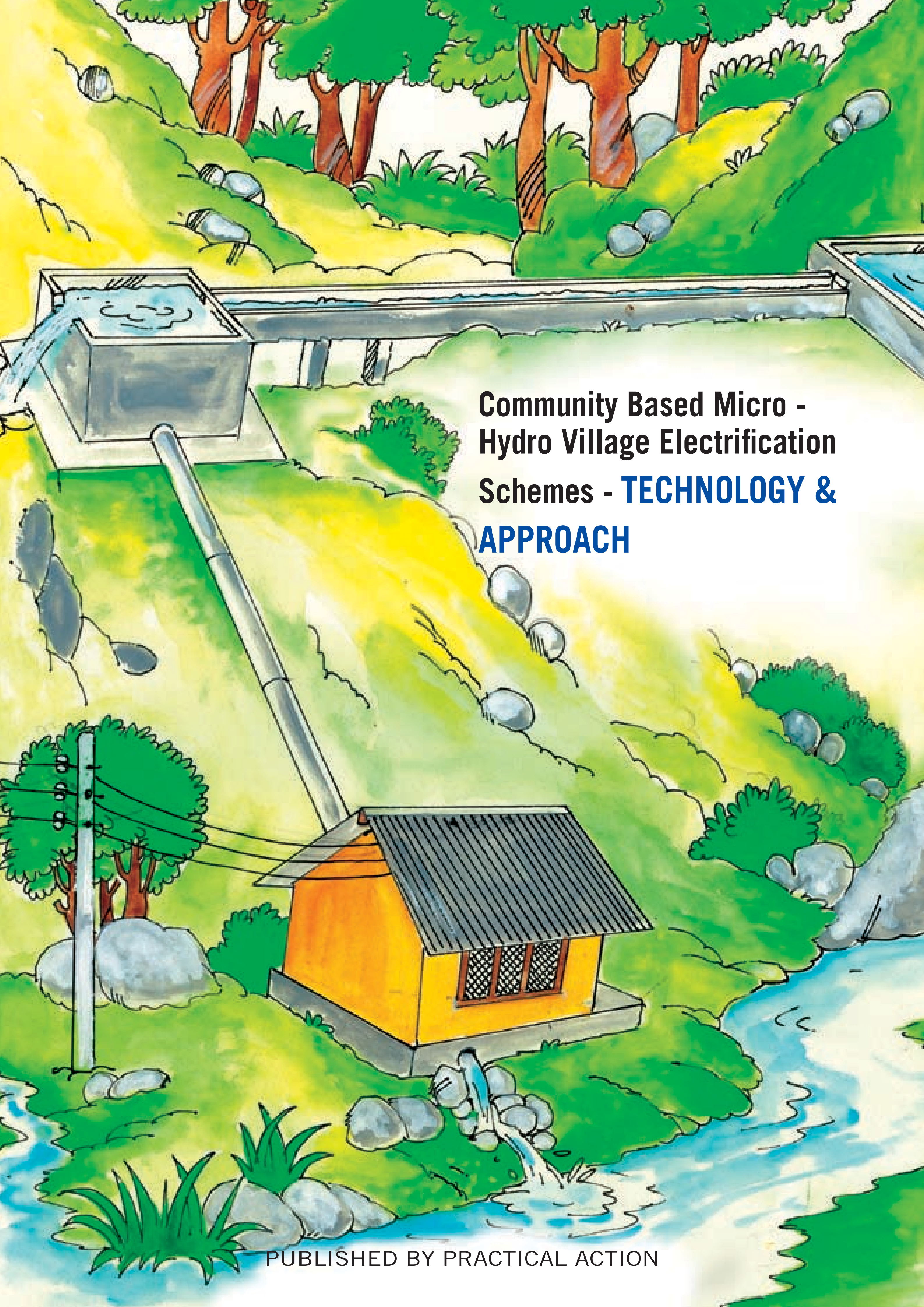
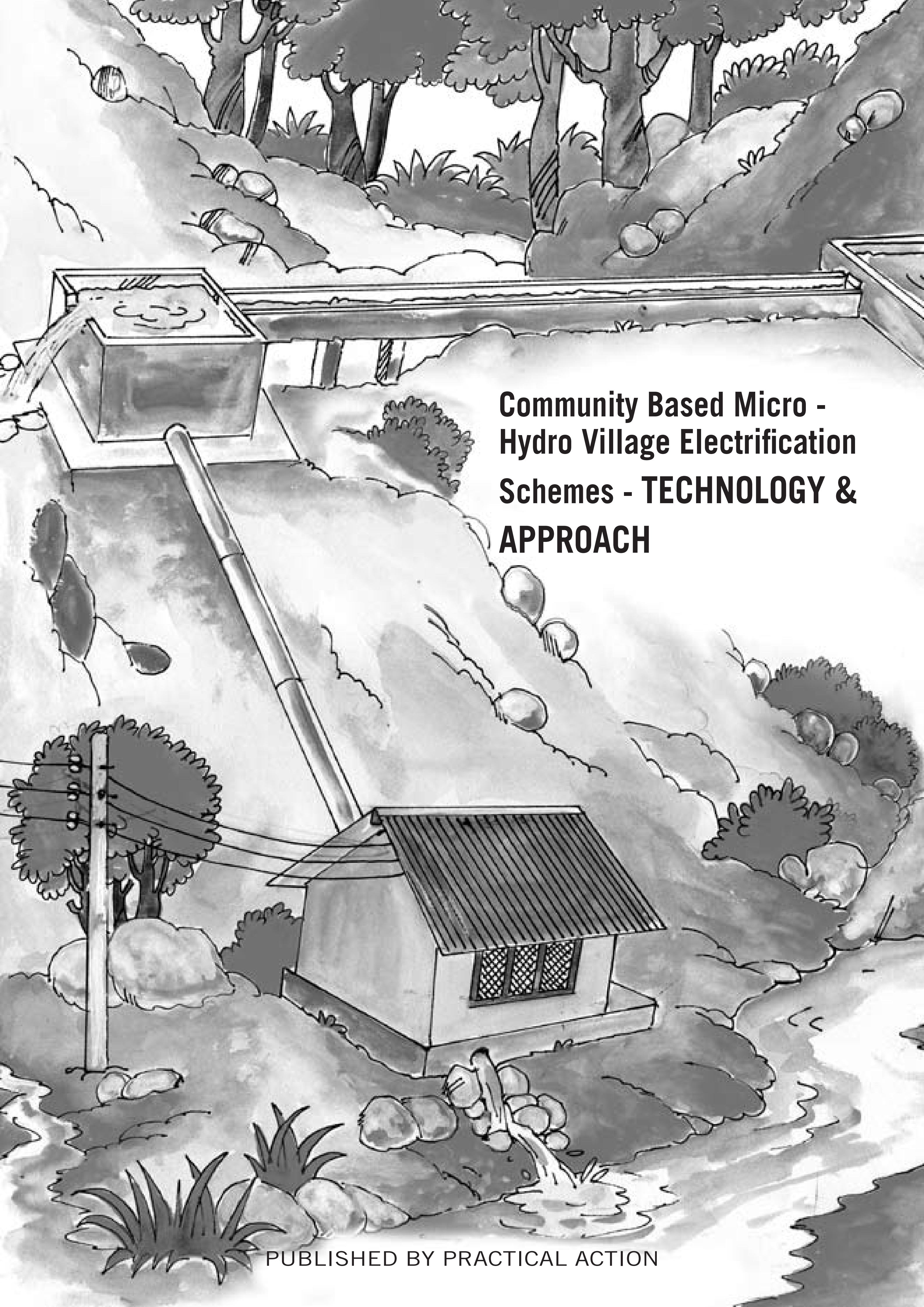


Community Based Micro - Hydro Village Electrification Schemes - TECHNOLOGY & APPROACH

PUBLISHED BY PRACTICAL ACTION



Community Based Micro - Hydro Village Electrification Schemes - TECHNOLOGY & APPROACH

PUBLISHED BY PRACTICAL ACTION

COMMUNITY BASED MICRO-HYDRO VILLAGE ELECTRIFICATION SCHEMES - TECHNOLOGY & APPROACH

ISBN 978-955-9417-49-1

5, Lionel Edirisinghe Mawatha,
Colombo 5, Sri Lanka

Tel	:	+94-11-2829412
Fax	:	+94-11-2856188
E-mail	:	srilanka@practicalaction.org.lk
Website	:	www.practicalaction.org, www.janathakshan.net

Funded by	:	DGIS Netherlands
Acknowledgment	:	Gram Vikas
Publisher	:	Practical Action
Complied by	:	P.G. Ajith Kumara
Edited by	:	Namiz Musafer, Tushani Kalugalagedera
Drawings	:	Hingulwela Dissanayake
Layout	:	Dinesh Pradeep, Minidu Abeysekera

FOREWORD

Understanding the basic science behind any technology helps future generations to be more pro-active in their inventions, innovations and technology improvements. Similarly, such an understanding would help the decision makers to make informed decisions based on facts. This booklet is designed for the decision makers (non-energy specialists) and the future generation to understand the basic science and technology behind community based micro-hydro village electrification schemes.

