GGGI

Module 9 - **Trainers Guide**

Pico Hydro in the Community

ENGLISH - SOLOMON ISLANDS

Funded by:

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Cover photo: Pico-Hydro System in operation. Source: Powerspouts, New Zealand.

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The "Pico-Hydro in the Community" training module is an introduction to the fundamentals of Hydro power systems.

Upon completion of the course, the learners will achieve the following learning outcomes:

- Describe Hydro Energy
- Explain the basic electrical parameters (V, I, P and E, AC, DC)
- Identify the various components used in a Hydro Power System
- Explain the function of each component in a Hydro system
- Describe the various types of Hydro Systems
- Identify basic test equipment and demonstrate its correct and safe usage
- Discuss key factors to consider when purchasing Hydropower system and/or its components
- Describe the importance of maintenance of Hydro Power Systems

OPTIONAL:

- Identify basic test equipment and demonstrate its correct and safe usage.

ADVANCED KEY LEARNING OUTCOME

- Assess the size of a potential hydropower scheme

HOW TO USE THIS GUIDE

The trainer guide is provided with the class notes and includes activities which need to be done after each section of the course. The guide acts as a recommendation only. After seeing the situation on the ground in each community, the experienced trainers may use their judgment to modify their delivery and assessment techniques to achieve better results.

The Trainer Guide provides detailed notes written in the form that can be directly delivered to the learners. However, the very detailed notes are intended to broaden the knowledge of the learner as well. You are not required to read each paragraph from the Trainer Guide, but you are expected to know the materials sufficiently to train others. Firstly, you must know what key concepts the learners need to learn. These are normally called learning outcomes. The learning outcomes are all listed at the start of the Trainer Guide, and you must ensure that at minimum, every learner achieves those 7 learning outcomes. You are required to take at least a week to go over the TG and go through the activities in the Learner Workbook. During the actual training you can refer to the Trainer Guide and explain it to the learners in your own words. If you are unsure of something always refer to the TG notes. Also note to take heed of the time recommended for each session and activity.

In case where learner literacy levels are low, trainers are advised to adapt to the situations and modify activities as appropriate. It is advisable to keep a continuous record of competencies of learners. All competencies are achieved when learners fulfil all learning outcomes.

HOW TO CONDUCT ACTIVITIES

Activities are best done in groups or pairs. It is recommended that in each group there is at least one who is more literate or a more active learner who can help to translate and explain the training contents to learners who are slower to understand.

- You may divide the learners into groups of at least 2 and preferably 3-4 learners and ask them to carry out a rigorous discussion within the group. Some activities can be given to the groups for overnight preparation. The trainer needs to be aware of the dynamics of relationships in the community when dividing learners into groups. Sometimes women and youth are not free to share their views when the men from the communities are present. The trainer should ideally ask learners for their guidance when organising them into groups for discussions.
- Ideally the learners may present the results of their activities to the class and have a class discussion based on their findings.
- It is not necessary that all groups present in the same activity.
- However, it is important that all groups are given opportunity to present or verbally discuss their answers.
- At all times, encourage learners to be interactive and participative in class.
- Learners must be encouraged to be vocal and to contribute actively in class discussions.
- To better improve learning, the learners must be encouraged to strongly inquire about the topics through questions.
- The activities allow trainers to observe if the learners have achieved the learning outcomes. If possible, do keep record of the learner's achievement of learning outcomes so that you can help them learn better. A sample record table is given in this guide.
- Adapt existing activities and/or alternative suitable activities in case the desired literacy levels of learners are not met or the desired resources are not available.

TEACHING TOOLS

The following tools/items may be required to enhance learner learning:

- Laptop/ computer and projector to play videos or present notes to the whole class. This will depend on availability. In case this is not available, you are recommended to take large prints of the key concepts and display to the learners while teaching.
- Provide each learner with pen or pencil, and paper to allow them to participate.
- Whiteboard and markers or black board and chalk can be made available to allow both facilitator and learner to state a point.
- The Learner Progress Record sample given below can be used to observe learners, note their feedback, and assess if they have achieved the specific learning outcome. This recording is useful for both the learner and trainer so you can focus on those who are falling behind. Note there are no marks to be awarded and the record is only to improve learning. This is entirely optional.

TABLE 1: **Learner Progress Record- (optional for trainers to use)**

Learner Progress Record (Optional)	Date:
Learners Name:	
Learning Outcome	**Achieved Outcome (Yes or No) and Comments**
1. Describe hydro energy	
2. Explain the basic electrical parameters (V, I, P and E, AC, DC)	
3. Identify the various components used in a Hydro Power System	
4. Explain the function of each component in a hydro system	
5. Describe the various types of hydro power systems	
6. Identify basic test equipment and demonstrate its correct and safe usage	
7. Discuss key factors to consider when purchasing hydropower system and/or its components	
8. Describe the importance of maintenance of Hydro Power Systems.	

LESSON PLAN AND TIMES

TABLE 2: **Lesson Plan and recommended timing of each session**

Chapter	Lesson Type	Recommended Time
1. Ice Breaker - Introductions	Theory and activity 1	30 minutes
2. What is Hydro Energy	Theory	20 minutes
	Activity 2	30 minutes
	Activity 3	10 minutes
3. Basics of Electricity	Theory	30 minutes
	Activity 4	20 minutes
4. Components of Hydro Power systems	Theory	10 minutes
	Activity 5	25 minutes
5. Type and size of Hydropower Systems	Theory	45 minutes
	Activity 6	60 minutes
6. Safety in Hydropower Systems	Theory	20 minutes
	Activity 7A (optional)	20 minutes
	Activity 7B	20 minutes
	Activity 8	20 minutes
	Activity 9 (Optional)	10 minutes
7. Purchasing Hydro Power Systems	Theory	40 minutes
	Activity 10	30 minutes
8. Maintenance of Home Hydro Systems	Theory	30 minutes
	Activity 11	30 minutes
	Activity 12 (Optional)	40 minutes

1

Ice Breaker Introduction

Trainers must understand that the learners who are attending the module have taken time from their usual daily activities which sustains their livelihood. Most will also be very nervous and unclear regarding what the module is all about. Hence the trainer must ensure that the learners are comfortable and not too nervous. It is important to make them feel at ease so that they can focus on the module and absorb as much knowledge as possible.

Tell them that this is an informative module and there will be no tests or marks in this. You must inform them that this module is being run so that they can take the information to help themselves to transition to renewable energy. Even if they do not use it, they can always use the knowledge to help others. In any way this module will better equip them to help grow their communities. Tell them to be at ease and focus on enjoying the day and asking as many questions as they want. Also tell them to not worry too much about complicated things as you will guide them through this.

ACTIVITY 1

Introduce yourself briefly to the learners. Ask if they are all comfortable at the venue. One by one ask them their names and tell them to give some details about themselves – such as what they would normally be doing at that time and what they hope to gain from the module at the end of the day. In addition, if time permits – ask them what they think about hydro energy. There is no correct answer, and the goal of this activity is simply to get them relaxed and engaged into the session. You may crack few light jokes as laughter always lightens the mood and helps learners relax. Ask the learners about their prior experiences in hydro energy and how much they know about the topic. Also ask them what they wish to gain from this training session and record their answers on paper so that it helps the trainer in setting a direction to the course. This input will help the trainer direct the training to the learners needs.

2

What is Hydro Energy

2.1 What is Energy?

Energy is the ability to do work. Energy cane be changed from one form to another and then use it to do work. Some of the forms of energy are:

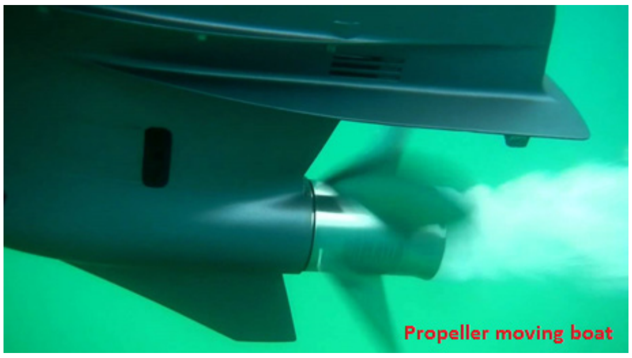
- **Heat energy** – Recall when you started a fire to boil some water. When you come near a fire you feel hot due to this energy.

FIGURE 1: How Heat Energy Boils Water[1]

The burning wood gives out heat energy and heats the pot. This heat helps to boil the water. The heat energy gets transfered to water. We all know how hot boiled water is.

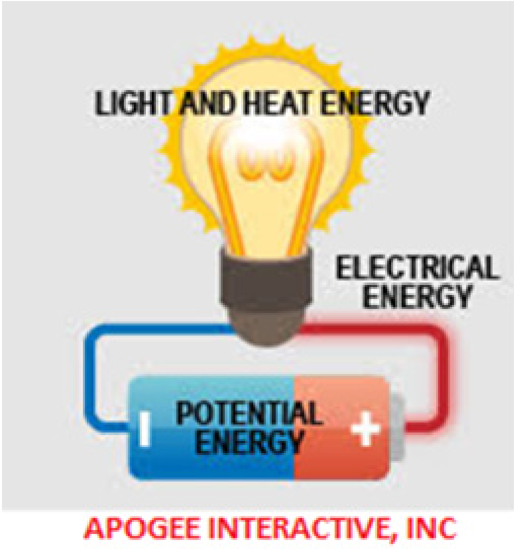
- **Mechanical energy** – this is the energy; your boat engine gives to rotate the propeller to move the boat. Similarly, the energy, a car engine gives to the tires to move the car.

FIGURE 2: Mechanical Energy from propeller[2]



- **Chemical energy** – Inside batteries, chemicals are used to store energy so you can use that to; turn on a radio, charge your phone or lights at night.
- **Electrical Energy** – this is the energy that flows through the wires to give power to your appliances.

FIGURE 3: Electrical Energy[3]



2.2 What is Hydro Energy?

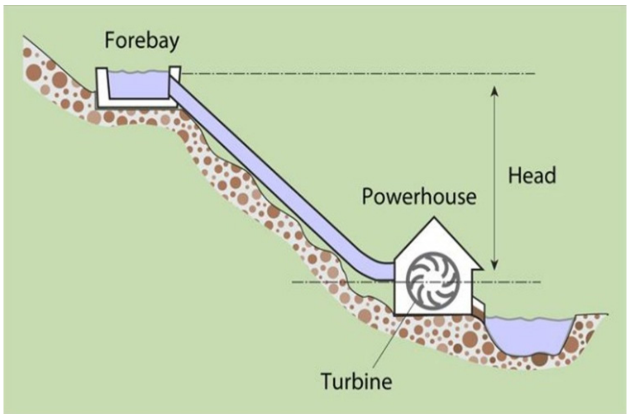
Hydro energy is power derived from the energy of falling or fast-running water, which may be harnessed for useful purposes. Hydro energy is a renewable energy. Since ancient times, hydropower from many kinds of watermills has been used as a renewable energy source for irrigation and the operation of various mechanical devices, such as, sawmills, textile mills, etc.

