16. What Can Be Learned

It is not only beneficial but also crucial to look back on an implemented project and to re-evaluate each step of the project in order to improve future efficiency. Thus it is important to evaluate the achievements in the light of the goals set during the planning stage and to evaluate the impact on the community in the light of its expectations before the project was implemented.

16.1. Timely Planning and Village Survey

Given the remoteness of Chauganphaya village it was crucial to start the village survey and project planning well in time. In order to identify and define the impact of the project on the community, it is important that the family-by-family village survey has taken place before any aspect of the project has been implemented. In this way the living conditions could be clearly accessed, and the forthcoming project discussed with the community, including presentations of examples. The survey also helped to understand the community's expectations of the various components of the project and where wrong hopes were raised they could be addressed before implementing the project. In the light of all this one is able to get a clearer picture of the impact the project has on the people who, now, enjoy the new facilities, such as light in their homes, the smokeless metal stove, the near by pit latrine and clean and pure drinking water from the tap stand.

Such an extensive survey proved enormously helpful in the initial planning stages. For example it gave us a clear picture of the social structure of the community of Chauganphaya with specific reference to the caste system which directs almost every aspect of the daily life of the people. So for e.g. due to the two major castes, Dalits (low caste) and Chetris and Thakuris (middle cast), living in Chauganphaya, and as per the dictates of the caste system, they are not able to drink from the same water taps. Such information is now included in the drinking water system planning, so as not to cause social frictions between the people and thereby jeopardise the success and thus the sustainability of the project. Further, for the solar PV lighting project one must not focus on installed capacity per household (as mostly done in Nepal with micro-hydro power plants, e.g. accounting for 120 Watt per household), but on meeting the minimal level of priority electricity services needed by the consumers, which more than anything else is light. Later on (which can be several years, according to the community's development stage), issues such as information, entertainment and industry, have to be looked into and addressed as well. Additionally, a careful assessment of the electrical load, the peak times, the days of autonomy needed with the impact on the system, as well as the inclusion of a realistic load growth, according to population growth, is essential.

The choice of the power generation technology for the lights should be based on the premise of "least – cost, preferred by the local community and sustainable", referring to the financial and economic performance throughout the life cycle of the project, the satisfaction of consumers and owners, with the power system doing what it is designed and warranted to do under the defined conditions.

16.2. Equipment Manufacturing, Purchasing, and Transportation

In order to strengthen the national economy, which has to be a part of each project, it is important to reduce the dependency on imported, equipment supplied by foreign sources. Technology transfer can take place, and thus in the long-term bring a healthy growth to the local economy and social structure. This is a very time demanding and often intensive process, as much research, is needed in order to contextualise the technology, which in turn involves the development, and testing of prototypes, before any final products can be brought on the market.

In the case of the WLED lights, this technology was first developed by LUTW (Light Up The World), an INGO based in Canada. With their initial advise and rights the first WLED lights were manufactured and tested in Nepal six years ago. Since then the WLED lights have become an indigenous product, aiming to address the remote and poor mountains community's need for basic light services. A company, PPN, has grown out of this, able to train and then employ two young Nepali men, enabling them now to have some financial stability to support their own families. Thus the value of local manufacturing has to be given ample thought, in order to generate more local income, to be able to maintain the supply of products and in order to provide repair facilities in the case of breakdown of equipment.

The solar PV modules had to be imported from India. This is done through a company in Kathmandu which imports them once they have a substantial order. This implies that the PV modules have to be ordered well ahead of time as it can take up to 6 months to get them into the country and through the customs.

Transport is an important and often underestimated issue. This is more so in places like Chauganphaya, which is a 16 day walk away from the next road (in Surkhet), or otherwise accessible only by small airplanes, flying in from Nepalgunj in the south, to Simikot, and from there on, an additional one day's walk. Understandably, much planning is needed to transport all the project equipment by this route. In the case of the Chauganphaya village projects (light, stove, pit latrine and drinking water), close to 10,000 kg had to be transported by airplane, 1,300 kg at the time. Beside this, the weather conditions in these high altitude areas are often very unpredictable, because of which cancellation of flights is a regular phenomena. Taking into account all these situations, the need for a well organised plan to transport all project materials is a must. The way this particular project handled this problem in a more effective way was to have a person living in Nepalgunj who handled all the transport issues.

16.3. Project Implementation

Much before the actual implementation phase of the project started, several initial meetings were organised together with the village elders in order to mark out clearly what jobs and responsibilities the local community would take on, as their part in the implementation of the project. It was agreed, by their initiative, that they carry all the equipment from Simikot to their village and organise all the needed locally available materials, such as wood, stones and mud. They also agreed to do all the manual labor work like digging for the underground cabling for the solar PV system, the drinking water system etc. Thus once the material arrived in Simikot by plane they were there to carry all the equipment to their village. They also chose 2 people from the village to be trained, for the maintenance of the solar system and the collection of the monthly fees. They underwent their one week training program in Simikot, learning from our HARS solar system.

The actual installation of the solar PV village system in Chauganphaya took place from the last part of December 2003 to the 15th January 2004. The two freshly trained local people participated in this and learned through hands on experience how a solar PV system is installed. At the same time they earned respect from their fellow village folk, as the ones who know how it works. On the 15th of January 2004 the village had electric lights for the very first time in its history.

Each implemented project has to run according to rules and regulations defined by the local community such as e.g.:

- Appointment of the key responsible person.
- Appointment of the operator(s).
- Defining the need for maintenance.
- Penalties for misuse of the system.
- Periodical fees to keep the system running.

16.4. Follow-Up

Initial periodic visits to the village were planned before the implementation of the project. This was to check on how people were adjusting to their new living conditions and to check on the performance of the solar PV system in its present state, as compared to the intentions when it was designed initially. The need for long-term follow-up has been realized and there is a willingness to dedicate time, resources and budget towards this.

16.5. Summary

This is a summary of some things that can be learned from this project:

- Define the existing conditions of a village before the project planning stage.
- Be sensitive to the culture and customs of the peoples.
- Involve the local community from the beginning in every step taken.
- Allot enough time for proper planning of the project.
- The choice of power generation technology has to be based on least – cost, preferred by the local community and sustainable.
- As much as is possible, manufacture locally.
- Incorporate time for technology transfer (teaching local manufacturers, developing and testing new products).
- Be aware of import policies and regulations and order accordingly.
- Organise transportation well ahead of time.
- Develop a training program for local people who will be operating and maintaining equipment.
- Once implemented, the project has to run according to the rules and regulations defined by the local community.
- Projects that can demonstrate environmental benefits will be easier to finance, implement and replicate.
- Effective cost recovery systems through periodical payments/fees.
- Long-term planned follow-up.

17. Conclusions

Many projects under the name of ”Rural Village Electrification” have been undertaken in Nepal. In many cases micro-hydro power plants have been the choice for electricity generation, because of the availability of ample water throughout the year. Costs for such projects are high due to the remoteness and thus increased transport costs. These projects need strong donor based support. In areas where villages do not have enough river water around the year, other renewable energy technologies such as solar PV or wind power, can be utilised. That is also the case for the remote mountain village of Chauganphaya in Humla, with its 63 homes, where a solar PV village system was installed in January 2004.

Through the Government subsidised SHS program 329 homes have been able to purchase a SHS in Humla, up until November 2003. Most of these families live either in the main bazaar area of Simikot or around it. For the bulk of the village-based families though, the actual cost for a SHS is still too high, and thus not affordable. The challenge that we face now is to enable even the poorest of the poor in the remote villages to have access to light in their homes through a solar PV system.

In order to make that happen, new approaches and technologies have to be developed and tested, both on the consumer (the lights) side, and the power generation (PV module) side. The actual lights have to be less power demanding, while the solar PV modules should generate more energy. On the consumer side, new lights, WLED lights, each consuming 1 Watt instead of the commonly used incandescent bulbs (40W - 60W) and fluorescent tubes (10W – 20W) have been developed and tested. On the solar PV module side, a new 2-axis self-tracking module frame has been developed and tested for nine months, including one winter with extremely cold temperatures and one spring, with its unpredictable gusts and thunderstorms. After various changes and improvements, this self-tracking frame provided enough reliable results to have it installed in the Chauganphaya village solar PV system, as a central power system. This, according to the writer, is the first time ever in Nepal, that a centrally located solar PV village system with a tracking device has been installed.

After 8 months of operation in the village, the 2-axis self-tracker is still working as designed, enabling the four 75 W solar PV modules to be perpendicular to the sun all day long, and thus generating on an average ~ 30% more energy per day. This figure has resulted from five months HARS data recording in Simikot, which took place during Nepal's monsoon season (with lower-than-average sunshine hours per day). Therefore it is estimated that the overall yearly increased energy generation through the 2-axis self tracking frame can reach even 10% - 15 % higher values. The cost of the tracker equals the cost of one PV module and has an amortisation time of less than one year. The WLED lights too have shown good results so far in providing the expected light output, just enough to be able to read and write as well as to socialize inside the homes around the smokeless metal stove. Thus with a 300 W solar PV array, 63 homes with 365 people and a total of 189 WLED lights can be powered.

One shortcoming has been recognised so far. One cluster with 18 homes has been connected to the main battery bank through a much longer distance than initially planned, almost doubling the length of the underground cable, which caused a voltage drop in the 12 Volt DC line system of 3.5V – 4 V (load dependent), providing the last homes in the clusters only with about 9 VDC. The WLED lights are designed to run ideally from 10.8 VDC to 24 VDC, thus the 9 VDC causes a significant drop in light output for the lights within that cluster. The action to remedy this situation is either to dig a new, shorter line (with the same cable), or to run another second underground cable parallel to the existing one. Unfortunately, this difficulty could not be addressed due to the political environment at present. It is important that the solar system is followed-up over the next 5 years, in close partnership with the locally trained people and the village community, to strive for sustainability and full acceptance by the consumers. Periodical follow-up visits for the first two years are already planned and approved, but the political condition in the region will be the determining factor as to how they can be carried out.

Each family in Chauganphaya Village now has three WLED lights, a smokeless stove, a pit latrine, as well as access to clean and fresh drinking water.

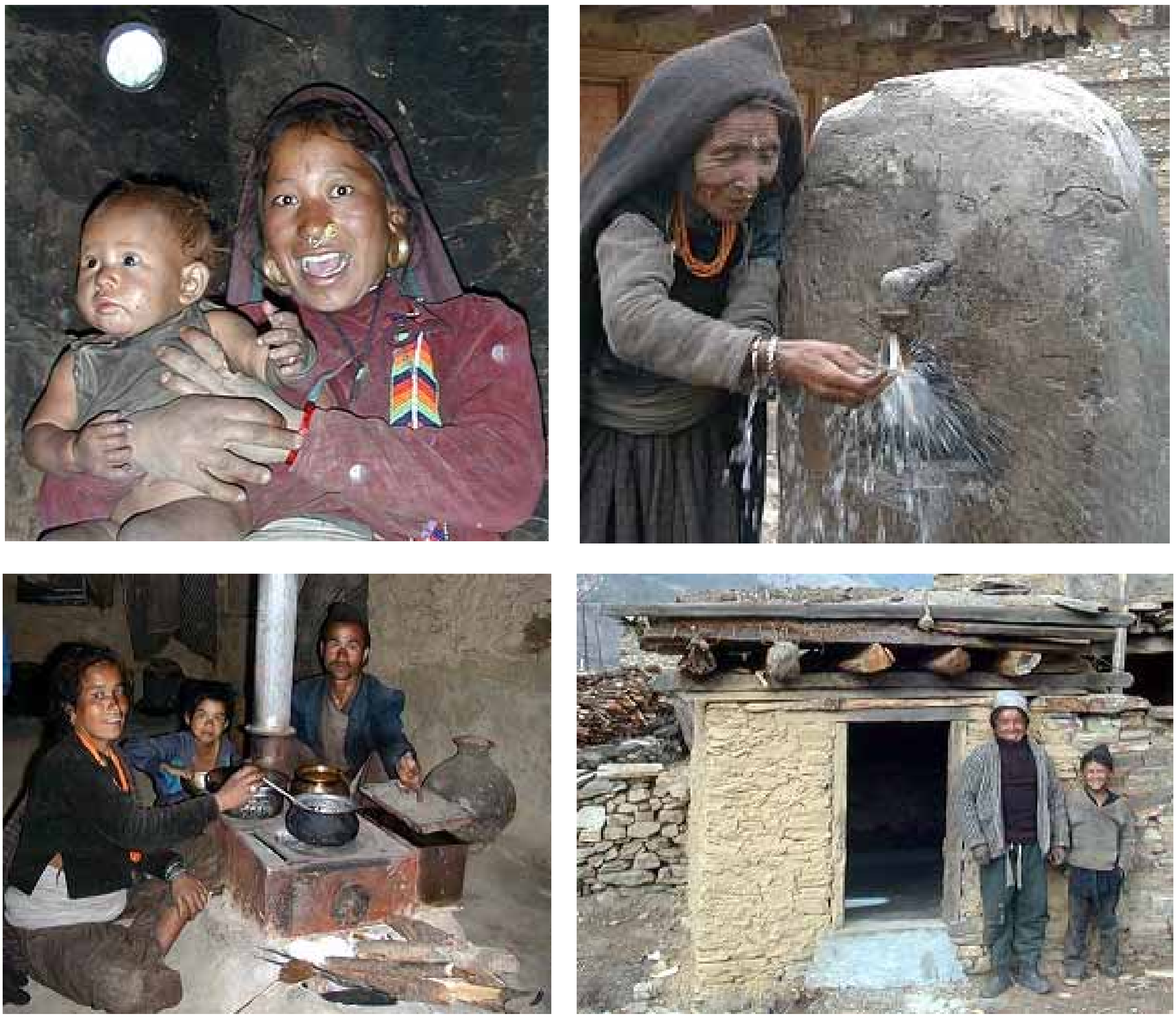


Figure 17-1: WLED light, Drinking Water, Smokeless Metal Stove and Pit Latrine

The more holistic community development approach, has found great acceptance among the local peoples. The planned yearly survey and interviews will show the actual long-term impact and benefits these four projects have for the life and the living conditions of the peoples of Chauganphaya. One of the encouraging feedbacks received so far is that just after half a year the local school teacher has recognised that many students are able to get better results in their studies. This, he believed, is due to increased opportunities to do their homework, as well as read, during the evening hours.

It can be concluded that this solar PV village system in Chauganphaya has enabled the poorest of the poor to have light in their dark, smoke filled homes. Important as light is inside the home, it is only one of the vital parts, that make up any holistic grass root community development project, the others being the smokeless metal stove, pit latrine, and clean drinking water. The stove gets rid of the smoke in the rooms, cooks their traditional food the way they like it and more efficiently. It also provides the needed heat during the cold months. The pit latrine keeps the village walking paths, fields and near by rivers clean, thus improving the overall hygienic conditions. Clean drinking water is crucial for a healthy life, and thus is another necessary part of a holistic community development project.

The synergetic effect of these four projects jointly implemented outweighs many times over the effect and benefit of each individual project, and therefore the resources made available have been put to work, striving for appropriateness and sustainability.

18. Appendix

18.1. Appendix to Chapter 5 Lighting Technologies

18.1.1. WLED Lights

Commercial research into LED technology started in the early 1962s at Bell Labs, Hewlett-Packard, IBM, and Monsanto. Work on gallium arsenide phosphide (GaAsP) led to the introduction of the first commercial 655nm red LEDs in 1968, by Hewlett-Packard and Monsanto. In the 1970s LED displays flourished as numeric displays in pocket calculators by Hewlett-Packard, Texas Instruments, and Sinclair.

There are essentially two technologies for generating white light from LEDs. One way is to mount a red die, a green die, and a blue die very close together within a package, and mix the light outputs in the correct proportions to achieve white light. This technology has turned out to be too expensive, as it needs 3 dice. The cheaper approach, is pioneered notably by Mr. Nakamura, the inventor of the blue, green and WLED from Nichia. He developed a two-flow MOVCD (metal-organic chemical vapor deposition) process in the early 90s, leading to much improved blue LEDs. These are used to produce WLEDs by coating the surface of a blue (Gallium Nitride) LED, with a phosphor layer (Yttrium Aluminum Garnet). The phosphor layer absorbs some of the blue light and fluoresces in a second colour to achieve a near-white.

18.1.2. Technical Aspects of LED Lights

By definition an LED is a solid-state device that controls current without heated filaments. That makes it very reliable and long lasting (as no actual consumption, or filament “burn out”, as in the incandescent bulb, can occur). The electrical behavior of an LED is similar to other semiconductor diodes. The forward voltage is higher, and is different for the different materials used for different colours (Figure 5-7). The forward voltage rises with current, and falls with temperature by about 2mV/°C. The optical behavior of the LED varies with temperature. First, the amount of light emitted by the LED lamp falls as the p-n junction temperature rises. This is because of an increase in the recombination of holes and electrons that make no contribution to light emission. Also, the emitted wavelength changes with temperature, mainly due to the semiconductor energy gap changing with temperature. Thus, like all semiconductors, the LED must be derated at higher operating temperatures.

