Case Study of a Solar Photovoltaic Elementary Lighting System for a Poor and Remote Mountain Village in Nepal

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Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

Signature: .....Alexander Zahnd .....
ABSTRACT

Nepal is situated in the lap of the Himalayas and landlocked between China to the north, and India to the south. The country is known for its natural beauty, and as the land of the highest mountains in the world. 88% of Nepal’s population live in remote and difficult to access mountain areas. It is one of the only countries in the world with a lower female life expectancy rate than the male. While in the cities it has become “normal” to have access to energy services, 85% of Nepal’s rural communities are deprived of even the most basic energy services. 99% of the 2 billion people in the world that are without access to electricity, live in developing countries. Nepal is one of these countries, and four out of five live in rural areas. Furthermore, over 90% of the population of Nepal belongs to the 2.4 billion people relying on traditional biomass such as firewood, agricultural residues and dung, for their day to day cooking, heating and lighting purposes.

The village of Chauganphaya, in the northwestern district of Humla, belongs to the poorest villages of Nepal. Here, as elsewhere in Nepal, the forests are gradually being stripped bare, to meet the minimum energy needs of cooking, heating and lighting for the village folk. Unfortunately this is being done without any sustainable reforestation efforts. Furthermore, cooking and heating indoors on open fire places has had a direct chronic impact on the health of village folk, resulting in the low life expectancy for women, and the high death rate of children under 5.

This thesis goes into detail about various lighting technologies available for the remote mountain communities and suggests that the WLED lights are a real option for elementary rural electrification. This conclusion has been drawn on the basis of an electrification project undertaken in the above mentioned village of
Chauganphaya. Efforts made through a solar PV village electrification project with low wattage WLED technology, were successful, in that all 63 homes of the village of Chauganphaya are now able to have three lights each in their homes. This was made possible with each light consuming only 1 Watt and with a locally developed and manufactured 2-axis self-tracking frame for the four 75-Watt solar PV modules. The powerhouse with the self-tracking frame, battery bank and its charging and discharging units are centrally located in the village. The whole village has been divided into four clusters, with 15-18 homes per cluster. The central powerhouse is connected to the main house of each of the clusters by means of an underground power line distribution network through armored cables. Likewise, each house in a cluster is connected to the main cluster home by means of an underground armored cable. In this way the power distribution is approximately equal and in the case of one cluster distribution line facing a problem, the other homes in that cluster are not effected and will still have power.

This rural electrification project was not undertaken in a vacuum but as one part of a wider holistic grass root community development project. In the initial stage, a detailed survey, with questions specifically designed for this community was conducted, in order to assess the living conditions of the people. In the next stage, with the help of the outcome of the survey, four integrated projects were developed to improve the living conditions of the people. These projects aim to address the most urgent needs of the people as identified by themselves. Following is a gist of these projects:

- The rural electrification project with low wattage WLED technology.
- Each family from the Chauganphaya village has been able to purchase an improved smokeless metal stove at a subsidized rate. This has been specially designed to accommodate their cooking and eating habits, based on locally
available foods. It also heats their rooms for most of the year, and has provisions for boiling water.

- In order to be able to purchase such a stove at a subsidised rate, each household had to build a pit latrine, after undergoing a simple training in building such a latrine.
- The whole village community participated in the repair, and rebuilding of their village drinking water system, with the result that there are several tap stands to be found in the village.

The survey undertaken before any of these projects were carried out will be repeated once a year, to assess the actual impact these projects have, on a long-term basis.

Developing and carrying out these projects in the challenging environment we find ourselves in, with the ongoing political unrest and the continuing war between the Government troops and the rebels, and the ever present caste system has been an enormous task. Nonetheless, at the time of writing this, the electrification project should have been fully installed and operational. There are some minor improvements still needed, such as, the unexpected voltage drop in one cluster due to extended underground cable installation. Mitigation of that is planned as early as the political situation allows it.

The thesis goes into details about various lighting technologies for remote mountain communities, arguing that WLED lights are a real option for this purpose. In order to design a solar PV system according to the local conditions, it is crucial to understand the available solar energy resource. As no solar irradiation data for Chauganphaya or Humla are available, a study was undertaken to gather data from the NASA web site, and to generate solar irradiation data through the
METEONORM software tool. As both these methods rely only on satellite data, a solar radiation monitoring and data recording system was designed, built and installed in the KU HARS in Simikot. Since May 2004, the daily solar radiation is being recorded on a horizontal, a 30° south inclined, and on a 2-axis self-tracking solar PV frame.

The Simikot HARS and Chauganphaya solar PV systems are designed with a back of the envelope, as well as with a professional solar PV system design software tool, called PVSyst3.31. All the different equipment used in both PV systems are looked at in detail in this thesis. In comparison to the HARS and the Chauganphaya village PV systems, the Tangin village SHS project, installed by a private company through the Government solar PV subsidy program, serves as a comparative case study.