Practical Action has worked on micro-hydro village electrification schemes for over 25 years. This community based renewable energy technology has proven to be an appropriate energy solution for remote rural villages which are not connected to the main electricity grid. At the heart of these schemes lie the village communities. They are not only the consumers and owners of the schemes but are also responsible for managing, operating and maintaining them.

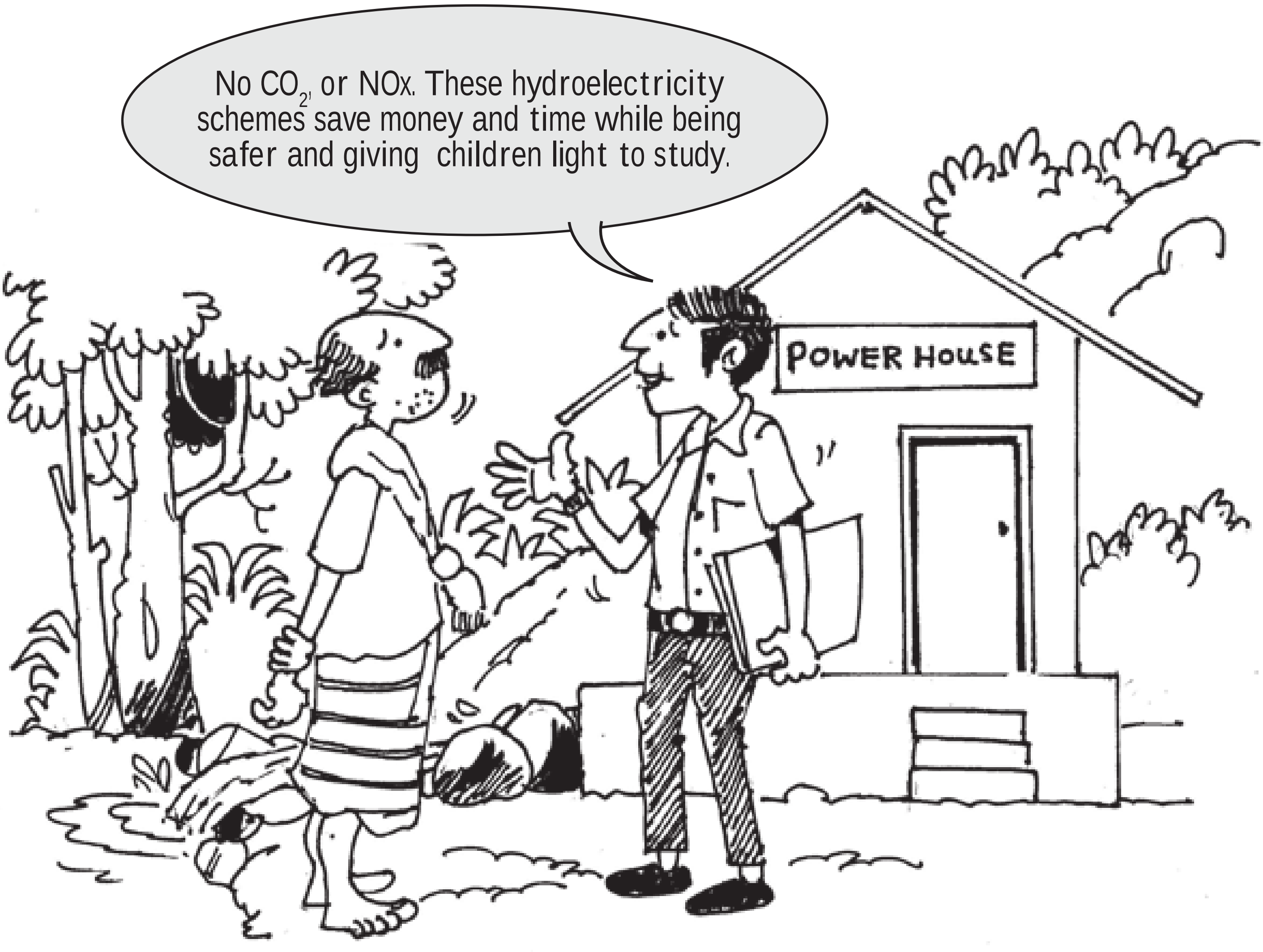
Collective action is strength. In a community based micro-hydro electrification scheme, people get together, realise that they can mutually benefit if they harness the natural resources available in their locality, and pool their own resources and strengths in order to achieve a common purpose. While getting some external support at the initial stages, once the scheme is in operation it is the communities which continue reaping the benefits with minimum external interference. External support would only be beneficial if those who provide it understand the benefits and challenges of these types of schemes.

To help people, the science has to be transformed into action. In this booklet, it is explained as to how the science is used in technology development and how this in turn is transformed into infrastructure. The main attributes to be considered, assessment of data, functions and selection of the components are explained to gain an understanding of the community based micro-hydro village electrification schemes.

CONTENTS

1. INTRODUCTION

Threats of climate change have drawn the attention of the world community to look for alternative sources of energy. Petroleum fuels, coal and electricity are the primary sources of energy amongst the developed nations. When it comes to the developing nations, it is mostly biomass. Over half of the world's electricity is produced by burning coal or petroleum fuels - adding more greenhouse gases, polluting the atmosphere and leading to climate change. On the other hand, these resources are fast depleting and their reserves will not last for more than a few more decades for humans to use. Renewable energy such as small hydro schemes can help face both these issues.



Community based micro-hydro village electrification schemes are used to electrify remote villages that are not connected to the national / state electricity grids. Such schemes can be operated and maintained by the community members themselves. A micro-hydro village electrification scheme can generally meet a household's basic electricity demand for lighting, TV, radio, phone charging, etc. In addition, it can be used to power electric irons and small scale machines with limitations.

Light for reading

These schemes can help improve the lifestyles of community members by reducing the money spent on conventional energy sources, improving children's education time and expanding the day's productivity by extended the working hours into the night (especially agricultural work), and improving safety. It also helps open the village to the outside world through different types of media and communication devices (radio, TV, phone). In addition, there are a lot of indirect benefits from these schemes such as being environmentally friendly with no greenhouse gas emissions, reducing the demand for national/state electricity grids, saving foreign reserves which would otherwise be used to import petroleum or coal, and increasing the harmony and cooperation among the communities living in the villages.

In order to generate electricity from a community based micro-hydro village electrification scheme there should be a stream with a reasonable flow of water passing above, through or near the village. Water should flow preferably throughout the year (in practice, in many areas, water may be available only during certain periods of the year), and with a considerable difference in the elevation between two points along the stream. The amount of power that can be generated depends mainly on these two factors. On the other hand, the harmony and the collective effort of the community members is a must for the successful implementation of such a scheme.

Height & Flow

2. Micro - hydro

TECHNOLOGY

As explained above, the community based micro-hydro village electrification scheme makes use of a water stream that flows through or near the village with a considerable flow of water and with a drop in elevation. The theoretical available energy of a stream is proportionate to the drop (height difference) and flow rate as given below. (This has been computed from laws of conservation of energy.)

By equating the potential energy at the top of the drop and the kinetic energy at the bottom of the drop, the power that is generated 'P' can be expressed as;

POWER (P) = ρgHQ (IN WATTS)

Where	ρ	=	Density of water (1,000 kgm^{-3})
	g	=	Gravitational force (9.81 ms^{-2})
	Head (H)	=	Drop (Height deference) (m)
	Flow Rate (Q)	=	Water flow rate (m^3s^{-1})

In the above expression, ρ and g are constants. Only the Head and Flow Rate are variables.

