ペルー共和国
エネルギー鉱山省

ペルー国
再生可能エネルギーによる
地方電化マスタープラン調査

第３巻
教 材

ファイナルレポート

平成 20 年 8 月
(2008)

独立行政法人
国際協力機構(JICA)

委託先
電源開発株式会社
日本工営株式会社

序　文

日本国政府は、ペルー共和国政府の要請に基づき、同国の再生可能エネルギー利用による地方電化マスタープラン調査を行うことを決定し、独立行政法人国際協力機構がこの調査を実施いたしました。

当機構は、平成 19 年 2 月から平成 20 年 8 月までの間、5 回にわたり電源開発株式会社の田中哲郎氏を団長とし、同社と日本工営株式会社の団員から構成される調査団を現地に派遣しました。

調査団は、ペルー共和国政府および同国エネルギー鉱山省関係者と協議を行うとともに、現地調査を実施し、帰国後の国内作業を経て、ここに本報告書の完成の運びとなりました。

この報告書が、ペルー共和国の地方電化の進展に寄与するとともに、両国の友好親善の一層の発展に役立つことを願うものです。

終わりに、調査のご協力とご支援をいただいた関係者各位に対し、心から感謝申し上げます。

平成 20 年 8 月

独立行政法人　国際協力機構
理事　永塚　誠一

平成 20 年 8 月

独立行政法人　国際協力機構
理事　永塚　誠一　殿

伝　達　状

「ペルー国再生可能エネルギー利用による地方電化マスタープラン調査」ファイナルレポートをここに提出いたします。本調査は、貴機構との契約に基づき、電源開発株式会社および日本工営株式会社が平成 19 年 2 月から平成 20 年 8 月まで実施いたしました。

本報告書は、ペルー国の山岳地帯やアマゾン流域に主に点在する、配電線延長による電化が困難な遠隔地域の村落に対する、再生可能エネルギー（太陽光と小水力）による電化のためのマスタープランをとりまとめております。この中で、地方電化促進に係わる課題に対して、法制度・組織・資金・環境・ジェンダーに関し、また技術面では太陽光・小水力・送配電の各分野につき政策提言をし、あわせて未電化村落の再生可能エネルギーによる長期電化計画を策定いたしました。

本マスタープランが、ペルー国の地方電化の推進に寄与し、ひいては、遠隔地の村落住民の貧困削減と生活向上に資することができますことを、心より願うものであります。

最後に、今回の調査で多くのご指導、ご支援を賜りました貴機構、外務省ならびに経済産業省各位に深く感謝申し上げます。また、調査遂行にあたり、ご協力、ご支援を頂いたペルー国エネルギー鉱山省等関係各省、および調査団が訪問いたしました州・地方政府ならびに村落住民の方々に、心より感謝申し上げます。

ペルー国再生可能エネルギー利用による
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総括　　田中　哲郎

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Department capital
Town
Airport
International boundary
Department boundary
Pan-American Highway
Road
Railroad
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0 100 200 mi
Callao has the status of a Department.
The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
Map No. 3838 Rev. 1 UNITED NATIONS
September 2000
Department of Public Information
Cartographic Section

Acronyms/Acrónimos	
ADINELSA	Administration Company of Electrical Infrastructure (Empresa de Administración de Infraestructura Eléctrica)
BCS	Battery Charging Station (Estación de Recargo de Batería)
CERER	Renewable Energy Center for Rural Electrification (Centro de Energías Renovales para Electrificación Rural)
CIRA	Certificate of Non-existence of Archaeological Relics (Certificado de Inexistencia de Restos Arqueológicos)
COES	Committee of Economical Operation of the System (Comité de Operación Económica del Sistema)
CONAM	National Coucil of Environment (Consejo Nacional del Medio Ambiente)
CTE	Electricity Tariff Commission (Comisión de Tarifas Eléctricas)
DEP	Executive Directorate of Projects (Dirección Ejecutiva de Proyectos)
DGER	General Diretorate of Rural Electrification (Dirección General de Electrificación Rural)
DGAAE	General Directorate of Energetic Environmental Affairs (Dirección General de Asuntos Ambientales Energéticos)
DGE	General Directorate of Electricity (Dirección General de Electricidad)
DIGESA	General Directorate of Environmental Health (Dirección General de Salud Ambiental)
DPR	Directorate of Projects (formerly DEP) (Dirección de Proyectos)
DREM	Regional Directorate of Energy and Mines (Dirección Regional de Energía y Minas)
FONCODES	National Fund of Cooperation for Development (Fondo Nacional de Cooperación para el Desarrollo)
FONER	National Fund for Rural Electrification (Fondo Nacional de Electrificación Rural)
FOSE	Electrical Social Compensation Fund (Fondo de Compensación Social Eléctrica)
F/S	Feasibility Study (Estudio de Factibilidad)
INRENA	National Institute of Natural Resources (Instituto Nacional de Recursos Naturales)
ITDG	Intermediate Technology Development Group (Soluciones Prácticas)

Acronyms/Acrónimos	
JBIC	Japan Bank for International Cooperation (Banco del Japón para Cooperación Internacional)
JICA	Japan International Cooperation Agency (Agencia de Cooperación Internacional del Japón)
MEF	Ministry of Economy and Finance (Ministerio de Economía y Finanzas)
MEM	Ministry of Energy and Mines (Ministerio de Energía y Minas)
MP	Master Plan (Plan Maestro)
OM	Operation and Maintenance (Operación y Mantenimiento)
OSINERGMIN	Supervisory Body of Investment in Energy and Mining (Organismo Supervisor de la Inversión en Energía y Minería)
OPI	Planning and Investment Office (Oficina de Programación e Inversiones)
PERNC	Plan of Non-conventional Renewable Energy (Plan de Energía Renovable Non Convencional)
PNER	National Plan of Rural Electrification (Plan Nacional de Electrificación Rural)
Pre F/S	Prefeasibility Study (Estudio de Prefactibilidad)
PSE	Small Electrical System (Pequeño Sistema Eléctrico)
SENAMHI	National Meteorology and Hydrology Services of Peru (Servicio Nacional de Meterorología e Hidrología del Perú)
SHS	Solar Home System (Sistema Fotovoltaico Domiciliario)
SIER	Information System for Rural Electrification (Sistema de Información de Electrificación Rural)
SNIP	National System of Public Investment (Sistema Nacional de Inversión Pública)
SPERAR	Peruvian Solutions to Rural Electrification in Isolated and Frontier Areas with Renewable Energies (Soluciones Peruanas a Electrificación Rural en las Areas Aisladas y de Frontera con Energías Renovables)
UNDP/GEF	United Nations Development Program/Global Environment Facility (Programa de Naciones Unidas de Desarrollo/ Fondo para el Medio Ambiente Mundial)
VAD	Value Added for Distribution (Valor Agregado de Distribución)

第３巻　教材

IV.　教材

IV-1　啓蒙用教材

IV-1.1　ビデオ

啓蒙用ビデオ作成の主要目的は、地方村落の末端利用者に広範かつ詳細な情報を提供することにある。内容は、電化システムと導入について、また持続可能な再生可能エネルギーシステムとするための、運営および維持管理方法と必要とされる組織についてなどがある。

啓蒙用ビデオの基本的な仕様は以下のとおりである。

1) 撮影時間 ：45 分間
2) フォーマット ：DVD（30 copies）, CD-ROM（30 copies）
3) 言語：スペイン語

啓蒙用ビデオの概要を以下に示す。

1) 地方村落における電力利用による生活環境の改善
2) 既存電力供給システムの情報
3) 持続可能なプロジェクトの成功例
4) 電力料金や維持管理などの経済面
5) バッテリー処理などの環境面
6) 小水力と太陽光発電の認証センターに関する情報
7) 電化のための地方組織の立ち上げ方法に関する情報
8) 技術と運営面の訓練内容
9) 地方電化の普及センターの役割
10) 村落レベルでのプロジェクト要求手段