WLEDs run at 3.6 Volt DC (see the blue LED curve in Figure 5-7, which can be phosphor coated to emit white light), with a current of 20 - 25 mAmps, thus dissipating a power of about 75 - 90 mWatts. Thus a WLED light, with 9 individual WLEDs, as manufactured for the Chauganphaya solar PV village elementary electrification project, consumes around 800 mWatt (see the power consumption curve in Figure 6-11, Appendix 18.2.1.). Considering some further losses in the house wiring, it is realistic to say that one 9 WLED light, as installed in the Chauganphaya Village, consumes 1 Watt.

Figure 5-4 in 5.4.3. defines the different parts of a LED. The positive power is applied to one side of the LED semiconductor through a lead (1 anode) and a whisker (4). The other side of the semiconductor is attached to the top of the anvil (7) that is the negative power lead (2 cathode). It is the choice of the materials for the semiconductor (6) that determines the colour of the LED light. The entire unit is totally enclosed in epoxy resin (3 and 5), which has three functions. It is designed to allow the most light to escape from the semiconductor, it focuses the light (view angle), and it protects the LED semiconductor elements. Thus, unlike standard incandescent bulbs, LEDs are resistant to shock and vibration and can be cycled on and off without excessive degradation. Considering all these parameters, LED lights are virtually indestructible, as there are no loose or moving parts within the solid epoxy enclosure.

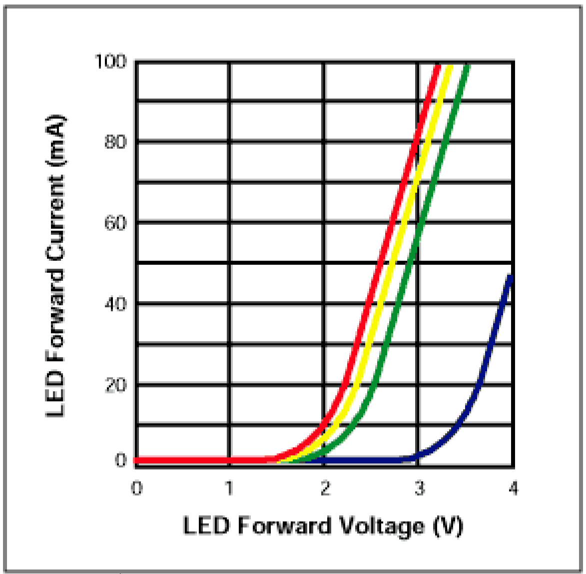


Figure 5-7[1]: LED Forward Voltage Diagram

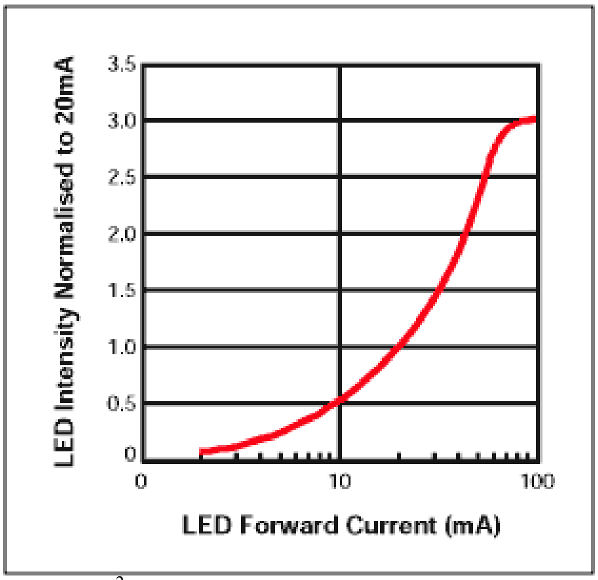


Figure 5-8[2]: LED Forward Current Diagram

The light intensity of an LED typically rises with forward current (Figure 5-8), presuming constant junction temperature. As LED drive currents increase, internal temperatures within the chip also increase. There is a point where the effect of the temperature increase causes a drop in the photon conversion efficiency, and thus negates the effect of the increased current density through the junction. At this point increasing drive currents can result in little, no change, or even a decrease in light outputs from the LED chip. Beside the drive current, the LED light output varies with the type of chip, encapsulation, and the efficiency of individual wafer lots. Several LED manufacturers use terms such as “super-bright,” and “ultra-bright” to describe LED intensity. Such terminology is entirely subjective, as there is no industry standard for LED brightness. The amount of light emitted from an LED is quantified by a single point, on-axis luminous intensity value (Iv) as seen in Figure 5-9[3]. LED intensity[4] is specified in terms of millicandela (mcd).

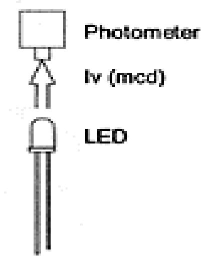


Figure 5-9: Single point on-axis luminous intensity measurement for LED

18.1.3. Lifetime of LED Lights

LEDs have a MTBF (mean time between failures) usually in the range of 100,000 and more hours[5], although the lamp driver circuit lifetime must also be considered. The useful measure of LED lifetime is its half-life, that is an LED is deemed to have reached the end of its life when the light output falls off, to half the original value. Thus, the Nichia NSPW510SB WLED lights (as used in the Chauganphaya Village elementary electrification project), with a life expectancy of 100,000 hours, can be in continuous daily operation for 12 hours, lasting for about 20 years. They are rated with a lumens/Watt value of 23 lumens/Watt[6], and their intensity is 1,800 mcd.

18.1.4. LED Lights Light Output

The latest white LEDs (as of January 2004) produce about 17 - 25 lumens of light per Watt of electricity delivered to the LED. As for the near future, Nichia claims that white LEDs that achieve 60 lumens/Watt will go into production in 2005. Cree[7] has achieved 65 lumens per Watt in laboratory prototypes using industry standard packaging and 74 lumens per Watt with special packaging[8].

The reason for the LED's light output drop is due to the non-uniform current flowing through a LED junction, resulting in small temperature differentials within the chip. These temperature differentials exert stress on the lattice, causing minute cracks to occur. These lattice defects accumulate with use, and reduce the photon conversion efficiency of the chip, and thus reduce the light output. The attrition rate varies according to the LED material, temperature, humidity, and the forward current.

18.1.5. LED Light Angle

A standard LED lens without any diffusion produces a relatively narrow viewing angle of about 12° on either side of the LED center. This narrow dispersion works well in applications, such as backlighting, in which the LED's output is directed at a translucent panel that further diffuses the light. By embedding tiny glass particles in the lens epoxy, the LED's viewing angle can be made much wider (Figure 5-3 in 5.4.3.). The viewing angle and the brightness of an LED usually vary inversely. A wider angle will result in lower brightness in any given direction (light output is spread over a larger area). For headlight applications, a 20° angle is appropriate (the tightest angle for a LED typically available, producing an intense beam).

18.2. Appendix to Chapter 6 Comparison of Incandescent, CFL, and WLED lights

18.2.1. Nichia and Lumiled WLED Lights Data Monitoring

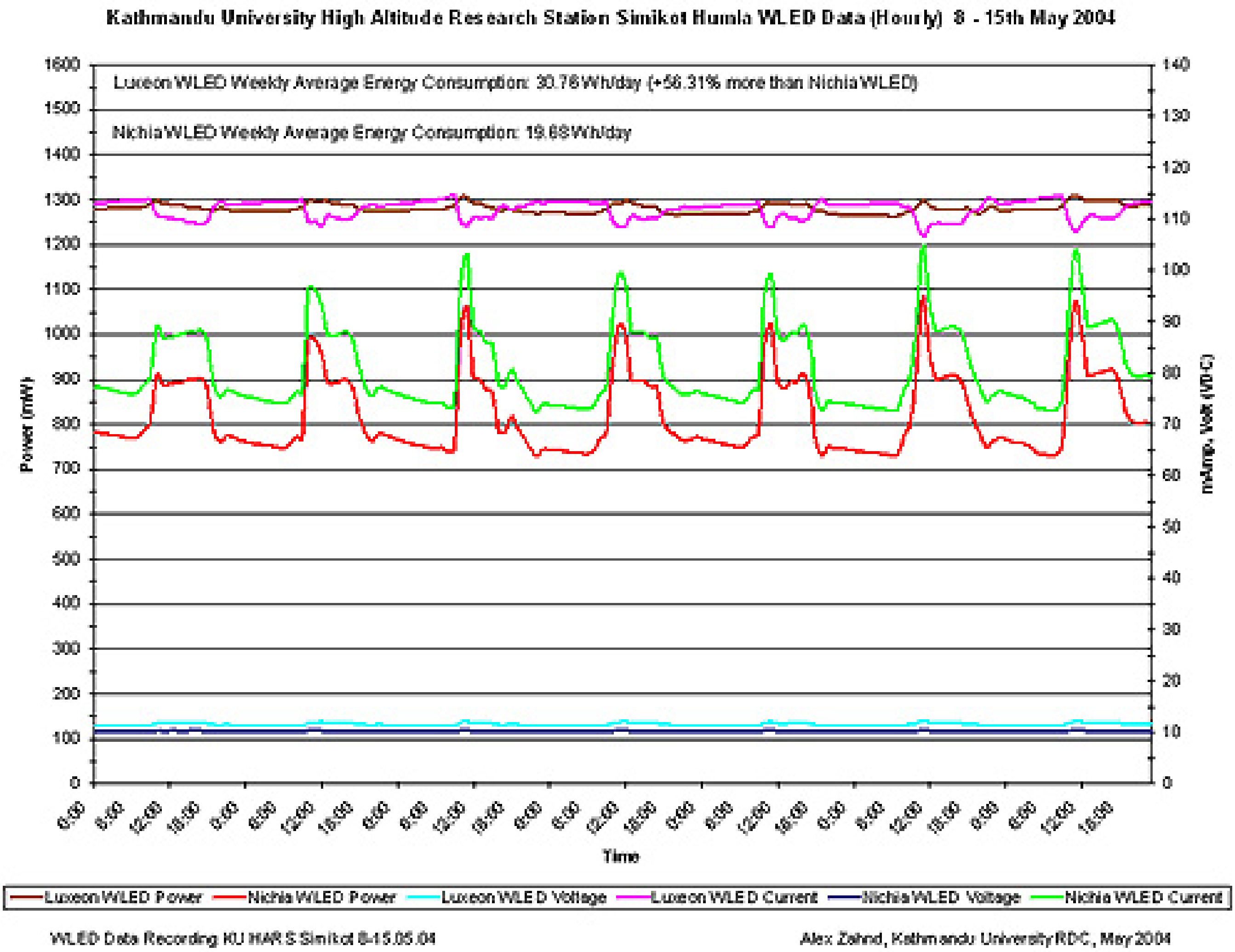


Figure 6-11: One Week Data Recording of a Nichia and a Lumiled WLED lights

The Nichia WLED light is the one installed in the Chauganphaya village solar PV system. It has 9 NSBW 510SB 50° diodes, and an average power consumption between 0.8 Watt and 1 Watt, consuming 19.68 Wh/day. The other WLED is a 1 Watt Lumiled diode, which shows under test a power consumption of around 1.3 W, consuming over one day an energy value of 30.76 Wh, which is 56.3% more than the Nichia WLED. It was not possible to measure the light output, as these long-term data recording take place in the HARS in Simikot. But the perceived light output (if one reads underneath the two different WLED lights at the same distance) of the Nichia WLED light seems slightly higher than the Lumiled WLED light.

18.2.2. Comparative Investment Analysis of the Incandescent, CFL and WLED Lights

ULTRALAMP High Power Factor CFL versus Incandescent Bulb Investment Analysis HARS Simikot

ULTRALAMP 11 Watt CFL (Compact Fluorescent Light) Bulb versus Incandescent 55 Watt Bulb Investment Analysis

Vary only *italic* **bolded** values.

Factor	**Unit**	**Value**	**Notes**
ENTER THESE VARIABLES		ENTER HERE	
Light use per day	Hours/day	*5*	Enter your estimate of how many average hours the bulb is on each day.
CFL bulb size	Watts	*11*	Enter wattage size of CFL bulb (not what the packaging says in the incandescent equivalent).
Brightness	Lumens	*660*	Ultralamp CFL Products: 7W = 350 lumens; 11W = 660 lumens; 15W = 900 lumens; 20W = 1200 lumens.
Rated CFL bulb life	Hours	*8000*	Average Ultramlamp CFL Light life expectancy is 8000 - 12000 hours (practical experienced)
Cost of electricity	US$/kWh	*1.027*	The solar PV generated kWh unit in the HARS Simikot, Humla costs 75NRp/kWh (1.027 US$).
Wattage of incandescent bulb replaced	Watts	*55*	Enter wattage of incandescent bulb replaced.
Lumens of incandescent bulb replaced	Lumens	*825*	15 lumens pro Watt are assumed as an average for an incandescent bulb
Rated incandescent bulb life	Hours	*1000*	Estimated Incandescent bulb life expectancy in Nepal is from 750 - 1000 hours.
Cost of incandescent bulb replaced	US$	*0.82*	The price (incl. 12% VAT) for a 55 W incandescent bulb in Simikot Humla is 60 NRp (0.82 US$)
Cost of CFL bulb (before any rebates)	US$	*4.65*	Total price (incl. 12% VAT) for a 11 Watt Ultralamp high power factor (0.9) CFL Bulb in Simikot Humla is 380 NRp.
Rebates	US$	*0*	Enter amount of any rebates.
Combined state taxes	%	*0.56*	12% VAT on top of the CFL purchase price
Cost of CFL bulb (after any rebates)	US$	4.65	US$/NRp exchange rate in April 2004 is: 1US$ = 73 NRp
Marginal increase in cost for CFL bulb	US$	3.83	The cost of your "investment instrument."
Power used	kWh/year	20.08	The amount of electricity the CFL bulb uses in a year.
Money spent on electricity consumed	US$/year	20.62	How much money you will spend annually with a CFL bulb.
Power not used	kWh/year	80.30	The amount of electricity the replaced incandescent bulb did not consume.
Money saved on electricity not consumed	US$/year	82.47	The amount of money not spent by converting an incandescent to a CFL bulb.
Power consumption of CFL v. incandescent bulb	%	20.00	The percentage of electricity used by a CFL bulb versus a comparable incandescent bulb.
Brightness efficiency of CFL Light	Lumens/watt	60.00	The amount of brightness per unit of energy consumed with a CFL Bulb.
Brightness efficiency of incandescent bulb	Lumens/watt	15.00	The amount of brightness per unit of energy consumed with an Incandescent Bulb.
Number of incandescent bulbs you don't change		7.00	Monetary savings (the value of your time) not quantified.
Simple payback on initial investment	Years	0.05	Simple payback in years.
Return on investment (tax-free)	%/year	2153.21	Tax-free figure as a percent of CFL bulb cost (including recouping capital cost of bulb).
Return on investment (taxable)	%/year	2165.34	The equivalent rate of return of a taxable investment. Money saved need not be earned. (If ROI negative, then strictly speaking, you use the CFL bulb so little as to not justify cost.)

Nichia 1 Watt WLED versus ULTRALAMP 11 Watt CFL Light Investment Analysis HARS Simikot

1 Watt WLED (White Light Emitting Diode) Light versus ULTRALAMP 11 Watt CFL Investment Analysis

Vary <u>only</u> *italic bolded* values.

Factor	Unit	Value	Notes
ENTER THESE VARIABLES		ENTER HERE	
Light use per day	Hours/day	*5*	Enter your estimate of how many average hours the light is on each day.
WLED Light size	Watts	*1*	One WLED consumes 25mA @ 3.6V DC. 9 WLEDs, 3 serial connected = one WLED Light: = 885mW, or ~ 1 W
Brightness	Lumens	*25*	Used WLED: Nichia NSPW510BS, 1.800 cd intensity, angle of 50°. One WLED Light has ~ 25 lumens brightness.
Rated WLED Light life	Hours	*50000*	WLED Light are rated with 100,000 hours life expectancy. Here 50,000 hours seem to be realistic.
Cost of electricity	US$/kWh	*1.027*	The solar PV generated kWh unit in the HARS Simikot, Humla costs 75NRp/kWh (1.027 US$).
Wattage of CFL Light replaced	Watts	*11*	Enter wattage of incandescent bulb replaced.
Lumens of CFL Light replaced	Lumens	*660*	Enter lumens rating from packaging.
Rated CFL Light life	Hours	*8000*	Average Ultramlamp CFL Light life expectancy is 8000 - 12000 hours (practical experienced)
Cost of CFL Light replaced	US$	*5.20*	The price (incl. 12% VAT) for 11 Watt Ultralamp high power factor (0.9) CFL Bulb in Simikot Humla is 380 NRp.
Cost of WLED Light (before any rebates)	US$	*18.30*	Total price (incl. 12% VAT) for a 1 Watt WLED Light is 1500 NRp (US$ 20.55). No rebates are available.
Rebates	US$	*0*	Enter amount of any rebates.
Combined state taxes	%	*2.20*	12% VAT on top of the WLED purchase price
Cost of WLED Light (after any rebates)	US$	18.30	US$/NRp exchange rate in April 2004 is: 1US$ = 73 NRp
Marginal increase in cost for WLED Light	US$	13.10	The cost of your "investment instrument."
Power used	kWh/year	1.83	The amount of electricity the WLED Light uses in a year.
Money spent on electricity consumed	US$/year	1.87	How much money you will spend annually with a CFL bulb.
Power not used	kWh/year	18.25	The amount of electricity the replaced CFL bulb did not consume.
Money saved on electricity not consumed	US$/year	18.74	The amount of money not spent by converting an CFL Bulb to a WLED Light.
Power consumption of WLED Light v. CFL Light	%	9.09	The percentage of electricity used by a WLED Light versus a comparable incandescent bulb.
Brightness efficiency of WLED Light	Lumens/watt	25.00	The amount of brightness per unit of energy consumed with a WLED Light.
Brightness efficiency of CFL Light	Lumens/watt	60.00	The amount of brightness per unit of energy consumed with a CFL Bulb.
Number of CFL Lights you don't change		5.25	Monetary savings (the value of your time) not quantified.
Simple payback on initial investment	Years	0.70	Simple payback in years.
Return on investment (tax-free)	%/year	143.07	Tax-free figure as a percent of WLED Light cost (including recouping capital cost of WLED Light).
Return on investment (taxable)	%/year	146.29	The equivalent rate of return of a taxable investment. Money saved need not be earned. (If ROI negative, then strictly speaking, you use the WLED Light so little as to not justify cost.)