Storage schemes – uses a dam or reservoir to store water from the flow of a river before it is released to a turbine to generate power for electricity use. This allows rainfall to be accumulated and used in both wet and dry seasons of the year. However, such hydro systems are usually complex, expensive, and applicable for large hydro applications only.

1 Source: Pikrepo, https://p0.pikrepo.com/preview/673/890/black-cooking-pot-on-fire.jpg, accessed on 16 June 2021.
2 Source: Wonderful engineering, https://wonderfulengineering.com/wp-content/uploads/2017/02/why-boats-have-propellers-at-the-back-1024x576.jpg, accessed 16 June 2021.
3 Source: APOGEE, https://www.apogee.net/, accessed 16 June 2021

Run-of-river schemes – diverts a portion of the flow of a running river to a pipe or channel then to a turbine to generate power. This is simpler to build and can be done locally at a low cost with less damage to the environment such as flooding. On the other hand, water is not used between wet and dry seasons and more appropriate designing is needed for this.

FIGURE 4: Basic Hydro power setup[4]



2.3 What is Pico Hydropower?

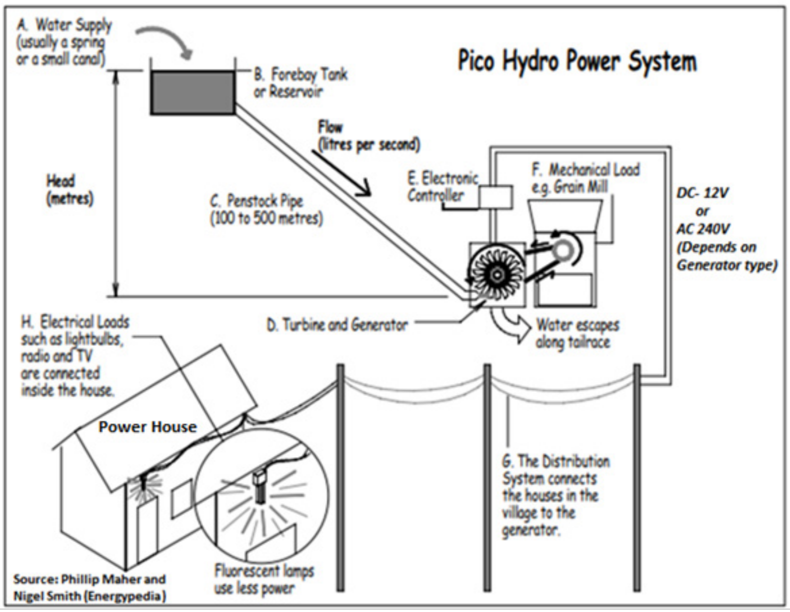
The concept of pico-hydropower (PHP) is like hydro power plants but at a much smaller scale. It is usually situated and designed for homeowners and agricultural use, but rarely used for grid power. For pico-hydro to work, there should be at least a total vertical drop of 1 metre and high flow rate of water. Pico-hydro setups typically are run-of-stream, meaning that a reservoir of water is not created, only a small weir is common, pipes divert some of the flow, drop this down a gradient, and through the turbine before being exhausted back to the stream.

The small Pico-hydro is like standalone solar PV systems where the generated energy is stored in batteries and used as and when required. Pico-hydro systems, utilize the potential energy in flowing water, to rotate a turbine and the kinetic power generated is converted into electricity using an electric generator. A typical setup:

A. Usually a small dam, normally referred as Weir created to direct the water source into Forebay tank (B)
B. Reservoir hold some water to direct the water into penstock (C)
C. Penstock carries water flow to a turbine (D)
D. Turbine. With the potential energy of water, the turbine rotates which is connected to a generator, generating electricity, or can be connected to any mechanical load (as shown as F).
E. Controllers are used to control/regulate the power output.
F. Transmission line carrying power to household.
G. The power generated can be either DC-12V or AC-240V. This is largely dependent on type of generator you are using and the power you are expected to produce.
H. House will equip other equipment. If DC power is transmitted, then battery, charge controllers, inverters and load will be required. If AC power is transmitted, then only AC load will be required.

The pressure provided by the drop in altitude, between forebay and powerhouse (household) is called **Head and is measured in meters.**

FIGURE 5: Typical setup of a pico-hydro system[5]



4 Source: U.S Department of Energy, "Planning a Micro Hydropower System", https://www.energy.gov/energysaver/planning-microhydropower-system

5 Adapted from the International Journal of Research in Engineering and Technology, " Design and Development of Pico Micro Hydro System by Using House Hold Water Supply, https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.672.5203&rep=rep1&type=pdf

FIGURE 6: Schematic and pictures of a typical Pico-hydro System[6]

ACTIVITY 2

1. **Do you think the use of hydro damns reduces pollution?**

Answer: Yes, the use of water to generate energy, does not create any pollution.

2. **What forms of energy can a hydro energy system can produce?**

Answer: Electricity and Mechanical energy

3. **Can hydro dams interfere with natural wildlife?**

Answer: Yes, Dams can affect migratory fish patterns and spawning habitats.

ACTIVITY 3

1. **Discuss in class if you have seen a hydropower system (like shown in figure 4)? Share your experience**

Answer: The learner may have seen a small community hydropower system, or they must have heard or seen a hydropower system used in their country. Encourage the learner to explain how much power may be produced by that system, can there be any threat to marine life, is there any pollution from this, do they see any other benefit? Learners will have different views. Encourage the learner to share their experience and have peer to peer discussions.

6 Source: News Sewa, June 2021, htttp://www.newssewa.com and DocPlayer, Manual for Renewable Energy Source, https://docplayer.net/45114164-Manual-per-burimet-e-energjive-te-rinovueshme.html

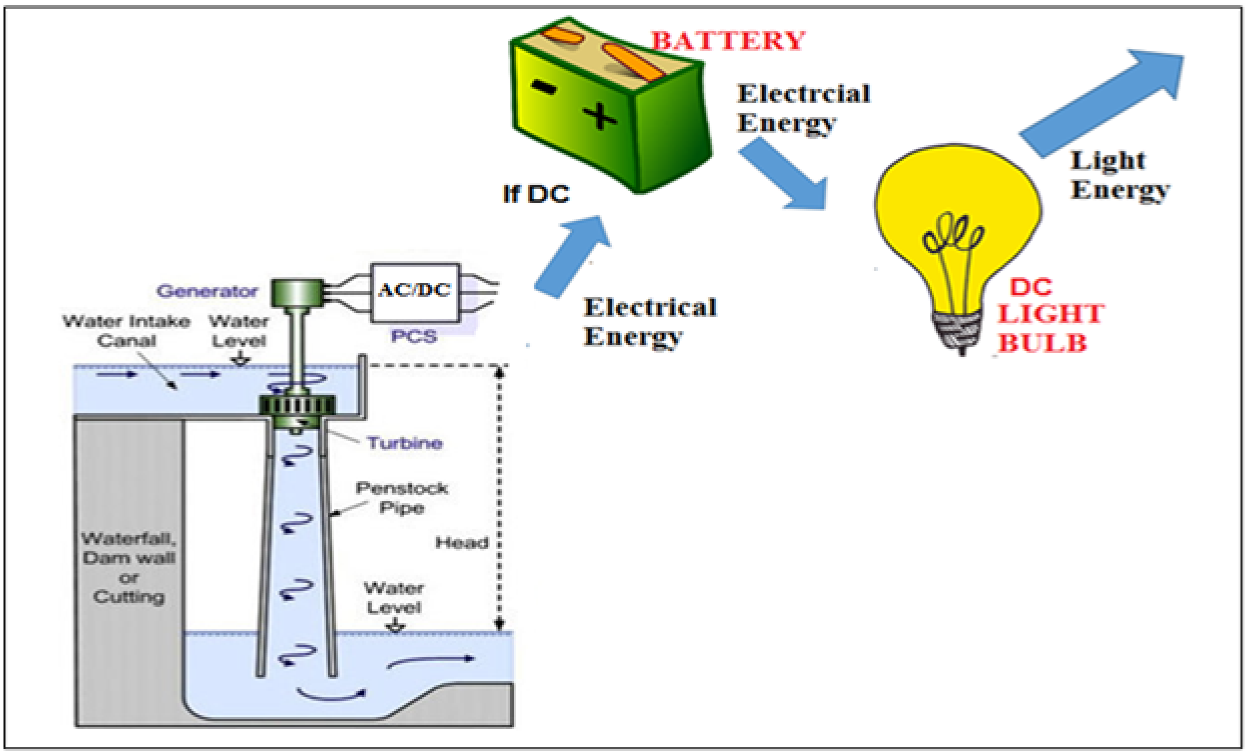
3

Basics of Electricity

3.1 Electrical Energy

Electrical energy is just another form of energy. The unit for measuring energy is Joules. It can come from, hydro or wind or solar or even heat energy. We want to change the water's energy into electrical energy to power lights and other appliances. In the figure below, we see how this happens.

FIGURE 7: How hydro energy changes forms of energy to give us light[7]



In Figure 7 above we see that the Hydro energy is changed to electrical energy by the Hydro turbine/generator. The turbine rotates the generator which generates AC power and power conversion system (PCS) can also be called rectifier converts AC power to DC. AC/DC power will be explained in later section. We can also store this electrical energy in a battery for later use.

3.2 Energy in a battery

The energy in a battery is stored using chemicals. Some batteries cannot be charged, like the small AA sizes while the larger ones which we use with Hydro panels can be charged using electrical energy. The figure below shows a rechargeable battery. Car batteries are rechargeable and though can be used, they are not ideal in a small for large electrical loads over long periods. In well-designed systems special deep cycle batteries are used. These are more expensive but can take greater discharge and loads and recharge cycles.

The most common rechargeable technology is lead acid batteries (like a car battery) though lithium-ion batteries like those used in mobile phones and laptops are starting to be used but are expensive.

FIGURE 8: Lead Acid Rechargeable Battery[8]

7 Source: TDM Electricity, http://www.tdmelec.fr/wp-content/uploads/uploadpeel/minikaplan4.jpg, accessed 21 June 2021

8 Source: JICA

SAFETY: Energy of any form whether electrical energy from a generator or from a battery is very dangerous and can cause harm if we are not careful. Always follow safety rules when working with energy.

3.3 Power

So how will we know how much energy we have used from a battery? Well very simply, we need to divide the energy we used by the time we used it for. In simple terms, we define power as the energy used in a given time. The units of power are Watts (W). We will be more concerned with power than energy when we talk about Hydro systems. We can know how much energy will be used from the battery if we know how much power each appliance needs.