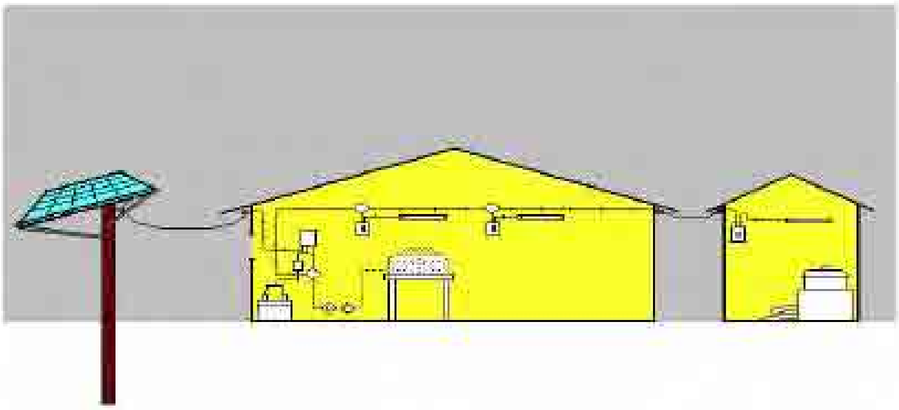
IV-1.2　啓蒙用パンフレット

IV-1.2.1　太陽光

太陽光発電は、既存電力系統の延長および小水力発電の開発が困難な地域での利用に適している。太陽光発電は、利用する地域および季節や天候に応じて発電量が異なるため、利用者による適正な利用および維持管理が必要となる。本マスタープランでは、太陽光発電の利用方法として、SHS、BCS および公共施設（学校、診療所）での利用を検討している。BCS および公共施設については、作成中の太陽光発電の導入・維持管理手法のマニュアルで紹介する。各世帯用の発電システムである SHS については、啓蒙用パンフレットを用いる。

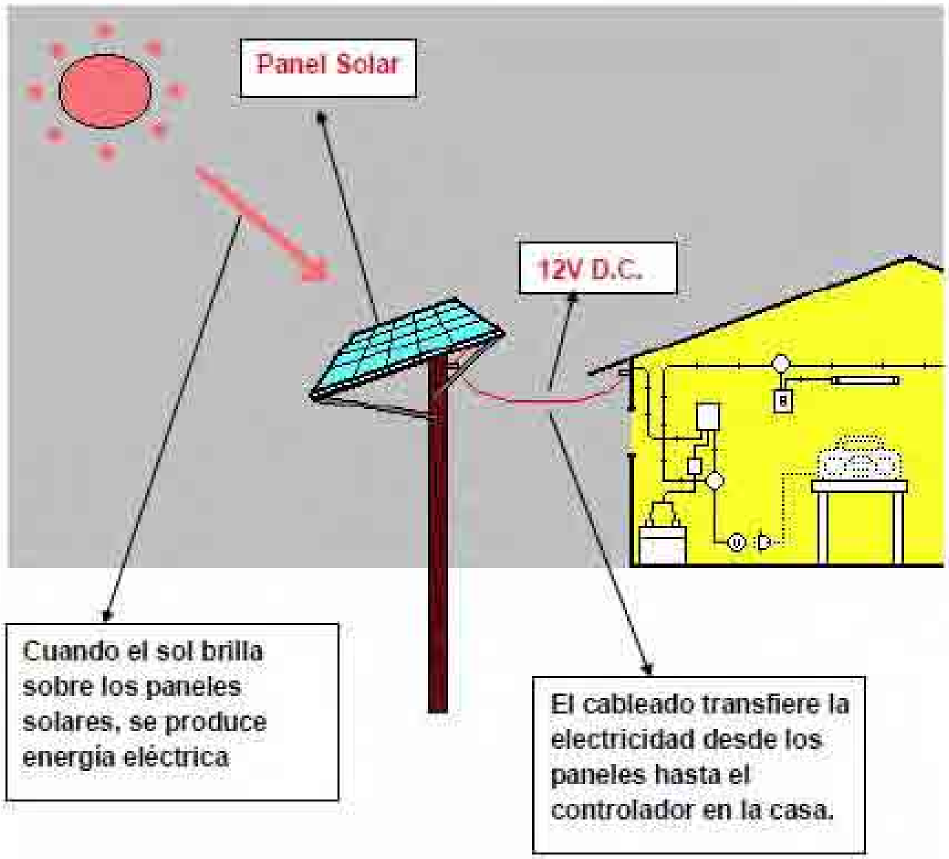
Manual del Usuario

Sistema solar domiciliario



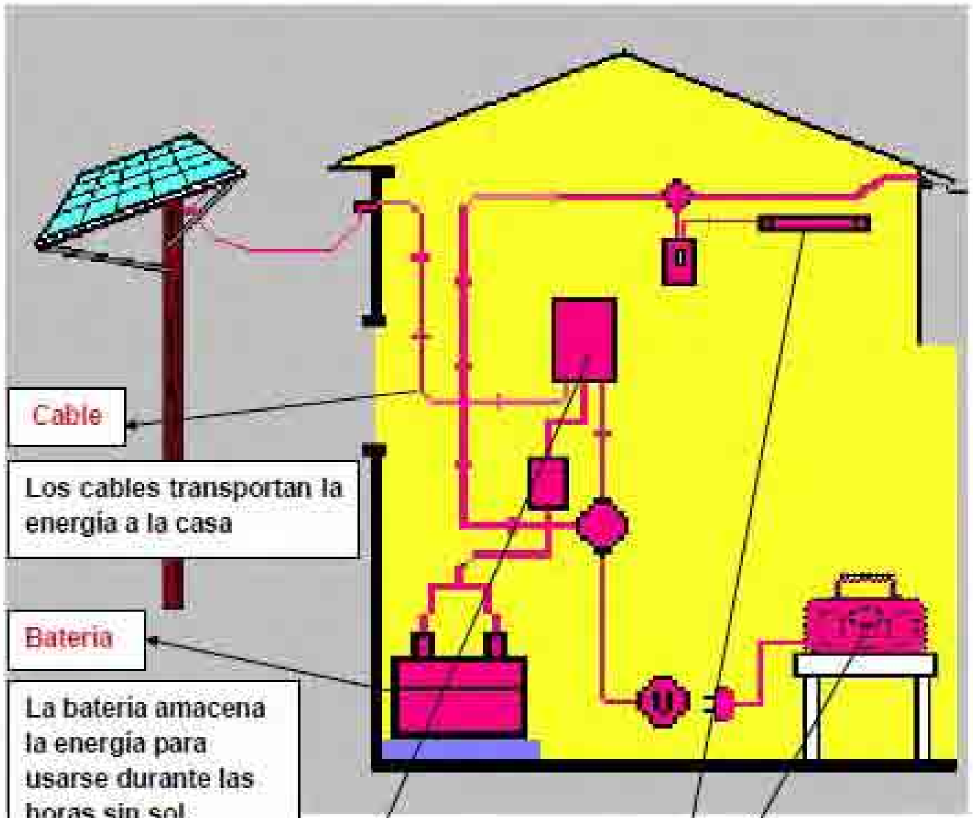
JICA Study Team

Energía Eléctrica Solar



1

Principales funciones de los equipos



Cable

Los cables transportan la energía a la casa

Batería

La batería amacena la energía para usarse durante las horas sin sol.