Basic Excel Worksheet from: www.homepower.com/files/kerrcflbulbs.xls, and changed for the HARS Simikot Light condition by Alex Zahnd, Kathmandu Nepal, April 20th, 2004

Nichia 1 Watt WLED versus Incandescent 25 Watt Bulb Investment Analysis HARS Simikot

1 Watt WLED (White Light Emitting Diode) Light versus Incandescent 25 Watt Bulb Investment Analysis

Vary <u>only</u> *italic bolded* values.

Factor	Unit	Value	Notes
ENTER THESE VARIABLES		ENTER HERE	
Light use per day	Hours/day	*5*	Enter your estimate of how many average hours the bulb is on each day.
WLED Light size	Watts	*1*	One WLED consumes 25mA @ 3.6V DC. 9 WLEDs, 3 serial connected = one WLED Light: = 885mW, or ~ 1 W
Brightness	Lumens	*25*	Used WLED: Nichia NSPW510BS, 1.800 cd intensity, angle of 50°. One WLED Light has ~ 25 lumens brightness.
Rated WLED Light life	Hours	*50000*	WLED Light are rated with 100,000 hours life expectancy. Here 50,000 hours seem to be realistic.
Cost of electricity	US$/kWh	*1.027*	The solar PV generated kWh unit in the HARS Simikot, Humla costs 75NRp/kWh (1.027 US$).
Wattage of incandescent bulb replaced	Watts	*25*	Enter wattage of incandescent bulb replaced.
Lumens of incandescent bulb replaced	Lumens	*375*	15 lumens pro Watt are assumed as an average for an incandescent bulb
Rated incandescent bulb life	Hours	*1000*	Estimated Incandescent bulb life expectancy in Nepal is from 750 - 1000 hours.
Cost of incandescent bulb replaced	US$	*0.62*	The price (incl. 12% VAT) of a 25 W incandescent bulb in Simikot Humla is 45 NRp (0.62 US$)
Cost of WLED Light (before any rebates)	US$	*18.30*	Total price (incl. 12% VAT) for a 1 Watt WLED Light is 1,500 NRp (US$ 20.55). No rebates are available.
Rebates	US$	*0*	Enter amount of any rebates.
Combined state taxes	%	*2.20*	12% VAT on top of the WLED purchase price
Cost of WLED Light (after any rebates)	US$	18.30	US$/NRp exchange rate in April 2004 is: 1US$ = 73 NRp
Marginal increase in cost for WLED Light	US$	17.68	The cost of your "investment instrument."
Power used	kWh/year	1.83	The amount of electricity the WLED Light uses in a year.
Money spent on electricity consumed	US$/year	1.87	How much money you will spend annually with a CFL bulb.
Power not used	kWh/year	43.80	The amount of electricity the replaced incandescent bulb did not consume.
Money saved on electricity not consumed	US$/year	44.98	The amount of money not spent by converting an incandescent to a WLED Light.
Power consump. WLED Light v. incandescent bu	%	4.00	The percentage of electricity used by a WLED Light versus a comparable incandescent bulb.
Brightness efficiency of WLED Light	Lumens/watt	25.00	The amount of brightness per unit of energy consumed with a WLED Light.
Brightness efficiency of incandescent bulb	Lumens/watt	15.00	The amount of brightness per unit of energy consumed with an Incandescent Bulb.
Number of incandescent bulbs you don't change		49.00	Monetary savings (the value of your time) not quantified.
Simple payback on initial investment	Years	0.39	Simple payback in years.
Return on investment (tax-free)	%/year	254.43	Tax-free figure as a percent of WLED Light cost (including recouping capital cost of WLED Light).
Return on investment (taxable)	%/year	260.15	The equivalent rate of return of a taxable investment. Money saved need not be earned. (If ROI negative, then strictly speaking, you use the WLED Light so little as to not justify cost.)

Basic Excel Worksheet from: www.homepower.com/files/kerrcflbulbs.xls, and changed for the HARS Simikot Light condition by Alex Zahnd, Kathmandu Nepal, April 20th, 2004

Nichia 1 Watt WLED versus Incandescent 55 Watt Bulb Investment Analysis HARS Simikot

1 Watt WLED (White Light Emitting Diode) Light versus Incandescent 55 Watt Bulb Investment Analysis

Vary <u>only</u> *italic* ***bolded*** values.

Factor	Unit	Value	Notes
ENTER THESE VARIABLES		ENTER HERE	
Light use per day	Hours/day	*5*	Enter your estimate of how many average hours the bulb is on each day.
WLED Light size	Watts	*1*	One WLED consumes 25mA @ 3.6V DC. 9 WLEDs, 3 serial connected = one WLED Light: = 885mW, or ~ 1 W
Brightness	Lumens	*25*	Used WLED: Nichia NSPW510BS, 1.800 cd intensity, angle of 50°. One WLED Light has ~ 25 lumens brightness.
Rated WLED Light life	Hours	*50000*	WLED Light are rated with 100,000 hours life expectancy. Here 50,000 hours seem to be realistic.
Cost of electricity	US$/kWh	*1.027*	The solar PV generated kWh unit in the HARS Simikot, Humla costs 75NRp/kWh (1.027 US$).
Wattage of incandescent bulb replaced	Watts	*55*	Enter wattage of incandescent bulb replaced.
Lumens of incandescent bulb replaced	Lumens	*825*	15 lumens pro Watt are assumed as an average for an incandescent bulb
Rated incandescent bulb life	Hours	*1000*	Estimated Incandescent bulb life expectancy in Nepal is from 750 - 1000 hours.
Cost of incandescent bulb replaced	US$	*0.82*	The price (incl. 12% VAT) of a 55 W incandescent bulb in Simikot Humla is 60 NRp (0.82 US$)
Cost of WLED Light (before any rebates)	US$	*18.30*	Total price (incl. 12% VAT) for a 1 Watt WLED Light is 1,500 NRp (US$ 20.55). No rebates are available.
Rebates	US$	*0*	Enter amount of any rebates.
Combined state taxes	%	*2.20*	12% VAT on top of the WLED purchase price
Cost of WLED Light (after any rebates)	US$	18.30	US$/NRp exchange rate in April 2004 is: 1US$ = 73 NRp
Marginal increase in cost for WLED Light	US$	17.48	The cost of your "investment instrument."
Power used	kWh/year	1.83	The amount of electricity the WLED Light uses in a year.
Money spent on electricity consumed	US$/year	1.87	How much money you will spend annually with a CFL bulb.
Power not used	kWh/year	98.55	The amount of electricity the replaced incandescent bulb did not consume.
Money saved on electricity not consumed	US$/year	101.21	The amount of money not spent by converting an incandescent to a WLED Light.
Power consump. WLED Light v. incandescent bu	%	1.82	The percentage of electricity used by a WLED Light versus a comparable incandescent bulb.
Brightness efficiency of WLED Light	Lumens/watt	25.00	The amount of brightness per unit of energy consumed with a WLED Light.
Brightness efficiency of incandescent bulb	Lumens/watt	15.00	The amount of brightness per unit of energy consumed with an Incandescent Bulb.
Number of incandescent bulbs you don't change		49.00	Monetary savings (the value of your time) not quantified.
Simple payback on initial investment	Years	0.17	Simple payback in years.
Return on investment (tax-free)	%/year	579.01	Tax-free figure as a percent of WLED Light cost (including recouping capital cost of WLED Light).
Return on investment (taxable)	%/year	592.03	The equivalent rate of return of a taxable investment. Money saved need not be earned. (If ROI negative, then strictly speaking, you use the WLED Light so little as to not justify cost.)

Basic Excel Worksheet from: www.homepower.com/files/kerrcflbulbs.xls, and changed for the HARS Simikot Light condition by Alex Zahnd, Kathmandu Nepal, April 20th, 2004

ULTRALAMP High Power Factor CFL versus Incandescent Bulb Investment Analysis Chauganphaya

ULTRALAMP 11 Watt CFL (Compact Fluorescent Light) Bulb versus Incandescent 55 Watt Bulb Investment Analysis

Vary only *italic bolded* values.

Factor	Unit	Value	Notes
ENTER THESE VARIABLES		ENTER HERE	
Light use per day	Hours/day	*5*	Enter your estimate of how many average hours the bulb is on each day.
CFL bulb size	Watts	*11*	Enter wattage size of CFL bulb (not what the packaging says in the incandescent equivalent).
Brightness	Lumens	*660*	Ultralamp CFL Products: 7W = 350 lumens; 11W = 660 lumens; 15 W = 900 lumens; 20 W = 1200 lumens.
Rated CFL bulb life	Hours	*8000*	Average Ultramlamp CFL Light life expectancy is 8000 - 12000 hours (practical experienced)
Cost of electricity	US$/kWh	*2.781*	The solar PV generated kWh unit in the Chauganphaya Village in Humla costs 203 NRp/kWh (PVSyst3.3 Sim.)
Wattage of incandescent bulb replaced	Watts	*55*	Enter wattage of incandescent bulb replaced.
Lumens of incandescent bulb replaced	Lumens	*825*	15 lumens pro Watt are assumed as an average for an incandescent bulb
Rated incandescent bulb life	Hours	*1000*	Estimated Incandescent bulb life expectancy in Nepal is from 750 - 1000 hours.
Cost of incandescent bulb replaced	US$	*0.82*	The price (incl. 12% VAT) of a 55 W incandescent bulb in Simikot Humla is 60 NRp (0.82 US$)
Cost of CFL bulb (before any rebates)	US$	*4.65*	Total price (incl. 12% VAT) for 11 Watt Ultralamp high power factor (0.9) CFL Bulb in Simikot Humla is 380 NRp.
Rebates	US$	*0*	Enter amount of any rebates.
Combined state taxes	%	*0.56*	12% VAT on top of the CFL purchase price
Cost of CFL bulb (after any rebates)	US$	4.65	US$/NRp exchange rate in April 2004 is: 1US$ = 73 NRp
Marginal increase in cost for CFL bulb	US$	3.83	The cost of your "investment instrument."
Power used	kWh/year	20.08	The amount of electricity the CFL bulb uses in a year.
Money spent on electricity consumed	US$/year	55.82	How much money you will spend annually with a CFL bulb.
Power not used	kWh/year	80.30	The amount of electricity the replaced incandescent bulb did not consume.
Money saved on electricity not consumed	US$/year	223.30	The amount of money not spent by converting an incandescent to a CFL bulb.
Power consumption of CFL v. incandescent bulb	%	20.00	The percentage of electricity used by a CFL bulb versus a comparable incandescent bulb.
Brightness efficiency of CFL Light	Lumens/watt	60.00	The amount of brightness per unit of energy consumed with a CFL Bulb.
Brightness efficiency of incandescent bulb	Lumens/watt	15.00	The amount of brightness per unit of energy consumed with an Incandescent Bulb.
Number of incandescent bulbs you don't change		7.00	Monetary savings (the value of your time) not quantified.
Simple payback on initial investment	Years	0.02	Simple payback in years.
Return on investment (tax-free)	%/year	5830.24	Tax-free figure as a percent of CFL bulb cost (including recouping capital cost of bulb).
Return on investment (taxable)	%/year	5863.07	The equivalent rate of return of a taxable investment. Money saved need not be earned. (If ROI negative, then strictly speaking, you use the CFL bulb so little as to not justify cost.)

Basic Excel Worksheet from: www.homepower.com/files/kerrcflbulbs.xls, and changed for the Chauganphaya Village Light condition by Alex Zahnd, Kathmandu Nepal, April 20th, 2004

Nichia 1 Watt WLED versus ULTRALAMP 11 Watt CFL Light Investment Analysis Chauganphaya

1 Watt WLED (White Light Emitting Diode) Light versus ULTRALAMP 11 Watt CFL Investment Analysis

Vary <u>only</u> ***italic bolded*** values.

Factor	Unit	Value	Notes
ENTER THESE VARIABLES		ENTER HERE	
Light use per day	Hours/day	***5***	Enter your estimate of how many average hours the bulb is on each day.
WLED Light size	Watts	***1***	One WLED consumes 25mA @ 3.6V DC. 9 WLEDs, 3 serial connected = one WLED Light: = 895mW, or ~ 1 W
Brightness	Lumens	***25***	Used WLED: Nichia NSPW510BS, 1.800 cd intensity, angle of 50°. One WLED Light has ~ 25 lumens brightness.
Rated WLED Light life	Hours	***50000***	WLED Light are rated with 100,000 hours life expectancy. Here 50,000 hours seem to be realistic.
Cost of electricity	US$/kWh	***2.7808***	The solar PV generated kWh unit in the Chauganphaya Village in Humla costs 203 NRp/kWh (PVSyst3.3 Sim.)
Wattage of CFL Light replaced	Watts	***11***	Enter wattage of incandescent bulb replaced.
Lumens of CFL Light replaced	Lumens	***660***	Enter lumens rating from packaging.
Rated CFL Light life	Hours	***8000***	Average Ultramlamp CFL Light life expectancy is 8000 - 12000 hours (practical experienced)
Cost of CFL Light replaced	US$	***5.20***	Price (incl. 12% VAT) for 11 Watt Ultralamp high power factor (0.9) CFL Bulb in Simikot Humla is 380 NRp.
Cost of WLED Light (before any rebates)	US$	***18.30***	Total price (incl. 12% VAT) of a 1 Watt WLED Light is 1500 NRp (US$ 20.50). No rebates are available.
Rebates	US$	***0***	Enter amount of any rebates.
Combined state taxes	%	***2.20***	12% VAT on top of the WLED purchase price
Cost of WLED Light (after any rebates)	US$	18.30	US$/NRp exchange rate in April 2004 is: 1US$ = 73 NRp
Marginal increase in cost for WLED Light	US$	13.10	The cost of your "investment instrument."
Power used	kWh/year	1.83	The amount of electricity the WLED Light uses in a year.
Money spent on electricity consumed	US$/year	5.07	How much money you will spend annually with a CFL bulb.
Power not used	kWh/year	18.25	The amount of electricity the replaced CFL bulb did not consume.
Money saved on electricity not consumed	US$/year	50.75	The amount of money not spent by converting an CFL Bulb to a WLED Light.
Power consumption of WLED Light v. CFL Light	%	9.09	The percentage of electricity used by a WLED Light versus a comparable incandescent bulb.
Brightness efficiency of WLED Light	Lumens/watt	25.00	The amount of brightness per unit of energy consumed with a WLED Light.
Brightness efficiency of CFL Light	Lumens/watt	60.00	The amount of brightness per unit of energy consumed with a CFL Bulb.
Number of CFL Lights you don't change		5.25	Monetary savings (the value of your time) not quantified.
Simple payback on initial investment	Years	0.26	Simple payback in years.
Return on investment (tax-free)	%/year	387.40	Tax-free figure as a percent of WLED Light cost (including recouping capital cost of WLED Light).
Return on investment (taxable)	%/year	396.12	The equivalent rate of return of a taxable investment. Money saved need not be earned. (If ROI negative, then strictly speaking, you use the WLED Light so little as to not justify cost.)

Basic Excel Worksheet from: www.homepower.com/files/kerrcflbulbs.xls, and changed for the Chauganphaya Village Light condition by Alex Zahnd, Kathmandu Nepal, April 20th, 2004

Nichia 1 Watt WLED versus Incandescent 25 Watt Bulb Investment Analysis Chauganphaya

1 Watt WLED (White Light Emitting Diode) Light versus Incandescent 25 Watt Bulb Investment Analysis

Vary only *italic bolded* values.