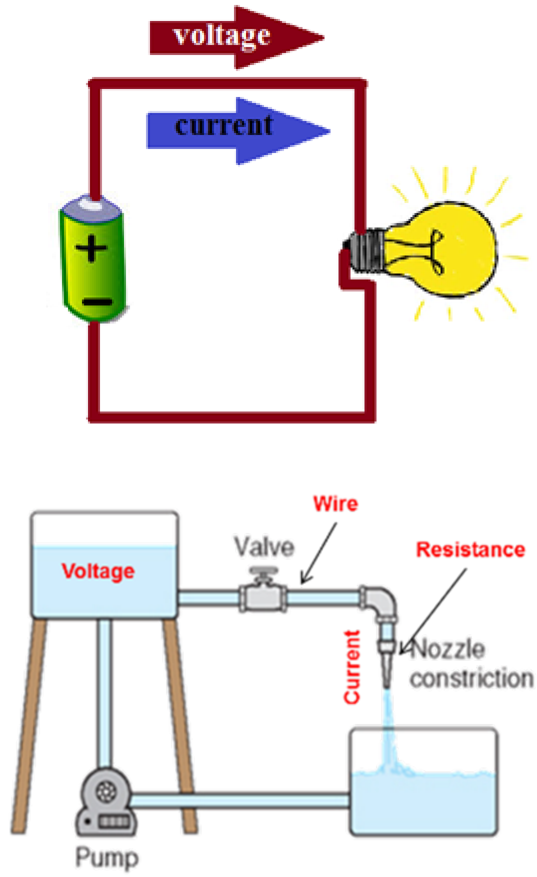
FIGURE 9: A 4W Light Bulb[9]

3.4 Voltage and Current

Voltage is the electrical potential, or the pressure that moves electrons through the wires (conductors) and can be compared to pressure in a water pipe. How is power transferred from the Hydro panels to a battery or to a light bulb or inverter or any appliance? We use copper wires. In these copper wires, power is transferred in two components or parts. Power is moved through the wires as voltage and current.

In technical terms power is carried in wires using electrons, and voltage is the force which pushes the electrons. Current is the collection of these electrons flowing. Just like water will flow from a higher place to a lower place by the force of gravity, current flows through wires using the force of voltage. However, we are not going to go in-depth with this.

FIGURE 10: Both voltage and current makeup power voltage is like pressure in a water tank[10]



Voltage is measured in the unit Volts and current is measured in Amperes or Amps. We always want to know how much current, and voltage are in our wires. We can say voltage is like the depth of a stream, or pressure of the stream while current is the flow of the stream. Even in small shallow streams – if the flow of water is too strong, it can drown us. Similarly, even in low voltage – current can be high enough to kill.

3.5 AC and DC Systems

Power from a battery flows steadily. The current we get from a battery is called direct current or DC because it does not change. In DC or direct current, the current flows directly from positive to negative terminal having one value only. In larger devices, we have AC current or alternating current where the current has a wavy form. In AC system, we have live, neutral and earth.

9 Source: Shopee.com, Philips Led Lights 4 Watt Yellow and White Colour, https://shopee.com.my/PHILIPS-4-WATT-LED-LIGHT-yellow-and-white-i.267756065.3536838685
10 Adapted from the Electricity Basics, Arizona State University (VOCTEC), http://voctec.asu.edu

FIGURE 11: Polarity of Battery[11]

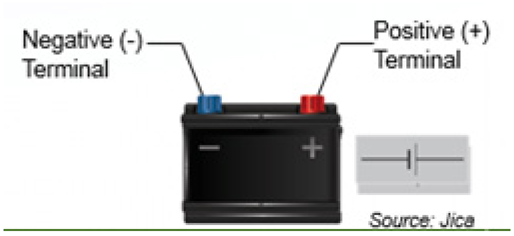
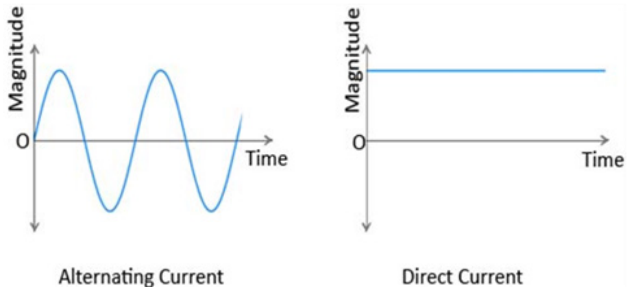


FIGURE 12: AC and DC have different voltage and current magnitude over time[12]

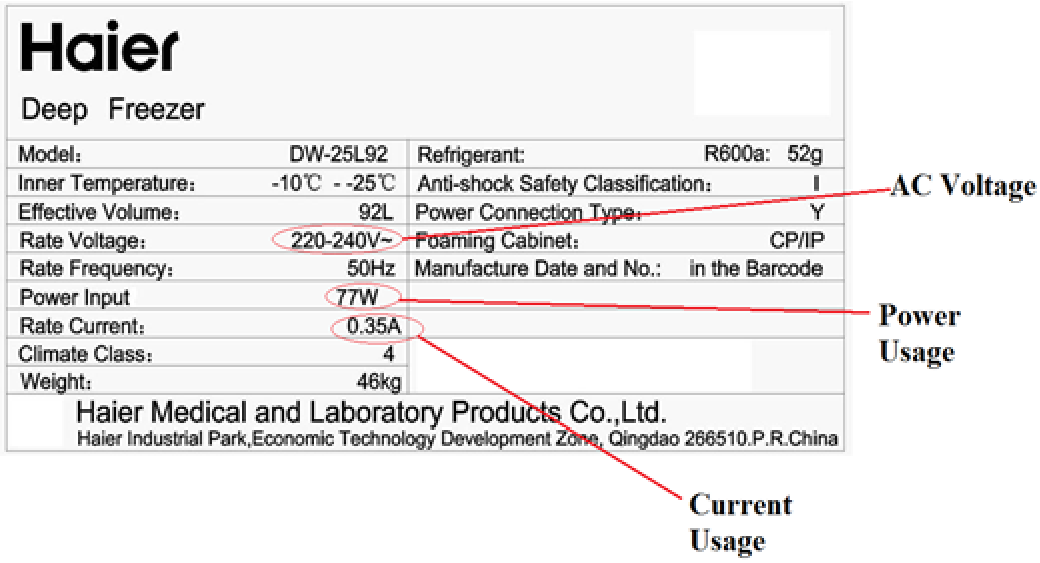


AC voltages are normally much higher, and most grid systems use AC to transfer power to homes. Hence the power coming from the power lines to your homes and flowing in homes is AC. Most appliances such as TV's, Radio; etc. are built to work within 220 to 240 Volts AC. This means that they will not work on a 12 volts DC system. Since Hydro gives out DC 12 to 24 Volts, we normally use a device called an inverter, to increase the voltage to 240 volts and change the Direct Current (DC) flow into Alternating Current (AC) flow. We will talk more about an inverter later. Normally if the back of an appliance says it runs on 240V it would be AC. A frequency of 50 -60 Hz stated on the device, means it is an AC appliance. Ensure you read the back of the appliances to determine whether it is AC or DC. The back label or the name plate of an appliance also has the information on the voltage and current needed for that appliance.

Here is a sample of a name plate of an AC powered chest freezer.

SAFETY: High Current and Voltage can cause serious injury and even death if they pass through your body. Always avoid bare wires and never ever work on live circuits. Always practice safety or get a qualified electrician.

FIGURE 13: Sample Name plate label of Chest Freezer[13]



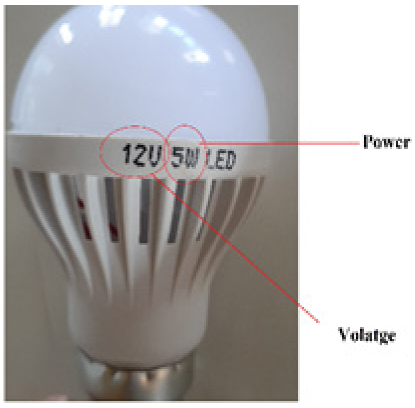
11 Source: JICA

12 Adapted from System Components: Charge Controllers &Inverters, Arizona State University (VOCTEC), http://voctec.asu.edu

13 Source: DocPlayer, "Deep Freezer-upright: HMRSM Haier Medical & Laboratory Products Co., Ltd

Something interesting here, is how power is calculated. We will leave the details for advanced modules. Power is found by multiplying voltage and current together. In case of Figure 13, we see 220V multiplied with 0.35. A current rating will give us a power of exactly 77W which is written on the Power input label. This may be useful if the power is not given directly, we can use the voltage and current to calculate. Here is a sample of a DC light name plate or label.

FIGURE 14: **DC Bulb Label Details**[14]



ACTIVITY 4

Provide the learners with at least 2 AC appliance nameplates such as AC light bulbs and AC fan. Also provide them with 2 DC appliance nameplates such as a DC bulb and a DC fridge. You must be careful not to separate the devices for them. In their teams they must do the following:

- Identify which devices are AC and which are DC.
- They must be able to read the voltage and current needed to run these devices.
- The must also be able to tell how much power each device will use.

(In case current rating is not given – you may calculate it from power and voltage and show the learners, some basic appliances do not show current on labels)

FIGURE 15: **AC Bulb 220-240V, 3W, 0.01A**[15]

FIGURE 16: ***AC Fan, 220V, 55W, 0.25A***[16]

FIGURE 17: ***DC Light 12V, 6W, 0.5A***[17]

14 Source: Amazon.com, "Led bulbs", https://m.media-amazon.com/images/I/31kJoFKty+L._AC_SY100_.jpg, accessed 21 June,2021

15 Amazon.com, "Led bulbs", https://m.media-amazon.com/images/I/31kJoFKty+L._AC_SY100_.jpg, accessed 21 June,2021

16 Source:Khind.com, https://www.khind.com.my/index.php?route=product/search&search=AC%20Fan%2C%20220V%2C%2055W%2C%200.25A%20, accessed 25 June 2021.

17 Source: AliExpress.com, https://www.aliexpress.com/item/1316122622.html, accessed 25 June 2021.

FIGURE 18: **DC Freezer, 12V/24V, 55W, 4.58 A/ 2.29A**[18]

1. What is the function of inverters?

Answer - An inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC)

2. Why do we need batteries?

Answer – To store excess energy from generator so that it can be used when water level is low.

SAFETY: Energy of any form whether electrical energy from a generator or from a battery is very dangerous and can cause harm if we are not careful. Always follow safety rules when working with energy.

18 Source: Made in China.com, "Solar Freezer", https://m.made-in-china.com/company-commercial-energy/ , accessed 25 June 2021.

4

Components of Pico Hydro Power Systems

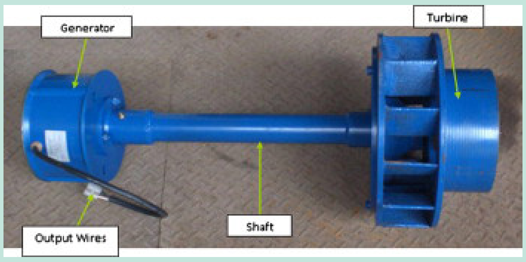
Hydro power systems have various components, which can be used to design and install a Hydropower system. These systems can be a stand-alone and hybrid system with solar system. The main components of a Hydropower system and its function is shown in the table below.