Controlador

El controlador trae la energía a la batería desde el panel y la transfiere a los puntos de descarga

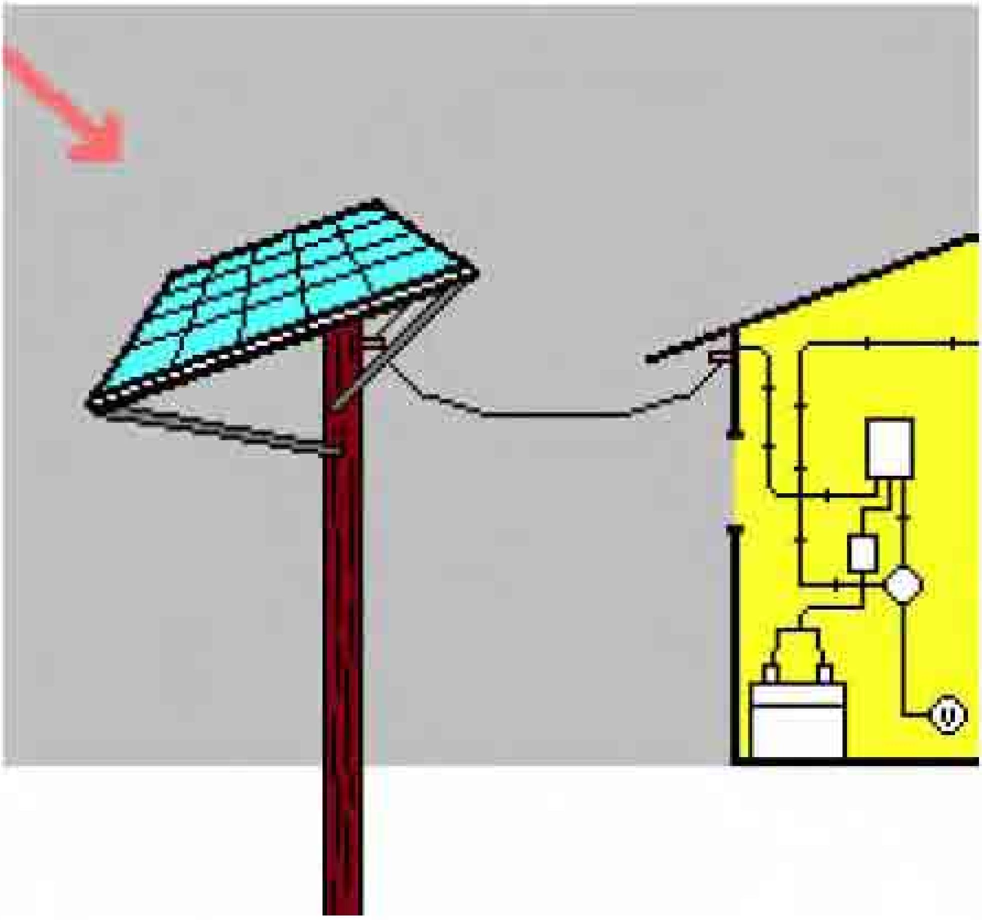
No use demasiada electricidad. De lo contrario dañara rápidamente la batería y es muy costoso.

Uso de carga de batería

El sistema es de 12V. DC. Puntos que usan carga de 12V. DC. Nunca use 220V. AC.

2

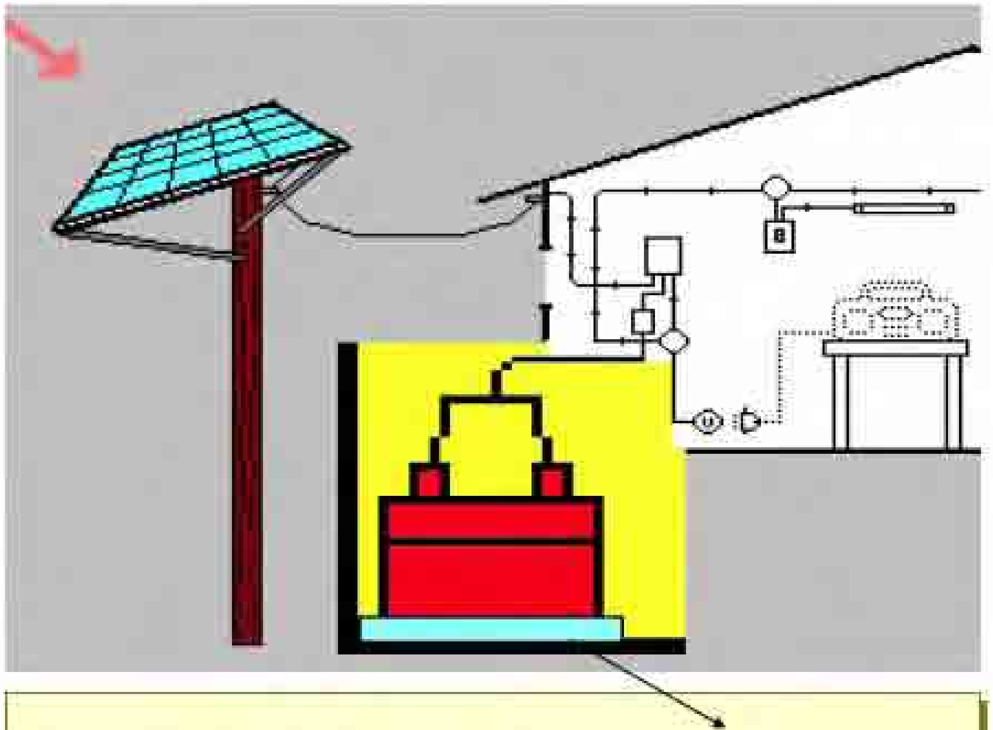
Panel Solar = Fotovoltaico



1. No mover el panel
2. No arroje piedras al Panel
3. No cuelgue nada en los cables

3

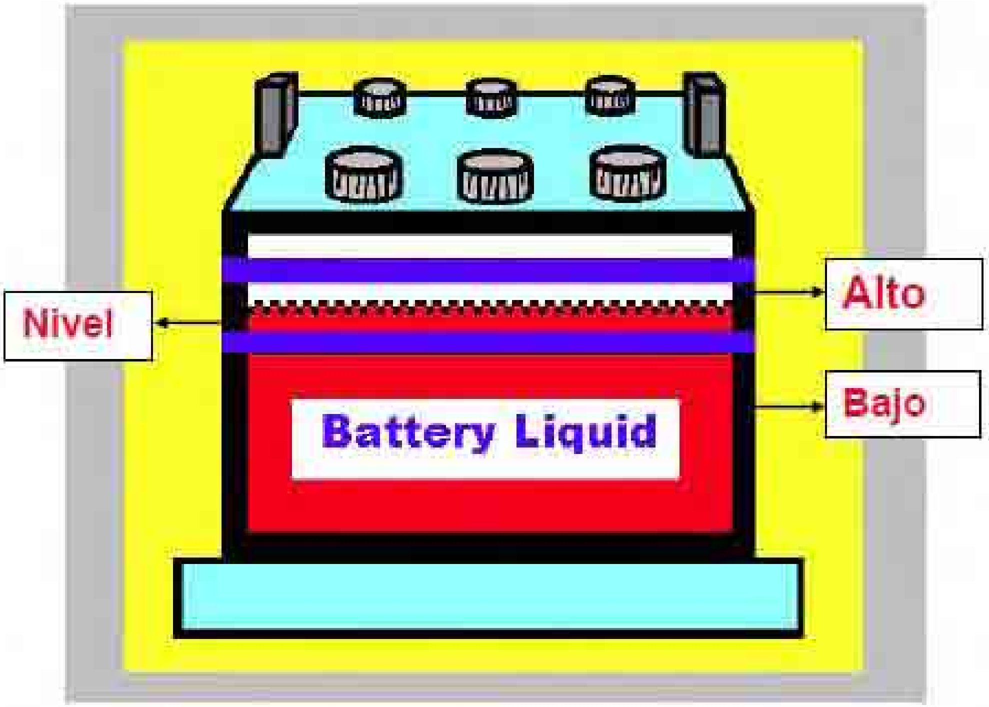
Batería



1. Coloque la batería sobre una base plana (madera o ladrillo)
2. La batería contiene ácido liquido nocivo
   - Abra la ventana sobre la batería
   - Nunca deje a los niños acercarse a la batería
   - Nunca tenga ganado en la habitación
3. No toque o mueva la batería
4. No coloque nada sobre la batería
5. No haga fuego cerca de la batería
6. No use la batería para otros propósitos

