Light for All, Intermediate Technology
for
Long-Term Solutions

Submitted to

Poverty Alleviation Fund (PAF)

Submitted by:

Centre for Renewable Energy (CRE),
Kathmandu, Nepal

in association with

Clean Energy Industries (CEI) ,
Biratnagar, Nepal

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We appreciate Clean Energy Industries, the Solar Tuki manufacturing company, for assisting the movement and providing technical support. Moreover, we appreciate local NGOs, microfinance institutes and local partners who initiated and promoted the **"Light for All"** movement in their locality.

Kiran Raj Joshi
Team Leader
Centre for Renewable Energy (CRE)

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1. Introduction

Household lighting is considered to be one of the basic requirements of society, and access to lighting is even being viewed as one of the basic rights of people. In Nepal, those who do not have access to electricity generally rely on kerosene based wick lamp (Tuki) for household illumination. There are about 2.4 million households in Nepal who rely on such Tukis to meet their evening and nighttime lighting needs at present. However, this form of lighting is neither cost effective nor environment-friendly.

The fumes and soot from the kerosene Tukis affect the eyes and lungs of the rural populace. Every Tuki is estimated to give off about 250 kg of carbon dioxide (CO_2) every year and thus contribute to global warming. Kerosene Tukis are also fire hazards, especially for those living in thatched-roof huts and bamboo shacks. Government of Nepal (GoN) spends billions of rupees annually to import kerosene. Apart from the up-front expenditure incurred in importing and subsidizing kerosene, there are also various hidden costs such as environmental and health related cost caused by burning the kerosene.

Although Nepal has a theoretical hydro-electrical potential of 83,000 MW, it is said that it is economically feasible to harness only 43,000 MW. But so far the total installed power capacity with Nepal Electricity Authority remains at 606 MW, of which 54 MW of power is from thermal power plants.

Even if Nepal were to tap the full hydropower potential, it would still not be economically feasible to have each and every Nepali household connected to the electrical grid due to the country's difficult topography and socio-economical conditions. This is a factor that forces us to seek alternative for energy / lighting sources. This makes it imperative for Nepal to develop decentralized renewable energy systems to provide sustainable energy sources to the rural people. In order to tap the huge potentiality of solar energy, GoN has introduced subsidy in this sector since 1996/97 and so far more than 85,000 Solar Home Systems (SHS) have been installed to electrify rural homes.

The cost of these SHS which ranges between Rs. 20,000 – Rs.35,000 is considered expensive for the rural and remote areas, more so when government subsidy is not

available. The high initial investment of this system is the limiting factor for wider dissemination of conventional SHS. Therefore it cannot be assumed that all remaining 2.4 million households who continue to rely on kerosene for lighting can afford to install these expensive conventional SHS even with government subsidy.

This is where the ***Solar Tuki*** comes in to the picture. Without the initial high investment of the typical solar home system, and the unfeasibility of kerosene as a fuel source, the "Solar Tuki" is seen as an ideal immediate intermediate alternative in Nepal.

2. Project Background

The initial adoptive research and development of White Light Emitting Diode (WLED) based low cost solar PV lighting system was initiated in May, 1999 by Centre for Renewable Energy (completed in December 2003) with the financial support from Swedish International Development Cooperation Agency (Sida) and coordination from Asian Institute of Technology (AIT), Bangkok under Renewable Energy Technologies (RETs) in Asia - a regional research and dissemination program Phase II. During this phase CRE conducted research on WLED lamps. Some prototypes of WLED lamps were developed and tested in the laboratory.

The research, development and dissemination activities were further continued during Phase III of RETs in Asia Project sponsored by Sida (February 2003 to June 2004). During this phase CRE developed real working prototype of Tukimara lighting system. Around 40 systems were installed as pilot project and the monitoring of the installed systems followed.

In February 2004 CRE and Renewable Energy Project Support Office (RESPO-Nepal) of Winrock International (WI) jointly implemented a demonstration pilot project "Rural Electrification Using Solar Energy Powered WLED" with the objective to test social acceptability, technical sustainability, financial viability and possibility for a Clean Development Mechanism (CDM) project. The duration of the project was 8 months. During this pilot project about 100 households (50 households in Hill area, Ilam and 50 households in urban area , Biratnagar) where provided with WLED lamps based solar PV lighting systems (Solar Tuki).

By December 2004 the first company, "Clean Energy Industries", that manufactures only Solar Tuki, was established by Laxmi Rai in Biratnagar.

This low cost form of lighting is a viable alternative to the traditional kerosene-wick lamps known as Tuki and has the potential to reduce greenhouse gas emissions by displacing kerosene lamps. On January 2005 CRE launched the "Light For All" Movement. In July 2005, Small Grant Program of Global Environmental Facilities GEF/SGP and World Bank supported the movement to initiate extended field test of the system to enhance quality of the product and to test non-subsidized micro-financing mechanism to commercialize the product.

The input to the quality assurance activities were achieved by collection and dissemination of the information about the latest development in the field of solid state lighting device, study and strict follow up of the norms and standards proposed or adopted by the government and the feedback received from the users of the system. Based on the analysis of these inputs identification and dissemination of quality products were assured.

3. Methodology adopted

The activities under this project have been categorized into Quality Assurance, Information dissemination, Entrepreneurship development, Dissemination of Technology package and compilation of the outcomes of the project.

Information dissemination activities have included demonstration of the technology package, exhibitions, field visits, talk programs and distribution of leaflets, brochures etc.

Entrepreneurs from private sectors (manufacturers of solar home systems or Electrical accessories as well as enterprising freelance technicians) were made familiar to the technology and its business opportunity through the series of trainings and discussions.

Feasibility of micro-financing was demonstrated through the creation of revolving fund for financing Solar Tuki in pilot project location

A comprehensive training manual was prepared for this purpose. The training manuals for the repair and maintenance of the Solar Tuki for the technicians of the service centre were prepared. Theoretical as well as hands on practical sessions were organized for the trainees.