The activity below needs to be covered, while you are introducing each component.

ACTIVITY 5

While covering the notes on each component, show them each component from the available Kit and if possible, pass it around to the learner groups to observe these components.

They can ask questions about these components during this session.

Turbine and Generator Assembly[19] 	Turbine is a device which uses water's energy and converts it into mechanical energy (rotation) and this turbine is connected to generator which produces power.
Penstock (PVC pipe)[20] 	PVC pipe can be used to channel the water from the reservoir to the turbine.
Battery[21] 	A battery is a device that can store electrical energy in the form of chemical energy and convert that energy into electricity. Batteries deliver electricity as direct current (DC) The common batteries produce 12V. Battery connects to the charge controller

19 Source: Researchgate.net, "Typical low head Pico hydro turbine", https://www.researchgate.net/figure/Typical-low-head-pico-hydro-turbine-courtesy-of-Hydrotec-Vietnam_fig1_257414899, accessed 25 June 2021.

20 Source: Creative Commons, adapted from Energypedia, https://energypedia.info/wiki/File:Penstock_La_Laguna.JPG

21 Source: JICA

Charge Controller[22] 	A charge controller primarily controls and regulates the charging of the battery from the generator. It can also limit the rate at which electric current is added to or drawn from batteries. It prevents overcharging and over-discharging and may protect against overvoltage or under-voltage, which can reduce battery performance, lifespan and pose a safety risk.
Inverter[23] 	• An inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC) • A typical power inverter device or circuit requires a relatively stable DC power source (12V, 24V) capable of supplying enough current for the intended power demands of the system The AC output voltage of a power inverter is often regulated to be the same as the grid line voltage, typically 240 VAC, 50 Hz
Cables[24] 	Electrical cables are used to connect two or more devices, enabling the transfer of electrical signals or power from one device to the other. In pico-hydro system, cables are connected from generator to batteries, batteries to inverter, inverters to power outlet, charge controllers to Batteries and dc power loads.
Breaker/Isolator[25] 	• A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by excess current from an overload or short circuit. Its basic function is to interrupt current flow after a fault is detected. • An isolator is a device used for isolating a circuit or equipment from a source of power. An isolator is a mechanical switching device that, in the open position, allows for isolation of the input and output of a device.
Electrical Power Outlet[26] 	A power outlet connects electric equipment to the alternating current (AC) power supply in buildings

22 Source: Solar4rvs.com, "Victron Smart Solar MPPT Charge controller, https://www.solar4rvs.com.au/assets/full/VIC-SCC110020160R.jpg?20210204030925, accessed 25 June 2021.

23 MorningStar, May 2021, https://www.morningstarcorp.com/products/suresine/

24 Source: Global Market, http://newimg.globalmarket.com/PicLib/group0/5e/73/c477defc613ecc9a0e47b82452f4 1.jpg

25 Source: Wave inverter.co, https://waveinverter.co.nz/shop/solar/solar-connectors/pv-dc-isolator-switch-mc4/ and POSO.com, http://poso.com.vn/wp-content/uploads/2020/04/1-2.png

26 Source: Eurotech NZ, "PDL 600 Series Power Points", https://www.kiwisparks.co.nz/collections/pdl-600-series-power-points/products/pdl-691, accessed 25 June 2021.

5

Types of Hydro Systems

5.1 Types of Classification of Hydropower

Hydro power systems can be classified as low, medium, and high head hydro. This refers to the head i.e., the height the water drops. This precise boundaries between these are not rigid but typically summarised Table 3 below.

TABLE 3: Classification according to "Head"

Classification	Head
Low	1-30m
Medium	30-100m
High	100m and above

5.2 Sizes of Hydropower

There are 6 types of hydro systems. These are set out in Table 4..All systems have the same concept, but the power output depends on how much water flow you have, and what can be the height distance (vertical distance) between reservoir and turbine. Usually for village community, a Pico or Micro hydro is commonly used.

5.3 Pico-Hydro

A Pico-hydro system is a small system (less than 5kW). It does not need large water flow and vertical distance. These are mostly used in small remote commnities and is the cheapest hydro solution and can be only few 100 watts and can be DC or AC voltage (will be covered in later on). Figure 19 below provides examples of pico hydro systems.

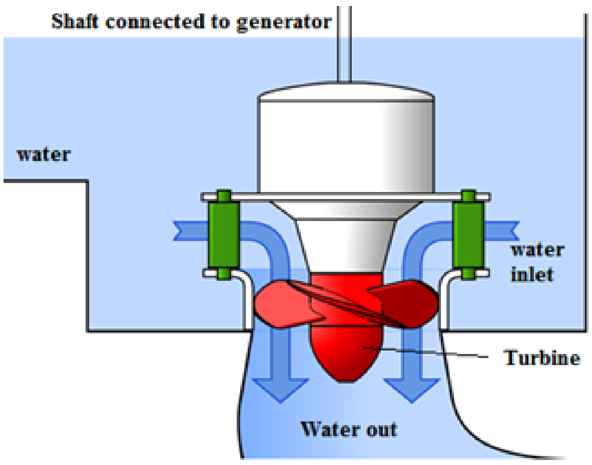
TABLE 4: Types of Hydro System

Classification	Plant Output (Capacity)
Pico-hydro	Less than 10kW
Micro-hydro (MH)	10kW-100kW
Mini hydro	100kW – 1 MW
Small hydro	1MW – 10MW
Medium hydro	10MW –100MW
Large hydro	More than 100MW

FIGURE 19: Pico-hydro system

A[27]

B[28]



27 Source: Baylor University, adapted from Wikipedia, "Pico Hydro", https://en.wikipedia.org/wiki/Pico_hydro

28 Source: Mechanical E- Notes, https://mechanicalenotes.com/wp-content/uploads/2019/08/kaplan-turbine-diagram-1000x550.png,accessed 16 June 2021.

5.4 Micro-Hydro

Micro-hydro (5-100kW) system is like Pico and the only difference is the type of turbine that can be used, as well as the generator capacity is bigger.

FIGURE 20: Micro -Hydro System[29]

5.5 Mini Hydro

FIGURE 21: Micro-hydro system[30]

5.6 Mini large hydro system

Mini to large hydro systems uses the same principle. However, this can be further classified into 2 different system (shown on the right is run off river and left is a hydro dam application). A hydro dam system (shown left in Figure 22) is mostly used to power large systems, where more control is available.

FIGURE 22: Left- hydro Dams & Right- Run off River[31]

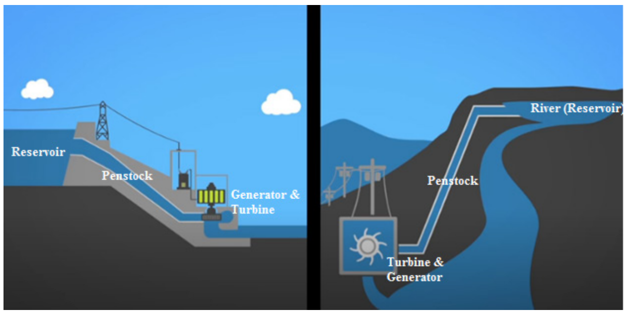
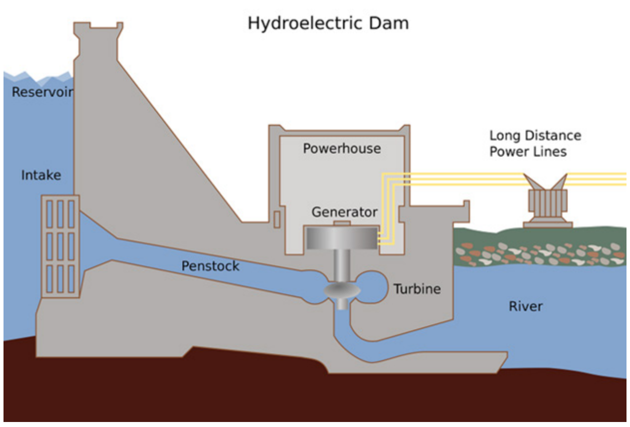


FIGURE 23: A Typical Large Hydro Power System[32]



29 SUNECO Hydro Turbines, June 2021, https://www.micro-hydro-power.com/

30 Source: Pinterest.com, "Mini hydroelectric Pelton Turbine, https://www.pinterest.com/pin/431360470538243882/

31 Earth & Science Space, "Hydroelectric power generation, https://grade8science.com/7-3-1-what-existing-technologies-could-solve-the-problem-of-global-warming/ or watch YouTube video: Student Energy, "Hydropower 101", 18 May 2015, https://www.youtube.com/watch?v=q8HmRLCgDAI

32 Source: Wikimedia Commons, Hydroelectric Plant, September 2015, https://upload.wikimedia.org/wikipedia/commons/thumb/5/57/Hydroelectric_dam.svg/2000px-Hydroelectric_dam.svg.png

5.7 Types of Turbines

The turbine converts the potential energy in the water into kinetic energy i.e. rotation energy. Depending on the head and flow (i.e. amount of water) governs the type of turbine used.

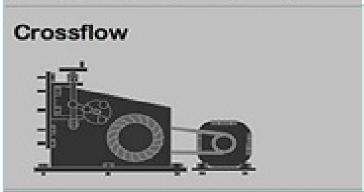
Turbines fall into two categories impulse and reaction turbines.

TABLE 5: Types of Turbines used at different water characteristics

Types of Turbines	Water Head (m)	Water Flow (litres/sec)
Propeller Turbines	1 - 5	14 - 55
Turgo Turbine	2 - 30	8 - 16
Pelton Turbine	3 - 130	0.5 - 8

FIGURE 24: Types of Turbines[33]

- The Pelton is a turbine used for a site that has a high head and low flow for a given output power and rotational speed
- Turgo is used at sites that have a head slightly lower than that of a Pelton, and a slightly higher flow than the Pelton for the same power output.



- The cross-flow turbine is a low-speed machine that is well suited for locations with a low head but high flow.

- These operate at very low heads and high flows.