Sustainability and appropriateness are crucial factors, which have to be considered in any rural community development project. What is appropriate technology and how one can strive towards more sustainable projects, is looked at on the basis of the experience of the Chauganphaya village project.

“What can be Learned” tries to highlight the most important lessons learned form this project, up to the present stage. The thesis concludes, that the installed solar PV village system in Chauganphaya is an appropriate way to enable the poorest of the poor to bring light into their dark homes. It also reiterates the fact that additional to the lights, the smokeless metal stove, the pit latrine, and access to clean and pure drinking water, are important integrated parts of an appropriate holistic community development endeavour. It is expected that their synergetic effect will multiply the final impact upon the improved living conditions of the local community as opposed to their individual benefits.
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Preface

From 1996 – end of 2000 the writer has lived and worked in Jumla, one of the most remote, impoverished and underdeveloped mountain areas of western Nepal, developing and leading an extensive holistic grass root village community development project. More and more projects included the application of renewable energy technologies (RETs), in particular solar photovoltaic home systems, for elementary electrification for light. The designed and installed solar PV systems have undergone constant development, testing and follow-up, in order to become more appropriate and sustainable for the communities’ context.

Since 2001, the writer has been working with the KU-RDC (Kathmandu University - Research, Development and Consultancy) Unit. As part of RDC’s consultancy work various projects in the area of applied RETs, such as solar PV systems for whole villages in the remote and impoverished district of Humla have started with the local communities, and in collaboration with local INGOs/NGOs.

It is paramount to these projects to constantly improve the RETs applied, in order to better serve the poor and remotely located mountain communities in more appropriate and sustainable ways. At the same time it is important to continue the ongoing research in these fields of expertise as a University. In this way newly gained knowledge is put into practice through prototype testing. This provides a good foundation for the wider dissemination of practical applications in the local communities, addressing their enormous development needs in more holistic and sustainable ways.
Objective