4. Objective

Light for All Intermediate Technology for Long Term Solution is oriented to promote entrepreneurship with Solar Tuki for reliable delivery of Solar Tuki to broader consumer groups. The specific objectives of this phase are:-

i. To encourage Micro Finance Institutes, cooperatives, and similar organizations to finance Solar Tuki and Solar Tuki enterprises
ii. To create awareness among stakeholders and beneficiaries
iii. To build capacity of the stakeholders for manufacture and repair of Solar Tuki
iv. To establish a sustainable Central Warehouse to regulate and stabilize supply of components for manufacture/repair of Solar Tuki

5. Activities

Under Light for All - Intermediate Technology for Long Term Solutions following activities are being implemented:-

a. Central Warehouse (CW) for stabilizing price and supply of standard Solar Tuki components is being established. The scope and structure of Central Warehouse are being determined and services of Central Warehouse are being developed.
   i. Explore the potential supplier or manufacturer of the electrical and electronic components of the Solar Tukis.
   ii. Prepare all necessary work to import the qualitative components in bulk in a cost effective manner.

b. The project is inciting individuals and organizations to forge collaborations to set up Solar Tuki manufacturing, repair, and distribution enterprises.
   i. The interested entities are being induced in the "Light for All" movement through CW.
   ii. The ***project*** [1] has been identifying potential entrepreneurs to establish new Solar Tuki manufacturing industries at local level and provide technical as well as financial assistance to them.

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[1] Unless otherwise stated, the term "**project**" refers to the project team from the implementing organizations namely Center for Renewable Energy (CRE) and Clean Energy Industries (CEI).

c. The project is inciting and supporting Micro Finance Institutes, cooperatives, and other organization of similar functions to facilitate consumer and enterprise financing for Solar Tuki.
   i. Existing partnering organizations are being supported through the Revolving Fund
   ii. The project has been exploring sources to expand Revolving Fund and support other interested organizations

d. The project is conducting trainings and awareness campaigns
   i. Clean Energy Walk-in Learning Center (CE-Walc), the training premises of Clean Energy Industries has been cunducting on-demand and on-the-job Solar Tuki manufacturing, repair and maintenance trainings.
   ii. On site assembly trainings are being conducted.
   iii. Awareness campaigns are being carried out.

e. The project is closely monitoring and evaluating activities of "Light for All" movement, Solar Tuki pruduction and activities of partner organizations:-
   i. Continuous monitoring and evaluation of the processing products and exploration of possible market niches to extend and expand the product range and to make the industry sustainable.
   ii. Modify and upscale the product to meet the demand of the rural/urban consumers.

6. Principle Obstacle was also caused

There were practically no obstacle to the project implementation except frequent strikes and transport blockades. Inconvenient was also caused by the daily long load shading duration.

7. Principle Positive Aspect

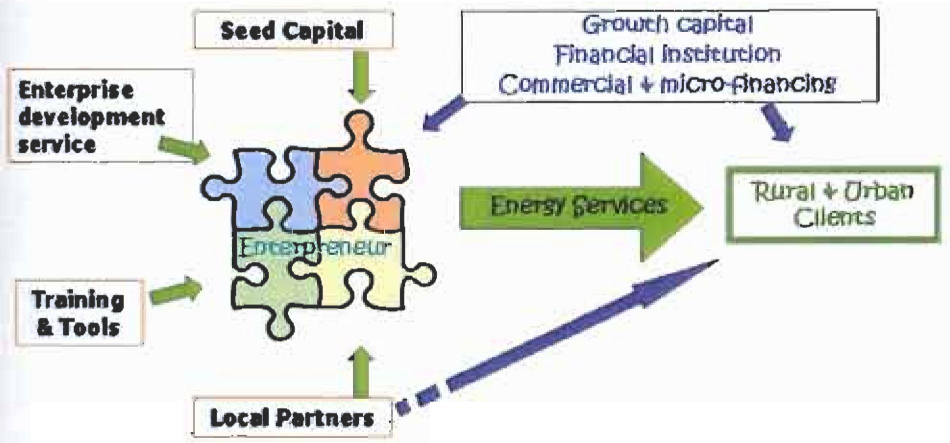
The Win – Win Approach

To reach the scattered rural poor households entrepreneurs need to be scattered as well. To be profitable they need to have access to the right information, technology, tools as well as capital. Even though there is a huge market for the Solar Tuki, small scale manufacturer/assembler of Solar Tukis will not be able to create a distribution network and to

provide after sales service effectively. They will need assistance. That is where government organizations (GOs), non governmental organizations (NGO) and INGOs can help by assisting them to build their technical and financial capacity through trainings and soft loans.

To create a quality product it requires quality components. In Nepalese context, electronic components including LEDs, PV panels have to be imported. To enable a constant supply of uniform components institutions that have the ability such as business houses could benefit by

CRE's Entrepreneur Development and Market promotion Model



importing in bulk and making it available to small entrepreneurs who will later add value by assembling the final product in their own region/ locality.

Making the product available is just an initial part of the effort. After sales service and customer satisfaction plays a vital role in commercializing the product. Local individuals, NGOs and Community Based Organizations (CBOs) can create linkages between the manufacturers and the consumers, by establishing service provider units. The incentive for the service providers would be the service fee that is integrated in the price of the Solar Tuki.

Though the price of the Solar Tuki set is NRs 3,500, majority of the consumer will not be able to pay up the entire amount in one installment. Here the role of micro finance institutions comes in for providing consumer loan to their members to fulfill the consumer's necessity for light.

The repayment schedule can be matched to the monthly expenditure on the kerosene of the household. This way it will not put any financial stress to the consumer and defaulter-risk, will be minimized. Thus, it is a new investment opportunity for Micro Finance Institutions (MFIs).