Example:

If the Flow Rate and Head of a micro-hydro site are 0.03 m^3/ sec and 60m respectively 1,000 X 9.81 X 60 X 0.03 = 17.658Watts Then the available power = 1,000 X 9.81 X 60 X 0.03 = 17.658 Watts

Although the potential of power is 17,658 Watts (17.658 kW), all this cannot be practically extracted. This is due to various energy losses in the power conversion steps as explained in the next section.

3. Basic Power CONVERSION Steps

The water at the top of the penstock (described on page 18) possesses potential energy. This is what is being finally transformed into electricity. This transformation takes a couple of steps as described below.

Water possessing Potential Energy
(at the top of the penstock)

↓

Potential Energy of water transforms into Kinetic
Energy up to the bottom of penstock

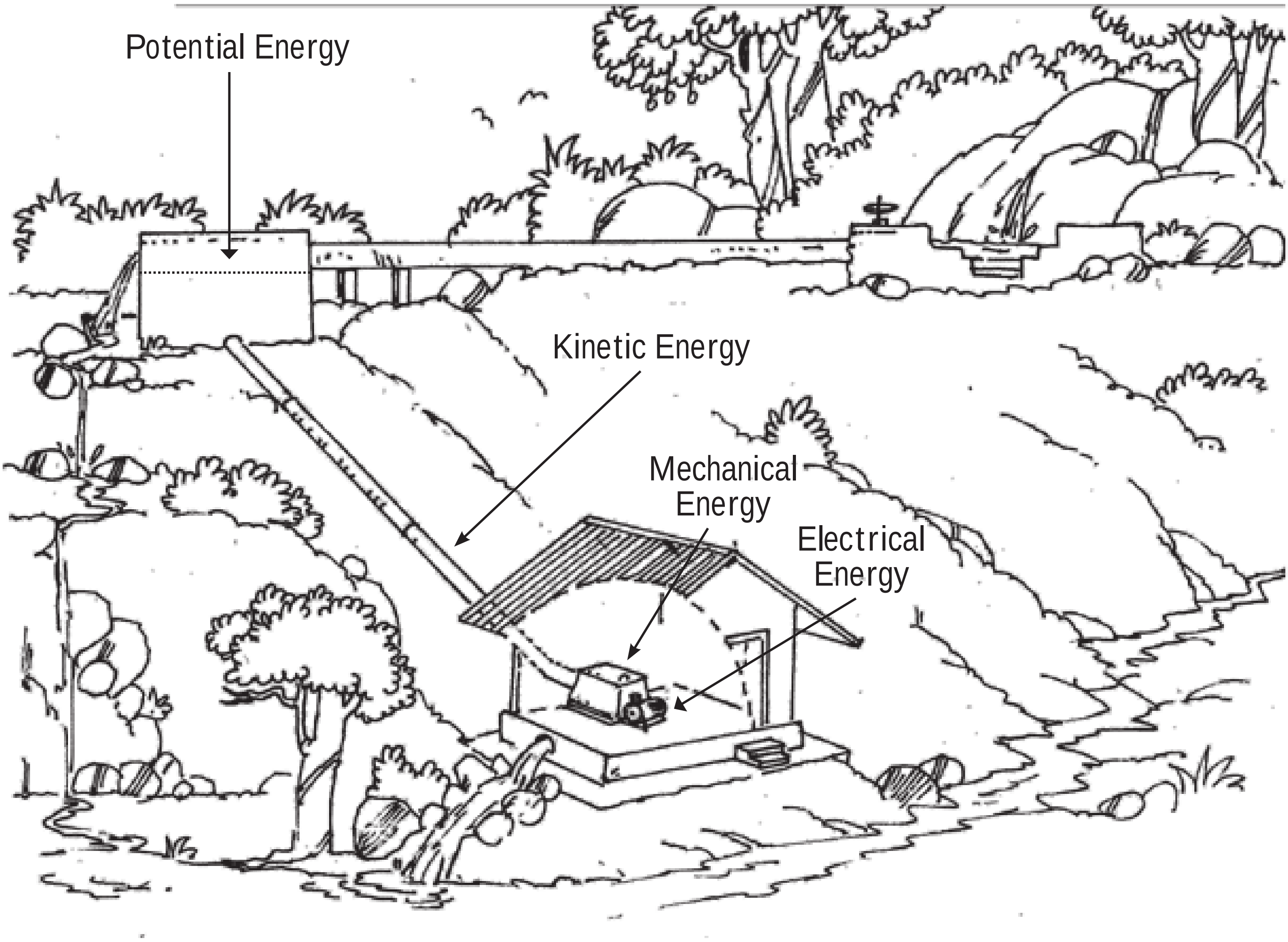
↓

Kinetic Energy of water transforms into Mechanical Energy by rotating the turbine

↓

Mechanical Energy transforms into
Electrical Energy by rotating the generator shaft

The micro-hydro technology is used to transform the energy in water into electricity. This technology needs certain infrastructure, as detailed in section 5. Energy loss takes place during the entire energy transformation process as well as at the infrastructure. The designers, constructors and implementers should pay due attention to ensure an optimum level of useful energy. A typical community based micro-hydro village electrification scheme hardly surpasses an overall efficiency of 60%.



The following tables provide an indication of the typical efficiencies (due to energy losses experienced) at some key components of the micro-hydro village electrification schemes.

Component	Efficiency (%)
Channel, filter and settling tanks	98
Penstock	90
Turbine	75
Generator	82

For example, if the only energy losses of a scheme are as stated above, the overall efficiency of the scheme can be expresses as the multiplication of the efficiencies at each stage. In this instance, the overall efficiency can be worked out as follows

Overall efficiency = 98% x 90% x 75% x 82%
= 54%

Therefore, the actual electrical power output that can be harnessed in the case of the example in section 2 above is,

Output electrical power = 17,658 X 54%
= 9,578 Watts

4. Steps for SURVEYING a Micro - Hydro Village Electrification Scheme Site

Once a suitable site has been assessed as having a potential for generating electricity using micro-hydro technology, this site has to be surveyed in detail. This helps to identify the best locations for each component of the construction for optimal overall performance of the scheme. It may be necessary to identify several locations for different components and then decide on the most optimal combination. The factors such as overall scheme capacity, cost, demand, distance to village, environmental aspects, ease of maintenance, safety and land use patterns, etc. may be considered before a final decision is made.