Factor	Unit	Value	Notes
ENTER THESE VARIABLES		ENTER HERE	
Light use per day	Hours/day	*5*	Enter your estimate of how many average hours the bulb is on each day.
WLED Light size	Watts	*1*	One WLED consumes 25mA @ 3.6V DC. 9 WLEDs, 3 serial connected = one WLED Light: = 885mW, or ~ 1 W
Brightness	Lumens	*25*	Used WLED: Nichia NSPW510BS, 1.800 cd intensity, angle of 50°. One WLED Light has ~ 25 lumens brightness.
Rated WLED Light life	Hours	*50000*	WLED Light are rated with 100,000 hours life expectancy. Here 50,000 hours seem to be realistic.
Cost of electricity	US$/kWh	*2.781*	The solar PV generated kWh unit in the Chauganphaya Village in Humla costs 203 NRp/kWh (PVSyst3.3 Sim.)
Wattage of incandescent bulb replaced	Watts	*25*	Enter wattage of incandescent bulb replaced.
Lumens of incandescent bulb replaced	Lumens	*375*	15 lumens pro Watt are assumed as an average for an incandescent bulb
Rated incandescent bulb life	Hours	*1000*	Estimated Incandescent bulb life expectancy in Nepal is from 750 - 1000 hours.
Cost of incandescent replaced	US$	*0.62*	The price (incl. 12% VAT) of a 25 W incandescent bulb in Simkot Humla is 45 NRp (0.62 US$)
Cost of WLED Light (before any rebates)	US$	*18.30*	Total price (incl. 12% VAT) for a 1 Watt WLED Light is 1,500 NRp (US$ 20.50). No rebates are available.
Rebates	US$	*0*	Enter amount of any rebates.
Combined state taxes	%	*2.20*	12% VAT on top of the WLED purchase price
Cost of WLED Light (after any rebates)	US$	18.30	US$/NRp exchange rate in April 2004 is: 1US$ = 73 NRp
Marginal increase in cost for WLED Light	US$	17.68	The cost of your "investment instrument."
Power used	kWh/year	1.83	The amount of electricity the WLED Light uses in a year.
Money spent on electricity consumed	US$/year	5.07	How much money you will spend annually with a CFL bulb.
Power not used	kWh/year	43.80	The amount of electricity the replaced incandescent bulb did not consume.
Money saved on electricity not consumed	US$/year	121.80	The amount of money not spent by converting an incandescent to a WLED Light.
Power consump. WLED Light v. incandescent bu	%	4.00	The percentage of electricity used by a WLED Light versus a comparable incandescent bulb.
Brightness efficiency of WLED Light	Lumens/watt	25.00	The amount of brightness per unit of energy consumed with a WLED Light.
Brightness efficiency of incandescent bulb	Lumens/watt	15.00	The amount of brightness per unit of energy consumed with an Incandescent Bulb.
Number of incandescent bulbs you don't change		49.00	Monetary savings (the value of your time) not quantified.
Simple payback on initial investment	Years	0.15	Simple payback in years.
Return on investment (tax-free)	%/year	688.91	Tax-free figure as a percent of WLED Light cost (including recouping capital cost of WLED Light).
Return on investment (taxable)	%/year	704.41	The equivalent rate of return of a taxable investment. Money saved need not be earned. (If ROI negative, then strictly speaking, you use the WLED Light so little as to not justify cost.)

Basic Excel Worksheet from: www.homepower.com/files/kerrcflbulbs.xls, and changed for the Chauganphaya Village Light condition by Alex Zahnd, Kathmandu Nepal, April 20th, 2004

Nichia 1 Watt WLED versus Incandescent 55 Watt Bulb Investment Analysis Chauganphaya

1 Watt WLED (White Light Emitting Diode) Light versus Incandescent 55 Watt Bulb Investment Analysis

Vary <u>only</u> ***italic bolded*** values.

Factor	Unit	Value	Notes
ENTER THESE VARIABLES		ENTER HERE	
Light use per day	Hours/day	*5*	Enter your estimate of how many average hours the bulb is on each day.
WLED Light size	Watts	*1*	One WLED consumes 25mA @ 3.6V DC. 9 WLEDs, 3 serial connected = one WLED Light: = 885mW, or ~ 1 W
Brightness	Lumens	*25*	Used WLED: Nichia NSPW510BS, 1.800 cd intensity, angle of 50°. One WLED Light has ~ 25 lumens brightness.
Rated WLED Light life	Hours	*50000*	WLED Light are rated with 100,000 hours life expectancy. Here 50,000 hours seem to be realistic.
Cost of electricity	US$/kWh	*2.781*	The solar PV generated kWh unit in the Chauganphaya Village in Humla costs 203 NRp/kWh (PVSyst3.3 Sim.)
Wattage of incandescent bulb replaced	Watts	*55*	Enter wattage of incandescent bulb replaced.
Lumens of incandescent bulb replaced	Lumens	*825*	15 lumens pro Watt are assumed as an average for an incandescent bulb
Rated incandescent bulb life	Hours	*1000*	Estimated Incandescent bulb life expectancy in Nepal is from 750 - 1000 hours.
Cost of incandescent bulb replaced	US$	*0.82*	The price (incl. 12% VAT) of a 55 W incandescent bulb in Simikot Humla is 60 NRp (0.82 US$)
Cost of WLED Light (before any rebates)	US$	*18.30*	Total price (incl. 12% VAT) for a 1 Watt WLED Light is 1,500 NRp (US$ 20.55). No rebates are available.
Rebates	US$	*0*	Enter amount of any rebates.
Combined state taxes	%	*2.20*	12% VAT on top of the WLED purchase price
Cost of WLED Light (after any rebates)	US$	18.30	US$/NRp exchange rate in April 2004 is: 1US$ = 73 NRp
Marginal increase in cost for WLED Light	US$	17.48	The cost of your "investment instrument."
Power used	kWh/year	1.83	The amount of electricity the WLED Light uses in a year.
Money spent on electricity consumed	US$/year	5.07	How much money you will spend annually with a CFL bulb.
Power not used	kWh/year	98.55	The amount of electricity the replaced incandescent bulb did not consume.
Money saved on electricity not consumed	US$/year	274.05	The amount of money not spent by converting an incandescent to a WLED Light.
Power consump. WLED Light v. incandescent bu	%	1.82	The percentage of electricity used by a WLED Light versus a comparable incandescent bulb.
Brightness efficiency of WLED Light	Lumens/watt	25.00	The amount of brightness per unit of energy consumed with a WLED Light.
Brightness efficiency of incandescent bulb	Lumens/watt	15.00	The amount of brightness per unit of energy consumed with an Incandescent Bulb.
Number of incandescent bulbs you don't change		49.00	Monetary savings (the value of your time) not quantified.
Simple payback on initial investment	Years	0.06	Simple payback in years.
Return on investment (tax-free)	%/year	1567.78	Tax-free figure as a percent of WLED Light cost (including recouping capital cost of WLED Light).
Return on investment (taxable)	%/year	1603.05	The equivalent rate of return of a taxable investment. Money saved need not be earned.
			(If ROI negative, then strictly speaking, you use the WLED Light so little as to not justify cost.)

Basic Excel Worksheet from: www.homepower.com/files/kerrcflbulbs.xls, and changed for the Chauganphaya Village Light condition by Alex Zahnd, Kathmandu Nepal, April 20th, 2004

18.3. Appendix to Chapter 7 Solar Irradiation Monitoring and Data Recording

18.3.1. Comparative curve of a 80SPC and Kipp-Zonen CM21 Pyranometer

When SolData was requested via email to confirm the accuracy of the three 80SPC pyranometers, they sent the diagram Figure 7-13, and wrote: "I attach a graph showing the 80SPC compared directly with a Kipp-Zonen CM21. Both are on a horizontal surface, for a typical, sunny day. If the sun is very low on the horizon that is when significant deviations will occur.

The 80SPC is temperature compensated. Therefore it is much better than the 15% that you have heard about. Without the temperature compensation it would be significantly affected by temperature variations.
You are welcome to use the attached figure in your report if it will be helpful." (Dr. Frank Bason, email from the 5th May 2004, SolData, Denmark)

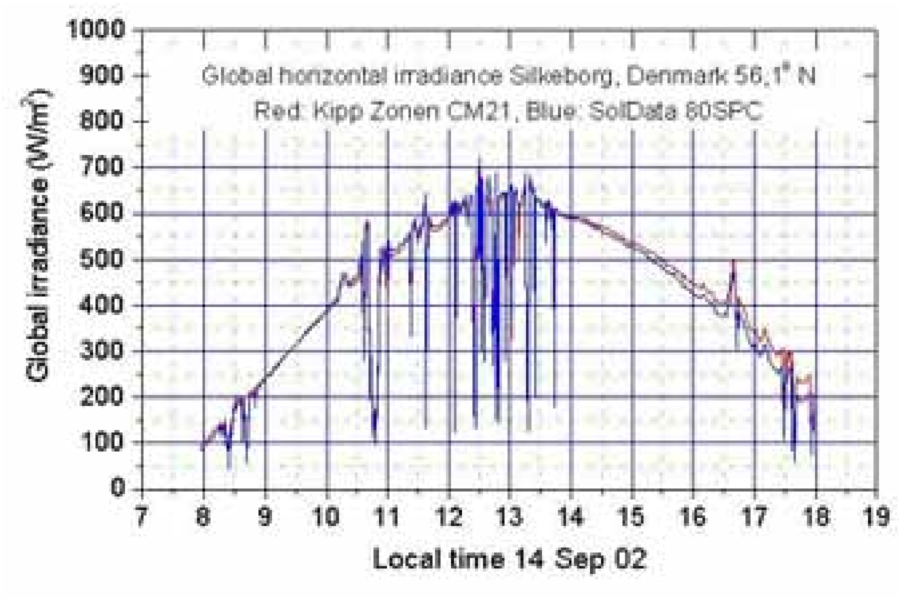


Figure 7-13: Global horizontal Irradiance comparison Kipp Zonen – SolData 80SPC Pyranometers
Global horizontal Irradiance comparison between a high quality Kipp-Zonen CM21[9], and a SolData 80SPC pyranometer (used with permission from Dr. Frank Bason SolData, Denmark).

The company's sales manager, Dr. Frank Bason, wrote in an email the following answer, when requested to indicate the temperature compensation techniques used and the pyranometers' accuracy.

"The 80SPC is compensated by means of a thermistor (NTC resistor) and a resistor in parallel short circuiting the cell. The pair has been carefully selected to correct for the temperature dependence of the silicon solar cell. Measuring global irradiance for a whole day the typical deviation from a Kipp-Zonen pyranometer is at the very most +/-3%[10]. Under unusual circumstances, e.g. very low solar elevation angles, the deviation can be higher. In the case of the HARS in Simikot, at an application around 30 degrees Northern latitude, the absolute accuracy is well within +/-3%. The relative accuracy when comparing e.g. one day with the next using the same instrument will normally be less than +/-1%."[11]

18.3.2. Details about the Data Monitoring and Recording System

Through Internet search and following up personal contacts with relevant companies, a suitable data monitoring and recording system was evaluated and chosen to monitor and record the 37 parameters, as defined in Appendix 18.3.4.

18.3.3. Summary List of Data Monitoring and Recording Equipment

The following is a summary list of the data monitoring and recording equipment that was purchased after the overall budget over US$ 14,500 could be raised:

- DataTaker DT605, with a 1 Mb internal memory. It has an integral display and keypad that allows users to view channel data, alarm status, and system information including time, battery status and amount of data stored. Function keys allow keypad control over the unit's operation (see Figure 7-22 in Appendix 18.3.9.).
- Channel Extension Module CEM.
- 2 x 4Mb, SRAM PC Card Memory Extension slots, each for additional approximately 1,390,000 readings, enabling the DT605 to continually record data for all the parameters for up to 2 x 28 days without downloading.
- DataTaker DeLogger 4 Pro software Version 2.16.
- 7 Current Transducers DCT247, from A.P.C.S. (Analog Process Control Services Ltd., NSW, Australia). They measure the DC current (with the ranges, up to 5Amp / 10Amp / 15Amp / and 20Amp adjustable) from the solar PV array, the battery bank in and out, and 2 different WLED lights. They provide a voltage signal from 0 – 10 VDC, with a 24 VDC support voltage from the battery bank (24 VDC system), which is recorded.
- 1 Power transducer, AWT190, from A.P.C.S. It measures the inverter power output up to 1,200 W, with an input voltage of 240 VAC. It is supported by a 24 VDC supply, producing an output signal of 0 – 10 VDC.
- 7 Thermocouples T-type 100 (Copper – Constantan with a temperature range of –50 °C to + 350 °C) for temperature measurements of the solar PV modules, ambient air temperature, and battery bank)
- 20 RTD Thermocouples (India made Platinum Resistance Temperature Detectors (with a calibration coefficient α = 0.003850 Ohm/Ohm/°C) with a

temperature range of –10 °C– + 300 °C) to measure the temperature at various places for the solar water heater and solar cooker (see definition of measured and recorded parameters in 6.3.2.).

- One Desktop PC PIV with a 15” colour monitor. The PC is able to record and play CDs (in order to record the monitored and recorded data on a weekly basis, and to send it to Kathmandu (via, courier, air plane and bus), and for educational purpose for the HARS staff. It has an 80 GB hard disk to store and handle all the recorded data.
- 2 Canon i905D colour printers, to be able to print the colourful curves, indicating the different related parameters on one graph.
- 3 SolData 80SPC pyranometers. A calibrated silicon photovoltaic cell.
- Thermocouple extension cables (with UV stabilized cover), customized aluminum frames for the horizontal and 30° pyranometers, and other small installation equipment.
- In the budget was also included the import custom duty and transport cost from Kathmandu to Nepalgunj by road, and by airplane on to Humla.

18.3.4. Measured and Recorded Data Parameters

The following 37 data are now measured and recorded with the data monitoring and recording system on a continuous basis since May 2004:

1. Solar irradiation on a horizontal surface.
2. Solar irradiation on a 30° south inclined surface (which is the most common position solar PV companies, and people install their solar PV modules in Humla, and allover Nepal).
3. Solar irradiation on the 2-axis self-tracking frame.
4. Ambient temperature East side of the HARS building.
5. Ambient temperature West side of the HARS building.

6. Ambient temperature East + West side average (calculated parameter).
7. Solar PV array Voltage.
8. Solar PV array Ampere.
9. Solar PV module A Temperature.
10. Solar PV module B Temperature.
11. Solar PV module Temperature average (calculated parameter).
12. Solar PV array Power Output (calculated parameter).
13. Solar PV array total Cell Area Efficiency (calculated parameter).
14. Solar PV array total Module Area Efficiency (calculated parameter).
15. Battery Bank Voltage.
16. Battery Bank Ampere In.
17. Battery Bank Power In (calculated parameter).
18. Battery Bank Ampere Out.
19. Battery Bank Power Out (calculated parameter).
20. Battery Bank Temperature.
21. Inverter Power (calculated parameter with a power transducer, A.P.C.S. AC Active Power transducer AWT190, 0 – 1200 Watt).
22. WLED Nichia Volt (9 NSPW 510SB WLED diodes).
23. WLED Nichia Current (with a A.P.C.S. DC current transducer DCT247).
24. WLED Nichia Power (calculated parameter).
25. WLED Luxeon Volt (Luxeon 1 Watt single diode WLED from Lumiled USA).
26. WLED Luxeon Current (with a A.P.C.S. DC current transducer DCT247)
27. WLED Luxeon Power (calculated parameter).
28. Solar cooker SK14 Focal Point Temperature.
29. Solar cooker SK14 Pressure Cooker Lower part Temperature (see Figure 7-24 in Appendix 18.3.10.).
30. Solar cooker SK14 Pressure Cooker Upper part Temperature.

31. Solar Water Heater cold Water Tank Intake Temperature.
32. Solar Water Heater Absorber 1 Temperature (first vertical copper pipe 100 mm height).
33. Solar Water Heater Absorber 2 Temperature (third vertical copper pipe 300 mm height).
34. Solar Water Heater Absorber 3 Temperature (fifth vertical copper pipe 500 mm height).
35. Solar Water Heater Absorber 4 Temperature (seventh vertical copper pipe 700 mm height).
36. Solar Water Heater hot Water Storage Tank Outlet Temperature.
37. Solar Water Heater hot Water Storage Tank half Irradiation Depth Temperature.

These 37 parameters (out of which the first 27 are of more or less relevance to this dissertation), 28 physical and 9 calculated parameters, are monitored and recorded in 4 different time basis, which are[12]:

1. Minute (every 10 seconds a value is taken, averaged over one minute).
2. Hour (each minute value is added and averaged over one hour).
3. Day (each hourly value is added and averaged over one day).
4. 30 Days (each daily value is added and averaged over 30 days).

18.3.5. Ambient Temperature Installation

For the two ambient temperature measurement parameters (one East and one West to be able to average the ambient temperature and compare it with the solar PV module temperature) a wooden box, each with ample air draft, but the prevention of direct solar radiation contact at any time of the year, had to be custom made. The following Figures show the two handmade, wooden boxes to install the ambient air temperature T-type thermocouple.