The entrepreneur development module developed and experimented has really proven to be effective. The quality Solar Tuki manufactured under these modules and efficient after sales service has built the trust among the users ultimately creating "Solar Tuki" brand.

8. Target population/beneficiaries

The project has mainly focused toward the deprived urban and rural population that can not afford to have either grid connection (urban population) or conventional Solar Home System (SHS). Likewise the target service provider groups will be the local entrepreneurs (creation of new business opportunity) willing to manufacture and commercialize the technology, local NGOs, CBOs and MFIs.

9. Activities completed during the "Light for All" movement

The major activity completed during the last twelve months of the "Light for All" movement as per this Nepal Development Market Place program(NDM) is establishment of the Central Warehouse (CW) in the concept of public private partnership (PPP) to guarantee the stable and efficient supply of quality electrical and electronic components for Solar Tuki manufacture and repair.

9.1 *Description of the Central Warehouse*

The Central Warehouse has been constituted to function as commercially sustainable entity. It will function as trading house. It will carry out the business of importing the electrical and electronic components in bulk and stably supplying these components to Solar Tuki manufacturers and service centers.

The CW will stock the components centrally and supply as per demand of the partner organizations at local (district) level. The small industries will not have to worry about the constant supply of the raw material. They can solely concentrate on their assembly activities and on meeting the demand of the local market. The CW will be the quality monitoring and market developing entity. In close cooperation of the capacity building institutions it will continue research and development activities to enhance the product quality and to make the price competitive

9.2 *Legal Basis of the Central Warehouse*

The project explored several legal alternatives while constituting the CW.

One of the options of operating this institution was as a NGO where all the partner organization that have been promoting Solar Tuki dissemination and capacity building activities would be the member. However, this approach would be in conflict with the philosophy that the business has to run in commercial basis with privilege to indulge in all the commercial activities and to. be self sustaining it has to make reasonable profit. Commercial financing and tie ups would be infeasible with the NGOs.

Another option was to register the CW as co-operative organization. The regulation needs at least 25 members for registration of a cooperative. This was identified as the major obstacle for constitution of CW as cooperative. There are so far four industries registered as Solar Tuki assemblers/manufacturers. NGO like CRE and other similar organizations are supporting their activities by facilitating them by providing training and market options

The third option was to register the CW as the private company. Most of the private companies are for profit and governmental/public resouces cannot be diverted for increasing profits of any particular private organization. Registration as pure private company as per the prevailing laws of Nepal would have reduced opportunities for collaboration with public and not-for-profit agencies.

However, as per the Company Act 2006 a private company can be registered and run involving the private, public and governmental institution as partners if the company is run on the principle of **None-Profit Distributing Company.** Such company can be registered at the Company Register's office at Tripureswore, Kathmandu under Chapter 19 of the company act 2006.

The benefits of registering CW as None-Profit Distributing Company are diverse. The CW could function as profit making commercially sustainable

entity and yet address concerns of associated stakeholders without biases. Private manufacturing companies along with NGOs like CRE and ECCA that are supporting their activities, supporting industries as Purna Metal Concern, and Suntech Energy Co. Pvt. Ltd that are supplying the components of Solar Tukis, and local service providers could join the CW as active member to set up the business. Therefore, the CW was registered as None-Profit Distributing Company with the name "Centre for Energy, Environment and Entrepreneurship (C E-Cube)".

9.3 *Services of the Central Warehouse*

Solar Tuki manufacturing and service providing industries and entrepreneurs are the potential clients of the CW's trading business. The CW as a trading house will be involved in importing the electrical and electronic components from abroad and in procuring locally available components from local market to guarantee regular supply of the quality raw material to the Solar Tuki manufacturers and service centers.

It will assist the new entrepreneurs, service providers, manufacturers, etc by building their capacities through appropriate trainings and by developing network of stakeholders. The CW will mobilize soft loan and initiate credit financing and short term credit facility for manufacturers procuring components (the loan well be minimum for 60 days at 6% interest rate).

In co-operation with CRE and other research and development institutions, the CW will work for improvement in available system's technology and design and will continuously conduct R&D to enhance the product and the business.

Categorically, the CW will consist of the following section/department

A. Components import/export Unit

B. Store management unit

C. Customer support unit

D. R & D Unit

10. Trainings, awareness, promotional campaigns

Training programs, one of the integral components of the campaign, have been instrumental in building awareness and enhancing capacities of stakeholders involved or willing to be involved in Solar Tuki assembly, distribution and maintenance.

Clean Energy Walk in Learning Centre has been facilitating on-job training for the technical staff of the newly established Solar Tuki service centers / Solar Tuki assembling industries. The training opportunities are open 365 days in year. Since the targeted populace is rural poor, the on-job training have been scheduled as per the trainee's demand and convenience.

i. Mr.Rajkumar Rai the technical supervisor of Khotang Bikash Manch's vocational training centre completed Solar Tuki assembly training. Khotang Bikash manch is now assembling Solar Tukis at their center in Diktel, Khotang and marketing it at local level.

ii. Similarly Mr. Lila Rai registered a Solar Tuki manufacturing industry in Morang after having month long on job training at Clean Energy Walk in Learning Centre of Clean Energy Industry. "Lila Solar Tuki Industry" has started assembling Solar Tukis in Itahari.

iii. Pathivara Solar Tuki is established in Birtamode, Jhapa. Mr. Prem basnet, Mr. Padam Acharya and Mr. Binod Kumar Khadga participated 9 days training and perfected in Solar Tuki assembly works and Solar Tuki industry management system.

iv. Mr. Buddhi Raj Shrestha, Mr. Tek Bahadur thapa, Mr. Chhedu Ram choudhary, Mr. Bindeshwore Prasad Choudhary and Mr. Dev Raj Rai participated in Solar Tuki Repair and Maintenance trainings.

11. Assessment of impact of project in the Global Environment

Climate Change is the focal area of the project. Savings in kerosene consumption by kerosene based wick lamp, reduces the emission of carbon dioxide and NOx gases which are the contributors of global warming.