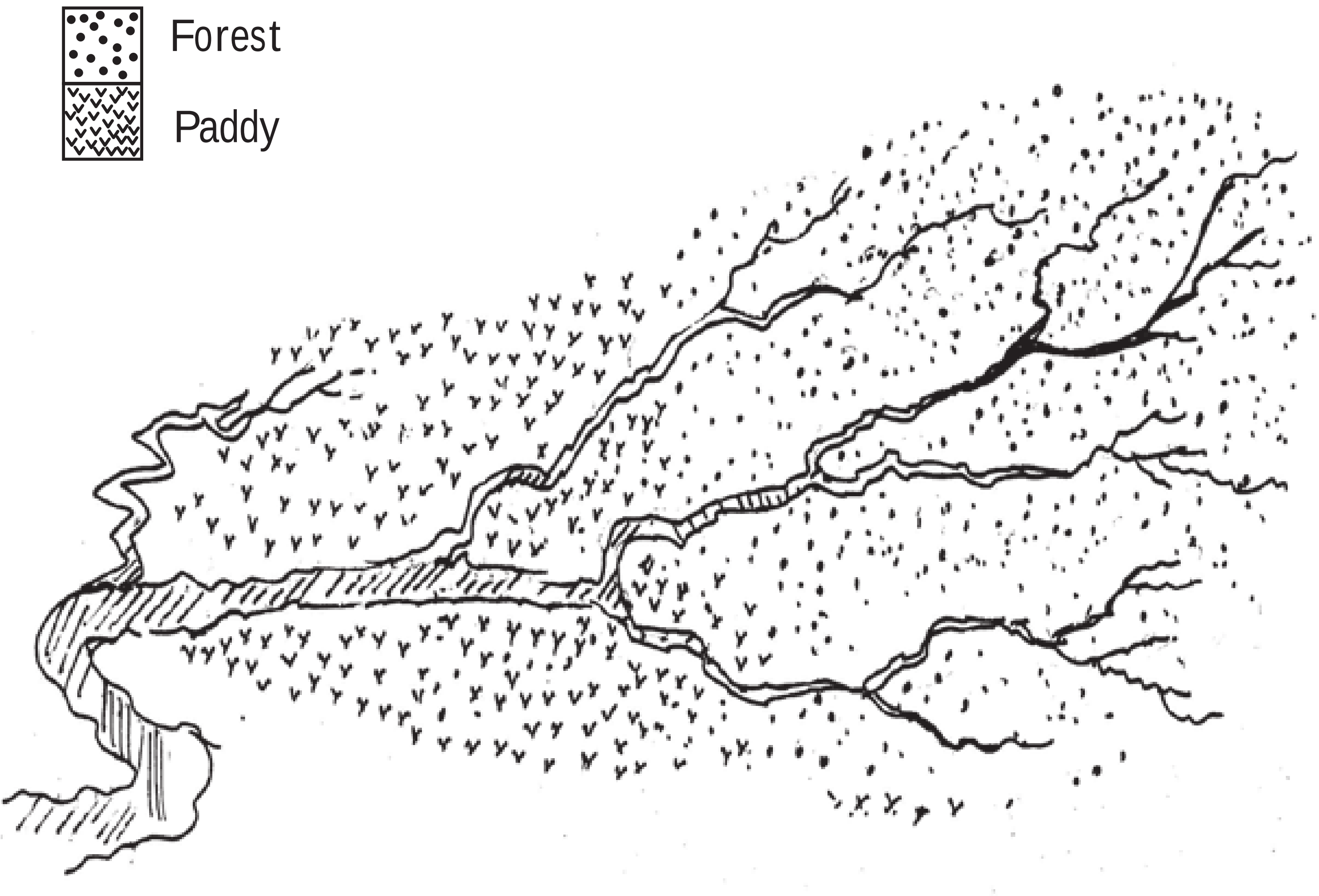
Site Survey

The survey would be used to assess the feasibility of the scheme and help determine the following;

- Design flow rate (of water)
- Head (difference of elevation of the water stream)
- Locations for civil construction
- Distribution lines
- Village demand

Determination of the design flow rate is not straightforward. This varies with the climate and water use patterns of the stream, which make the flow of water change continuously. A mere site survey with a spontaneous measurement of the water flow cannot reasonably predict the power that can be generated. Most designers use a cumulative flow duration curve for the stream for a year, and then decide on the design flow rate for the scheme.

Measuring the flow rate



Some of the methods used to assess the flow rate of the stream are;

a. Measuring the water flow rate several times throughout the year
b. Estimate the water flow rate using rainfall data from the catchment area
c. Getting ideas from the local communities

5. MAIN COMPONENTS of a Micro-hydro Electrification Scheme

The main components of a micro-hydro power scheme are;

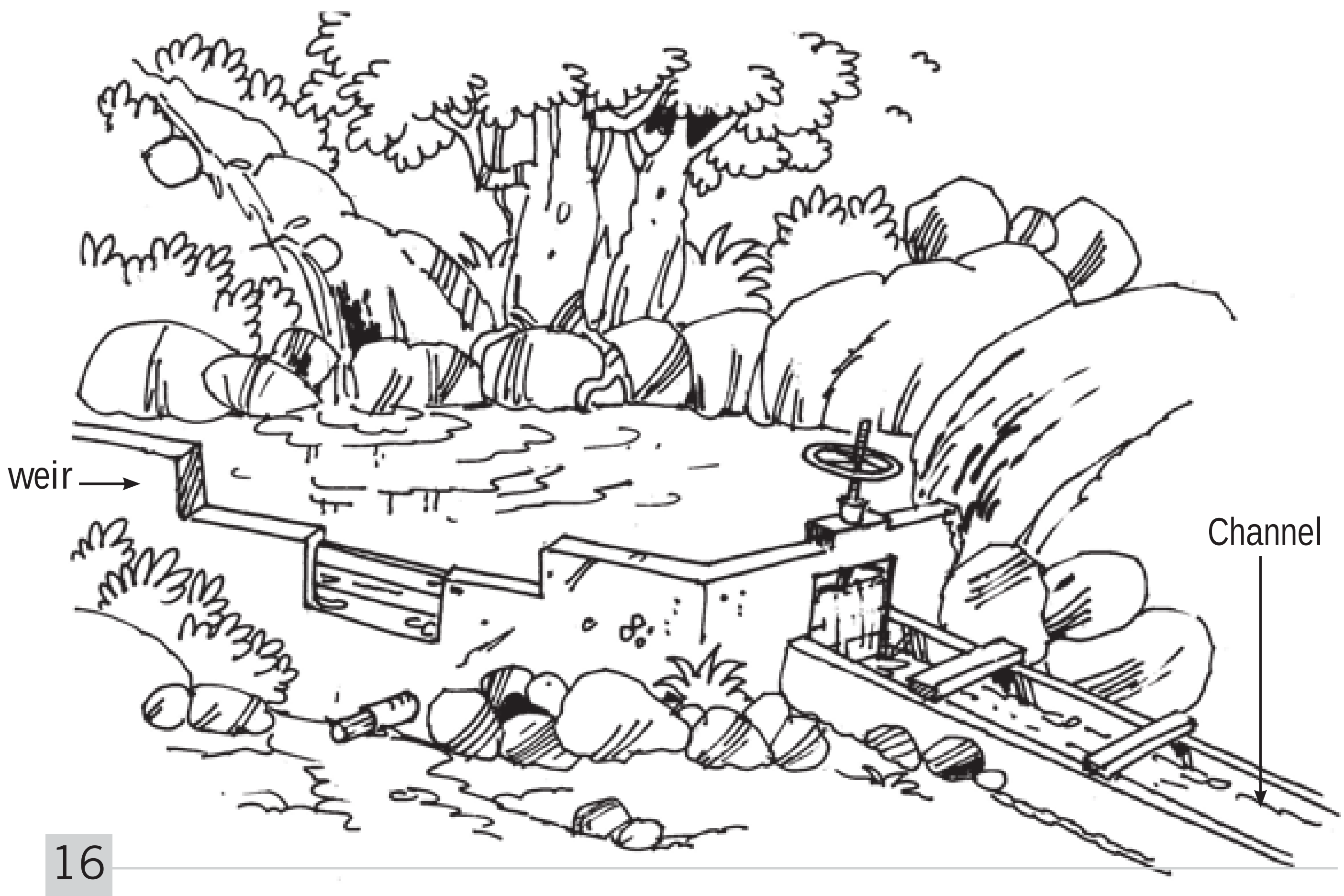
a. Weir
b. Channel
c. Settling tank
d. Forebay tank
e. Penstock
f. Power house
g. Turbine
h. Drive System
i. Generator
j. Control panel
k. Distribution panel
l. Distribution lines

Micro-hydro electrification schemes should be designed by competent and experienced personnel. The main functions and considerations of each component are explained below.

a. WEIR

The weir is a small dam built across the stream to divert water to the turbine. Selecting a narrow location of the stream minimises the construction cost. The weir must be easily accessible for maintenance work, including during the rainy seasons. Release of excess water, controlling of intake water and flushing out of the silt (de-silting) behind the weir are important functions associated with the weir.