4

Revisar la batería

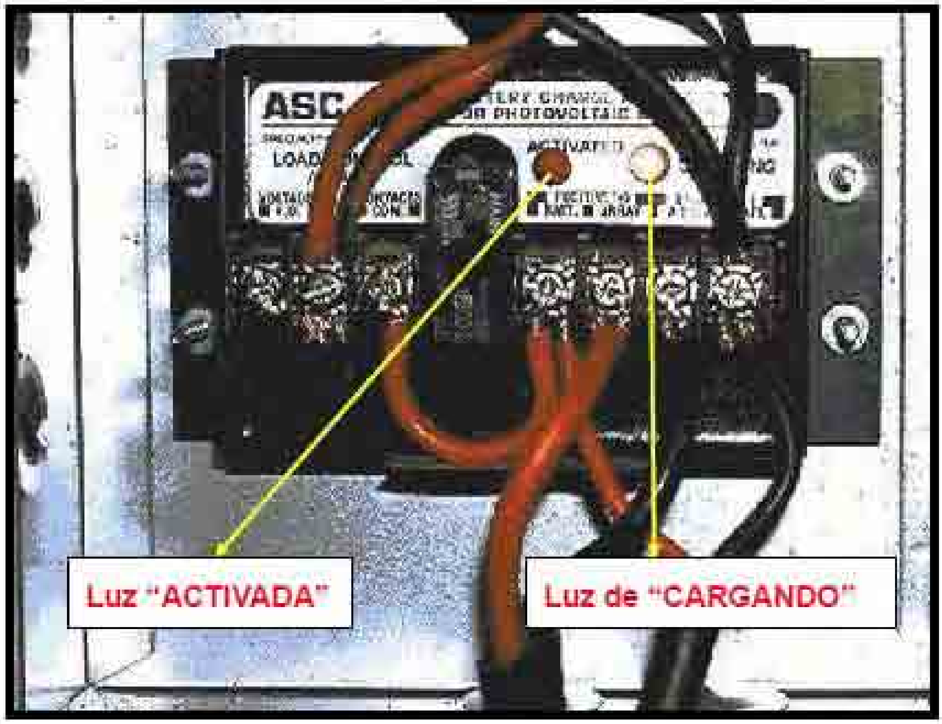


1. Revise el nivel de electrolito de la batería
   El nivel estará entre las dos líneas

2. Si el nivel esta bajo la línea inferior, deje de usar energía y solicite a su Operador para que lo llene con agua destilada.

5

Controlador

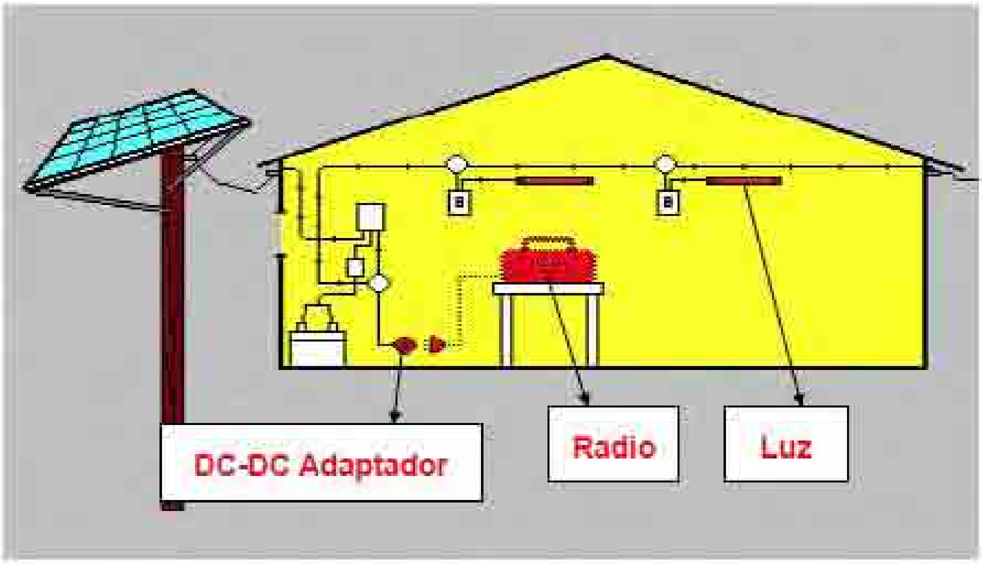


1. Luz de CARGANDO
   ON: La batería se esta cargando

2. Luz de ACTIVADO
   ON: La batería tiene bajo voltaje
   : El Usuario no puede hacer uso de la energía

6

Uso de la carga de batería



La descarga será de 12V / DC. No 220V / AC

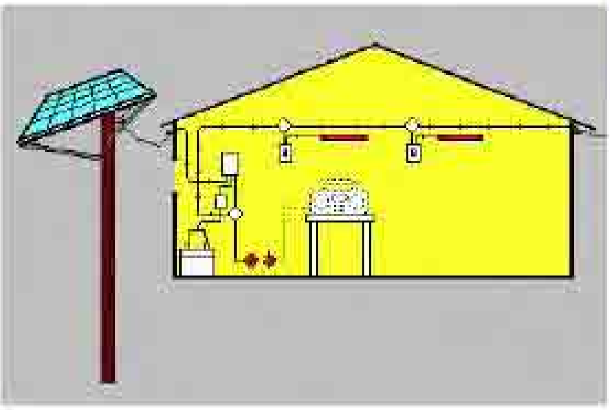
Conecte el enchufe correctamente :

Use solo accesorios para enchufe y adaptador DC - DC

1. Los focos deben estar limpios
2. Reemplace los focos rotos
3. En caso de reemplazo de focos y compra de Radio y TV, solicite consejo al Operador para la especificación de las comparas

7

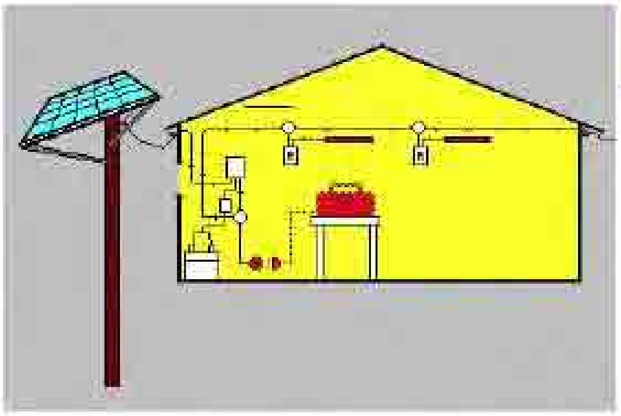
Plan de uso de energía



Luz

Uso diario

Foco uno : 7 horas
Foco dos : 4 + 3 horas
Foco tres : 3+2+2 horas



Luz + Radio

Uso diario

Dos Focos : 3 + 2 horas
Radio : 2 horas

Luz + TV B/N

Uso Diario

Dos Focos : 3 + 2 horas
TV B/N : 1 hora

8

Regla General del Usuario

- Una cuidadosa y apropiados manera de uso diario
- Se debe pagar:

  Costo de tarifa por consumo de energía 18 soles / mes

Debe Hacer

- Mantener el uso del Sistema Fotovoltaico todo el año en un mismo nivel (La bateria debe ser cargado constantemente).
- Observar la indicación del nivel de liquido de la batería
- Mantener las horas de uso de acuerdo a la siguiente tabla

FOCO : 15 W
RADIO: 15 W / Max 2 hrs
TV B/N: 20 W / Max 1 hr

Patrón de Uso de Carga

CARGAS / USO	FOCOS DE LUZ			FOCO + RADIO	FOCO + TV
	UNO	DOS	TRES		
POTENCIA (W)	15	15+15	15+15+15	15+15+15	15+15+20
USO (horas)	7	4+3	3+2+2	3+2+2	3+2+1
TOTAL (Wh)	105	105	105	105	95

9

- Usar demasiada carga podría causar inconvenientes, como la desconexión frecuente del controlador.
- Informar la molestia de problemas técnicos al jefe de la comunidad para que comunique al operador.

No debe Hacer

- No tocar ni manipular nada excepto los focos y tomacorrientes.
- No permitir que los niños se acerquen a la batería
- No manipular nada especialmente en caso de problemas.
- No acercarse a ninguna de las partes del sistema fotovoltaico en caso de relámpagos o truenos.