The Solar Tukis has reduced the consumption of kerosene in the pilot project localities and in adjacent VDC. Each Solar Tuki used in the rural household saves at least three liters of kerosene burning per month. Approximately 75,000 households have so far adopted Solar Tuki lights, that means 225,000 liters of kerosene is consumed less every month.

12. Future Plans:

"Light for All" movement is on going program till all the households in Nepal replaces the kerosene based lamps. As mentioned above there are yet huge demand, our effort will be continuous support for capacity building of local service providers and local assemblers/manufacturers of Solar Tukis and its components.

CRE in Joint collaborative partnership with "Clean Energy - Walk in Learning Centre" will be providing Repair and Maintenance Training for local Solar Tuki service providers and Solar Tuki assembling training for entrepreneurs who wish to establish Solar Tuki manufacturing industries.

Additional Remarks:

The publication "LIGHT FOR ALL" Delivery Mechanism for Solar Tuki is the detailed report of the project and should be considered as part of the final report..

13. Assessment of the lessons learned

A. Effect of project in Global environment

Saving kerosene consumption by kerosene based wick lamp, reduces the emission of carbon dioxide and NOx gases which are the contributor of global warming.

Each Solar Tuki used in the rural households saves at least three liters of kerosene burning per month. Approximately 75,000 household has so far adopted Solar Tuki. consumption of kerosene has reduced by 225,000 liters per month.

The Solar Tuki program has potential to benefit from Clean Development mechanism CDM by preparing PIN documents for Carbon trading.

Commercialization of the Solar Tuki system has partially achieved by winning the trust of the rural consumers.

B. Project link to sustainable livelihood

The Solar Tuki Lighting system provides rural and poor families with a reliable. safe source of light that exceeds the illumination of the existing kerosene based lamps. Solar Tuki is based on freely available renewable source of energy the extended operation of the light in the night does not cause additional cost, where as the cost of kerosene increases as the hours of use increase. The working hour of the solar tuki user has increased so has their productivity and their study time.

In Terai, Solar Tuki users can extend their children's study hour without worrying about mosquitoes for they can use the light inside mosquito curtain.

C. Community driven approach

The Solar Tuki marketing strategy is based on concepts such as establishment of village level service centre for after sales service. and creation of revolving fund for soft loan to Local micro-finance institutes or community based organization for Solar Tuki financing. Capacity building of the local existing community and micro-finance institution. saving credit group, and the service providers are the other activities of the program; hence the local community based organizations are the driving force to popularize the Solar Tukis.

D. Capacity building components

Solar Tuki technology is very simple. An individual even without any technical back ground is able to understand the system. Training is an integral part of the business plan. The standard training is three day long during which trainees are taught to assemble and repair Solar Tuki Lamps and to maintain records. More than 65 technicians have been trained so far, in other words, .a new work force has been created.

Besides service centre operators. entrepreneurship training is provided to individuals, groups and cooperatives who are interested to set up a manufacturing (assembly) industry in their locality.

The training programs have been instrumental in building awareness and enhancing capacities of stakeholders involved in Solar Tuki distribution, maintenance, and net-working.

E. Enhanced public awareness

Public awareness about the Solar Tuki System and the delivery mechanism were propagated through local community based organizations and publications of articles about its benefit. Similarly field demonstration was another tool for enhancing awareness of the rural populace.

F. Indigenous people involvement

The product is fulfilling the basic need of all those who do not have access to grid system. There was no special provision based on cast or economical status. All the members of the community are equitably benefited by the lighting system and the marketing modality.

G. Sustainability of the project

The Solar Tuki systems are marketed without any kind subsidy. The credit financing of the system was the driving force to make the light affordable. The Solar Tuki has created its market in rural areas so it has proved to be sustainable. Replications of the Solar Tuki technology are happening in other districts without any hurdle.

14. Influence in government policy

Solar Tuki program has been in line with the both long term vision of 'The Tenth Plan or PRSP' and objectives of 'Rural Energy Policy 2006.' It has to be noted that unlike other RET programs Solar Tuki was not subsidized and performed under normal market conditions.

PRSP Long Term Vision	Solar Tuki Achievements
Accelerating economic development, improving living standard of the rural people, increasing the employment opportunities, and maintaining environmental sustainability through the development of rural energy systems	Solar Tuki replaces Kerosene wick lamps thus reduces pollution caused by it and usage of imported fossil fuel. Working and study hours have extended, and semi skilled rural workforce has flourished.
Commercializing the alternate energy technologies and reducing the dependence on imported energy through planned technology development.	Solar Tuki process has made corridor for future technology diffusion through market forces and without subsidy.
Keeping in mind long term consequences of the use of natural resources, use of traditional energy resources would be slowly replaced by the modern energy sources that are within the reach of purchasing power of rural people	Consumer financing and ties with financial institutions that have given rise to consumer financing have improved bank-ability of renewable energy entities and increased purchasing power of the consumers.

REP Objectives (REP, 2006)[12]	Solar Tuki Achievements
Reduce dependency on traditional energy and conserve environment by increasing access to clean and cost effective energy in rural areas	Solar Tuki replaces kerosene wick lamps and fatwood (jharrow and diyalo) as lighting source
Increase employment and productivity through development of rural energy resources	The process where entrepreneurship among consumers is emphasized encourages involvement of indigenous workforce, local production, and adds employment opportunities

Increase living standards of rural population by integrating rural energy in social and economic activities	Services and diffusion process are inclined to integrate social and economic activities. Solar light provides clean light and access to communication.

15. Conclusions and recommendations

Solar Tuki business model has proven that subsidies do not essentially popularize a product. As business ventures Solar Tukis were sensational because of internal business strategies to meet the consumer demand, effective distribution, consumer oriented marketing, revolving fund and infallible product quality. Business approach of similar nature could be utilized in other business ventures with Solar Energy and other RET products.