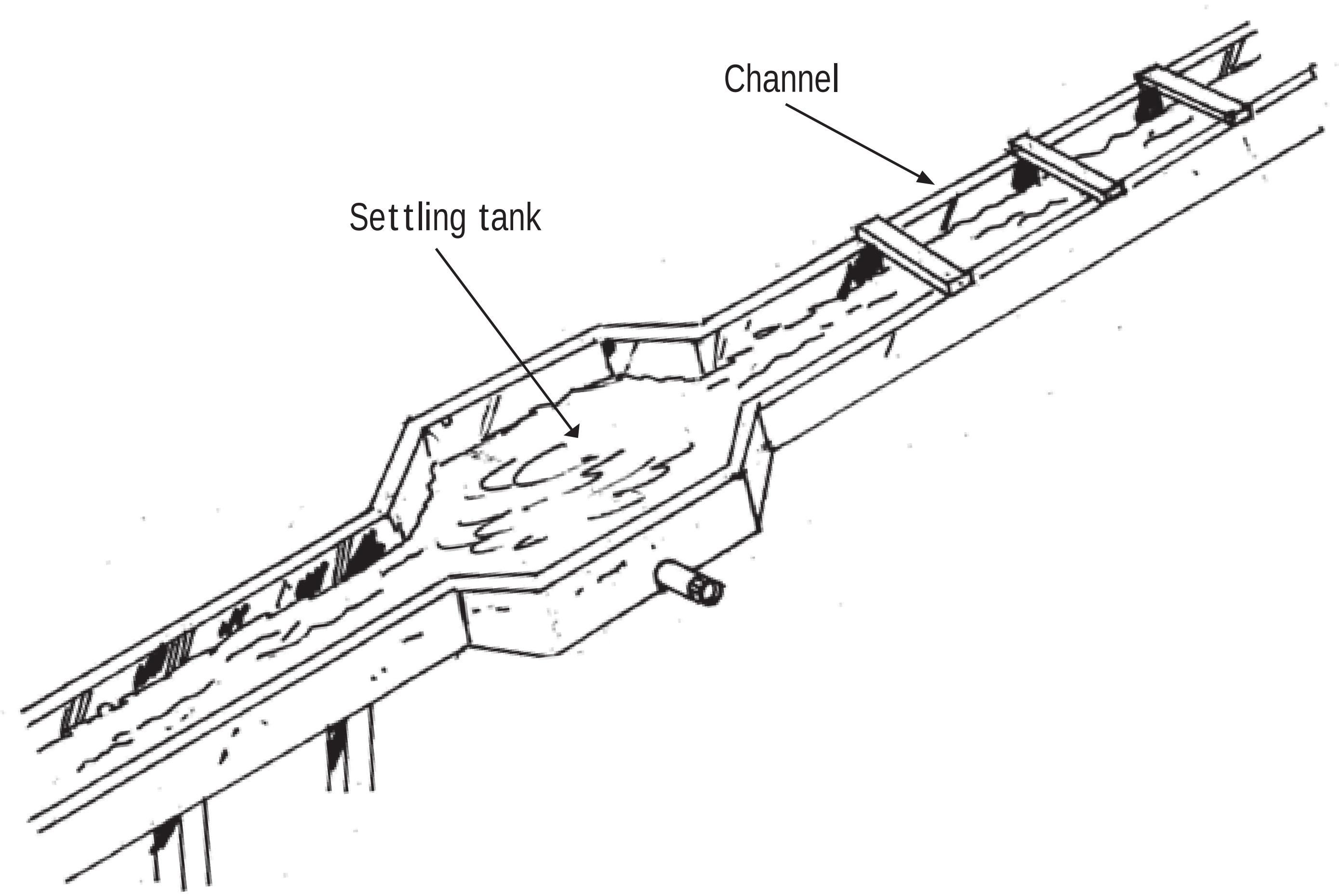
Weir



b. CHANNEL

The channel carries the water from the weir to the forebay tank. In rare cases where the forebay tank is attached to the weir, a channel would not be designed to be a part of the scheme. The channel is designed to have a minimum gradient to ensure that the drop of elevation of the diverted water stream is minimum. Channels are often constructed with concrete, random rubble, bricks, or earth. In most cases, the physical appearance of a channel resembles a drain.

Channel with Settling Tank



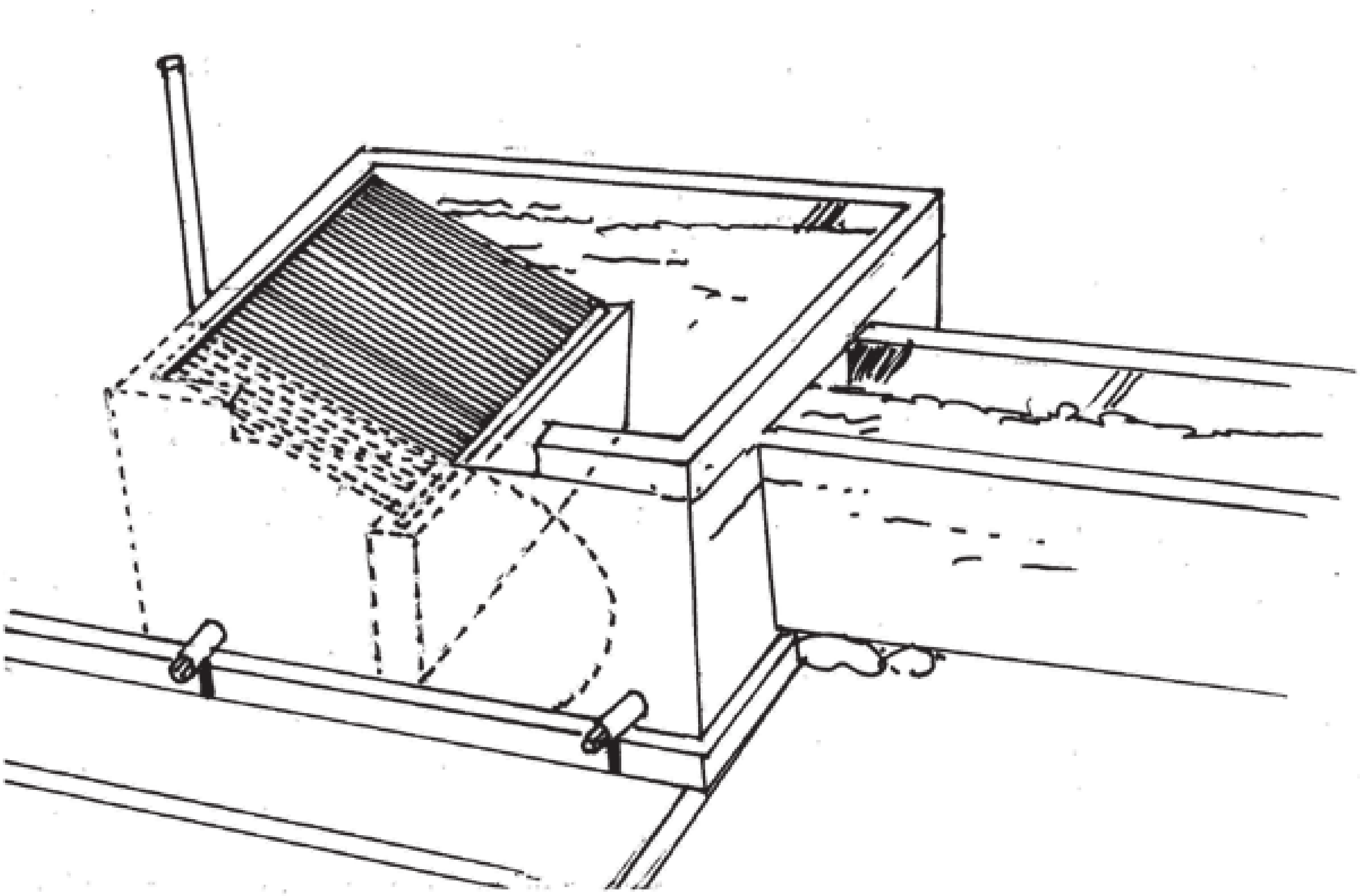
c. SETTLING TANK

Any solid particles in water can either block the nozzles (jets) or damage the blades of the turbine. The settling tank attempts to reduce any solid particles that enter the nozzles/turbine blades. Depending on the circumstances, there can be more than one settling tank designed for a micro-hydro scheme. In the case of reaction type turbines, even a slight wear in the turbine blades can drastically reduce the performances of the scheme.

d. FOREBAY TANK

Maintaining a constant water height (level) is the main function of the forebay tank. In addition, it also helps further reduce any foreign solid particles entering the penstock and stops any air getting into the penstock. To achieve this, the forebay tank must hold a considerable volume of water and maintain it. Forebay tanks are designed with different shapes and sizes by the designers.