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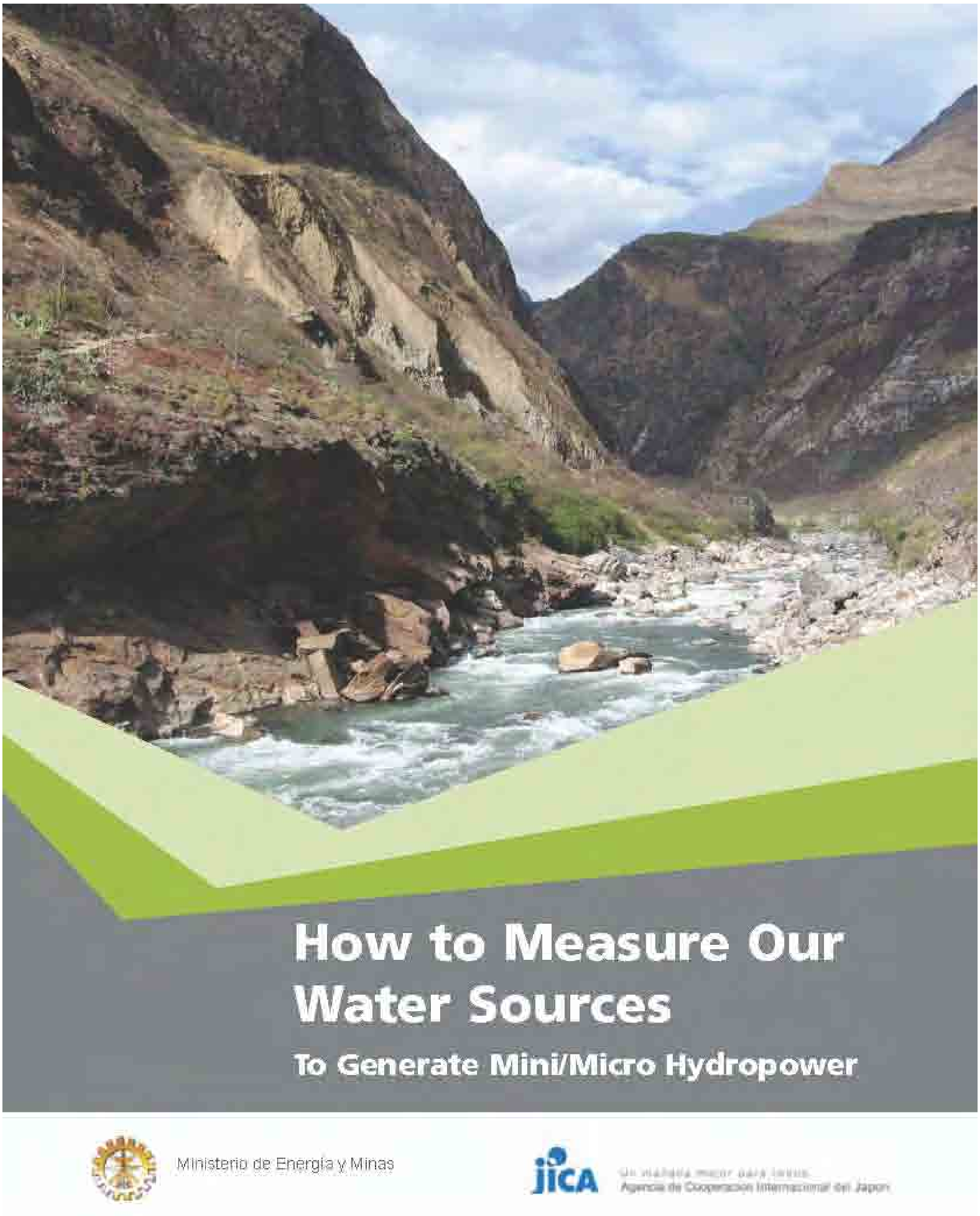
IV-1.2.2　小水力

小水力地点の詳細な調査・検討は、専門的な知識を有する技術者などが実施する必要がある。このため啓蒙用パンフレットは、地元住民が小水力ポテンシャルの確認や地点情報を専門的知識のある人材を有する地方・中央政府などの適切な開発支援機関に提供できることを目的とする。したがってパンフレットでは、小水力による地方電化を望む地元住民などを対象とした小水力ポテンシャルを確認するための簡便な方法などを紹介する。


How to Measure Our
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To Generate Mini/Micro Hydropower
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INTAKE
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OF ELECTRICITY

JICA
Japan International Cooperation Agency

Founded in 1974, the Japan International Cooperation Agency is an implementation agency for technical assistance, focusing on systems building, organization strengthening and human resource development that will enable developing countries to pursue their own sustainable socio-economic development. JICA's work is broad in scope and reflects international concerns and changing needs in developing countries. To traditional sectors such as agriculture and social infrastructure, JICA has recently added assistance to combat infectious diseases, support to encourage free market economies or set up legal systems, and support for the peace-building and reconstruction efforts in countries.

JICA uses an issue-based approach to comprehensively analyze issues to be resolved and to expedite various types of programs. "Development Studies" is one of their programs, and this assistance is for formulating development plans at the national or regional level in various social and economic fields. It includes drawing up master plans to act as blue-prints for medium- and long-term development programs, and also includes studying the technical, economic or environmental aspects of proposed project implementations as the basis for feasibility studies.

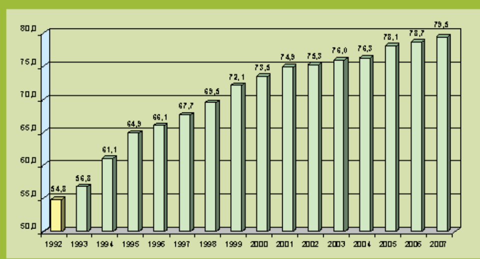
In the Republic of Peru, JICA implemented "the Master Plan Study for Rural Electrification by Renewable Energy" from February 2007 to July 2008 as one of the supports to Peru based on the above.

MINISTRY OF ENERGY AND MINES GENERAL DIRECTION
OF RURAL ELECTRIFICATRION

RURAL ELECTRIFICATION IN PERU

The beginning of rural electrification in Peru comes from the middle of the last century, when in 1955 the new law of Industrial Electricity was created. Its purpose was to encourage private investment in order to promote the electrification in isolated areas.
Complementing this, in the year 1962 the National Electrical Service Law (SEN) was approved, which regulate the supply of electricity in the areas with no private investment, in the same way promote the development of Hydropower Plants by the Government.
In 1992, with a new Law No.19521, Ley Normativa de Electricidad, started the process of the public service of electricity in charge of the government. It was declared the necessity, utility and security of the electricity supply, and the Ministry of Energy and Mines became the entity in charge of the regulation and protection. This new responsibility was entitled to ELECTROPERU S.A which is part of National Electrical Services (SEN), Mantaro Corporation (CORMAN), and Santa Corporation (CORSAN) and other. ELECTROPERU remained in charge of urban and rural electrification in Peru.
Ten years later, in 1982, the General Law of Electricity was created, transferring the energy distribution right given at first to ELECTROPERU, to the Regional Companies, with the purpose that ELECTROPERU stay as the Head company, having all the shares from the government and being responsible of the planning and Electrical equipment by doing the Master Plan of Electricity, Studies and Execution of Generation and Transmission works. This law allowed the development of the electrical sector in all Peru.
In that year, the extension of electricity reached 40%. In ELECTROPERU, was created an organization dedicated exclusively to the electrification in provinces and districts in all rural areas.
In 1992, appeared the Law of Electrical Concessions, Law No.25844 that divided in three parts the activities in the electrical sector: Generation, Transmission and Distribution; giving concessions and authorizations, all of them regulated by the government. With this fact, the government assured more efficiency in electricity matters and also the participation of private sector, but rural electrification was not taken into account. The percentage of national electrification up to that time was 54.8 %.
The Direccion Ejecutiva de Proyectos (DEP) was created under supreme decree No.021-93- EM, in 1993 as part of the Ministry of Energy and Mines with self technical, administrative and financial rights, in charge of the execution of energetic projects with the fund of different sources.