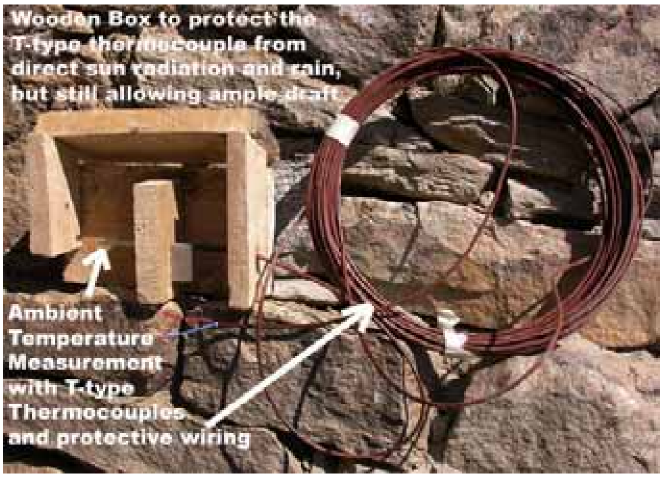


Figure 7-14: Ambient Temperature Measurement Box
Hand made wooden box for the East side ambient temperature measurement and data recording.

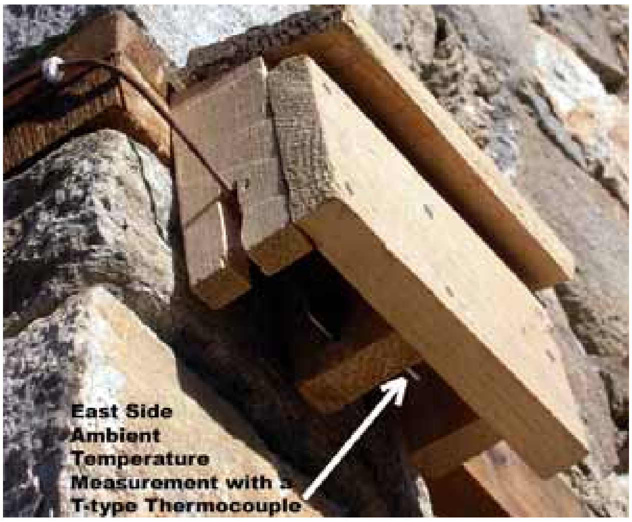


Figure 7-15: Ambient Temperature East
Installed East side ambient temperature thermocouple.

Figure 7-16: Ambient Temperature West
Installed West side ambient temperature thermocouple.

In order to have reliable and accurate ambient temperature data measured and recorded, on each, the East and West side, one T-type thermocouple is installed. The two data are recorded individually and the average value is calculated and recorded. It is this averaged value which is included in the solar irradiation graphs, to be compared with the average solar PV module temperature.
From the averaged temperature graphs for the two solar PV modules and the averaged ambient temperature it is recognised that the shielding effect of the ambient temperature thermocouples' wooden box and the location near the building wall differ during the night hours from the solar PV modules temperature by approximately 2 °C.
It is important that the wooden boxes made are fulfilling the following tasks to achieve accurate and reliable data:

- Allow ample and free wind flow through the box and around the thermocouple.
- Prevent at any time direct sun contact
- Prevent at any time that rain can come in direct contact with the thermocouple.
- No heat is building up inside the box.
- No snow can cover the wooden box or block the thermocouple.

18.3.6. Solar PV Module Temperature Measurement

Another important data value to measure is the solar PV module temperature through the day, as the solar PV module used (mono-crystalline BP275F module) has a temperature coefficient of -0.44% per °C increase. That means, that the module's power output decreases by 0.44% for each °C increased. In order to measure this parameter as accurately as possible, a T-type thermocouple was installed with a handmade wooden beam on the back of the solar PV module. A thread was cut into the wooden beam, in order to screw the thermocouple, which is fitted into a galvanized piece of metal pipe with a thread, into the beam. That allows the adjustment of the pressure of the thermocouple tip upon the backside of the solar PV module. The following Figures demonstrate the technique used and equipment made.

Figure 7-17: PV Module Temperature Measurement

This Figure shows the backside of one of the three 2-axis self-tracking frames with each 4 BP275F solar PV modules installed at the HARS in Simikot Humla. One frame thus generates up to 300 W_R, under ideal sunshine conditions. The solar PV modules are always running under a higher temperature than the ambient temperature. High energy photons give their energy to the electrons, moving them up into the conduction band leaving a hole in the valence band. By relaxing to the band edges, the electron-hole pair releases heat, thus increasing the solar PV module's temperature. Increased temperature reduces the band gap, thus lower energy is needed to break the bond, resulting in lower power output. The parameter most affected by an increase in temperature is the dropping of the open-circuit voltage.

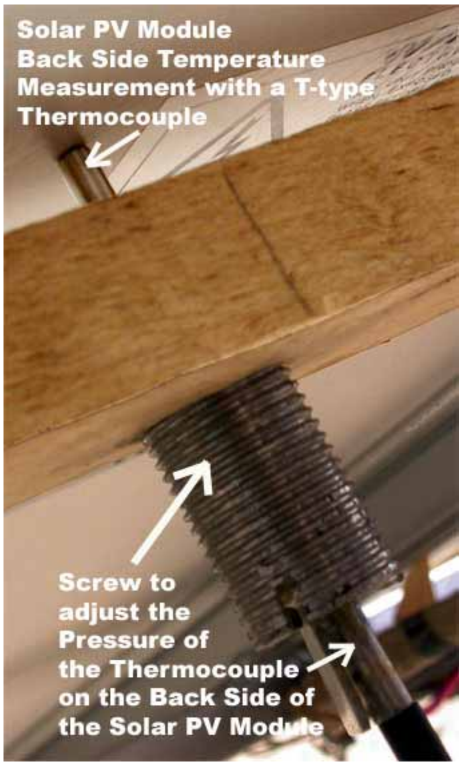


Figure 7-18: T-type Thermocouple for PV Module

On two solar PV modules, on the same self-tracking frame, the backside module temperature is measured, and recorded, enabling the calculation of the solar PV module power generation loss, due to increased module temperature. The tip of the thermocouple has to press slightly onto the backside of the PV module, in order to provide a firm contact surface for the temperature transmission. An additional piece of wood (not shown in the Figure) was carved, to cover and protect the thermocouple tip from any wind, influencing the thermocouple tip temperature, and thus its actual value.

However, the actual solar PV module p-n junction temperature is an estimated 2°C higher, as only the solar PV back side and not the solar cell junction temperature is measured.

18.3.7. Battery Bank Temperature

The battery bank is a central part of the solar PV system. Unfortunately the long-term performance of batteries is very difficult to predict exactly. This is so even for the manufacturers. That is because the battery is a chemical energy storage facility. The chemical process depends on many internal and external factors and circumstances, which are hard to define exactly. Some of them are: the technology used (floated or gel), thickness of the lead plates, gravity of the sulfuric acid electrolyte, charging and discharging technology, current charging and discharging values, and time rates, as well as temperature, just to mention a few. Thus, to understand the battery bank in more detail it has to be monitored over an extended time period during its operation and in its environment. Only then more reliable information of its state of charge and discharge condition, performance during various seasons, and expected life cycle, for a particular application and location, can be extracted. Therefore the HARS's solar PV system's battery bank has been installed with the following data monitoring parameters, connected to the dataTaker DT605 logger.

- The battery bank voltage.
- The In-coming current.
- Power In (calculated and recorded value).
- The Out-going current.
- Power Out (calculated and recorded value).
- Battery bank temperature (at 2 places and averaged).

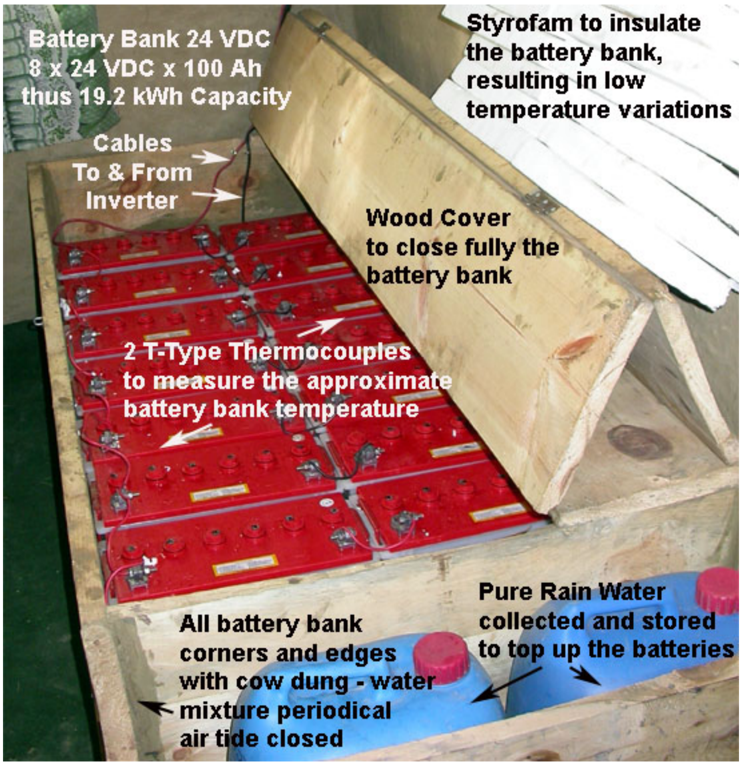


Figure 7-19: HARS Battery Bank
The HARS Simikot Humla Solar PV System Battery Bank, with solar deep cycle batteries.

The HARS Solar PV System battery bank is designed as a 24 VDC system. Its capacity allows to store electricity for up to 4 days with the normal daily load demand of the HARS of 2.5 kWh/day, if the sun is not shining. The overall battery performance (charging and discharging) is at it's best around 15°C-20°C. In order to achieve that, all the 16 batteries are installed in a solid, locally made wooden box. The gaps and inequalities of the wood blanks are filled in with a cow dung-mud-water-mixture, to make the box as air tight as possible. A hole (with a metal mesh to prevent mice from entering) at the bottom and one at the upper end, connected to the outside air, guarantee the needed air draught. That prevents any possible dangerous hydrogen gas accumulation due to the periodical boosting cycle.
Due to the remoteness, no distilled water is either brought in, or locally produced. As there is no air pollution as such, the rainwater is periodically collected in clean plastic basins, and stored in a dark place in plastic drums in an attached chamber to the battery bank. The battery bank is used as sitting place as well as a bed at night.
The installation and charge and discharge conditions allow the battery bank to have a life expectancy of 8 - 10 years.

The voltage, power input and output, and the temperature of the battery bank are continuously monitored and recorded. These values already provide an insight into the battery bank's condition and charge status. But in order to have a clear understanding of the battery bank's energy storage and energy provision capacity, one more important value needs to be known, the density of the electrolyte. During the charging process, lead oxide is formed at the anode (+ pole), and pure lead is formed at the cathode (- pole), with sulhpuric acid being liberated in the electrolyte. That increases the density of the electrolyte. In contrast to that is the discharge process, during which lead sulphate is formed at both electrodes and sulphuric acid is removed from the electrolyte. That results in a lower density of the electrolyte.

While the battery bank's voltage and temperature can be measured and its data recorded with a datalogger, the density cannot be easily measured and recorded in an automated way. That has still to be done by hand on a periodical basis with a hygrometer. One further aspect is that the stratification of the electrolyte, has to be considered in order to get a realistic data for the battery bank's condition. The stratification of the batteries' electrolyte occurs under normal operation conditions. The batteries tend to have a non-uniform electrolyte distribution with the densest electrolyte at the bottom of the battery container. This promotes corrosion and sulphation of the bottom part of the negative electrode. To avoid that, the battery charger is programmed to overcharge the battery bank slightly on a regular basis (boost charging). That causes some gassing, stirring and mixing of the electrolyte, so that the density is once again more uniform throughout the batteries.

Additionally, the battery bank is installed in a customised, locally made, and insolated wooden box, to ensure throughout the year under all possible circumstances, that the electrolyte does not freeze during the operation. Without this precaution, the 4 cold winter months, with temperatures down to – 20 °C, could have a disastrous effect on the battery bank's condition and life expectancy. And finally, the state of charge of the batteries is kept as high as possible (resulting in high density), rather than having an increased electrolyte density to start with (which would provide more capacity but as well more wear and tear on the battery and thus shorter life time expectancy). These measures taken and checked periodically, keep the battery bank protected and in stable and satisfactory conditions. With these data monitored, measured and precautions followed, accurate data for the battery bank's condition and status are achieved.

18.3.8. HARS Power Consumption Measurement and Data Recording

One aim of the data monitoring and recording of all these 28 physical and 9 calculated parameters is to enable a detailed understanding of the available solar energy and the energy consumption (or better conversion) of the various equipment used. The power generated by the solar array and the power consumed by the various consumers (inverter providing power to all the office equipment, WLED lights etc.) is calculated for the DC lines by simply multiplying the measured voltage by the measured amperes flowing. The DC voltage up to 100 VDC can be directly measured and recorded by the DT605 data logger. Thus, the solar PV array's voltage, 0 VDC – 40 VDC, the battery bank's voltage, 23.6 VDC – 28.8 VDC, and the 2 WLED's voltage, 10.8 VDC – 14.4 VDC (depending on the battery bank's condition), are directly connected. The equipment related currents are measured by current transducers. Each DCT247 transducer can be defined with a specific current range through setting the internal jumpers accordingly. Thus enabling one product to be used for current ranges 0 – 5 amperes up to a range of 0 – 50 amperes.

Current is detected by means of a toroidal Hall Effect sensor. For very low current inputs, such as from the WLED lights with 80 mAmp – 100 mAmp current consumption for one WLED light with 9 diodes, a defined amount of turns through the transducer's toroid can be used to magnify the current flow to the related transducer current measurement range. That enables the measurement of very low current (as in the case of the WLED lights), but still with the need accuracy. The measured current is transformed into an output signal of 0 – 10 VDC for the dataTaker logger. With this method the power consumption of the defined equipments can be calculated and recorded exactly as a derived parameter.

To measure AC power is different than to measure DC power, as the cos φ of the consumer has to be included in the power calculation. Thus the inverter AC power output, dependent on the HARS office equipment demands, is measured with an AC power transducer AWT 190. It can convert instantaneous power input of a single or 3 phase balanced load system into a standard 0 VDC – 10 VDC output signal that is proportional to the measured value. That output signal is suitable for the dataTaker and thus can be used as the recording input, with the related power range logarithm programmed in the logger's software for the inverter channel. The AC power transducer has input capabilities of 63.5 VAC to 415 VAC and input currents of 0.5 Amp – 10 Amp. This Australian designed and manufactured power transducer is designed as a class 2 (AS1384-1973) equipment, with long term stability, and it offers a good range of input and output combinations.

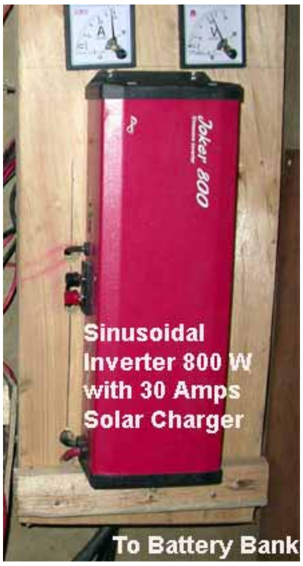


Figure 7–20:
Joker 800 Watt Sinusoidal Inverter.

For various applications, such as the desktops, laptops, CFL lights, and battery charger, AC power is needed. As the battery bank stores and delivers DC power, this power is inverted with an 800 Watt sinusoidal inverter, providing perfect AC power of 228 VAC ±2VAC for all the following main AC consuming equipment installed in the HARS office in Simikot Humla.

- 2-3 desktop PCs (each 120 W – 200 W consumption)
- 1 – 3 laptops (each 50 W – 90 W consumption)
- 1 bubble jet printer (50 W consumption
- 11 CFL bulbs for 11 rooms (each 11 W consumption)
- 2 battery chargers (each ~10 W consumption)
- 2 radios (each ~10 W – 20 W consumption)

The inverter provides 800-Watt power output continuously, with a surge rating (up to 5 seconds) of up to 3,000 Watt. With 94% efficiency, and a power consumption in the stand by mode of 0.4 Watt and ~ 5 Watt in the running mode, it is a high quality product[13].

It has a solar charger integrated with up to 30 Ampere charging capacity. That matches the maximum solar PV array output of all three self-tracking frames and 12 x 75 W BP275F solar PV modules.

The inverter is mounted on a wooden board, to protect it from the cold stonewall and any possible moisture. A Solar PV Array Volt and Ampere meter provide quick reference for the instant solar energy generated.

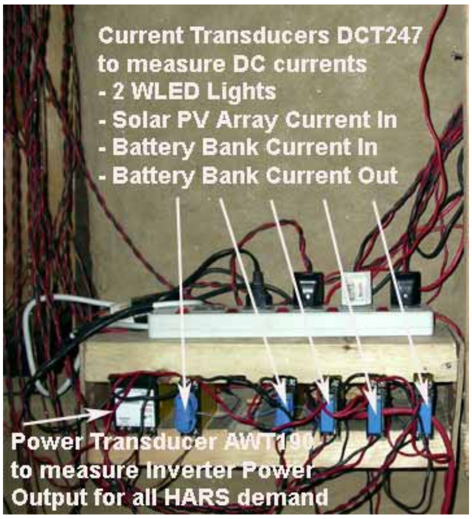


Figure 7–21: Current Transducers

A special wood holder for all the current transducers and the power transducer was hand made, to fit all the 5 current transducers. The holder allows ample airflow between each transducer, preventing any possible accumulated heat, which could increase the loss values in the wires, and thus influence the accuracy of the data readings.