Section of Forebay Tank



e. PENSTOCK

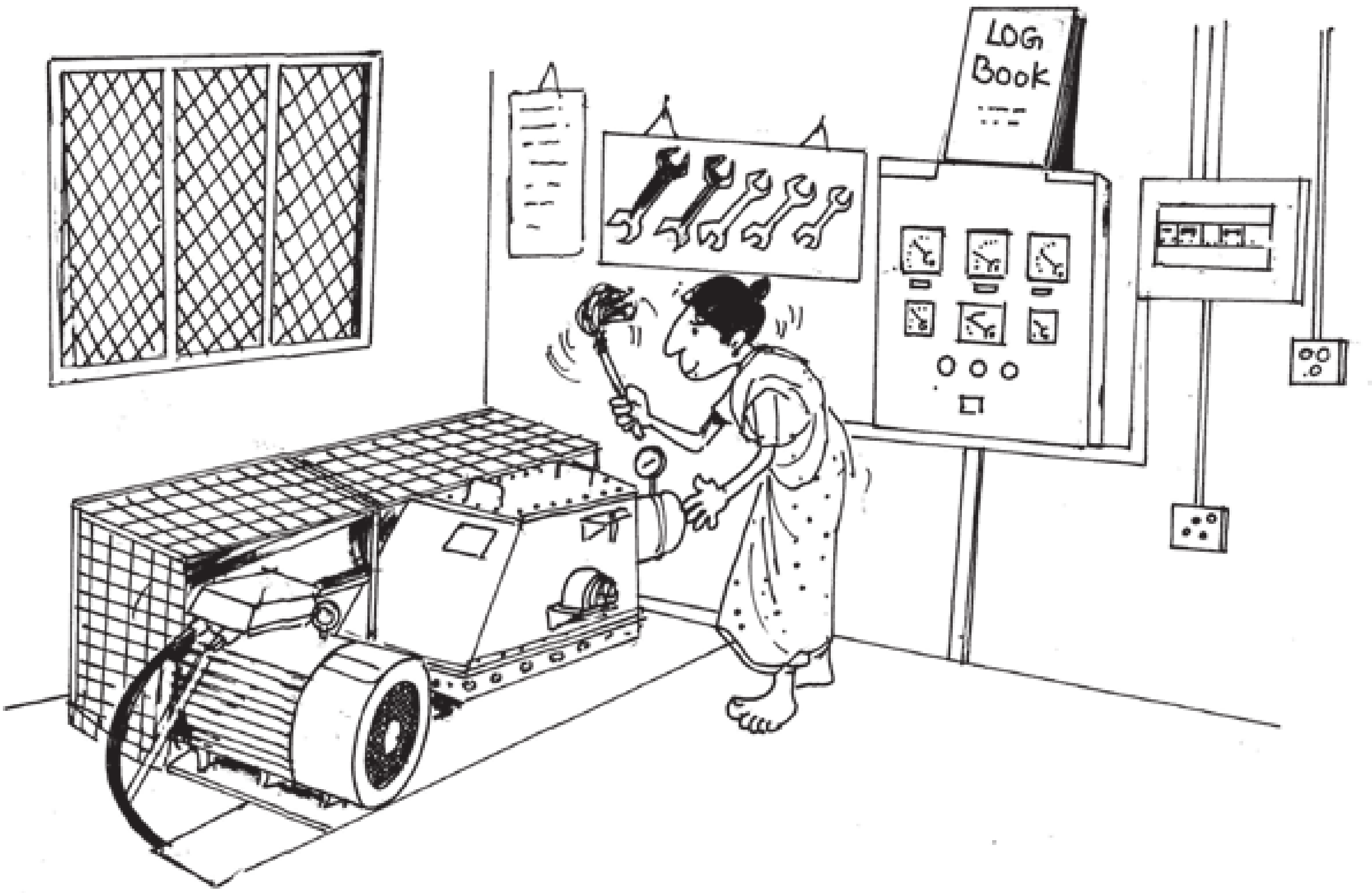
Sending the water from the forebay tank to the turbine with minimum losses is the main function of the penstock. It appears like a big pipe that brings down water from a higher elevation to a lower elevation. Penstocks can be made out of uPVC (Ultraviolet PVC), steel or any other piping material recommended by the designer. Inside the penstock, the potential energy of water transforms into pressure energy. By constructing the penstock to have the minimum number of bends and to be of the shortest length, the energy loss in the penstock can be minimised.

f. POWER HOUSE

Power house is a small permanent building that houses the electromechanical and controlling equipment. Micro-hydro schemes generally would have a one or two roomed building as the power house. To ensure safety and proper operations and maintenance, it is important for a power house to meet the following requirements;

- Free (additional) space
- Good ventilation and illumination (daylight or bulbs)
- Main door should be opened to the outside of the building (for emergency evacuations)
- Wide doors that can accommodate the carrying of (large) mechanical equipment into and out of the power house

A Neat Power House

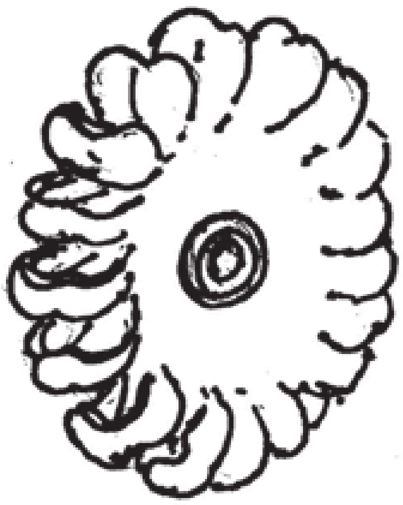


g. TURBINE

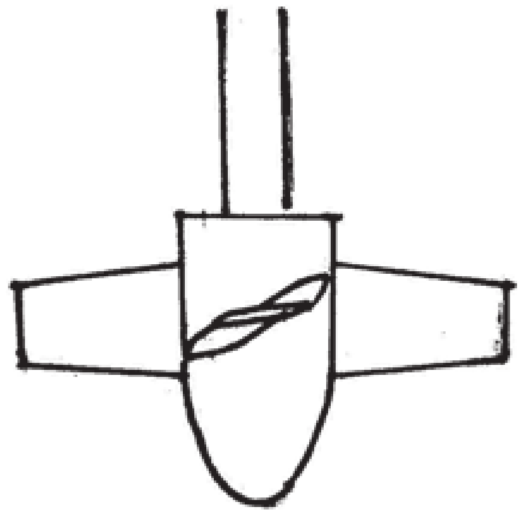
Turbine is the main component which converts energy in the water into mechanical (rotating) energy. The type, size and the other specifications of a turbine are designed by experienced and competent personnel according to the site specifications. Although there are so many types of turbines, the most common types are Pelton, Turgo, Cross Flow, Francis, Propeller and Kaplan.

Turbines can broadly be categorised into two types - Impulse and Reaction. In impulse turbines, a jet of water is made to strike the turbine blade making the turbine rotate. Pelton and Turbo turbines fall into this type. In Reaction turbines, the turbine housing is designed in such a way that the water coming from the penstock is guided to flow along a specific path so as to effectively rotate the turbine. In these types of turbines, the turbine housing and guide vane play an important role. Housing of the Reaction turbines should have smooth curves for water to flow and not to allow air to enter. Francis, Propeller and Kaplan are reaction type turbines. Centrifugal water pumps also can be used as reaction turbines.

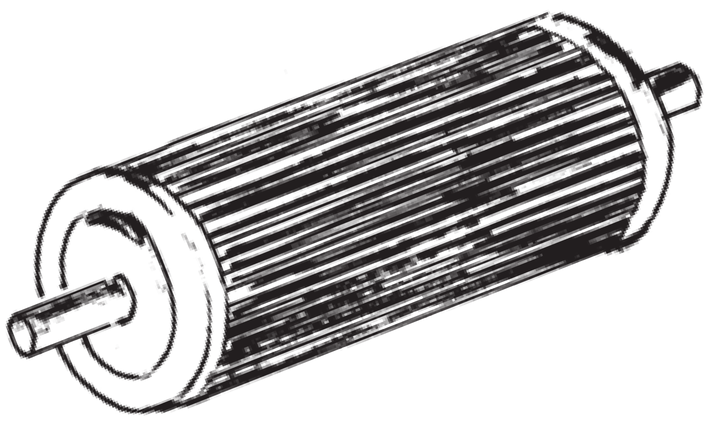
Pelton Turbin



Propeller Turbine



Cross flow Turbine

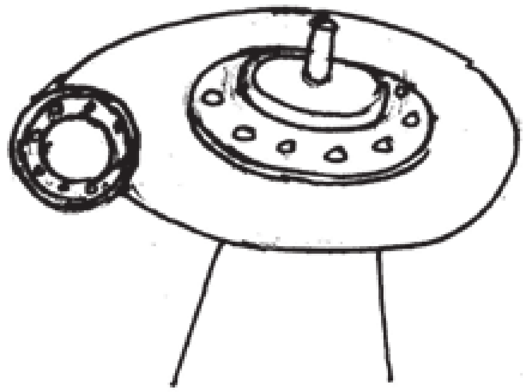


Impulse type turbines are suitable for sites with a relatively high head but a low flow rate. Their efficiency changes only marginally with the change of the flow rate. These generally can be operated even at 20% of the designed flow. Reaction type turbines are appropriate for the sites with a low head and a high flow rates. As mentioned, the housing and the geometry of the components of these turbines are very important and with a small wear in its inner surface, the efficiency of the turbine can reduce significantly. On the other hand, these generally can run only beyond 50% of the designed flow rate.