Since August 1993 until the end of 2006, more than 5.6 million people have been benefited with electricity, being the increment of national electrification from 56.8% in 1993, to 78.7% in 2006.
In this period of time, 672 projects were executed, with a total investment of US$ 665 millions. This means: 57 Transmission Systems Projects (Transmission lines and substations), 310 Distribution Projects (Mini hydro, Primary and Secondary Networks), 63 Hydropower Projects, 207 Thermal Generation Projects, 2 Wind Energy Projects and 4 programs of Solar Panels.
We have commissioned 2, 872 km of transmission lines and 20, 852 km of distribution lines, increasing the isolated generation in more than 150 MW of thermal and hydraulic potency.
The Supreme Decree No.026-2007-EM, dated May 05, 2007 proposed the creation of Direccion General de Electrificacion Rural (DGER) as an entity that would be part of the office of the Vice Ministry of Energy and Mines (MEM), through the joint of DEP and FONER.
Likewise, the Supreme Decree No.031-2007-EM, dated June 26, 2007 that approved the Regulations of the Scopes and Organization of MEM declared that: DGER/MEM is responsible for the execution of the National Plan for Rural Electrification which is a duty of the Energy and Mine sector. Also encloses the execution or coordination of electromechanical projects having as priority the rural areas and extreme poverty places.
This legal item declares that DGER/MEM is conformed by the following entities: Direccion Ejecutiva de Proyectos (DEP) and Direccion de Fondos Concursables (FONER).

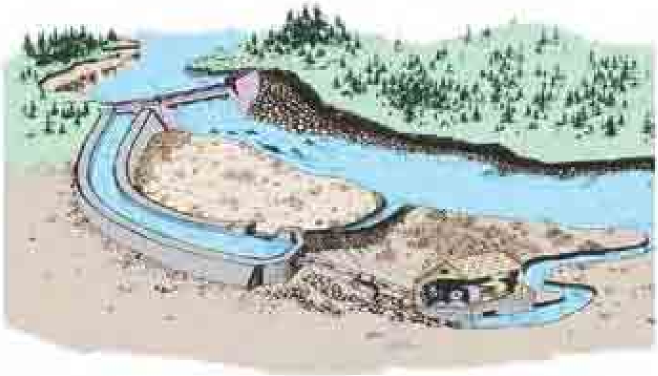


1. INTRODUCTION

Mini/micro hydropower is a whole of steps and equipment to be implemented to take advantage of waterfalls and generate electricity.

More than a century has passed since man started to generate electricity from hydraulic energy, in which time we have built large installations known as hydroelectric power stations.

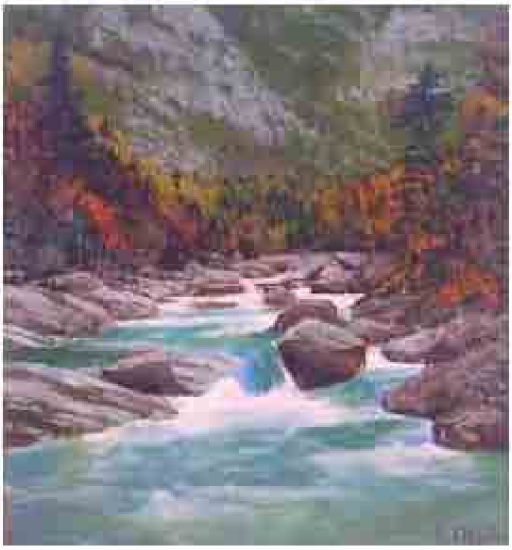
Nevertheless bringing the electricity generated by these power stations to rural communities is a slow process and an enormous challenge. One solution is the construction of small-scale installations in the community using the water resources available to us to meet our needs for electricity. And thus we improve our quality of life by transforming our products and facilitating our work.



2. USES OF ELECTRIC ENERGY

Domestic use	Productive uses
Lighting	Carpentry workshop
Refrigerator	Workshop metalworking
Television	Agribusiness
Radio transistor	Battery charger
	Grain mill
	Grinding cane
	Radio station

3. WHERE CAN WE FOUND WATER BE USED TO GENERATE ENERGY?



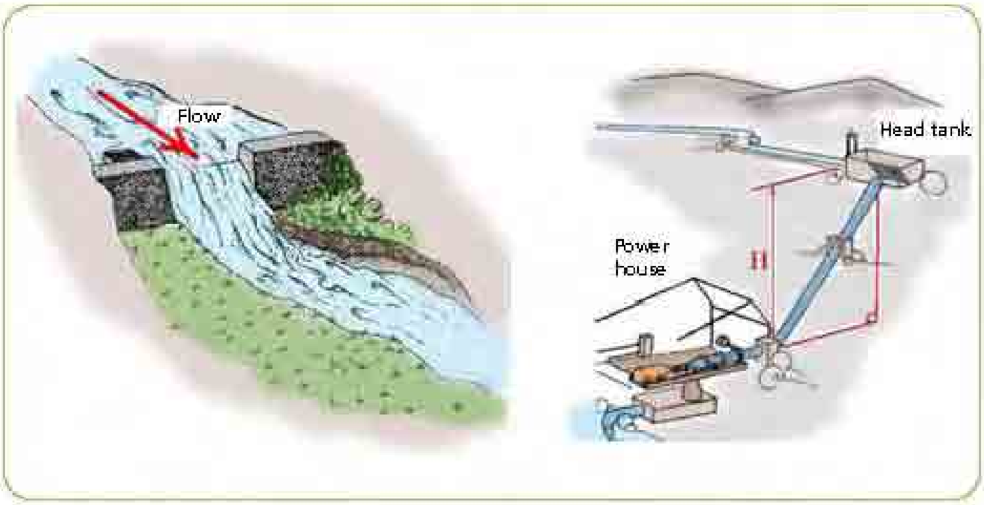
Good use should be made of all the water sources existing in the community or in the surrounding areas, including rivers, streams, springs, irrigation canals, or other sources.
Therefore, it is important to know all the water falls or high levels of water sources that may be taken advantage of in each case.
Additionally, the following information should be recorded in a notebook:

- the name of the water source,
- the name of the place where the water fall or high level is located, and
- the approximate distance between the water source and the community.

4. WHAT DO WE NEED TO KNOW?

We need information on 2 variables:

- the volume of flow or the amount of water that a water source has, and
- the level or water fall existing between the canal and the possible place where the machine house will be located.



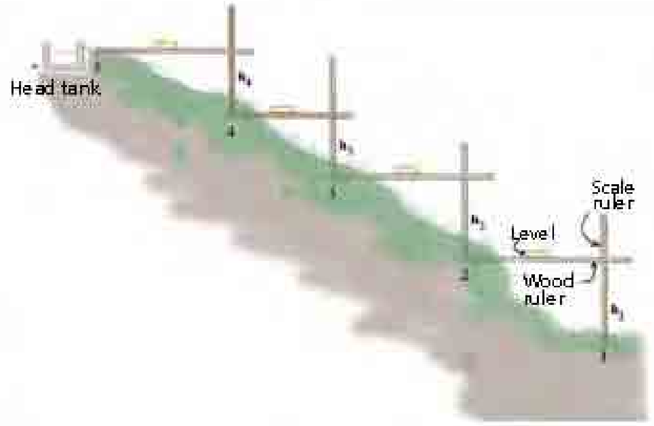
It is important to have information on these variables because this will allow us to calculate the electric power than may be generated. It is important that the river or any other water source has a constant volume throughout the year.

5. HOW CAN WE MEASURE THE LEVEL?

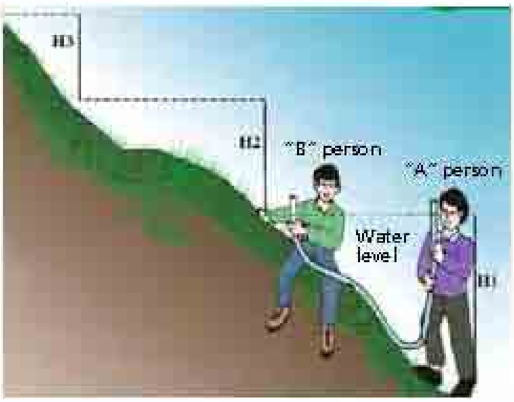
There are methods that may be easily applied by community using local materials and Instruments.

Measuring the height with a leveling hose

This method is appropriate for places with a small distance between the high place and the low place. The only thing we need is a transparent hose with water in it.
To get a reliable measurement, we need to make sure that no air bubble remains inside the water in the hose.
Two people are required to measure the total height by sections.