Most of the targeted populace are geographically scattered. To provide them an efficient back up service strong and wide spread networking of all the stakeholders (NGOs, CBOs, manufactures, service providers, finance institutes as well as government agencies and appropriate national policies) is essential.

Network alone can not work efficiently until enough funds are available. Funds are needed for production, marketing and importing the raw material from abroad.

16. Financial report

Financial statement

Description	Budget amount	Expenses	Income	Balance
Fund received from PAF			1,350,000.00	1,050,000.00
Matching fund from Clean Energy Ind			541,800.00	1,891,800.00
Personnel:	250,000.00	250,000.00		1,641,800.00
Materials and Equipment:	1,200,000.00	741,800.00		900,000.00
Training:	200,000.00	200,000.00		700,000.00
Travel:	180,000.00	180,000.00		520,000.00
Others:	200,000.00	200,000.00		320,000.00
Evaluation/Information dissemination:	120,000.00	120,000.00		200,000.00
General Administration/Overhead:	350,000.00	350,000.00		-150,000.00
AC receivable from PAF			150,000.00	0.00
Total	**2,500,000.00**	**2,041,800.00**	**2,041,800.00**	**0.00**

Annexes

Annex 1 : Solar Tuki Assembly, Repair & Maintenance Training details and schedule

Clean Energy – Walk in Learning Centre. (CE-WaLC)

Tel. 021-421076, Email: cei@enet.com.np Biratnagar 5, Morang, Nepal

Solar Tuki assembly training schedule

Day -1	
Theoretical training:	Basic of electricity and Brief history of SHS in Nepal
Day 2	
Theoretical training:	Basic of electricity Solar Tuki component's function
Practical training:	Solar Tuki component's assembly. Cutting and preparation of PCV unit for solar Tuki light head
Day - 3	
Theoretical training:	Basic of electricity and Wire sizes
Practical training:	Solar Tuki - Wire assembly and Preparation of PCV unit for solar Tuki light head
Day - 4	
Theoretical training:	Basic of electricity and component wiring
Practical training:	Solar Tuki – Wiring and assembly of Solar Tuki Lamp. Assembly of Solar Tuki light head
Day - 5	
Theoretical training:	Basic of electricity and component wiring
Practical training:	Solar Tuki – Wiring and assembly of Solar Tuki Lamp. Assembly of Solar Tuki light head
Day - 6	
Theoretical training: & Practical	Basic of electricity and component wiring Assembly of Solar Tuki light head
Day - 7	
Theoretical training: & Practical	Basic of electricity and component wiring Assembly of Solar Tuki light head
Day - 8	
Theoretical training: & Practical	Basic of Solar Electricity, Photo-voltaic Pannel and its wiring for Solar Tuki set charging. Use of Multi-meter and Trouble shooting Solar Tuki
Day - 9	
Theoretical training: & Practical	Basic of Management of Solar Tuki Assembling Business Accounting and Book Keeping of Solar Tuki Assembling Business

Solar Energy

The energy from the sun can be exploited directly in the form of heat or first converted into electrical energy and then utilized. Accordingly the solar energy is classified into solar thermal and solar photovoltaics (PV).

Solar thermal class of RE has found numerous applications like water heating, drying vegetables and agricultural products, cooking etc. In Nepal the solar water heaters are being extensively used in urban areas. The applications of solar dryers and cookers have found moderate use simply because of the low level of dissemination of these technologies.

The solar PV can be considered the only form of electricity that can be generated any time and anywhere provided sunshine is available.

History of Development of PV Technology

The birth of PV technology dates back to 1839 AD when Edmund Becquerel, the French experimental physicist, discovered the photovoltaic effect while experimenting with an electrolytic cell made up of two metal electrodes placed in an electricity conducting solution—generation increased when exposed to light.

In 1876 William Adams and R. Day discovered that the junction of selenium and platinum also exhibit photovoltaic effect. This discovery led the foundation for the first selenium solar cell construction in 1877.

The photovoltaic effect remained theoretically unexplained until the great scientist Albert Einstein described this phenomenon in 1904 along with a paper on his theory of relativity. For his theoretical explanation of photo-electric effect, Albert Einstein was awarded a Nobel Prize in 1921.

Another breakthrough in development of PV technology was the discovery of the method for monocrystalline silicon production by Polish scientist Czohralski in 1918. This discovery enabled monocrystalline silicon solar cells production. The first silicon monocrystalline solar cell was constructed only in 1941.

In May 1954 The Bell Laboratories of USA (Researchers D, Chapin, C. Fuller and G. Pearson) published the results of discovery of 4.5% efficient silicon solar cells.

First commercial photovoltaic product with 2% efficiency was introduced in 1955 by Hoffman Electronics-Semiconductor Division. The cost of a 14 milli Watt peak power solar cell was US$ 25 (or US$ 1,785 per Watt). The efficiency of commercially available solar cell increased to 9% in 1958.

The first PV powered artificial satellite of the earth, Vanguard I, with 0.1 W of solar cell occupying an area of approximately 100 cm^2 and powering a 5 mW back-up transmitter was launched in 17 March 1958. Three more PV powered satellites were launched in the same year. The first PV powered telephone repeater also was built in Americus, Georgia, USA in the same year.

Sharp Corporation was the first company to develop the first usable PV module (group of solar cells put together in a single module) in 1963.

By 1974 the cost of PV power came down to US$ 30 per watt from US$1785 per watt in 1955. With the dramatic reduction in the cost, the PV power once affordable only in space vehicle became an alternative source of electrical energy for terrestrial applications. The fig. 2.1 below illustrates the decrease in price (US$ per peak watt)

Electrical Power Supply Systems

Electrical energy is a very convenient form of energy, which can be easily generated, transmitted, stored and used. Any other form of energy can be easily converted into electrical energy. An example of this is solar electricity in which the energy from the sun (solar radiation) is converted into electrical energy by solar cells. Electricity is the branch of science that studies the theory and practices of electrical energy. Electrical engineering on the other hand is a branch of engineering that deals with generation, transmission, distribution and use of electrical energy.