Five current transducers DCT247 are installed for the current measurement of the following equipment (from right to left).
Battery bank current IN flow (range 0 – 30 Amps)
Battery bank current OUT flow (range 0 – 50 Amps)
Solar PV array generated current flow (range 0 – 30 Amps)
Lumiled Luxeon 1 W single WLED light current flow. With 33 turns through the toroid, the 0 – 5 Amps range is scaled down to measured a range of only 0 – 151.5 mAmp, with the output of 0 – 10 VDC. That allows utilising the same measurement accuracy. The Luxeon WLED consumes under normal conditions between 100 – 130 mAmp at 10.8 VDC.
Nichia WLED light current flow. With 50 turns through the toroid, the 0 – 5 Amps range is scaled down to measure a range of only 0 – 100 mAmp for the total output range of 0 – 10 VDC, thus not loosing any accuracy in the measured data. The Nichia WLED (with 9 single WLEDs) consumes under normal conditions between 70 – 100 mAmp at 10.8 VDC.
One AC power transducer AWT190 is installed for the current measurement of the DC-AC 800 Watt sinusoidal inverter (see Figure 7-21). It transforms the AC current into a 0 - 10 VDC voltage, taking the cos φ of the AC load into consideration, and records it in the DT605 logger. With the proper programmed range, the logger provides the recorded value as an instant power consumption value in Watt.
As explained, the DC voltages are measured directly by the DT605 logger. Thus the related voltages and DC currents of each equipment are multiplied (with the related programmed range) and recorded as a calculated power consumption parameter in Watt.

18.3.9. DT605 dataTaker plus CEM (Channel Extension Module)

The DT605 data logger is the heart of the whole data recording system. In order to monitor and record all the 37 parameters accurately (as some parameter signals demand a single channel) a channel extension module (CEM) was needed.

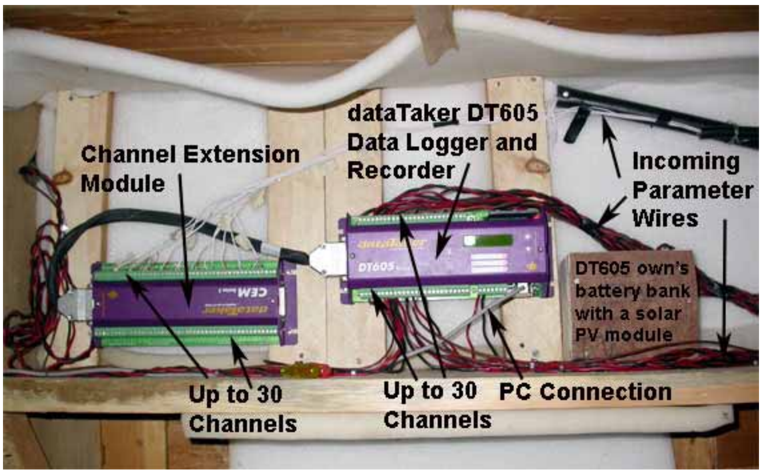


Figure 7–22 DT605 with CEM

DT605 dataTaker with the CEM (Channel Extension Module), the own small, solar charged battery bank, and all the measured parameters' wiring connections.

For the DT605 dataTaker a special place, insulated with foam and surrounded with wood was created, to keep it in as clean conditions as possible (within a stone and mud house), as well as at a stable constant temperature as possible (in an environment with a rather huge ambient temperature difference of + 30 °C down to – 25 °C at its extreme seasons). Though the solar PV system has a good sized battery bank, the DT605 has been installed with an own small solar PV charged system and battery bank. This to accommodate the 6 VDC needed to run the DT605, while the big battery bank has a 24 VDC system voltage, and second to assure a long-term own power generation independent of the big battery bank. Thus a 10 W, 6 VDC solar PV module is charging the 6VDC x 8Ah (2 x 4Ah 6 VDC gel batteries parallel connected) battery bank (see in Figure 7-22 at the right side of the Figure).

For each monitored parameter the data logger demands a small programme, written in the dataTaker provided software (DeLogger 4 Pro Version 2.16), identifying the parameter, telling it how to record the incoming data and how to use the incoming data for any further calculations. With 37 different parameters measured, recorded and calculated, an extensive programme had to be written to handle the rather huge amount of data constantly coming in. To keep track of the written software, an Excel data bank, identifying each parameter clearly, has been developed. It includes all the needed data specified and programmed for the DT605 data logger to identify each parameter clearly and separately. For more details on how the monitored parameters are all connected to the various DT605 and CEM channels, and the Excel spreadsheet of the details of each parameter for each of the four time schedules monitored and recorded, see Appendix 18.3.12.

18.3.10. Additional Monitored Parameters

The HARS in Simikot also serves as a test station for other research projects such as the high altitude solar water heater, and the parabolic solar cooker SK14. The monitoring and recording system is designed in such a way that it can also monitor and record 10 parameters for these projects.

Additional preparatory work and customised manufacturing of tools and equipment took place, to be able to monitor and record the 10 parameters for the additional ongoing research projects on a long-term basis. These 10 parameters measured with the DT605, plus the fixed installed pressure manometer for the solar cooker and the two elevated poles for the air sampler are divided in the three research projects:

- Solar water heater for high altitude mountain areas (Figure 7-23).
- SK 14 Solar Cooker (Figure 7-24).
- Air pollution Sampler (Figure 7-25).

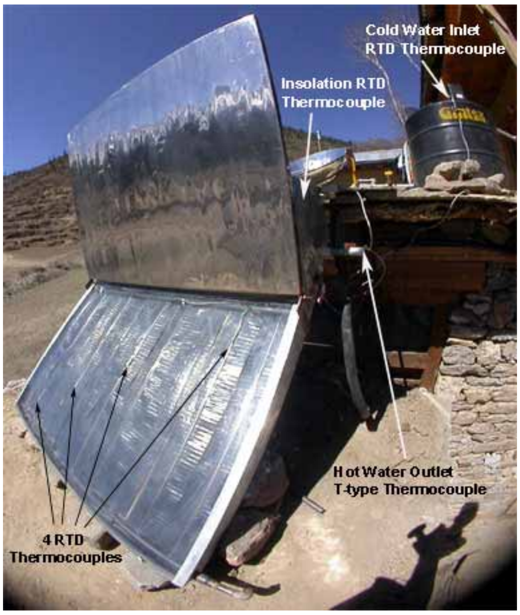


Figure 7–23: Solar Water Heater

Solar Water heater with 7 monitoring parameters, with T-type and RTD type thermocouples. 4 thermocouples glued to the copper absorber fins, one measuring the outlet hot water, one the cold inlet water, and one measuring the insulation temperature half way into the hot water tank insulation.

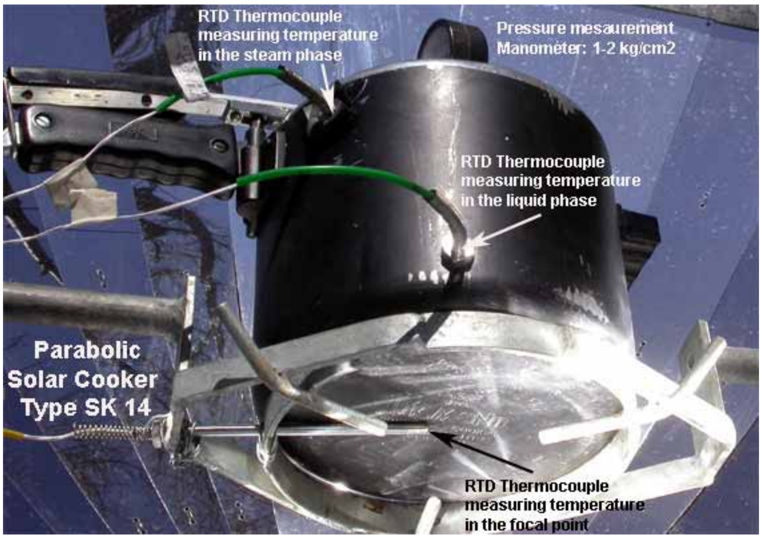


Figure 7–24: Parabolic Solar Cooker SK 14

SK 14 Solar Cooker with 4 monitoring parameters, all with RTD type thermocouples (made in India).

One RTD measures the temperature of the parabolic solar cooker's focal point.

One RTD measures the lower, liquid part of the food cooked inside the pressure cooker.

One RTD measures the upper, steam part of the food being cooked.

A 1 – 2 bar absolute pressure manometer provides an instant reading of the pressure cooker inside pressure.

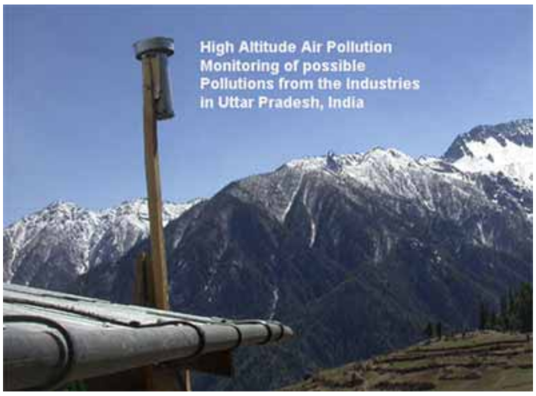


Figure 7–25: Air Pollution Sampler

In collaboration with the University of Manitoba in Canada, a newly started air pollution sampling project has started with 2 samplers, to monitor the possible air pollutions in high altitude Himalayan regions in one year time periods. Possible expected pollutions come from the uncontrolled pollution generation of India's massive growing heavy industries in the northern territories of India. The states most probably affecting Nepal's Himalayan regions are, Bihar and Uttar Pradesh (India's biggest populated state), both along side Nepal's southern boarder.

Figure 7–26: HARS Simikot Humla

HARS (High Altitude Research Station) in Simikot Humla, at latitude 29° 58' and longitude 81° 49', at an altitude of exact 3,000 m.a.s.l. The 900 W solar PV system provides the electricity for the whole station. Part of ongoing research projects are the solar irradiation (started through this dissertation), solar PV self-tracking frame (part of the dissertation's Chauganphaya village electrification scheme), 2 SK14 solar cookers, a high altitude solar water heater, a smokeless metal stove for high altitudes (inside the kitchen), and 2 air pollution samplers.

18.3.11. Monitored and Identified Parameters Connected to the Data Logger

Table of the 28 physical parameters' channel details, number and identification:

The Data Taker DT605 Channel Details

S.N.	dataTaker	Channel No.	Channel ID	Channel Detail	Wire Configuration
1	DT605	1	TaEastTtypeCh1	Ambient Temp. East side	between + / -
2	DT605	2	InsolHorCh2	Solar Irradiation Horizontal	between R/*
3	DT605	2	Insol30DegCh2	Solar Irradiation 30 Degree	between R/+
4	DT605	2	InsolTrackCh2	Solar Irradiation Tracking	between R/-
5	DT605	3	WLEDLuxeonAmpCh3	1 bulb WLED Current	between R/*
6	DT605	3	PVTemp1TtypeCh3	PV Panel Back Temp.	between + / -
7	DT605	4	WLEDLuxeonVoltCh4	1 bulb WLED Voltage	between R/*
8	DT605	4	BattTempCh4	Battery Temp.	between + / -
9	DT605	5	PVArrayVoltCh5	Array Voltage	between R/*
10	DT605	5	TaWestTtypeCh10	Ambient Temp. West side	between +/-
11	DT605	6	PVArrayCurrCh6	Array Current	between R/*
12	DT605	6	BattAmpInCh6	Battery Current In	between R/+
13	DT605	6	BattAmpOutCh6	Battery Current Out	between R/-
14	DT605	7	WLEDNichiaVoltCh7	9 bulb WLED Voltage	between R/*
15	DT605	7	WLEDNichiaAmpCh7	9 bulb WLED Current	between R/+
16	DT605	8	InverterPowerCh8	Inverter Power	between + / -
17	DT605	9	PVTemp2TtypeCh9	PV Panel Back Temp.	between + / -
18	DT605	10	BattVoltCh10	Battery Voltage	between R/*

Table 7-10: DT605 Channel Details

The Data Taker CEM Channel Details

19	CEM	1	SWHTabs1CEMCh1	SWH Absorber Temp.	4 wire configuration
20	CEM	2	SWHTabs2CEMCh2	SWH Absorber Temp.	4 wire configuration
21	CEM	3	SWHTabs3CEMCh3	SWH Absorber Temp.	4 wire configuration
22	CEM	4	SWHTabs4CEMCh4	SWH Absorber Temp.	4 wire configuration
23	CEM	5	SWHTinCEMCh5	SWH Cold water temp.	4 wire configuration
24	CEM	6	SWHToutCEMCh6	SWH Hot water temp.	4 wire configuration
25	CEM	7	SWHTinsulCEMCh7	SWH Tank Insulation temp.	4 wire configuration
26	CEM	8	SCTfocusCEMCh8	Solar cooker focus temp.	4 wire configuration
27	CEM	9	SCTupCEMCh9	Pressure cooker inside (up) temperature	4 wire configuration
28	CEM	10	SCTlowCEMCh10	Pressure cooker inside (lower) temperature	4 wire configuration

Table 7-11: CEM Channel Details

Each equipment, either installed in the HARS in Simikot (such as the inverter, or the WLED lights), or used to measure and monitor data (such as the pyranometers or the current transducers) has a different range of operation and unit, such as e.g. a pyranometer measuring the solar radiation in W/m^2 with a mV output signal, proportional to the intensity of the solar radiation falling on its surface. Likewise, the inverter has a rated power output of 800 W, which has to be changed into a 0 - 10 Volt DC signal, including possible start up spike power demands of up to 1,200 Watt. The following list identifies the physical range, the sensor range, sensor unit and output unit of each of the equipment used to programme the DT605 data logger system.

Physical Ranges, Sensor Ranges, Sensor Units, Output Units

Span	Description	Physical Range	Physical Unit	Sensor Range	Sensor Unit	Output Unit	Remarks
1	InsolHorCh2	0-1500	W/m^2	0-234	mV	W/m^2 - 1	
2	Insol30DegCh2	0-1500	W/m^2	0-231	mV	W/m^2 - 2	
3	InsolTrackCh2	0-1500	W/m^2	0-220.5	mV	W/m^2 - 3	
4	PVArrayCurrCh6	0-35	A	0-10	V	Amp - 4	
5	BattAmpOutCh6	0-50	A	0-10	V	Amp - 5	
6	InverterPowerCh8	0-1200	W	0-10	V	Watt - 6	
7	WLEDNichiaAmpCh7	0-100	mV	0-10	V	mAmp - 7	50 windings
8	WLEDLuxeonAmpCh3	0-200	mV	0-10	V	mAmp - 8	33 windings

Table 7-12: Physical Ranges, Sensor Ranges, Sensor Units and Output Units of each of the Equipment used to programme the DT605 Data Logger Software.

The 4 Excel spreadsheets developed (according to the monitored and recorded time schedules A, B, C, and D in Appendix 18.3.12.), with the identification and programmed conditions and constraints for each of the monitored 37 parameters, include the following headings:

- *Serial number* for each physical and calculated parameter (1 – 9 / 28 / 34 / 35, according to the time schedule D / C / B / A).

- *Time Schedule* of measurement (4 times schedules, A (each minute), B (each hour), C (each 24 hour day), D (each 30 days), are logged and recorded).
- *Channel* (each parameter is connected to the DT605 or the CEM through a defined channel and wiring schemata).
- *Parameter* measured (e.g. Irradiation, Voltage or a calculated parameter such as power).
- *Code name* for the parameter given for the DT605 software programming (e.g. InsolHorCh2 for the horizontal irradiation measurement and recording in channel 2 of the DT605, or SWHTabs3CEMCh3 for the solar water heater absorber temperature 3 in the channel extension module channel 3 measured and recorded).
- *Schedule Time* interval (recording interval 1 min, 1 hour, 1 day (24 hours), or 30 days).
- *System* referring to the various session defined according to the area/topic of the data recording, such as e.g. "Meteorological system", including all three solar irradiation data measured, and the 2 ambient temperature data measured, and the calculated average ambient temperature data. Or the "PV system", including the solar PV array generated voltage and current measured, the calculated solar PV array power output, the 2 solar PV module measured back side temperature and the calculated average solar PV module back side temperature, the measured battery bank voltage and current in and out and the calculated power values accordingly, the battery bank's temperature, and the inverter's power generation according to the load demand.
- *Sub-system,* identifying the actual equipment, as e.g. the "inverter", though it is part of the PV system systems.