- First we measure the height of the person that will serve as reference, from the person's feet up to his eyes. Say, for example, that the height is 1.65 m. Then we write this measurement in the notebook.
- As shown in the figure, we place one end of the hose at the level of the eyes of the person serving as reference and we place the other end in front of the person until the water level is even. We then mark this point on the ground. This new point serves as the new reference for the following measurement.
- The number of measurements made is written down, for example, 13 measurements.
- The total height is obtained by multiplying the height of the person who serves as reference by the number of times measurements were made, for example, 1.65 x 13 = 21.45 m.



6. HOW CAN WE MEASURE THE VOLUME OF FLOW?

We can use two methods:
- The container method
- The float method

This measurement should be carried out in the dry season when the volume of flow of the water source is at its lowest level. Additionally, we should have historical information on the conduct of the river: if the river has ever dried up or if there are many outflows in the rainy season. This information may be provided by people who have lived many years in the community.

Now let's see how each method works:

6.1. Measuring the volume of flow through the container method

This method is effective to measure the volume of flow of small rivers or streams, and consists of measuring the time it takes to fill a container or bucket with the river water.

We need:
- 1 bucket or a cylindrical container whose capacity in litres we know,
- 1 chronometre or a watch, and
- Corrugated roof tiles or plastic sheets.

To measure the volume of flow, we will do the following:
- Locate the part of the river where we will measure the volume of the water.
- In this part of the river, we will orient the river course to form a waterfall (See figure).
- Finally, we will place the bucket or cylindrical container so that the water falls into it and we take the time it takes until the water fills the container.
- We then write down the time in the notebook. We have to do this at least three times.

For example, if we use a bucket with a 60 litre capacity and the time it took to fill up with water was 6, 7, 8 seconds, then the volume of flow will be calculated in the following way:

- Calculate the average time

$$Average\ time = \frac{t_1 + t_2 + t_3}{3} \text{ in seconds}$$

$$Average\ time = \frac{6 + 7 + 8}{3} = 7s$$

- Calculating the volume of flow

$$Flow = \frac{Capacity\ (litres)}{Average\ T\ (seconds)}$$

$$Flow = \frac{50}{7}\ \frac{\ell}{s} = 8.6\ \frac{\ell}{s}$$

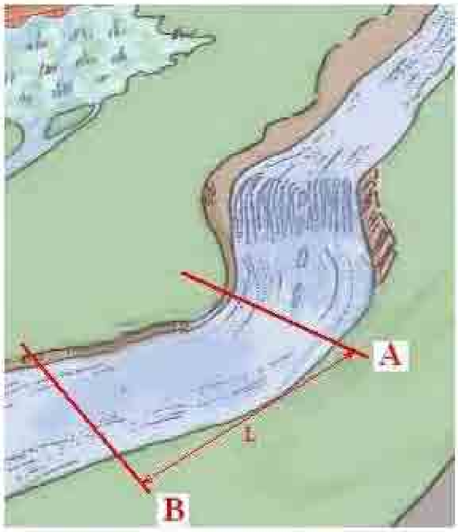
6.2. Measuring the volume of flow through the float method

A basic knowledge of mathematics is required to use this method. It is then important that the community has the support of people that have these skills or we can ask the teacher of the school community to help us.

To apply this method we will need the following:

- A floating object, such as a small plastic bottle, a cork, etc.
- A chronometre or watch
- A tape measure or ribbon
- A ruler or scaled board

To calculate the volume of flow we go through the following steps



First: Select the appropriate place

We must find a part of the river that is 10-20 metres long where the water runs at an even pace, without turbulence. To do so, we must make sure that there are no big stones or logs that prevent the water from running freely.

Second: Measure the speed

We must identify two points in the selected section of the river: point A will be the start point and point B will be the point of arrival.

Then we measure the distance between these points. For example, the distance between point A and point B is 15 m.

One person will stand with the floating object in point A and another person will stand with the watch in point B. When the first person lets the floating object go off, the second person will measure the time the float takes to go from point A to point B. Then you write down the time in the notebook. Do this at least three times.

To calculate the speed, we use the average time that is calculated in the same way as in the first method.

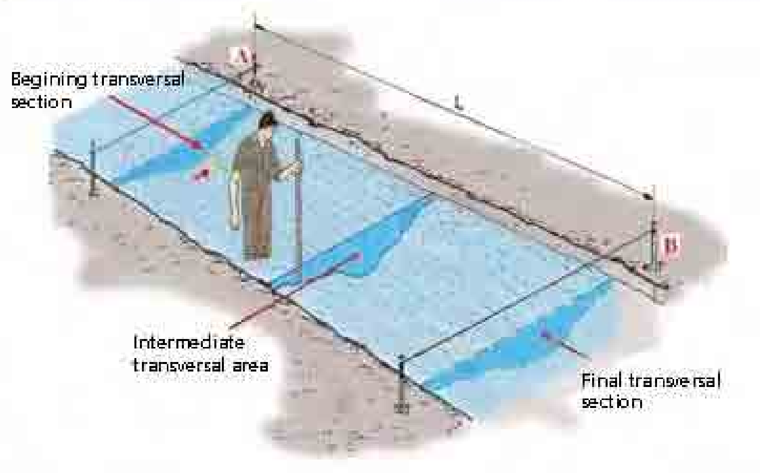
Example: the average time is 10 s.

We use the following formula:

$$Speed = \frac{Distance\ \overline{A-B}\ (metres)}{Average\ Time\ (seconds)}$$

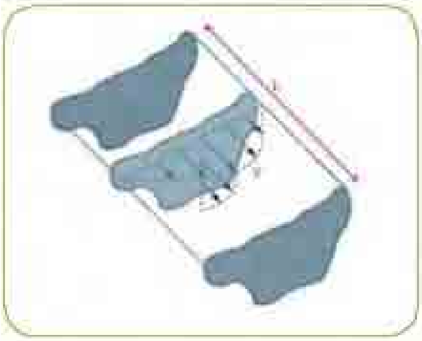
In our example:

$$Speed = \frac{15}{10}\ \frac{m}{s} = 1.5\frac{m}{s}$$



Third: Measure the area of the transversal section of the river or canal

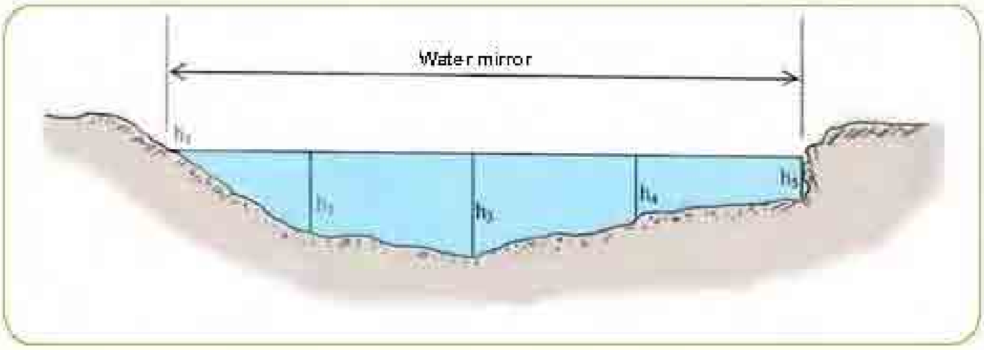
In the selected area, determine the place where the transversal section will be calculated. This place should have no obstacles so that we can comfortably do the measurements required to calculate the area.



First we have to measure the width of the river in the selected place (see figure). For example, the width is 2.5 m.

Then we have to estimate the average depth so that we can finally calculate the transversal area. The average depth is obtained by dividing the river width in at least 4 sections and by measuring the depth in each of these sections.

For example:



Depth	Metres
h1	0.00
h2	0.25
h3	0.38
h4	0.46
h5	0.30

Then we calculate the average of these depths:

$$h_{AVERAGE} = \frac{h_1 + h_2 + h_3 + h_4 + h_6}{5}$$

$$h_{AVERAGE} = \frac{0 + 0.25 + 0.38 + 0.46 + 0.20}{5} = 0.26 \text{ m}$$

Finally, the area of the transversal section is calculated by multiplying the river width by the average depth.

$$A_T = Width\ (m) \times Average\ Depth\ (m)$$

In our example:

$$A_T = 2.5 \times 0.26 = 0.65\ m^2$$

Fourth: Calculate the volume of flow

Once we know the speed and the transversal area, we can calculate the volume of flow of the river using the following formula:

$$Flow\ (m/s) = K \times Speed\ (m/s) \times Area\ (m^2)$$

Where K is a correction value associated with the speed.
This value is determined according to the characteristics of the river and its depth (see the table below).