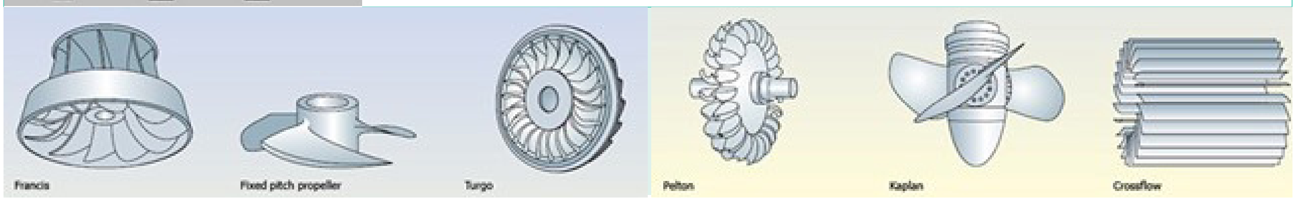


FIGURE 25: Propeller Turbine (exploded view)[34]

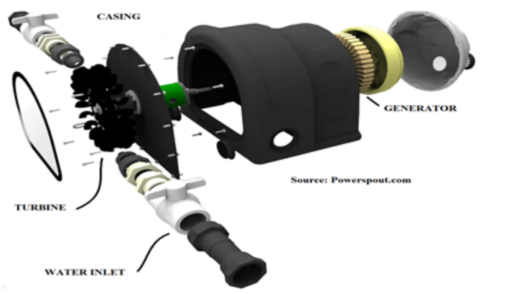
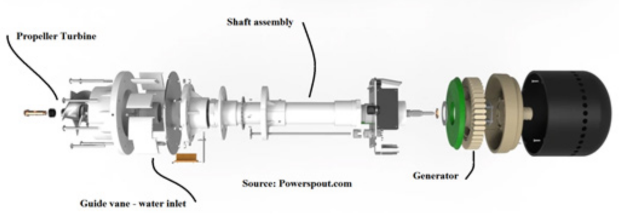


FIGURE 26: Propeller Turbine Generator (Exploded view)[34]



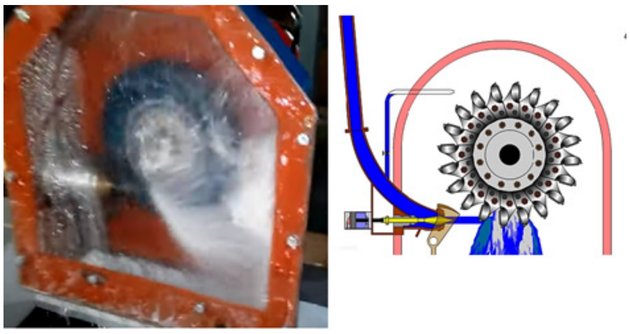
33 Source: Public Research Institute, June 2021, http://www.publicresearchinstitute.org/Pages/hydroturbines/images/TypesOfHydroTurbines.jpg

34 Source: Powerspout.com, accessed 16 June 2021.

5.7.1 Action of water on Turbine

In a hydro system, water having a potential energy (while being at height) is converted to mechanical energy, when water jet hits the turbine forcing the turbine to rotate, as shown in figure below. Refer to for better understanding.

FIGURE 27: Water forcing Turbine to Rotate[35]



ACTIVITY 6

1. **Imagine a water source (creek, streams, waterfalls etc) in your local area. Draw with the idea of Pico-hydro system, how you can use this water to generate electricity. Label major setup component**

Answer: Encourage the learner to visualise the water source and a pico-hydro system. They should make catchment, penstock, turbine-generator etc. They should also draw how far the system will be from their house and how can they make the system easy to use.

2. **In hydropower system, identify some hazards which needs to be considered closely.**

Answer:

- Slip while working in wet areas – can lead to severe bodily harm or death
- Electric shock – severe bodily harm or death

3. **What are the three different classifications hydro power systems?**

Answer: Refer to Table 3

4. **Name three different types of turbines that are most likely to be used in a pico-hydro system.**

Answer: Refer to Table 5

35 Source: www.mekanizmalar.com also see YouTube video: mekanzimalar, "Pelton turbine", 12 October,2013, https://www.youtube.com/watch?v=qbyL--6q7_4

6

Safety in Hydropower Systems

Whether you are a technician who often works with electricity, or a non- technical person who simply owns or operates a solar power system, safety should be the first concern when dealing with Hydropower systems. A hydropower system produces electricity, and a battery stores large amounts of electricity, which if not used or maintained correctly, can cause electric shock, fire, and injury. No matter how small or large a power system is, you may never let your guard down when dealing with electrical systems. Here are some very important safety tips to follow to stay safe and keep others safe when dealing with Hydropower systems.

1. Always turn the power off before making any additional connections or adjustments. Never attempt to work on a circuit which is still active with power.

FIGURE 28: Warning Signs[36]

2. Always get a trained electrician to do house wiring. Never attempt to do house wiring yourself.

FIGURE 29: Wear Insulated Gloves[37]

3. Always wear PPE (personnel protective equipment) such as insulted gloves, eye goggles and safety footwear.

4. Never attempt to repair faulty batteries on your own. Batteries contain dangerous chemicals which can cause serious harm.

FIGURE 30: Acid Warning[38]

5. Never store batteries near a fire or inside living rooms – some batteries give of toxic gases even if we do not see this.

FIGURE 31: Fumes Warning[39]

6. Never store batteries in confined spaces or near fuels as they can cause a fire from sparks. Always place batteries in well ventilated areas. Lead acid batteries give off small quantities of hydrogen gas over time so must be in placed in well ventilated areas.

FIGURE 32: Battery Warning[40]

36 Source: AviationPros, https://www.aviationpros.com/tools-equipment/safety-equipment/article/11148860/ground-handling-safety-signs
37 Source: Safety workblog.com, https://safetyworkblog.com/assets/understanding-the-2015-edition-of-nfpa-70e-the-arc-flash-hazard.jpg
38 MSDS online, https://www.msdsonline.com/2014/07/22/sulfuric-acid-safety-tips-sulfuric-acid-msds-information/
39 Source: National Safety Signs, https://nationalsafetysigns.com.au/wp-content/uploads/2020/02/D10332-Toxic-Fumes-sign.png
40 We Need Signs.com, "Ansi Battery Charging Safety Signs", http://www.weneedsigns.com/home.php?cat=403

7

Purchasing Pico-Hydropower Systems

While we have just learnt about some Hydro system basics, let's look at how to use the knowledge in shopping for a pico-hydropower system, or buying good replacement parts.

7.1 Buying a home Hydro system

Hydropower system is quite complex until you identify what size system you require. Let's spend some time talking about how to go about purchasing these items. For simplicity, we will not go into calculations, and we assume you have talked to a Hydro expert who has advised you on the system sizes. Usually the "Department of Energy" will have some information on this which will help you to choose what system to buy and from where.

7.2 Some questions to ask the seller

1. Does the product have any warranty? – what if you take the turbine/generator home and it stops working in 3 days- will the seller replace or repair it? A warranty assures you that any faults for a certain time will be taken care of by the seller.

A longer warranty is always better. For example, buying a system with a 10-year warranty, is better than a system with 1-year warranty. Regardless of any part – ask if they give warranty. It is better to spend a few dollars and get a good quality branded product with warranty, as it will last longer.

FIGURE 33: Warranty Symbol[41]

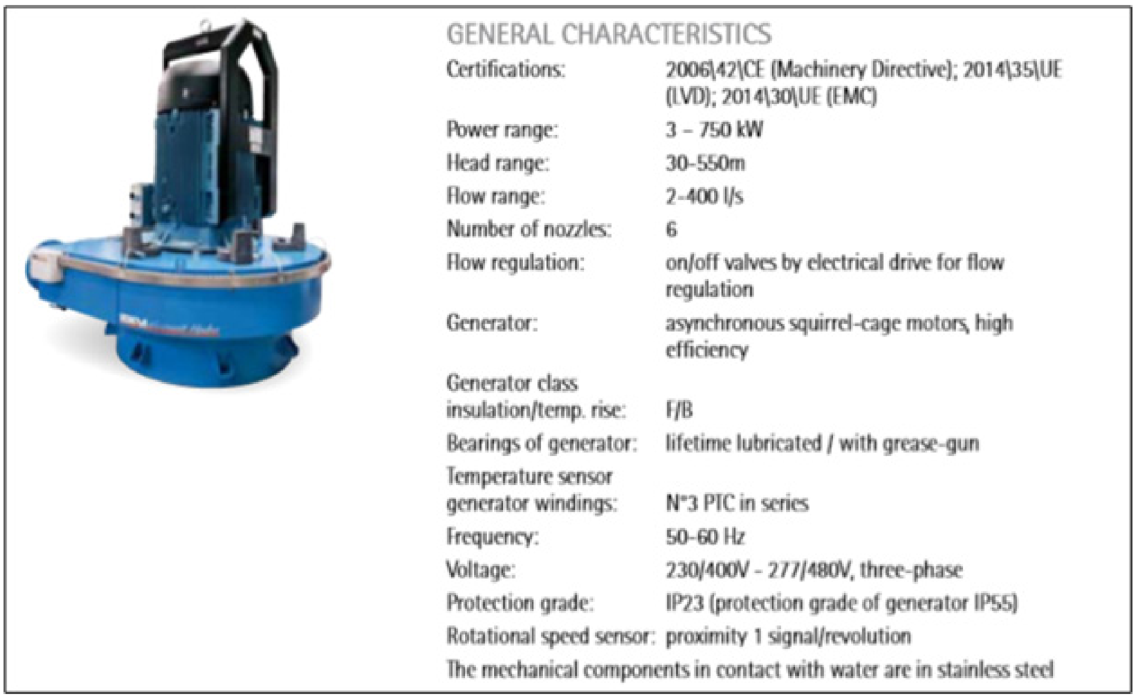
2. What type of turbine is in the system? What is the power output of the generator? Is the system DC or AC. If AC, ask is the automatic voltage regulator included. Get the details of general characteristics of the system.

FIGURE 34: Types of Turbines[42]

41 Source: PNGWING, https://www.pngwing.com/en/free-png-kfvth

42 Source: Power Spout, June 2021, www.powerspout.com

FIGURE 35: General Characteristics[43]



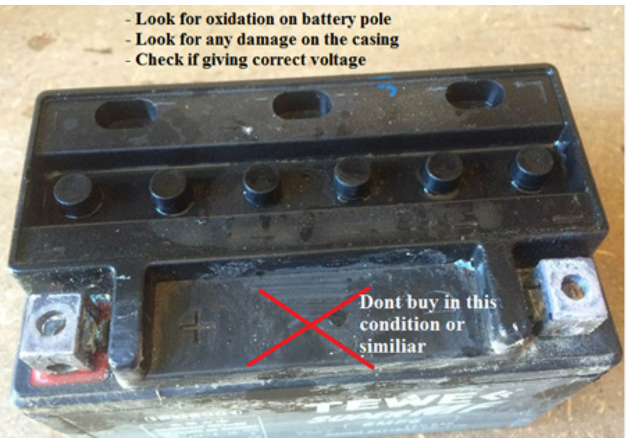
GENERAL CHARACTERISTICS

Certifications:	2006\42\CE (Machinery Directive); 2014\35\UE (LVD); 2014\30\UE (EMC)
Power range:	3 – 750 kW
Head range:	30-550m
Flow range:	2-400 l/s
Number of nozzles:	6
Flow regulation:	on/off valves by electrical drive for flow regulation
Generator:	asynchronous squirrel-cage motors, high efficiency
Generator class insulation/temp. rise:	F/B
Bearings of generator:	lifetime lubricated / with grease-gun
Temperature sensor generator windings:	N°3 PTC in series
Frequency:	50-60 Hz
Voltage:	230/400V - 277/480V, three-phase
Protection grade:	IP23 (protection grade of generator IP55)
Rotational speed sensor:	proximity 1 signal/revolution

The mechanical components in contact with water are in stainless steel

3. Check for signs of damage – Do not buy damaged products. Always ask the seller to show you if the product works. If components appear; cracked, dirty or damaged do not buy them. If batteries appear leaking or bloated – do not buy them.