Electrical energy is transmitted from one point to another by means of charged particles called electrons. There are three fundamental terminologies used in electricity: Voltage, Current and Resistance.

Voltage

Voltage or the potential difference is a force that compels the electrons to move from one point to another in predetermined manner. In water supply system analogy, the voltage can be compared with the pressure of water in the storage tank that forces the water to flow in the pipeline. The unit of measurement of the voltage is Volt and is abbreviated and symbolically represented as 'V'.

Current

Current is the quantity of charged particles flowing in given direction per unit time. The current can be compared with the amount of water flowing in the pipeline per unit time. The unit of measurement of electrical current is Ampere and is abbreviated as 'A'. Symbolically the letter "I" represents the current.

Resistance

Resistance is the property of the material to oppose the flow of current through it. The unit of resistance is Ohms and abbreviated as 'Ω'. Symbolically the letter 'R' represents the resistance.

The electrical law that relates the above three fundamental parameters is called Ohm's law. According to this law, assuming that all other parameters remain constant, the current through an electrical circuit is directly proportional to the applied voltage and inversely proportional to the resistance of the circuit:

$$I = \frac{V}{R} \quad (3.1.1)$$

The electric current is further classified into direct current (DC) and alternating current (AC). The current is called DC if the direction of flow of current does not change with time. It means the DC current always flows in one direction only. The voltage that causes the flow of DC current is referred to as DC voltage. Examples of DC voltages are the output voltages of storage batteries, DC generators etc.

If the direction of flow of current changes periodically with time then such current is called AC current. And the voltage causing the flow of AC current is called AC voltage. Examples of AC voltages are the city supply, output of AC generator etc. The rate or frequency at which the direction of current changes is termed as cycle per second or Hertz (Hz). In one cycle the current changes its direction of flow. In Nepal the frequency of AC voltage is 50 cycles per second or 50 Hz.

The other terminologies used in electrical supply systems are power, energy, active load, reactive load, power factor, crest factor, harmonics and loss of load (LoL) probability.

Power and Energy

Electrical power may be defined as the energy delivered by the electrical source (generator) to the load (acceptor) per unit time-

$$P = \frac{E}{t} \quad (3.1.2)$$

where P is the power in Watts (W), E is the energy in Joules (J) and t is the time in seconds.

If the supply system is DC, then the power can be expressed as the product of voltage and current, i.e.

$$P = V \times I = \frac{V^2}{R} = I^2 \times R \quad (3.1.3)$$

Re-writing the formula (3.1.2), we can define the energy as product of the power and time-

$$E = P \times t \quad (3.1.4)$$

Thus the energy can be defined as the power delivered to the load in given duration of time. In electrical terms the energy is expressed in Watt- Hours (Wh)

t and Diffused Radiation at the Earth's Surface

ht is attenuated by at least 30% during its passage through the earth's atmosphere. The auses of such attenuation are:

- Rayleigh scattering or scattering by molecules in the atmosphere.
- Scattering by : erosols and dust particles.
- Absorption by the atmosphere and its constituent gases.

gree of attenuation is highly variable. The most important parameter determining the ncident power under clear conditions is the length of light path through the atmosphere ed to as Air Mass or AM).

tal radiation received at the earth's surface is the cumulative total of direct radiation iffused radiation. The figure 3.2.1 illustrates the various components of radiation ed on the earth's surface. The composition of terrestrial sunlight is further complicated fact that, apart from the component of radiation directly from the sun, atmospheric ing gives rise to a significant indirect or diffuse component. Even in clear, cloudless the diffuse component can account for 10 to 20% of the total radiation received by a ntal surface during the day. For less sunny days, the percentage of radiation on a ntal surface that is diffuse generally increases. Sun light reflected from the ground also butes significant radiation to an inclined surface. Snow mirrors about 70% to 80% of ht it receives, while a grass field reflects only about 15 to 20%. These effects are n as "Albedo Effect".

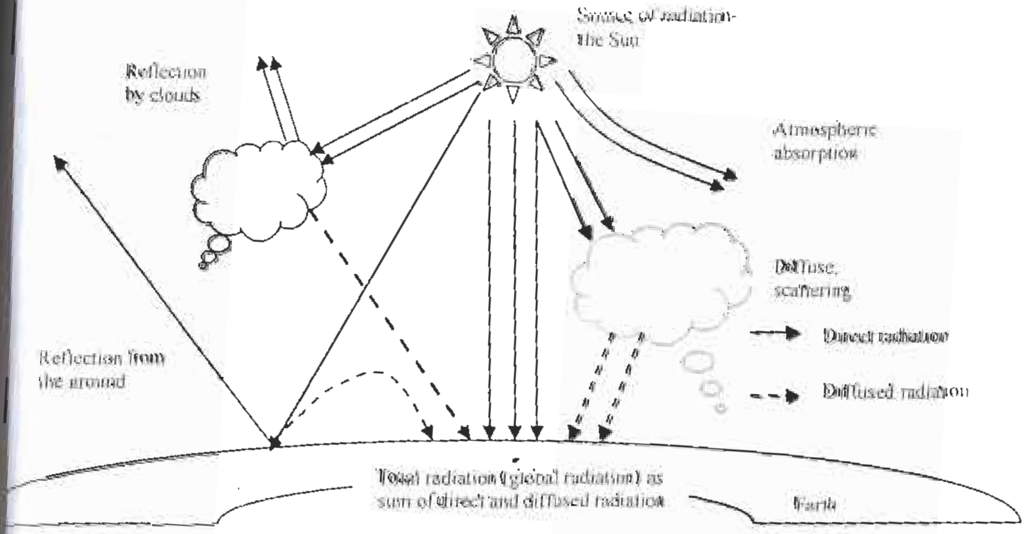


Fig. 3.2.1 Direct, diffuse and total radiation on the earth's surface

Sun

sun is the number obtained by division of insolation by 1000 W per sq.m. per day. In cases, the peak sun or the insolation is treated as a single parameter because they are related by a constant coefficient.