Type of canal or river	K Factor
Canal walls coated with concrete, depth of water higher than 15 cm	0.8
Earth canal, depth of water higher than 15 cm	0.7
River or stream, depth of water higher than 15 cm	0.5
Rivers or earth canals, depths lower than 15 cm	0.5 a 0.25

In our example, we have that:

K = 0.5
Speed = 1.5 m/s
Transversal area = 0.58 m^2

$$Flow = 0.5 \times 1.5 \times 0.58 = 0.435 \frac{m^3}{s}$$

If 1 m^3/s = 1000 ℓ/s
Then the volume of flow will be: 435 ℓ/s

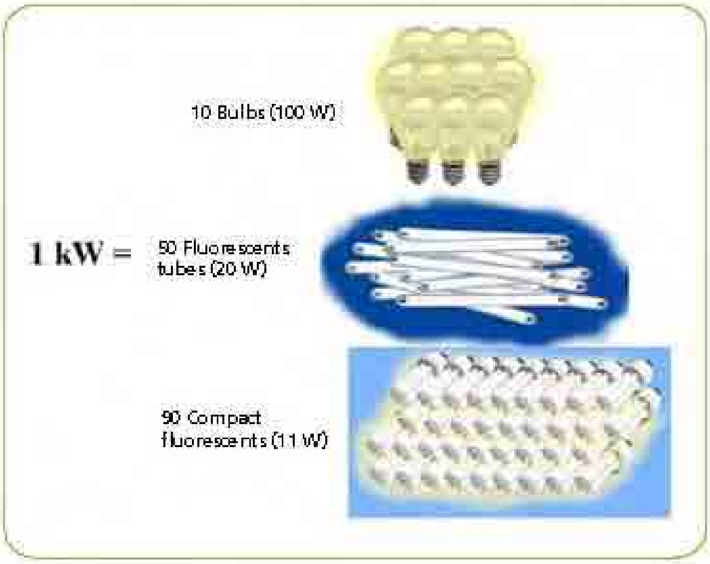
7. HOW MUCH POWER CAN BE GENERATED?

To calculate the power that can be generated, we need to know the value of the flow of volume and the height. Once we have this information, we estimate the power using the following formula:

$$Power\ (kW) = C \times Height\ (m) \times Flow\ (\frac{m^3}{s})$$

C: is equal to 6 for mini hydropower
C: is equal to 5.5 for micro hydropower

In order to understand the value of the power, we can make the following comparison:



Practical example

We have found that the volume of flow of the stream is 80 l/s and that the height is 45 m. What is the power that can be generated?

Answer:

We know that the

Volume of flow = 80 ℓ/s = 0.08 m^3/s

Height = 46 m

Then, the value of C = 5.5

Introducing the values obtained into the formula:

$$Power\ (kW) = 5.5 \times 46m \times 0.08\ \frac{m^3}{s}$$

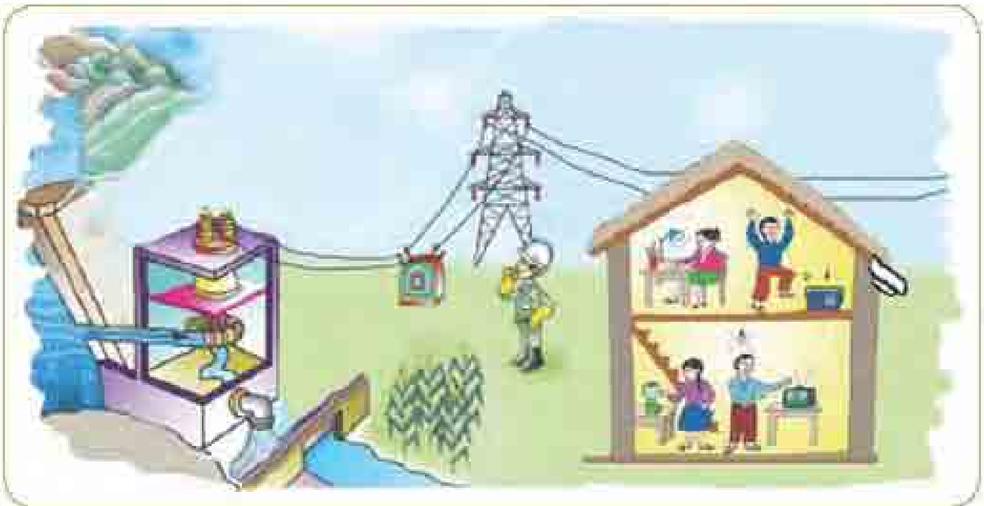
$$Power\ (kW) = 20\ kW$$

8. WILL THIS POWER BE ENOUGH TO COVER OUR NEEDS?

This will depend on our community's demand for energy, that is to say, it will depend on what we will use energy for.

A specialist is required to determine said demand. The specialist will request all the relevant information, such as:

- The total population living in the community.
- The number of households in the community that want to have connections to the electricity service.
- What other basic services does the community have: health center, school, municipality, etc.
- How many businesses or workshops are there in the community.



9. HYDROPOWER COMPONENTS

In general, MHSs have the following components:

- Civil works
- Electromechanical equipment

Transmission and distribution networks

a) Civil works

The principal civil works components are: the intake, inlet channel, sand trap, head tank, penstock, generator hall, etc.

Intake

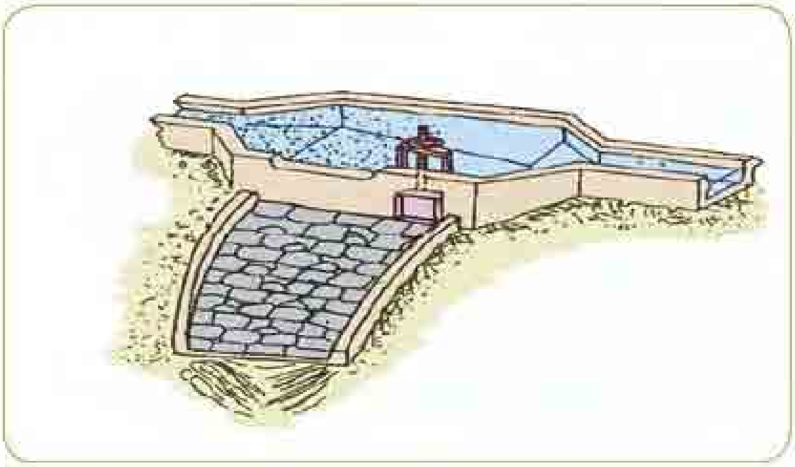
- A hydraulic installation whose function is to regulate a given water flow for the production of hydropower, whether mechanical or electrical.
- The intake may be built from concrete, stone, concrete and timber, etc.

Inlet channel

- The purpose of the inlet channel is to conduct water from the intake to the head tank.
- It is similar to the irrigation channels used in our community.

Sand trap and head tank

The purpose of the sand trap is to remove stones and sand carried by the water from the river on the way to the turbine.



The head tank ensures that the penstock is always full, preventing air from entering.

Penstock

- The penstock carries water under pressure from the head tank to the turbine.
- Mini/micro hydroelectric stations use high pressure PVC pipe as it is lighter, easy to install and costs less than steel pipe.

Power house

The power house contains all the generation and control equipment. It is located at the start of the tailrace, which takes the water from the turbine to the river.

b) Electromechanical equipment

Contained in the power house and consists of all the components involved in generating and controlling the electricity. Turbine, generator, regulator, control panel, etc.

What is a turbine?

A machine that transforms hydraulic energy into mechanical energy, as we can see from the turbine spinning under the force of the water.

Turbine types

Pelton turbine

Michell-Banki turbine

Francis turbine

Axial flow turbine

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Ministerio de Energia y Minas