FIGURE 36: Checking for any damage[44]



4. For batteries you may ask the seller to show you the battery voltage through measurement. For a 12V lead acid battery – the voltage must not drop below 12V.

5. Rotate the turbine to see free movement. Ask if the supplier can show that generator is producing power (if he can do a test run).

FIGURE 37: Seek assistance from seller[45]

6. Look for branded products – Search for products with proper brands and logo and instruction manuals. Do not buy products with no brands, poorly written or missing instruction manuals.

7. When selecting inverters, ask the seller if the output of the inverter, is a pure sine wave. It must be stated on the inverter, that it is a sine wave inverter. Check the voltage and wattage on the labels or name plates.

43 Source: Direct Industry.com, "Hydraulic turbine", https://www.directindustry.com/prod/irem-spa/product-16995-2302864.html, accessed 25 June 2021.

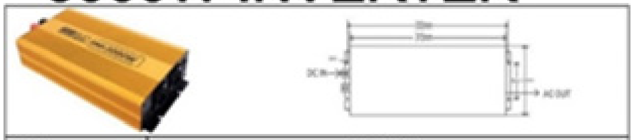
44 Source: The DIY Life, Tech &Electronics, https://www.the-diy-life.com/wp-content/uploads/2016/05/battery-opened.jpg, accessed 25 June 2021.

45 Amazon.com, "Electric Measuring instrument", https://www.amazon.com/Electric-Measuring-Instrument/s?k=Electric+Measuring+Instrument, accessed 25 June 2021.

FIGURE 38: Power Inverter[46]

8. Inspect the name plates in detail. The product can be mistakenly packed in wrong boxes – so always read the name plate to find the right voltage, current or wattage of the components.

FIGURE 39: Power Inverter[47]

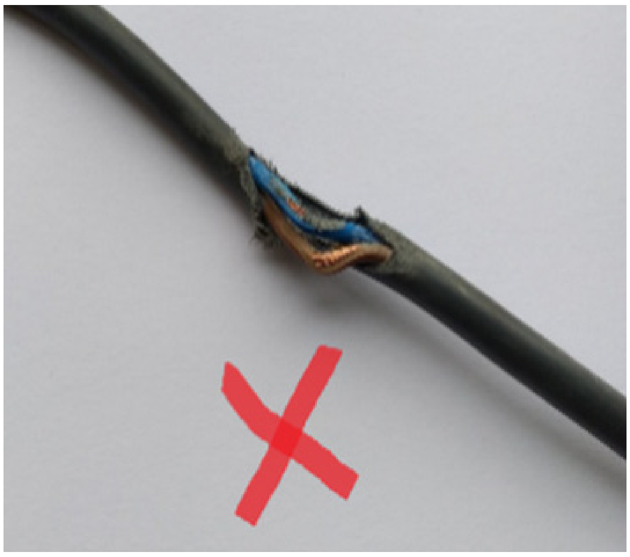


3000W INVERTER

Model	YX-3000W-S					
Continuous Power	3000W					
Peak Power	6000W					
DC Voltage	DC12V	DC24V	DC48V	DC12V	DC24V	DC48V
AC Voltage	100VAC or 110VAC or 120VAC ± 5%			220VAC or 230VAC or 240VAC ± 5%		
No Load Current Draws	1.4A	0.7A	0.3A	1.4A	0.7A	0.3A
Frequency	50HZ ± 0.5HZ or 60HZ ± 0.5HZ					
Output Waveform	Pure Sine Wave					
AC Regulation	THD<3% (Linear load)					
Output Efficiency	up to 92%					
DC Voltage Range	10-15.5V	20-31V	40-62V	10-15.5V	20-31V	40-62V
Low Voltage Alarm	10.5V±0.5V	21.5V±0.5V	43V±1V	10.5V±0.5V	21.5V±3.5V	43V±1V
Low Voltage Shut Down	10V±0.5V	20.5V±0.5V	40V±1V	10V±0.5V	20.5V±3.5V	40V±1V
Over Voltage Shut Down	15.5V±0.5V	31.5V±0.5V	62V±1V	15.5V±0.5V	31.5V±3.5V	62V±1V
Low Voltage Recovery	12.7V±0.5V	25V±0.5V	49V±1V	12.7V±0.5V	25V±0.5V	49V±1V
Over Voltage Recovery	14.7V±0.5V	29.5V±0.5V	59V±1V	14.7V±0.5V	29.5V±3.5V	59V±1V
Protection Function	Low voltage shutdown		Buzzer sounds 3 times interruptedly and fault light turns red			
	Over input voltage protection		Buzzer sounds 4 times interruptedly and fault light turns red			
	Over temperature protection		Buzzer sounds 5 times uninterruptedly and fault light turns red			
	Over load protection		Buzzer sounds 3 times uninterruptedly and fault light turns red			
	Short circuit protection		Recover automatically			
	Reverse polarity protection		Built-in fuse or Built-out fuse			
Working Temperature	-10°C~+50°C		Production Size		12V 465x220x80mm; 24V 445x220x80mm	
Storage Temperature	-30°C~+70°C		Packing Size		45x28x14.3cm	
Warranty	12 months		N.W. / G.W. (KG)		12V: 7.3KG/9.0KG; 24V: 6.9KG/8.0KG	
Start	Bipolar soft-start		Quantity / Carton		2pcs	
Cooling Way	Intelligent cooling fan		Carton Size		56.5x28.5x32.5CM	
Certification	CE		Carton Weight		12V: 18KG; 24V:17KG	

9. Ensure the products are safe to use. Do not buy if you see exposed wires, or the product looks poorly designed as this could cause accidental injury.

FIGURE 40 : Exposed Wires[48]



10. Always shop around, and compare the; prices, quality, warranty, sizes, brands, safety etc of the products that you want to buy. Ask others who have Hydro systems about where they got theirs from and ask them direction to the shops. Once you visit the city or town it will be easier for you to find the right shops and ask the questions mentioned above.

11. Ask the seller of the costs associated with having a professional to come over to do the installation. Since a hydro system is more complex to install and configure (compared to a solar system), it is always better to have an experienced installer to come and install it for you. After the installation, the installer will provide a full run through the system and provide training on how to operate and maintain the system properly. Also ask for the full name of technician, full name of company with physical address and phone contacts of those who can be called to seek advice if the hydro system stops working in future.

46 Source: COCOON ecolima, "HIP-300-12 Inverter 12V-230V 300W", https://cocoon.gr/wp-content/uploads/2020/04/HIP_300_12V-scaled.jpg

47 Source: Goteborgsaventyr, https://goteborgsaventyrscenter.se/product/z59qoeznno47/mexxsun-3000-watt-12-v-24-v-220-v-pure-sine-wave-inverter

48 Source: IOL, "How to fix frayed cables", https://www.iol.co.za/technology/how-to-fix-frayed-cables-49412981

ACTIVITY 7

Ask the learners to get in groups. Display the turbine/generator, battery, inverter, charge controller and lights from the available Kit. Ask the learners to approach a desk where all these products are set up nicely. The learner must then imagine the trainer is the seller and use the above-mentioned tips to ask the trainer more information about products. Help the learners by guiding them to ask the right questions. Allow the learner to take their products and discuss in teams if it was the right 'purchase'.

Some important questions they need to ask are:

1. How much does it cost?
2. How much is the voltage, current or power rating?
3. Do you provide warranty – for what period?
4. Can you show me the voltage (in case of battery)?
5. Can you test to see if this works (in case if lights)
6. Do you have replacements of these?
7. Do they come with an instruction manual?
8. Can you show me how to use it or install it?

8

Maintenance of Home Hydro Systems

All hydro power systems require some form of regular maintenance to ensure safe and proper operation as well as to get the maximum life from the system. Without regular maintenance, the system may not function at its maximum potential, and this can also lead to malfunctions or early component failures that can lead to costly repairs or replacements.

8.1 Why Hydropower systems fail?

There are many ways our Hydro system starts giving problems. We may notice this at times, and at times we fail to notice till the system fails.

8.1.1 Turbine Maintenance

- Inspect for debris in the turbine
- Check screens on the inlet to ensure the turbines are clear.

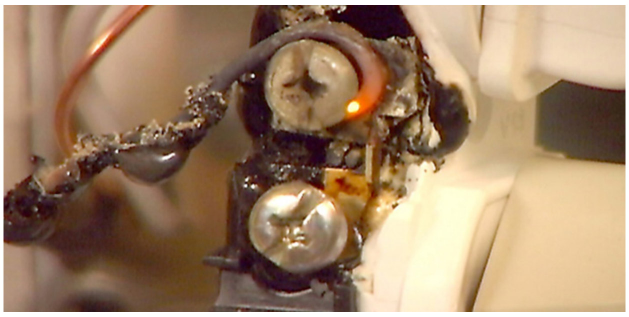
FIGURE 41: Debris[49]

- Check that all drains in the turbine assembly, are clear
- Ensure bearings are greased and not worn

8.1.2 Generator Maintenance

1. Keep it clean and air passage clear. Use blower to remove dust, from inside the generator.
2. Ensure that water is not getting close to generator
3. Do not dismantle generator to clean dust
4. Inspect the terminals

FIGURE 42: Terminal Connection[50]



5. In the above picture, one terminal over heated and changed colour. As soon as there is a slight change in colour, attend to it. Tightening the nut may not help. It may be necessary to cut out the bad part of the cable and redo the connection.
6. Check bearings – off the generator or disengage from turbine and rotate with hand to hear any rubbing noise. If present, bearing needs changing.
7. Read generator manual and follow other necessary maintenance instruction.

SAFETY: DO NOT TOUCH ANY TERMINALS AND MOVING COMPONENT WHILE GENERATOR IS RUNNING

8.1.3 Penstock & Channel Maintenance

1. Penstock pipe needs to be checked for leakage and repaired
2. Ensure water pathways are clear

FIGURE 43: Ensure sidewalks don't break[51]

3. Ensure you have a good flow of water to the turbine. Remove any obstacle
4. After rainy day, carry out inspections
5. Ensure overgrown vegetation is cleared.