The objective of this dissertation is the investigation of the design and design process, implementation and the social impact and technical lessons learned of an elementary solar photovoltaic lighting system in a remote and impoverished mountain village in Nepal.
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<tr>
<td>AC / DC</td>
<td>Alternating current / Direct Current</td>
</tr>
<tr>
<td>AEPC</td>
<td>Alternative Energy Promotion Centre (under the Nepali Government)</td>
</tr>
<tr>
<td>Ah</td>
<td>Amp-hour</td>
</tr>
<tr>
<td>AM</td>
<td>Air Mass</td>
</tr>
<tr>
<td>AMP</td>
<td>Amperes</td>
</tr>
<tr>
<td>A.P.C.S.</td>
<td>Analog Process Control Services ltd in NSW Australia</td>
</tr>
<tr>
<td>BOS</td>
<td>Balance of System</td>
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<tr>
<td>BTU</td>
<td>British Thermal Unit (1 BTU = 1.06 kJ, or 0.293 Wh)</td>
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<tr>
<td>°C</td>
<td>Degrees Celcius</td>
</tr>
<tr>
<td>CEM</td>
<td>Channel Extension Module</td>
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<tr>
<td>CFL</td>
<td>Compact Fluorescent Lamp</td>
</tr>
<tr>
<td>DANIDA</td>
<td>Danish International Development Agency</td>
</tr>
<tr>
<td>DDC</td>
<td>District Development Committee</td>
</tr>
<tr>
<td>DoD</td>
<td>Depth of Discharge</td>
</tr>
<tr>
<td>DT605</td>
<td>dataTaker 605</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency (a USA Government Agency)</td>
</tr>
<tr>
<td>ESAP</td>
<td>Energy Sector Assistance Project (run by DANIDA and AEPC)</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>HARS</td>
<td>High Altitude Research Station</td>
</tr>
<tr>
<td>HDI</td>
<td>Human Development Index</td>
</tr>
<tr>
<td>HMG</td>
<td>His Majesty Government of Nepal</td>
</tr>
<tr>
<td>IEA</td>
<td>International Energy Agency</td>
</tr>
<tr>
<td>ISPs</td>
<td>Institutional Solar PV Systems</td>
</tr>
<tr>
<td>KLDP</td>
<td>Karnali Local Development Program, Jumla, Nepal</td>
</tr>
<tr>
<td>KU</td>
<td>Kathmandu University</td>
</tr>
<tr>
<td>km</td>
<td>kilometer</td>
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<tr>
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<td>kilowatt</td>
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<tr>
<td>kWh</td>
<td>kilowatt-hour</td>
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<tr>
<td>LOL</td>
<td>Loss of Load</td>
</tr>
<tr>
<td>l/s</td>
<td>Litres per second</td>
</tr>
<tr>
<td>LED/WLED</td>
<td>Light-Emitting Diode / White Light Emitting Diode</td>
</tr>
<tr>
<td>LUTW</td>
<td>Light Up The World, Calgary, Canada</td>
</tr>
<tr>
<td>m</td>
<td>Meter</td>
</tr>
<tr>
<td>MHP</td>
<td>Micro Hydropower Plant/Project</td>
</tr>
<tr>
<td>MJ</td>
<td>Mega Joule (1 MJ = 0.278 kWh)</td>
</tr>
<tr>
<td>MOLD</td>
<td>Ministry of Local Development</td>
</tr>
<tr>
<td>MOST</td>
<td>Ministry of Science and Technology</td>
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<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>MOVCD</td>
<td>Metal Organic Chemical Vapor Deposition</td>
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<tr>
<td>MPP</td>
<td>Maximum Power Point</td>
</tr>
<tr>
<td>MTBF</td>
<td>Mean Time Between Failures</td>
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<tr>
<td>MW</td>
<td>Mega Watt (1 MW = 1,000 kW, or $10^6$ W)</td>
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<tr>
<td>MWh</td>
<td>Megawatt hour (1 MWh = 3.6 GJ)</td>
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<td>NEA</td>
<td>Nepal Electricity Authority (Government-owned), Kathmandu</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-Governmental organization</td>
</tr>
<tr>
<td>NOTC</td>
<td>Nominal Operation Collector Temperature</td>
</tr>
<tr>
<td>NM</td>
<td>Nano Meter (1 nm = $10^{-9}$ meters)</td>
</tr>
<tr>
<td>NPV</td>
<td>Net Present Value</td>
</tr>
<tr>
<td>NREL</td>
<td>National Renewable Energy Laboratories, USA</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisations for Economic Cooperation and Development</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>Operation and Maintenance</td>
</tr>
<tr>
<td>PPN</td>
<td>Pico Power Nepal</td>
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<tr>
<td>PSH</td>
<td>Peak Sun Hours</td>
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<tr>
<td>PV</td>
<td>Photovoltaic</td>
</tr>
<tr>
<td>PVSOL</td>
<td>Solar Photovoltaic System design software (Germany)</td>
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<td>PVSyst3.31</td>
<td>Solar Photovoltaic System design software version 3.31 (Switzerland)</td>
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<td>Remote Area Power Supply</td>
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<tr>
<td>RDC</td>
<td>Research Development &amp; Consultancy</td>
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<tr>
<td>RET</td>
<td>Renewable Energy Technology</td>
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<tr>
<td>RETScreen</td>
<td>Renewable Energy Technology Screening software (Canada)</td>
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<tr>
<td>RTD</td>
<td>Resistance Temperature Detector</td>
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<tr>
<td>SHS</td>
<td>Solar Home System</td>
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<tr>
<td>STC</td>
<td>Standard Testing Conditions</td>
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<tr>
<td>TWh</td>
<td>Tera Watt Hour (1 TWh = 1,000 GWh, or $10^{12}$ Wh)</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>US</td>
<td>United States of America</td>
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<tr>
<td>UV</td>
<td>Ultra Violet</td>
</tr>
<tr>
<td>V</td>
<td>Volts</td>
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<tr>
<td>VAT</td>
<td>Value Added Tax</td>
</tr>
<tr>
<td>VDC</td>
<td>Village Development Committee</td>
</tr>
<tr>
<td>W</td>
<td>Watt</td>
</tr>
<tr>
<td>Wh</td>
<td>Watt-hour</td>
</tr>
<tr>
<td>WECS</td>
<td>Water and Energy Commission Secretariat</td>
</tr>
<tr>
<td>WLG</td>
<td>Wisdom Light Group</td>
</tr>
<tr>
<td>Wp</td>
<td>Watt peak power output</td>
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US$1 = 70 NRp (Nepali rupees) / AU$1 = 50 NRp
1. Inspiration for the Dissertation

This dissertation is an integrated part of an ongoing applied KU-RDC research project, the Chauganphaya village solar photovoltaic (PV) system, running from June 2003 – into 2005.

The following points inspired the dissertation:

- To understand the conditions of the village through a detailed survey before the project started.
- What an appropriate lighting technology for the context could be.
- To design and install a solar radiation monitoring and data recording station in the HARS office in Humla.
- Monitoring, recording and interpreting actual solar irradiation data for Humla.
- Changes that were brought about in the community/families after the first 8 months of experience with light in their homes.
- Evaluation of the installed solar village PV system after 8 months in use.
- Crucial issues for such a PV system project with regard to sustainability and appropriateness.
- Lessons that can be learned from the solar village PV system project.