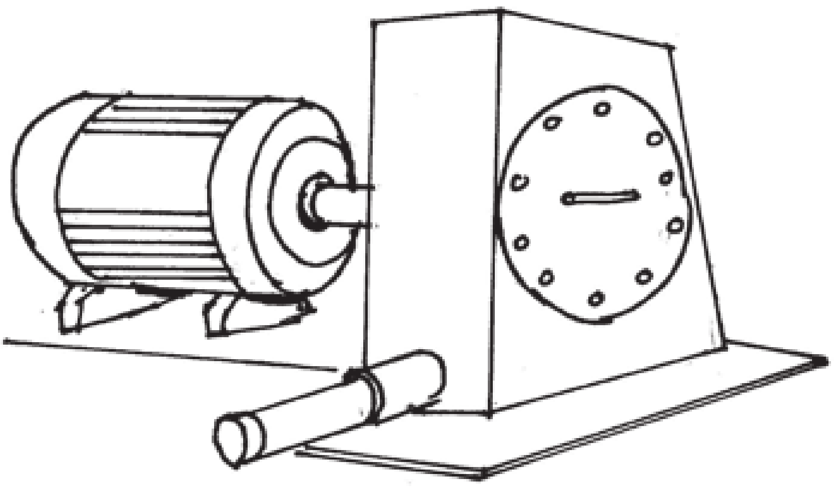
Cross Flow Turbines have features of both impulse and reaction types. Therefore, Cross Flow Turbines are considered as medium head turbines.

The main specifications of a turbine are its Pitch Circle Diameter (PCD), number of buckets / blades, rated speed, output power, number of jets and size and the material of the turbine. When the water jet hits the turbine blades / buckets, along with them, the shaft of the turbine rotates.

Francis Turbine



Pelton Turbine

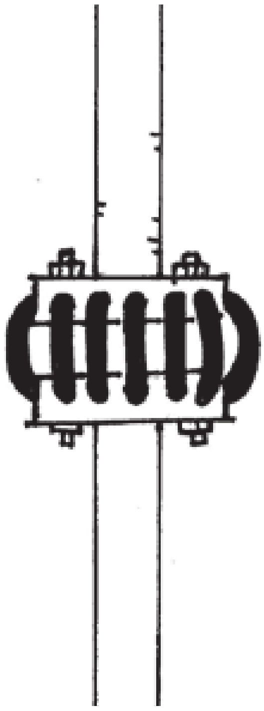


h. DRIVE SYSTEM

For the generated power to be smooth and consistent, the rotational speed of the shaft must be equal to the rated rotational speed of the generator. If these two are equal, the turbine shaft is directly connected to the shaft of the generator. This is called 'direct coupling'. In the cases where the rotational speed of the turbine shaft is different to the rated rotational speed of the generator or if the generator cannot withstand additional loads developed on the turbine, a drive system is introduced in between. It can be a belt, gear box, or coupling, etc.

Belt

Coupling



i. GENERATOR

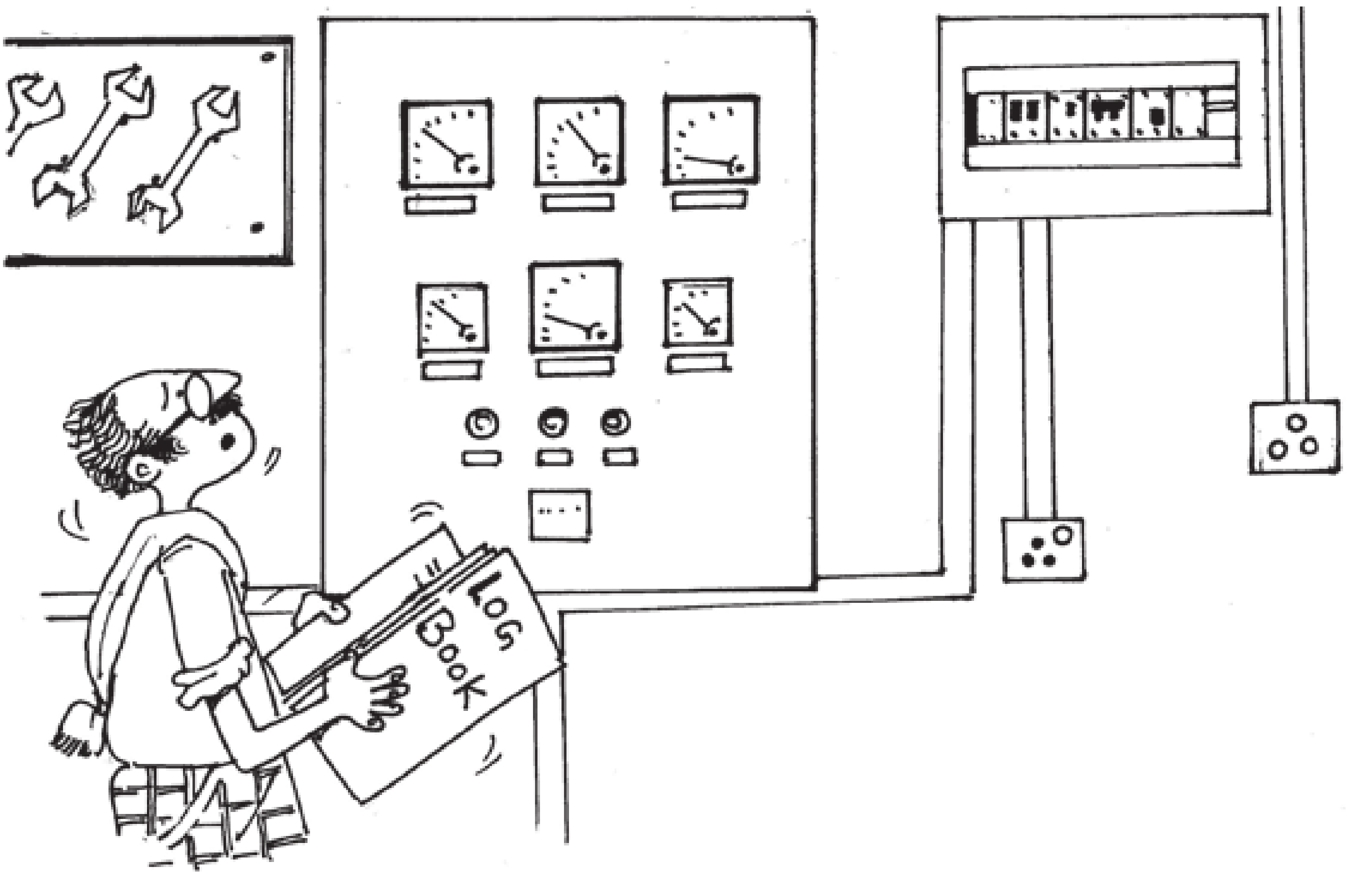
There are many types of generators available in the market. For community based micro-hydro electrifications schemes, the induction motors and synchronous generators are bought from the markets. Although the synchronous generators can be bought off-the-shelf, induction generators are hardly available. The induction motors are internally modified by introducing some capacitors.

j. CONTROL PANEL

Generally, micro-hydro power schemes generate constant power. This can vary when the water entering the jets is regulated by operating the valve, but often, the rate at which water is supplied is not changed. The demand for (and use of) electricity by the communities fluctuates all the time. In order to keep the overall system stable, (say 230 V and 50 Hz), a control panel is introduced. In cases where the demand for electricity by the communities is less than the electricity produced, the excess electricity would be channelled to the ballast, which would burn it out. That ballast may be made out of electrical heaters, bulbs or any other electricity consuming element. When demand for electricity exceeds that which is generated, then the controller cannot maintain the system at 230 V / 50 Hz and the generator cannot supply to that demand.

The generator then slows down and decreases the above values (230 V / 50 Hz). If it drops severely it can be harmful to the generator and appliances. Therefore, the control panel would cut off the electricity supply to the community. These panels may be supported with several display indicators or meters.