49 Source: Walczak, N. (2018). Operational Evaluation of a Small Hydropower Plant in the Context of Sustainable Development. Pages 7-8. https://www.mdpi.com/2073-4441/10/9/1114/htm

50 Source: EC&M, https://www.ecmweb.com/maintenance-repair-operations/article/20890352/the-basics-of-electrical-overheating

51 Source: Wisions of Sustainability, "Demonstration of Sustainable Low Head Pico-Hydro to Deliver Enhanced Rural Energy Services to the Terai Region Of Nepal", https://www.wisions.net/projects/demonstration-of-sustainable-low-head-pico-hydro-to-deliver-enhanced-rural-

8.1.4 Battery Maintenance

Battery maintenance involves various tasks depending on the type of battery, and manufacturer requirements, including:

- Inspecting and cleaning battery racks, cases trays and terminations.
- Measuring battery voltage if you have a multi-meter or by simply reading the battery voltage from the charge controller. For e.g., a 12V battery, must not go below 12V for long times. If it does, then it may be nearing its end of life.
- Some charge controllers have display screens while simpler ones just show the amount of charge level of the battery with led lights.

FIGURE 44: LED lights indicate the battery charge level[52]

- Some charge controllers display the battery voltage and other, measurements directly on their display screen. You will need to consult the manual of these controllers to see how different measurements can be displayed.

FIGURE 45: Charge controller with battery voltage display[53]

- Periodic battery maintenance should include checks of all terminals for corrosion and proper tightening of terminals. Also check battery water and replace with distilled water for flooded lead acid batteries if the level is low. Try to do this every 2 – 4 weeks as required
  1. Use a steel brush to clean oxides at connections. Wear insulation gloves always.
  2. Check for loose wires and connections and damaged wires. Get immediate help to repair damaged wires.

FIGURE 46 : Cleaning Terminal Corrosion[54]

52 Source: Sundaya Apple, "Sundaya Apple Regulator, Quick Start Manual", https://assets.website-files.com/5a2fb65f5701c800018e826f/603e4f42254a71b39b6e33a9_Sundaya%20apple%20-%20English.pdf

53 Source: Amazon, "iSunergy MPPT Solar Charge Controller", https://www.amazon.com/iSunergy-Controller-Intelligent-Regulator-Batteries/dp/B081GSFDKC, accessed 25 June 2021.

54 Source: Jim Dunlop Solar

SAFETY: Use safety goggles and rubber gloves when servicing batteries. Wear old clothes, because you can get acid on them (if flooded batteries)

Keep an open box of baking soda and a plastic pan of water nearby while servicing your batteries—in case of a spill, you can dump the baking soda in the water, stir it, and use the mixture to quickly neutralize any spilled acid

Low voltage isn't a shock hazard, but high current is. A wrench dropped across terminals can quickly burn your hand and possibly explode the battery. Be careful!

It is useful to create a basic checklist to help you carry out routine maintenance on your system. If you find any faults – contact an electrician immediately. A sample checklist is given below, and you may keep it for your own use.

8.1.5 Basic Maintenance Checklist

TABLE 6: **Basic Home Hydro Maintenance Weekly-Monthly Checklist.**

Item	Weekly Checklist - Basic	Done (tick)
1	Check water channel	
2	Check turbine rotating freely without debris	
3	Clean turbine and generator	
4	Check terminals and wires	
5	Check system mounting, tighten where required	
6	Check battery voltage in charge controller - if possible	
7	Check and clean battery terminal corrosion	
8	Check and tighten any loose terminal connections	
9	Check battery water in flooded batteries and refill with distilled water if level is low	
10	Check battery storage area is cool and ventilated	
11	Check that all lights and appliances of the system are working	

ACTIVITY 8 – MAINTENANCE CHECKLIST

Create a maintenance checklist of what all routine tasks need to be done to extend the life of your pico-hydro system. Allow the learners to form groups and write down a set or regular checks that they would need to do to ensure their hydro system works well and longer. Help them by giving them some hints. You may use the above stated checklist to discuss and help them review the checks and if possible, write it down so they better understand it. You could make copies of the checklist and give it out to them.

Learners may come up with some new checks or ideas!

ACTIVITY 9

The purpose of the exercise is to get all members of the community to appreciate the key role women play in decision making and, in the management and use of the technology. Read them this case study and help them answer the questions. You may need to animate the narration to make the dialogues more realistic.

How women bring about change

Sala and her husband Mario live in Afio, on Malaita with their 3 children. They don't have electricity in their village. Mario is a village head and is a fisherman and must be out to sea before sunrise to catch the finest fish and deliver to the fishery station with the only ice room on the island. Sometimes Mario brings the smaller fish home for cooking. They have 3 children, Lilly aged 9, Timoci aged 10 and Salote aged 13 who all go to a school that is about 4 km away from their house. It is about an hour's walk from their home to the school. They also have a large garden at home. Lots of sweet potatoes, yams, cabbage, and tomatoes for their daily needs. Mario's elderly parents also live with them. Mario works hard and normally has a lot of other things to do such as repairing the boat, getting ice, taking passengers to other islands in his boat in the evenings. Sala is equally busy with looking after Mario's parents, taking care of the house, looking after the children, and keeping up with community obligations.

One evening their 13-year-old daughter Salote was studying using the kerosene lamp. The smell of kerosene filled the house as they had 3 lamps lit that night. Mario was yet to return from a neighbour's place where he had gone for some grog. Their 9-year-old, Lilly complained a lot as the smell of kerosene made her feel sick. An argument broke out between the kids because Timoci and Salote both wanted to use the lamp. Lilly jokingly picked the lamp and ran around playfully as she wanted to play. As they chased each other around the house, the lamp suddenly fell from her hands, landed on the map which caught fire instantly. Salote yelled for help and the neighbours rushed to put the fire out but most of Salote's books were ruined by the fire. Lilly was now too afraid to use the kerosene lamp. Later, that evening Salote told Mario about an idea.

Mario: Relax – no one got burnt, I will get her new books by end of this week. Why are you worried?

Sala: I think it is time we stop using these kerosene lamps in our house.

Mario: What? Are you crazy – what will we use?

Sala: Well, I heard that we could use good running water stream to generate power. We have a nearby stream, can you talk to other villagers as a head of the village and discuss if they interested in electric light in their houses. My mother's village has pico-hydro, and the village kids are doing well in school since they can study easily in the bright light.

Mario: Wow, you have been so demanding. You women always (Sala interrupts)

Sala: What do you mean "you women".

Mario: Umm.

Sala: We women have to drive the change because we feel how life is without electricity. I have to wake up when it is dark and light that smelly kerosene lamp and cook the food. I have to take care to store the extra food and fish, so it does not go bad and make us sick. I have to make sure the kids' homework is done in the dim light of the lamps. I must save money to spend on kerosene.

Mario: Ok I agree we need to get electricity. I would like to have a freezer to keep our fish. But Jone has been telling me that the pico-hydro system he bought and installed has not been working for a week. What if it goes bad or doesn't work? And also, this system is going to cost us money? What if villagers don't agree?

Sala: Oh my god. Let's try at least. Discuss with villagers and if they agree, we all can save a bit of the money you make from the fish you sell each week and if we save every week now until Christmas we should have enough for a system. We can speak to department of energy for assistance. And don't worry about the maintenance, we can get help from people who have this system, and I am sure our local authority will provide much help. I can go for some training.

Mario. That's a great idea Sala. I'm so glad we can agree on this, and I am happy to take care of the kids and my parents when you need to go for training on the pico-hydro system. I will talk to villagers tomorrow

End of play

After the story has ended, get the participants into groups, and help them think of all they have learnt and ask them to help Sala answer these two questions again:

What things should Sala, Mario and the villagers look for when buying a pico-hydro system?

Answer: Given in notes under "**Some questions to ask the seller"**

How should Sala and the women take care of the pico-hydro system, so it lasts longer?

Answer: The answer is provided in your notes as part of activity **Chapter 8.**

9

Estimating Potential size of Hydropower System

We have learnt that each appliance be it a light bulb, freezer, television, etc., each uses a specific amount of power (Watts). Adding all these up gives you an idea as to how much power is needed.

A pico-hydropower system being relatively small can only power a small number of appliances and it is important that users understand the limits of a system.

The amount of power that a hydropower system can generate is dependent upon the following.

1. Head – as we know this is the height the water drops and is measured in metres (m)
2. Flow – this is the volume of water that can be put through the turbine and is measured in cubic meters per second (m^3/s). Note: 1 cubic meter/second equals 1,000 litres bottle of water passing a second.
3. Gravity – This is a constant (stays the same) and is 9.81m/s (metres / second)
4. Efficiency of the turbine and electrical equipment. An overall system efficiency of 50% would be reasonable assumption (0.50)

It is possible to roughly estimate the size of a Pico hydropower system based on these factors and this can be done by the local community with some assistance. The simple formula below can be used:

Electrical Power Output (kW) =
Head (m) x Flow (m^3/s) x Gravity(m/s) x Efficiency

The head can be measured by site surveying. This might be possible with a tape measure and spirit level.

The river or stream flow will vary depending on season and time of day. To get a good idea it is sensible to measure this frequently over different times of a year though taking a measurement at lowest levels will give an idea of the minimum flow and lowest amount possible to generate.

A river / streams flow rate can be measured by several methods including on site measurement such as bucket and pipes, cross section/velocity and salt flow. This is outside scope of this workshop but important to understand and the local community can help in undertaking with assistance from local Government Energy or Environment Department.

Exercise:

A site has a head of 2m, and the stream has a flow rate of 5l/s a second (same as filling a bucket ever section), what size pico-hydropower system might be possible if all the water is used?

Answer:

The flow is in litres second and need to convert to cubic meters a second so divide by a 1000. i.e., 5/1000= 0.005m^3/s

- Electrical Power (kW) =
  Head (2m) x Flow (0.005 m^3/s) x 9.81 m/s x 0.5
- Electrical Power (Kilowatts) = 0.04905 kW
- Electrical Power (Watts) = 0.04905kW x 1000 = 49 Watts

Question: How many light bulbs could this light up at 5 watts each?

Answer = 49 /5 = 9.8 so 9 bulbs

If the head being doubled i.e., 4 meters, what would the size of the Hydro System be in watts?

- Electrical Power (kW) =
  Head (4m) x Flow (0.005 m3/s) x 9.81 m/s x 0.5
- Electrical Power (Kilowatts) = 0.0981 kW
- Electrical Power (Watts) = 0.0981kW x 1000 = 98 Watts

It is important to illustrate that you need a constant large flow and good head to be able to install a large system.

10

Annex

10.1 Annex A: How to Do Basic Measurements Using a Clamp-Meter

This section shows how to do basic measurements using a clamp meter. Note that some meter brands might not have all the features shown.