Direct and Diffused Radiation at the Earth's Surface

Sun light is attenuated by at least 30% during its passage through the earth's atmosphere. The main causes of such attenuation are:

- Rayleigh scattering or scattering by molecules in the atmosphere.
- Scattering by aerosols and dust particles.
- Absorption by the atmosphere and its constituent gases.

The degree of attenuation is highly variable. The most important parameter determining the total incident power under clear conditions is the length of light path through the atmosphere (referred to as Air Mass or AM).

The total radiation received at the earth's surface is the cumulative total of direct radiation and diffused radiation. The figure 3.2.1 illustrates the various components of radiation received on the earth's surface. The composition of terrestrial sunlight is further complicated by the fact that, apart from the component of radiation directly from the sun, atmospheric scattering gives rise to a significant indirect or diffuse component. Even in clear, cloudless skies, the diffuse component can account for 10 to 20% of the total radiation received by a horizontal surface during the day. For less sunny days, the percentage of radiation on a horizontal surface that is diffuse generally increases. Sun light reflected from the ground also contributes significant radiation to an inclined surface. Snow mirrors about 70% to 80% of the light it receives, while a grass field reflects only about 15 to 20%. These effects are known as "Albedo Effect".

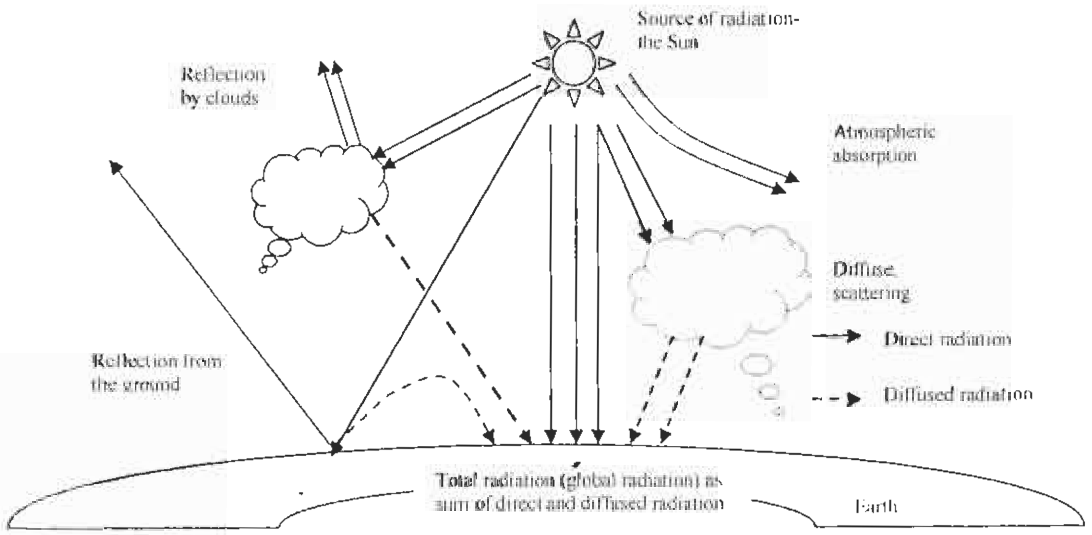


Fig. 3.2.1 Direct, diffuse and total radiation on the earth's surface

Peak Sun

Peak sun is the number obtained by division of insolation by 1000 W per sq.m. per day. In most cases, the peak sun or the insolation is treated as a single parameter because they are interrelated by a constant coefficient.

Annex 2: Training activities photos

1. Solar Tuki Repair & maintenance training

1.1 Solar Tuki Repair & Maintenance training – Solar Tuki-user group – Hashuliya, Kailali.

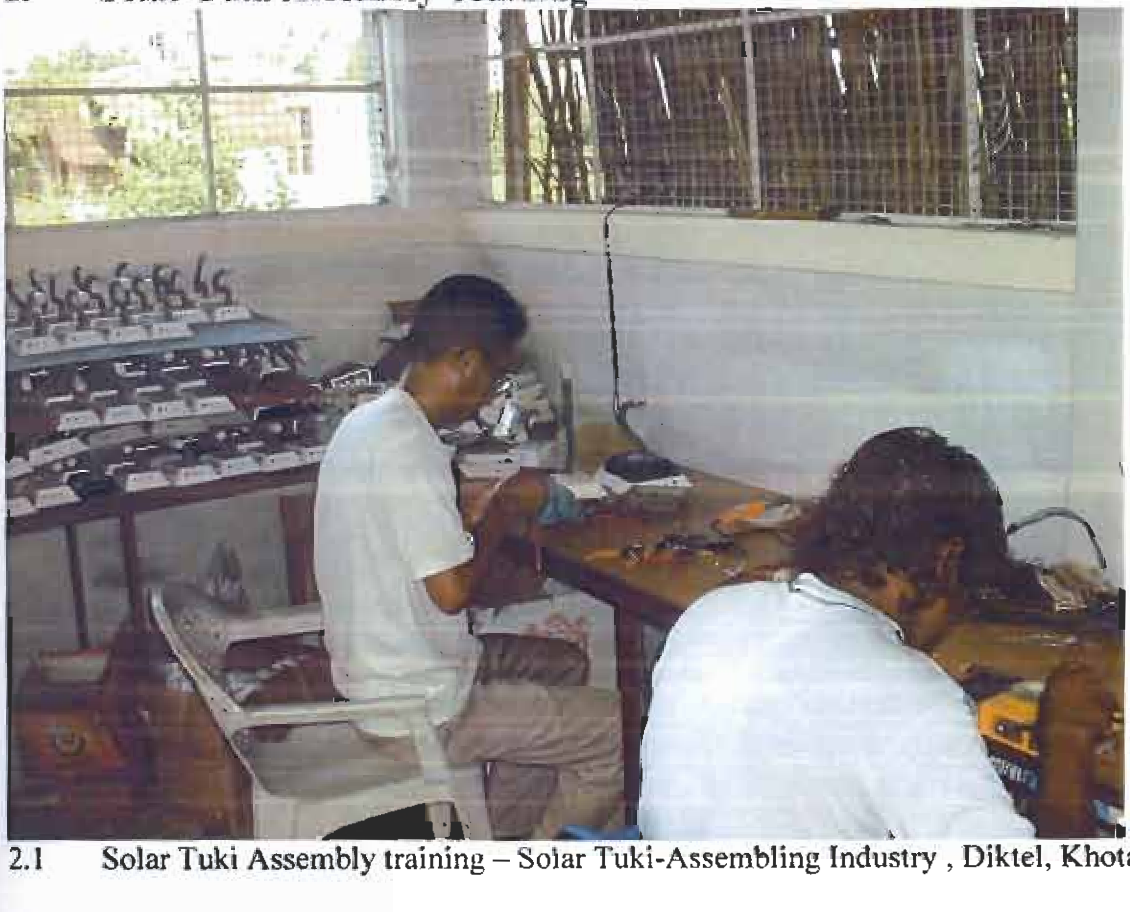
1.2 Solar Tuki Repair & Maintenance training – Solar Tuki-user group – Hashuliya, Kailali.