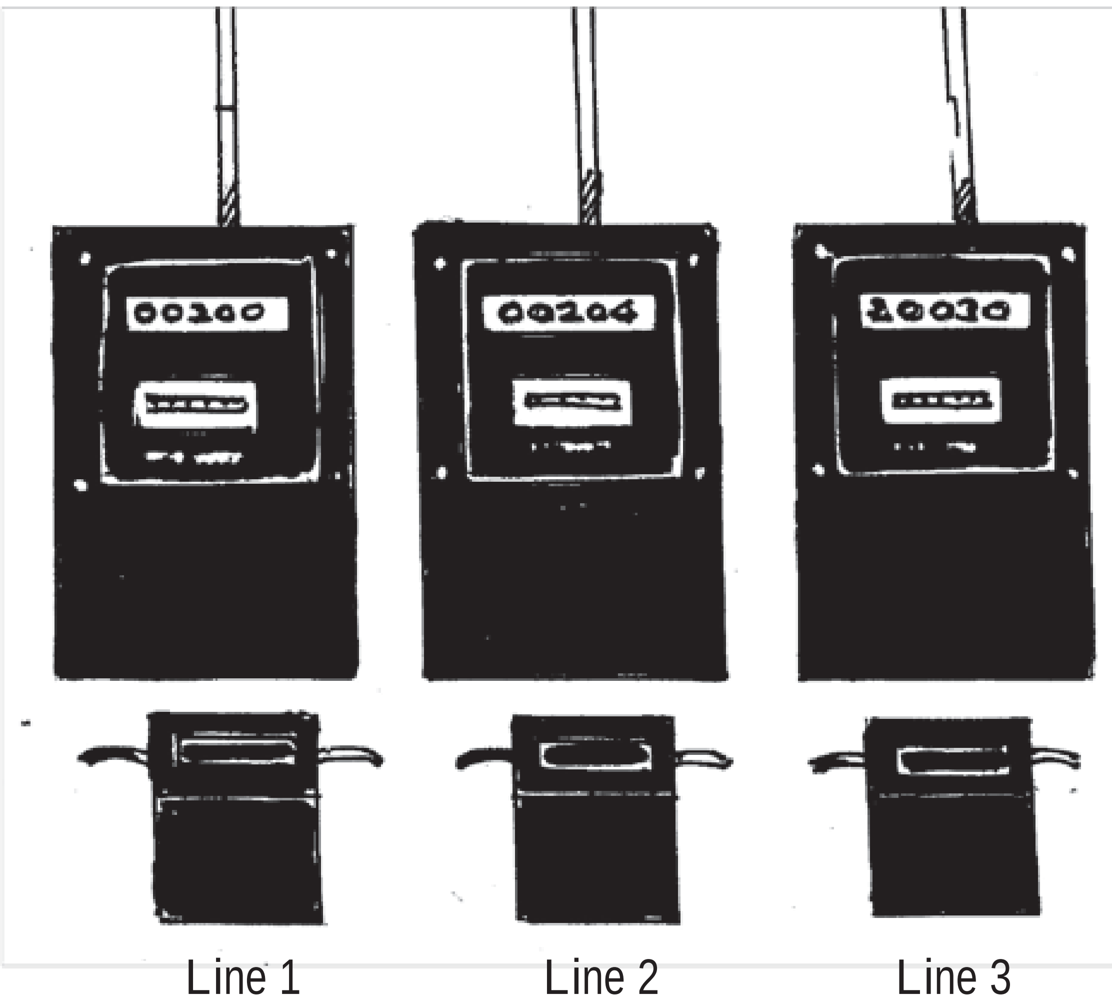
Control Panel



k. DISTRIBUTION PANEL

Distribution panel gives additional safety for the beneficiaries. There are overload cut off switches and earth leakage trip switches for each distribution line. In case of any electric shock or fault in the distribution lines, the relevant line will get automatically switched off.

Distribution Panel



l. DISTRIBUTION LINE

According to the nature of the distribution (scattering) of the houses in the village, the electrification scheme may have one or a few number of distribution lines that starts from the power house. Generally aluminum (bare/insulated) conductors are used to reduce the cost. However, the copper wires have a better performance but they are comparatively expensive.

6. Applications &

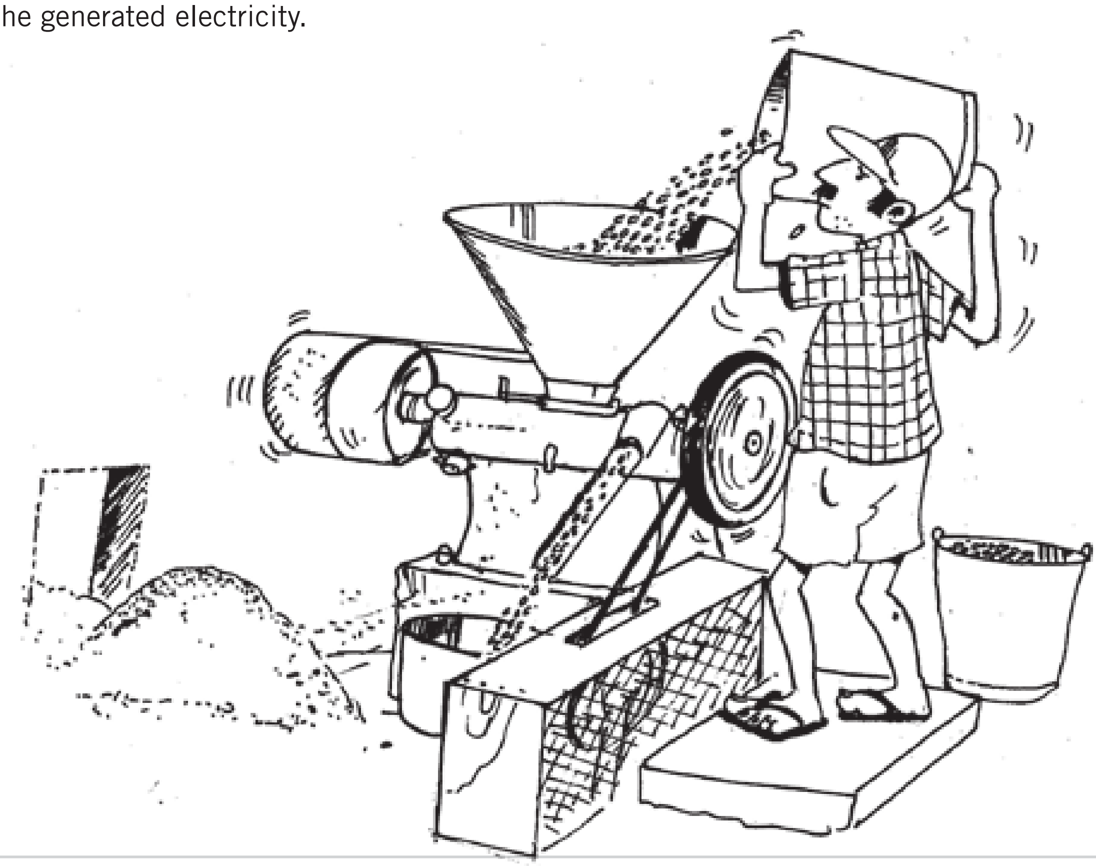
LOAD CALCULATION

Our past experience has shown that the demand for electricity in the villages reaches the maximum level around 1800 hr to 2200 hr. The appliances used by community members of a village to meet their basic energy needs, their power rating and the number of items they may typically use are given in the following table. From this, the maximum demand at a time for power can be calculated.

Appliance	Power (W)	No. of items	Total power (W)
TV (Colour)	70	1	70
CFL bulb	10	4	40
CFL bulb	7	5	35
Radio	10	1	10
Total power			155

In the above example, the maximum demand from a household is worked out to be 155 W and as designers, each house can thus be designed for 200 W leaving a safety margin. Therefore, if a village of 50 families with similar demands for power should be designed for a micro-hydro scheme - 50 x 200 W = 10,000 W = 10 kW to be the minimum required power generation.

During the day time, the electrical power for the above appliances is not used often. Therefore, other activities such as ironing cloths, battery charging and any other economic activity can be undertaken using the generated electricity.



Practical Action
Regional Programme (India, Pakistan, Sri lanka)
5, Lionel Edirisinghe Mawatha, Colombo 5, Sri Lanka.
T I +94 - 11 - 2829412
F I +94 - 11 - 2856188
E I srilanka@practicalaction.org.lk
W I www.practicalaction.org www.janathakshan.net