10.1.1 Measuring DC Voltage using probes

FIGURE 47: **DC Voltage measurement schematic**[55]

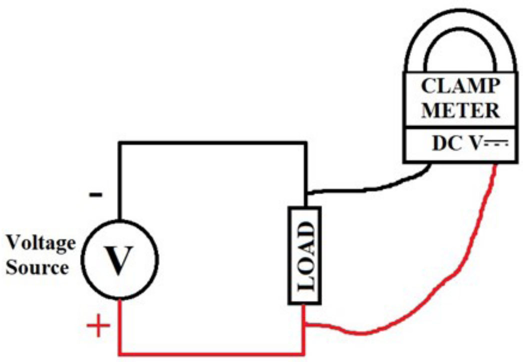


FIGURE 48: **DC Voltage measurement on clamp-meter**[56]

Steps:

1. Set Clamp-meter dial to DC Voltage mode (DCV or V=)
2. Ensure probes are connected to "V" and "Com" ports of the clamp meter
3. Touch the end of probes across the load in the circuit to measure its voltage. Voltage measurements are done in parallel to the load. Clamp-meter screen with show measured voltage

10.1.2 Measuring AC Voltage using probes

FIGURE 49: **AC Voltage measurement schematic**[57]

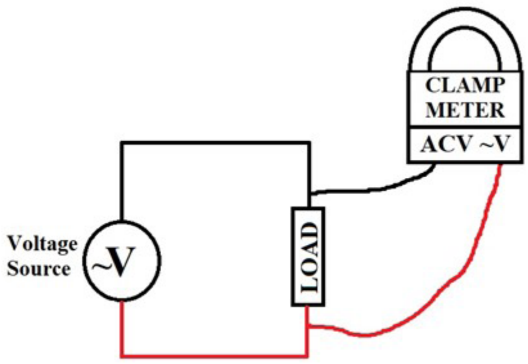


FIGURE 50 : **AC Voltage measurement on clamp-meter**[58]

Steps:

1. Set Clamp-meter dial to AC Voltage mode (ACV or ~V)
2. Ensure probes are connected to "V" and "Com" ports of the clamp meter
3. Touch the end of probes across the load in the circuit to measure its voltage. Voltage measurements are done in parallel to the load. Clamp-meter screen with show measured voltage

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10.1.3 Continuity testing using probes

FIGURE 51: **Continuity testing schematic**[59]

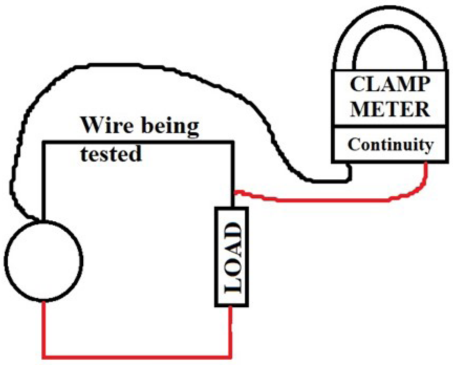

FIGURE 52: **Continuity testing on clamp-meter**[6]

Steps:

1. Turn OFF power supply in the circuit when doing this test.
2. Set Clamp-meter dial to Continuity mode. If this mode is not available, you can also use resistance (Ω) mode.
3. Ensure probes are connected to "V" and "Com" ports of the clamp-meter
4. Touch the end of probes across the wire in the circuit to test its continuity. The clamp-meter will "beep" or show "0" if the wire is continuous. If the wire is not continuous or open, the clamp meter will "not beep" or show "1".

10.1.4 Measuring DC current using clamp

FIGURE 53 : DC current measurement schematic[61]

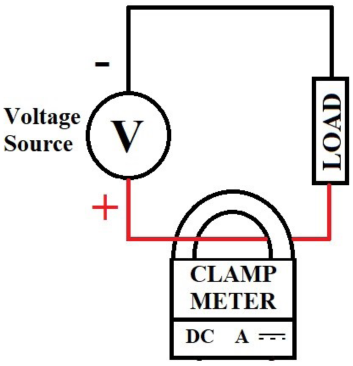

FIGURE 54: DC current measurement on clamp meter[62]

Steps:

1. Set Clamp-meter dial to DC current mode (DCA or A=)
2. Open the clamp and put the wire inside the clamp.
3. The clamp-meter screen will show the measured current in the wire. The clamp-meter probes are not used in this test.

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10.1.5 Measuring AC current using clamp

FIGURE 55: AC current measurement schematic[63]

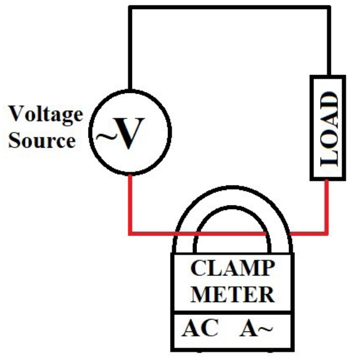

FIGURE 56: AC Current measurement on clamp-meter[64]

Steps:

1. Set Clamp-meter dial to AC current mode (ACA or A~)
2. Open the clamp and put the wire inside the clamp.
3. The clamp-meter screen will show the measured current in the wire. The clamp-meter probes are not used in this test.

10.2 Annex B: How to do Basic Measurements using a multi-Meter

This section shows how to do basic measurements using a multi-meter. Note that some meter brands might not have all the features shown.

10.2.1 Measuring DC Voltage using probes

FIGURE 57: DC Voltage measurement schematic[65]

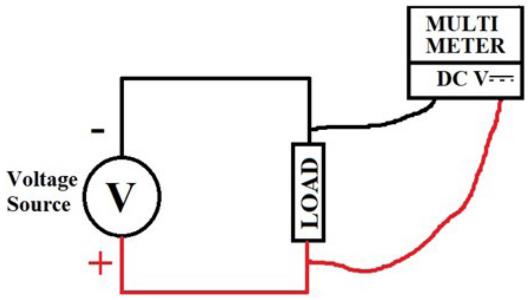

FIGURE 58: DC Voltage measurement on multi-meter[66]

Steps:

1. Set multi-meter dial to DC Voltage mode (DCV or V=)
2. Ensure probes are connected to "V" and "Com" ports of the clamp meter
3. Touch the end of probes across the load in the circuit to measure its voltage. Voltage measurements are done in parallel to the load. Multi-meter screen with show measured voltage

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10.2.2 Measuring AC Voltage using probes

FIGURE 59: AC Voltage measurement schematic[67]

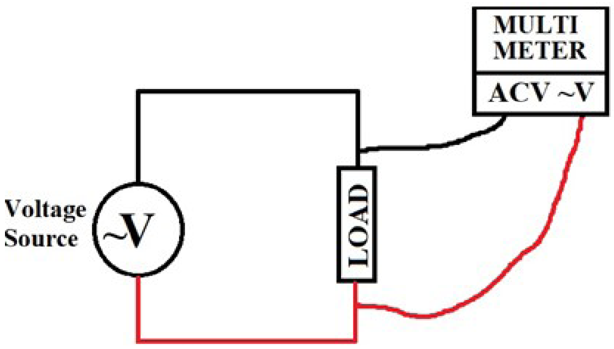

FIGURE 60: AC Voltage measurement on multi-meter[68]

Steps:

1. Set multi-meter dial to AC Voltage mode (ACV or ~V)
2. Ensure probes are connected to "V" and "Com" ports of the multi-meter
3. Touch the end of probes across the load in the circuit to measure its voltage. Voltage measurements are done in parallel to the load. Multi-meter screen with show measured voltage

10.2.3 Continuity testing using probes

FIGURE 61: Continuity testing schematic[69]

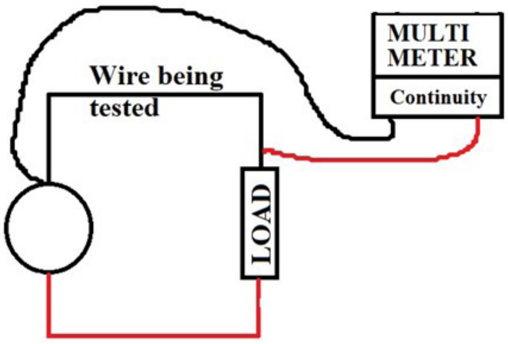

FIGURE 62: Continuity testing on multi-meter[70]

Steps:

1. Turn OFF power supply in the circuit when doing this test.
2. Set multi-meter dial to Continuity mode ")))". If this mode is not available, you can also use resistance (Ω) mode.
3. Ensure probes are connected to "V" and "Com" ports of the multi-meter
4. Touch the end of probes across the wire in the circuit to test its continuity. The multi-meter will "beep" or show "0" if the wire is continuous. If the wire is not continuous or open, the multi-meter will "not beep" or show "1".

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10.2.4 Measuring DC current using probes

FIGURE 63: DC current measurement schematic[71]

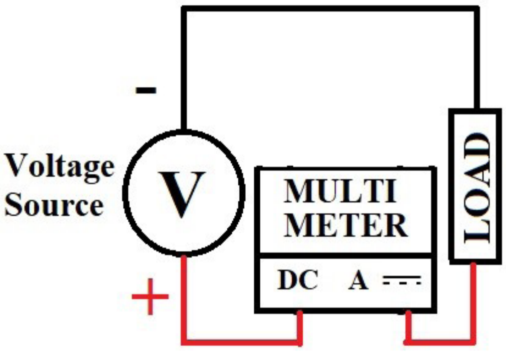

FIGURE 64: DC current measurement on multi meter[72]

Steps:

1. Turn OFF the circuit
2. Set multi-meter dial to DC current mode (DCA or A= or mA=)
3. Connect the red probe to the "A=" or "mA=" port of the multi-meter and black probe to "Com" port of the multi-meter. Ensure that the measured current does not exceed the maximum rated current of the meter. If the current is very small, then you can use the "mA=" port and "mA=" meter mode to measure smaller currents more accurately.
4. Connect the multi-meter in series to the circuit. This means that the circuit must be broken to connect the meter in series.
5. Turn ON the circuit
6. The multi-meter screen will show the measured current in the wire.

10.2.5 Measuring AC current using probes

FIGURE 65: AC current measurement schematic[73]

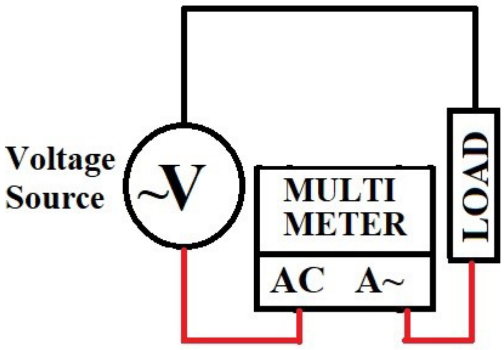

FIGURE 66: AC current measurement on multi meter[74]

Steps:

1. Turn OFF the circuit
2. Set multi-meter dial to AC current mode (ACA or A~ or mA~)
3. Connect the red probe to the "A~" or "mA~" port of the multi-meter and black probe to "Com" port of the multi-meter. Ensure that the measured current does not exceed the maximum rated current of the meter. If the current is very small, then you can use the "mA~" port and "mA~" meter mode to measure smaller currents more accurately.
4. Connect the multi-meter in series to the circuit. This means that the circuit must be broken to connect the meter in series.
5. Turn ON the circuit
6. The multi-meter screen will show the measured current in the wire.

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