- *Parameter Detail,* defining the actual parameter measured more preciously, such as e.g. the parameter irradiation, defined as "horizontal irradiation", "30° irradiation" and "tracking irradiation".
- *Equipment,* defining the measurement equipment used to monitor and record the data, such as e.g. "pyranometer (SolData)" for all three irradiation measurements, or "9 bulb WLED" to distinguish the Nichia WLED from the Lumiled Luxeon (with just one WLED diode).
- *Output Parameter,* identifying the parameter in terms of e.g. "voltage" for all mV DCV, or DCV output equipment such as the pyranometers, the current transducers, the Watt transducer, or "temperature" for all the T-type or RTD thermocouples.
- *Output unit,* to specify the output parameters' unit such as e.g. "mV' for the pyranometers, "W" for the Watt transducer, "V" for the current transducers.
- *Sensitivity/Span,* identifying and defining the DT605 programmed span or sensitivity for each parameter. Thus, e.g. one of the three SolData 80SPC pyranometer to measure the solar irradiation on the tracking frame has a sensitivity/span value of 220.5 mV at 1,500 W/m^2, with its calibration factor (defined by the manufacturer) of 147mV at 1,000 W/m^2. Or the Nichia WLED light has a span of 0 - 100mAmp (with 50 turns through the toroid to utilise the full output span of the current transducer of 0 - 10VDC at a range of 0 – 5 Amp).
- *Derived/Virtual Parameter,* identifying the output unit of the parameter, such as e.g. "W/m^2" for the solar irradiation data, or "A" for the various current transducers, "W" for the Watt transducer.
- *Channel Variable (CV).* While programming each parameter in the DT605 own software packet DeLogger 4 Pro, each parameter is assigned a CV

number, which can be used within the software as a parameter for any calculation or combination with other parameters. E.g. the solar PV array's recorded voltage has an identification of "4CV", and the solar PV array's current is identified with "5CV". Thus the solar PV array's power data, identified with 6CV is calculated as a virtual data by multiplying 4CV with 5CV.

- *CV Expression,* identifying the algorithms used through the CV, such as e.g. the previously explained solar PV array output power calculated by the multiplication of the voltage CV and the current CV, (4CV x 5CV).
- *Statistical,* defining the statistical calculation used in the program for the various parameters, such as e.g. "AV" as the statistical average calculation of the data recorded for each minute (in schedule A) as the averaged data reading of every 15 seconds.
- *Wiring Configuration,* identifying the wiring configuration used for the connection of each parameters' wires in the defined channels in the DT605 or CEM. One data recording channel can take up to 3 different parameters (if they match from their output unit, range and even more important from their parameter measurement characteristics and behaviour point of view).
- *Remarks,* for any other, important and previously unidentified, information.

18.3.12. Excel Spreadsheets with the 4 Different Monitoring Time Schedules

On the following 6 pages the developed Excel Schedule spreadsheets with all the parameters monitored and recorded (as according to the above defined system) for each of the 4 different time schedules A (each minute), B (each hour), C (each day), and D (each 30 days) are listed.

Schedule A (1 Minute logging) Details

6.	Session	Schedule	Channels	Parameter	Code name	Schedule Time	System	Sub-system	Parameter Detail	Equipment	Output parameter	Output unit	Sensitivity / Span	Derived / Virtual Parameter	Derived unit	Channel Variable (CV)	CV Expression	Statistical	Wiring Configuration	Remarks
		Schedule A				1 min.												15sec ave		
1	1	Schedule A	Channel 2	Irradiation	InsolHorCh2	1 min.	Meterological system		Horizontal irradiation	Pyranometer (SolData)	Voltage	mV	1500W/m^2=234 mV (1000W/m^2=156 mV)	W/m^2	W/m^2	48CV		AV	SE wire connection (R/*)	
2	1	Schedule A	Channel 2	Irradiation	Insol30degCh2	1 min.	Meterological system		30 degree Irradiation	Pyranometer (SolData)	Voltage	mV	1500W/m^2=231 mV (1000W/m^2=154 mV)	W/m^2	W/m^2	47CV		AV	SE wire connection(R/+ve)	
3	1	Schedule A	Channel 2	Irradiation	InsolTrackCh2	1 min.	Meterological system		Tracking Irradiation	Pyranometer (SolData)	Voltage	mV	1500W/m^2=220.5mV (1000W/m^2=147 mV)	W/m^2	W/m^2	1CV		AV	SE wire connection (R/-ve)	
4	2	Schedule A	Channel 5	Voltage	PVArrayVoltCh5	1 min.	PV system	PV array	PV Array Voltage	Direct measurement	Voltage	V	0-100V DC			4CV		AV	SE wire connection (R/*)	
5	2	Schedule A	Channel 6	Current	PVArrayCurrCh6	1 min.	PV system	PV array	PV Array Current	0-35 A DC current transducer	Voltage	V	0-35A(0-10V)	A	Amp	5CV		AV	SE wire connection (R/*)	
6	2	Schedule A		Power	PVArrayPower	1 min.	PV system	PV array	PV Array Power		Watt	W				7CV, 6CV	(4CV*5CV)			
7	2	Schedule A	Channel 3	Temp	PVTemp1TtypeCh3	1 min.	PV system	PV array	Panel back temp.	T-type Thermocouple sensor	Temp.	C				13CV		AV	Differential +ve/-ve	
8	2	Schedule A	Channel 9	Temp	PVTemp2TtypeCh9	1 min.	PV system	PV array	Panel back temp.	T-type Thermocouple sensor	Temp.	C				14CV		AV	Differential +ve/-ve	
9	2	Schedule A		Temp	PVTempAverage	1 min.	PV system	PV array	Panel back temp. ave.		Temp.	C				15CV	(13CV+14CV)/2			
10	3	Schedule A	Channel 10	Voltage	BattVoltCh10	1 min.	PV system	Battery bank	Battery voltage	Direct measurement	Voltage	V	0-100V DC			16CV		AV	SE wire connection (R/*)	
11	3	Schedule A	Channel 6	Current	BattAmpInCh6	1 min.	PV system	Battery bank	Battery current in	0-35 A DC current transducer	Voltage	V	0-35A(0-10V)	A	Amp	17CV		AV	SE wire connection (R/-ve)	
12	3	Schedule A		Power	BattPowerIn	1 min.	PV system	Battery bank	Battery power in		Watt	W				18CV, 19CV	(16CV*17CV)			
13	4	Schedule A	Channel 6	Current	BattAmpOutCh6	1 min.	PV system	Battery bank	Battery current out	0-50 A DC current transducer	Voltage	V	0-50A(0-10V)	A	Amp	21CV		AV	SE wire connection (R/+ve)	
14	4	Schedule A		Power	BattPowerOut	1 min.	PV system	Battery bank	Battery power out		Watt	W				22CV,23CV	(16CV*21CV)			
15	4	Schedule A	Channel 4	Temp	BattTempCh4	1 min.	PV system	Battery bank	Battery temp.	T-type themocouple sensor	Temp.	C						AV	Differential +ve/-ve	
16	5	Schedule A	Channel 8	Power	InverterPowerCh8	1 min.	PV system	Inverter	Inverter Power	AC power transducer	Voltage	V	0-1200W (0-10V)	W	Watt	25CV		AV	Differential +ve/-ve	
17	10	Schedule A	Channel 4	Voltage	WLEDLuxeonVoltCh4	1 min.	Load		1 bulb WLED	Direct measurement	Voltage	V	0-100 VDC			27CV		AV	SE wire connection (R/*)	
18	10	Schedule A	Channel 3	Current	WLEDLuxeonAmpCh3	1 min.	Load		1 bulb WLED	0-5A DC current transducer	Voltage	V	0-5A (0-10V) with 33 windings thus 0-151.5mA	mA	mAmp	28CV		AV	SE wire connection (R/*)	Transducer has 33

													(0-10V)							windings
19	10	Schedule A		Power	WLEDLuxeonPower	1 min.	Load		1 bulb WLED			mAV				29CV	(27CV*28 CV)			
20	10	Schedule A	Channel 7	Voltage	WLEDNichiaVoltCh7	1 min.	Load		9 bulb WLED	Direct measurement	Voltage	V	0-100 VDC			31CV		AV	SE wire connection (R/*)	
21	10	Schedule A	Channel 7	Current	WLEDNichiaAmpCh7	1 min.	Load		9 bulb WLED	0-5A DC current transducer	Voltage	V	0-5A (0-10V), with 50 windings thus 0-100mA (0-10V)	mA	mAmp	32CV		AV	SE wire connection (R/+ve)	Transducer has 50 windings
22	10	Schedule A		Power	WLEDNichiaPower	1 min.	Load		9 bulb WLED			mAV				33CV	(31CV*32 CV)			
23	8	Schedule A	Channel 1	Temp	TaEastTtypeCh1	1 min.	Meterological system		East side ambient temp.	T-type thermocouple sensor	Temp.	C				35CV		AV	Differential +ve/-ve	
24	8	Schedule A	Channel 5	Temp	TaWestTtypeCh5	1 min.	Meterological system		West side ambient temp.	T-type thermocouple sensor	Temp.	C				36CV		AV	Differential +ve/-ve	
25	8	Schedule A		Temp	TaAverage	1 min.	Meterological system		Ave. ambient temp.		Temp.	C				37CV	(35CV+36 CV)/2			
26	7	Schedule A	CEMChannel 8	Temp	SCTfocusCEMCh8	1 min.	Solar Cooker	SC	Focal Temp.	PT-100 RTD	Temp.	C						AV	4-wire config.	
27	7	Schedule A	CEMChannel 9	Temp	SCTupCEMCh9	1 min.	Solar Cooker	Pressure cooker	Pressure cooker inside temp.(top)	PT-100 RTD	Temp.	C						AV	4-wire config.	
28	7	Schedule A	CEMChannel 10	Temp	SCTlowCEMCh10	1 min.	Solar Cooker	Pressure cooker	Pressure cooker inside temp.(bottom)	PT-100 RTD	Temp.	C						AV	4-wire config.	
29	6	Schedule A	CEMChannel 1	Temp	SWHTabs1CEMCh1	1 min.	SWH system	Absorber	Absorber Temp.	PT-100 RTD	Temp.	C					38CV	AV	4-wire config.	
30	6	Schedule A	CEMChannel 2	Temp	SWHTabs2CEMCh2	1 min.	SWH system	Absorber	Absorber Temp.	PT-100 RTD	Temp.	C					39CV	AV	4-wire config.	
31	6	Schedule A	CEMChannel 3	Temp	SWHTabs3CEMCh3	1 min.	SWH system	Absorber	Absorber Temp.	PT-100 RTD	Temp.	C					40CV	AV	4-wire config.	
32	6	Schedule A	CEMChannel 4	Temp	SWHTabs4CEMCh4	1 min.	SWH system	Absorber	Absorber Temp.	PT-100 RTD	Temp.	C					41CV	AV	4-wire config.	
33	6	Schedule A	CEMChannel 5	Temp	SWHTinCEMCh5	1 min.	SWH system	Tank	Inlet Water Temp.	PT-100 RTD	Temp.	C					43CV	AV	4-wire config.	
34	6	Schedule A	CEMChannel 6	Temp	SWHToutCEMCh6	1 min.	SWH system	Tank	Outlet hot water temp.	PT-100 RTD	Temp.	C					44CV	AV	4-wire config.	
35	6	Schedule A	CEMChannel 7	Temp	SWHTinsulCEMCh7	1 min.	SWH system	Tank	Storage Tank Insulation Temp.	PT-100 RTD	Temp.	C						AV	4-wire config.	

Schedule B (1 Hour logging) Details

S. N.	Sessions	Schedule	Channels	Parameter	Code name	Schedule Time	System	Sub-system	arameter Detail	Equipment	Output parameter	Output unit	Sensitivity / Span	Derived/Virtual Parameter	Derived unit	Channel Variable (CV)	CV Expression	Statistical	Wiring Configuration	Remarks
		Schedule B				1 hour												15sec ave		
1	1	Schedule B	Channel 2	Irradiation	InsolHorCh2	1 hour	Meterological system		Horizontal irradiation	Pyranometer (SolData)	Voltage	mV	$1500W/m^2$=234 mV($1000W/m^2$=156 mV)	W/m^2	W/m^2	48CV		AV	SE wire connection (R/*)	
2	1	Schedule B	Channel 2	Irradiation	Insol30degCh2	1 hour	Meterological system		30 degree Irradiation	Pyranometer (SolData)	Voltage	mV	$1500W/m^2$=231 mV($1000W/m^2$=154 mV)	W/m^2	W/m^2	47CV		AV	SE wire connection(R/+ve)	
3	1	Schedule B	Channel 2	Irradiation	InsolTrackCh2	1 hour	Meterological system		Tracking Irradiation	Pyranometer (SolData)	Voltage	mV	$1500W/m^2$=220.5mV($1000W/m^2$=147mV)	W/m^2	W/m^2	1CV		AV	SE wire connection (R/-ve)	
4	2	Schedule B	Channel 5	Voltage	PVArrayVoltCh5	1 hour	PV system	PV array	PV Array Voltage	Direct measurement	Voltage	V	0-100V DC			4CV		AV	SE wire connection (R/*)	
5	2	Schedule B	Channel 6	Current	PVArrayCurrCh6	1 hour	PV system	PV array	PV Array Current	0-35 A DC current transducer	Voltage	V	0-35A(0-10V)	A	Amp	5CV		AV	SE wire connection (R/*)	
6	2	Schedule B		Power	PVArrayPower	1 hour	PV system	PV array	PV Array Power		Watt	W				7CV,6CV	(4CV*5CV)			
7	2	Schedule B		Efficiency	PVArrayCellEfficiency	1 hour	PV system	PV array	PV Cell Efficiency		Percent	%				9CV,10CV	(6CV/(1CV*6.7392))*100			
8	2	Schedule B		Efficiency	PVArrayModuleEfficiency	1 hour	PV system	PV array	PV Module Efficiency		Percent	%				11CV,12CV	(6CV/(1CV*7.56))*100			
9	2	Schedule B	Channel 3	Temp	PVTemp1TtypeCh3	1 hour	PV system	PV array	Panel back temp.	T-type Thermocouple sensor	Temp.	C				13CV		AV	Differential +ve/-ve	
10	2	Schedule B	Channel 9	Temp	PVTemp2TtypeCh9	1 hour	PV system	PV array	Panel back temp.	T-type Thermocouple sensor	Temp.	C				14CV		AV	Differential +ve/-ve	
11	2	Schedule B		Temp	PVTempAverage	1 hour	PV system	PV array	Panel back temp. ave.		Temp.	C				15CV	(13CV+14CV)/2			
12	3, 4	Schedule B	Channel 10	Voltage	BattVoltCh10	1 hour	PV system	Battery bank	Battery voltage	Direct measurement	Voltage	V	0-100V DC			16CV		AV	SE wire connection (R/*)	
13	3	Schedule B	Channel 6	Current	BattAmpInCh6	1 hour	PV system	Battery bank	Battery current in	0-35 A DC current transducer	Voltage	V	0-35A(0-10V)	A	Amp	17CV		AV	SE wire connection (R/-ve)	
14	3	Schedule B		Power	BattPowerIn	1 hour	PV system	Battery bank	Battery power in		Watt	W				18CV, 19CV	(16CV*17CV)			
15	4	Schedule B	Channel 6	Current	BattAmpOutCh6	1 hour	PV system	Battery bank	Battery current out	0-50 A DC current transducer	Voltage	V	0-50A(0-10V)	A	Amp	21CV		AV	SE wire connection (R/+ve)	
16	4	Schedule B		Power	BattPowerOut	1 hour	PV system	Battery bank	Battery power out		Watt	W				22CV, 23CV	(16CV*21CV)			
17	3, 4	Schedule B	Channel 4	Temp	BattTempCh4	1 hour	PV system	Battery bank	Battery temp.	T-type themocouple sensor	Temp.	C						AV	Differential +ve/-ve	
18	5	Schedule B	Channel 8	Power	InverterPowerCh8	1 hour	PV system	Inverter	Inverter Power	AC power transducer	Voltage	V	0-1200W(0-10V)	W	Watt	25CV		AV	Differential +ve/-ve	
19	10	Schedule B	Channel 4	Voltage	WLEDLuxeonVoltCh4	1 hour	Load		1 bulb WLED	Direct measurement	Voltage	V	0-100V DC			27CV		AV	SE wire connection (R/*)	
20	10	Schedule B	Channel 3	Current	WLEDLuxeonAmpCh3	1 hour	Load		1 bulb WLED	0-5A DC current	Voltage	V	0-5A (0-10V) with 33 windings	mA	mAmp	28CV		AV	SE wire connection	Transducer has

										transducer			thus 0-151.5mA (0-10V)						(R/*)	33 windings
21	10	Schedule B		Power	WLEDLuxeonPower	1 hour	Load		1 bulb WLED			mAV				29CV	(27CV*28CV)			
22	10	Schedule B	Channel 7	Voltage	WLEDNichiaVoltCh7	1 hour	Load		9 bulb WLED	Direct measurement	Voltage	V	0-100 VDC			31CV		AV	SE wire connection (R/*)	
23	10	Schedule B	Channel 7	Current	WLEDNichiaAmpCh7	1 hour	Load		9 bulb WLED	0-5A DC current transducer	Voltage	V	0-5A (0-10V), with 50 windings thus 0-100mA (0-10V)	mA	mAmp	32CV		AV	SE wire connection (R/+ve)	Transducer has 50 windings
24	10	Schedule B		Power	WLEDNichiaPower	1 hour	Load		9 bulb WLED			mAV				33CV	(31CV*32CV)			
25	8	Schedule B	Channel 1	Temp	TaEastTtypeCh1	1 hour	Meterological system		East side ambient temp.	T-type thermocouple sensor	Temp.	C				35CV		AV	Differential +ve/-ve	
26	8	Schedule B	Channel 5	Temp	TaWestTtypeCh5	1 hour	Meterological system		West side ambient temp.	T-type thermocouple sensor	Temp.	C				36CV		AV	Differential +ve/-ve	
27	8	Schedule B		Temp	TaAverage	1 hour	Meterological system		Ave. ambient temp.		Temp.	C				37CV	(35CV+36CV)/2			
28	6	Schedule B	CEMChannel 1	Temp	SWHTabs1CEMCh1	1 hour	SWH system	Absorber	Absorber Temp.	PT-100 RTD	Temp.	C					38CV	AV	4-wire config.	
29	6	Schedule B	CEMChannel 2	Temp	SWHTabs2CEMCh2	1 hour	SWH system	Absorber	Absorber Temp.	PT-100 RTD	Temp.	C					39CV	AV	4-wire config.	
30	6	Schedule B	CEMChannel 3	Temp	SWHTabs3CEMCh3	1 hour	SWH system	Absorber	Absorber Temp.	PT-100 RTD	Temp.	C					40CV	AV	4-wire config.	
31	6	Schedule B	CEMChannel 4	Temp	SWHTabs4CEMCh4	1 hour	SWH system	Absorber	Absorber Temp.	PT-100 RTD	Temp.	C					41CV	AV	4-wire config.	
32	6	Schedule B	CEMChannel 5	Temp	SWHTinCEMCh5	1 hour	SWH system	Tank	Inlet Water Temp.	PT-100 RTD	Temp.	C					43CV	AV	4-wire config.	
33	6	Schedule B	CEMChannel 6	Temp	SWHToutCEMCh6	1 hour	SWH system	Tank	Outlet hot water temp.	PT-100 RTD	Temp.	C					44CV	AV	4-wire config.	
34	6	Schedule B	CEMChannel 7	Temp	SWHTinsulCEMCh7	1 hour	SWH system	Tank	Storage Tank Insulation Temp.	PT-100 RTD	Temp.	C						AV	4-wire config.	