1.3 Solar Tuki Repair & Maintenance training – Solar Tuki-user group – Chure Mahila Batabaran Samrachhan Samiti, Damak .

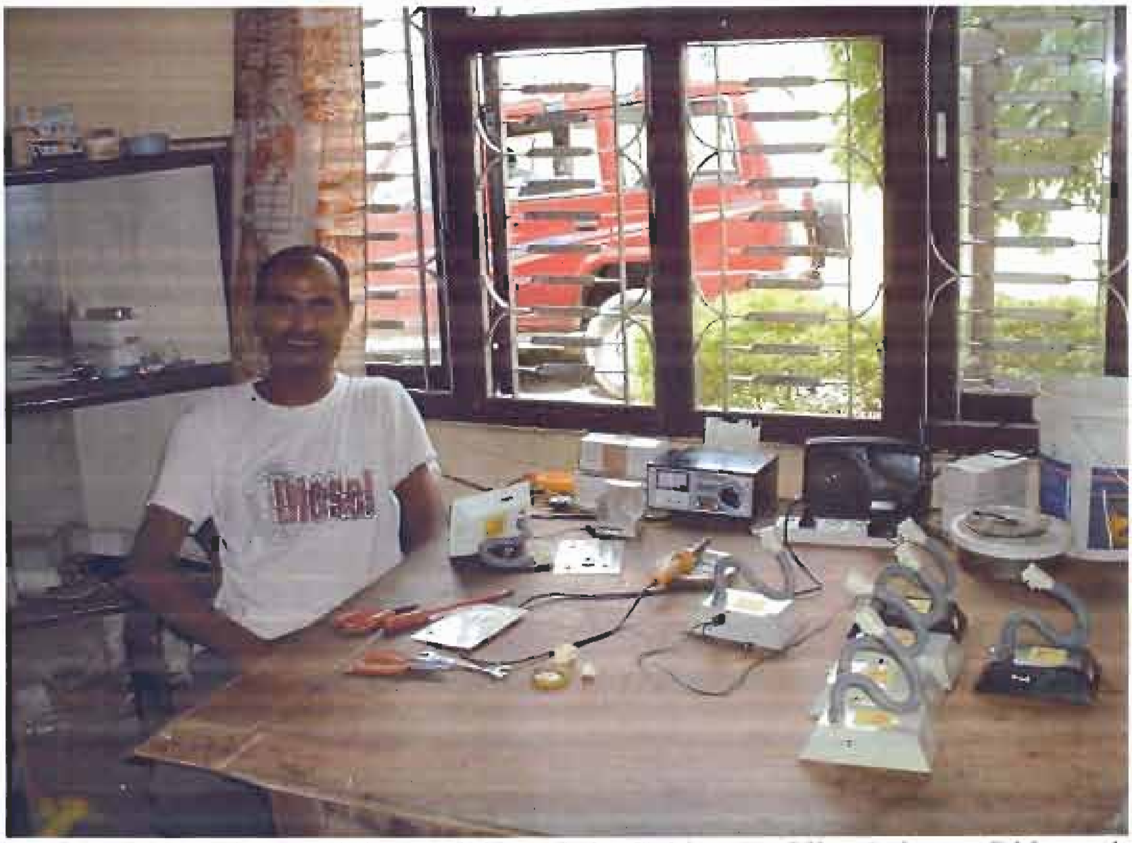
1.4 Solar Tuki Repair & Maintenance training – Solar Tuki-user group – Bhojpur

1.3 Solar Tuki Repair & Maintenance training – Solar Tuki-user group – Rauta VDC, Udayapur.

2. Solar Tuki Assembly Training



2.1 Solar Tuki Assembly training – Solar Tuki-Assembling Industry , Diktel, Khotang



2.2 Solar Tuki Assembling Training – Solar Tuki Assembling Industry, Bidtamode. Jhapa.

2.3 Solar Tuki Assembling Training – Solar Tuki Assembling Industry, Bidtamode, Jhapa

3. Interaction with local level Solar Tuki user group

3.1 Solar Tuki user group "Bikalpa Gyan Kendra" Sanichare, Morang

3.2 Visitors from udayapur at CE-Walc

3.3 Interaction with Community Forest User Group Coordination Committee, Khata, Bardiya

3.4 Interaction with Community Forest User Group Coordination Committee, Khata, Bardiya