Schedule C (1 Day logging) Details

S. N.	Sessions	Schedule	Channels	Parameter	Code name	Schedule Time	System	Sub-system	Parameter Detail	Equipment	Output parameter	Output unit	Sensitivity / Span	Derived / Virtual Parameter	Derived unit	Channel Variable (CV)	CV Expression	Statistical	Wiring Configuration	Remarks
		Schedule C				1day												15sec ave		
1	1	Schedule C	Channel 2	Irradiation	InsolHorCh2	1day	Meterological system		Horizontal irradiation	Pyranometer (SolData)	Voltage	mV	1500W/m^2=234 mV(1000W/m^2= 156 mV)	W/m^2	W/m^2	48CV		AV	SE wire connection (R/*)	
2	1	Schedule C	Channel 2	Irradiation	Insol30degCh2	1day	Meterological system		30 degree Irradiation	Pyranometer (SolData)	Voltage	mV	1500W/m^2=231 mV(1000W/m^2= 154 mV)	W/m^2	W/m^2	47CV		AV	SE wire connection(R/ +ve)	
3	1	Schedule C	Channel 2	Irradiation	InsolTrackCh2	1day	Meterological system		Tracking Irradiation	Pyranometer (SolData)	Voltage	mV	1500W/m^2=220. 5mV(1000W/m^2 =147mV)	W/m^2	W/m^2	1CV		AV	SE wire connection (R/-ve)	
4	1	Schedule C		Irradiation	InsolHorDaily	1day	Meterological system		Daily Horizontal irradiation							50CV	48CV/86400	INT		
5	1	Schedule C		Irradiation	Insol30degDaily	1day	Meterological system		Daily 30 degree irradiation							51CV	47CV/86400	INT		
6	1	Schedule C		Irradiation	InsolTrackDaily	1day	Meterological system		Daily Tracking irradiation							52CV	1CV/86400	INT		
7	2	Schedule C	Channel 5	Voltage	PVArrayVoltCh5	1day	PV system	PV array	PV Array Voltage	Direct measurement	Voltage	V	0-100V DC			4CV		AV	SE wire connection (R/*)	
8	2	Schedule C	Channel 6	Current	PVArrayCurrCh6	1day	PV system	PV array	PV Array Current	0-35 A DC current transducer	Voltage	V	0-35A(0-10V)	A	Amp	5CV		AV	SE wire connection (R/*)	
9	2			Power	PVArrayPower	1day	PV system	PV array	PV Array Power		Watt	W				7CV, 6CV	(4CV*5CV)			
10	2	Schedule C	Channel 3	Temp	PVTemp1TtypeCh3	1day	PV system	PV array	Panel back temp.	T-type Thermocouple sensor	Temp.	C				13CV		AV	Differential +ve/-ve	No Log
11	2	Schedule C	Channel 9	Temp	PVTemp2TtypeCh9	1day	PV system	PV array	Panel back temp.	T-type Thermocouple sensor	Temp.	C				14CV		AV	Differential +ve/-ve	No Log
12	2	Schedule C		Temp	PVTempAverage	1day	PV system	PV array	Panel back temp. ave.		Temp.	C				15CV	(13CV+14CV)/2			
13	3, 4	Schedule C	Channel 10	Voltage	BattVoltCh10	1day	PV system	Battery bank	Battery voltage	Direct measurement	Voltage	V	0-100V DC			16CV		AV	SE wire connection (R/*)	
14	3	Schedule C	Channel 6	Current	BattAmpInCh6	1day	PV system	Battery bank	Battery current in	0-35 A DC current transducer	Voltage	V	0-35A(0-10V)	A	Amp	17CV		AV	SE wire connection (R/-ve)	
15	3	Schedule C		Power	BattPowerIn	1day	PV system	Battery bank	Battery power in		Watt	W				18CV, 19CV	(16CV*17CV)			
16	4	Schedule C	Channel 6	Current	BattAmpOutCh6	1day	PV system	Battery bank	Battery current out	0-50 A DC current transducer	Voltage	V	0-50A(0-10V)	A	Amp	21CV		AV	SE wire connection (R/+ve)	
17	4	Schedule C		Power	BattPowerOut	1day	PV system	Battery bank	Battery power out		Watt	W				22CV, 23CV	(16CV*21CV)			
18	3, 4	Schedule C	Channel 4	Temp	BattTempCh4	1day	PV system	Battery bank	Battery temp.	T-type themocouple sensor	Temp.	C						AV	Differential +ve/-ve	
19	5	Schedule C	Channel 8	Power	InverterPowerCh8	1day	PV system	Inverter	Inverter Power	AC power transducer	Voltage	V	0-1200W(0-10V)	W	Watt	25CV		AV	Differential +ve/-ve	
20	10	Schedule C	Channel 4	Voltage	WLEDLuxeonVoltCh4	1day	Load		1 bulb WLED	Direct measurement	Voltage	V	0-100V DC			27CV		AV	SE wire connection (R/*)	

21	10	Schedule C	Channel 3	Current	WLEDLuxeonAmp Ch3	1day	Load		1 bulb WLED	0-5A DC current transducer	Voltage	V	0-5A (0-10V) with 33 windings thus 0-151.5mA (0-10V)	mA	mAmp	28CV		AV	SE wire connection (R/*)	Transducer has 33 windings
22	10	Schedule C		Power	WLEDLuxeonPower	1day	Load		1 bulb WLED			mAV				29CV	(27CV*28CV)			
23	10	Schedule C	Channel 7	Voltage	WLEDNichiaVoltCh7	1day	Load		9 bulb WLED	Direct measurement	Voltage	V	0-100V DC			31CV		AV	SE wire connection (R/*)	
24	10	Schedule C	Channel 7	Current	WLEDNichiaAmpCh7	1day	Load		9 bulb WLED	0-5A DC current transducer	Voltage	V	0-5A (0-10V), with 50 windings thus 0-100mA (0-10V)	mA	mAmp	32CV		AV	SE wire connection (R/+ve)	Transducer has 50 windings
25	10	Schedule C		Power	WLEDNichiaPower	1day	Load		9 bulb WLED			mAV				33CV	(31CV*32CV)			
26	8	Schedule C	Channel 1	Temp	TaEastTtypeCh1	1day	Meterological system		East side ambient temp.	T-type thermocouple sensor	Temp.	C				35CV		AV	Differential +ve/-ve	No Log
27	8	Schedule C	Channel 5	Temp	TaWestTtypeCh5	1day	Meterological system		West side ambient temp.	T-type thermocouple sensor	Temp.	C				36CV		AV	Differential +ve/-ve	No Log
28	8	Schedule C		Temp	TaAverage	1day	Meterological system		Ave. ambient temp.		Temp.	C				37CV	(35CV+36CV)/2			

Schedule D (30 Days logging) Details

S. N.	Sessions	Schedule	Channels	Parameter	Code name	Schedule Time	System	Sub-system	Parameter Detail	Equipment	Output parameter	Output unit	Sensitivity / Span	Derived / Virtual Parameter	Derived unit	Channel Variable (CV)	CV Expression	Statistical	Wiring Configuration	Remarks
		Schedule D				30 days												15sec ave		
1	1	Schedule D	Channel 2	Irradiation	InsolHorCh2	30 days	Meterological system		Horizontal irradiation	Pyranometer (SolData)	Voltage	mV	1500W/m^2=234 mA(1000W/m^2= 156 mV)	W/m^2	W/m^2	48CV		AV	SE wire connection (R/*)	
2	1	Schedule D	Channel 2	Irradiation	Insol30degCh2	30 days	Meterological system		30 degree Irradiation	Pyranometer (SolData)	Voltage	mV	1500W/m^2=231 mA(1000W/m^2= 154 mV)	W/m^2	W/m^2	47CV		AV	SE wire connection(R/+ve)	
3	1	Schedule D	Channel 2	Irradiation	InsolTrackCh2	30 days	Meterological system		Tracking Irradiation	Pyranometer (SolData)	Voltage	mV	1500W/m^2=220.5mA(1000W/m^2 =147mV)	W/m^2	W/m^2	1CV		AV	SE wire connection (R/-ve)	
4	1	Schedule D		Irradiation	InsolHorMonthly	30 days	Meterological system		Daily Horizontal irradiation							50CV	48CV/2592000	INT		
5	1	Schedule D		Irradiation	Insol30degMonthly	30 days	Meterological system		Daily 30 degree irradiation							51CV	47CV/2592000	INT		
6	1	Schedule D		Irradiation	InsolTrackMonthly	30 days	Meterological system		Daily Tracking irradiation							52CV	1CV/2592000	INT		
7	2	Schedule D	Channel 5	Voltage	PVArrayVoltCh5	30 days	PV system	PV array	PV Array Voltage	Direct measurement	Voltage	V	0-100V DC			4CV		AV	SE wire connection (R/*)	
8	2	Schedule D	Channel 6	Current	PVArrayCurrCh6	30 days	PV system	PV array	PV Array Current	0-35 A DC current transducer	Voltage	V	0-35A(0-10V)	A	Amp	5CV		AV	SE wire connection (R/*)	
9	2	Schedule D		Power	PVArrayPower	30 days	PV system	PV array	PV Array Power		Watt	W				7CV,6CV	(4CV*5CV)			

18.3.13. Definition and Identification of the 10 Sessions

In order to have an easier to understand, and a clearer concept of the vast amount of data recorded, the recorded data are organised into 10 different sessions. Each session presents an area of interest and includes the relevant recorded data. Each session can be handled, and the data investigated and looked at, individually. For example session 1 includes all solar irradiation data recorded, for all 4 time schedules A - D. Or session 9, which includes all the PV system Power related data such as the PV system array power generation, the battery bank power in- and out-put, as well as the inverter power output to meet the HARS AC equipment demand. Again, this session includes all 4 times schedules, in order to compare the various power generation and demand on a minute by minute, hourly, daily or monthly basis.

The following 10 sessions with the following data parameters and time schedule (A = minute, B = hourly, C = daily, D = 30 days) are created:

1. Session 1: *Meteorological data:* This session includes: solar irradiation with the A, B, C, D time schedules.
2. Session 2: *PV Array data:* This session includes: The solar PV array voltage, current power, solar PV module temperature and solar PV cells and modules efficiency with the time schedule A, B, C, D.
3. Session 3: *Battery Bank In data:* This session includes: The battery bank incoming voltage, current, power, battery temperature, with the time schedule A, B, C.
4. Session 4: *Battery Bank Out data:* This session includes: The battery bank outgoing voltage, current, power, battery temperature, with the time schedule A, B, C.

5. Session 5: *Inverter data:* This session includes: The inverter power data with the time schedule A, B, C.
6. Session 6: *Solar Water Heater (SWH):* This session includes: The solar water heater's 4 absorber temperatures (at 4 different heights on the copper fins), cold water incoming temperature, hot water outlet temperature, half thickness insulation temperature, with the time schedule A, B.
7. Session 7: *Solar Cooker data:* This session includes: The SK14 solar cooker's focal point temperature, the bottom end and top end pressure cooker temperature, with the time schedule A.
8. Session 8: *Ambient Temperature data:* This session includes: The eastern side ambient and western side ambient temperature plus the averaged value, with the time schedule A, B, C.
9. Session 9: *PV System Power data:* This session includes: The PV array power output, the battery bank power input and output, the inverter power output, with the time schedule A, B, C, and the solar PV array power output as well in the D time schedule.
10. Session 10: *WLED light data:* This session includes: The Lumiled Luxeon WLED and Nichia WLED lights' voltage, current and power, with the time schedule A, B, C.

Schemata for Monitoring with Datataker 605 (Session wise)

S.N.	Sessions	Session Name	Schedule	Schedule Time	Channels (DT605 & CEM)	Parameter	Channel Code name	Parameter Detail	Remarks
	Session 1	Meterological data							
1			Schedule A	1 min.	Channel 2	Irradiation	InsolHorCh2	Horizontal Irradiation	
2			Schedule A	1min.	Channel 2	Irradiation	Insol30DegCh2	30 Degree Irradiation	
3			Schedule A	1 min.	Channel 2	Irradiation	InsolTrackCh2	Tracking Irradiation	
4			Schedule B	1hr	Channel 2	Irradiation	InsolHorCh2	Horizontal Irradiation	
5			Schedule B	1hr	Channel 2	Irradiation	Insol30DegCh2	30 Degree Irradiation	
6			Schedule B	1hr	Channel 2	Irradiation	InsolTrackCh2	Tracking Irradiation	
7			Schedule C	1 day	Channel 2	Irradiation	InsolHorCh2	Horizontal Irradiation	
8			Schedule C	1 day	Channel 2	Irradiation	Insol30DegCh2	30 Degree Irradiation	
9			Schedule C	1 day	Channel 2	Irradiation	InsolTrackCh2	Tracking Irradiation	
10			Schedule C	1 day		Irradiation	InsolHorDaily	Horizontal Irradiation	
11			Schedule C	1 day		Irradiation	Insol30degDaily	30 Degree Irradiation	
12			Schedule C	1 day		Irradiation	InsolTrackDaily	Tracking Irradiation	
13			Schedule D	30 days	Channel 2	Irradiation	InsolHorCh2	Horizontal Irradiation	
14			Schedule D	30 days	Channel 2	Irradiation	Insol30DegCh2	30 Degree Irradiation	
15			Schedule D	30 days	Channel 2	Irradiation	InsolTrackCh2	Tracking Irradiation	
16			Schedule D	30 days		Irradiation	InsolHorMonthly	Horizontal Irradiation	
17			Schedule D	30 days		Irradiation	Insol30degMonthly	30 Degree Irradiation	
18			Schedule D	30 days		Irradiation	InsolTrackMonthly	Tracking Irradiation	
	Session 2	PV array data							
19			Schedule A	1min.	Channel 5	Voltage	PVArrayVoltCh5	PV Array Voltage	
20			Schedule A	1min.	Channel 6	Current	PVArrayCurrCh6	PV Array Current	
21			Schedule A	1min.		Power	PVArrayPower	PV Array Power	
22			Schedule A	1min.	Channel 3	Temp.	PVTemp1TtypeCh3	Panel back temp.	
23			Schedule A	1min.	Channel 9	Temp.	PVTemp2TtypeCh9	Panel back temp.	
24			Schedule A	1min.		Temp.	PVTempAverage	Panel back temp. ave.	
25			Schedule B	1 hr	Channel 5	Voltage	PVArrayVoltCh5	PV Array Voltage	
26			Schedule B	1 hr	Channel 6	Current	PVArrayCurrCh6	PV Array Current	
27			Schedule B	1 hr		Power	PVArrayPower	PV Array Power	
28			Schedule B	1 hr		Efficiency	PVArrayCellEfficiency	PV Cell Efficiency	
29			Schedule B	1 hr		Efficiency	PVArrayModuleEfficiency	PV Module Efficiency	
30			Schedule B	1 hr	Channel 3	Temp.	PVTemp1TtypeCh3	Panel back temp.	
31			Schedule B	1 hr	Channel 9	Temp.	PVTemp2TtypeCh9	Panel back temp.	
32			Schedule B	1 hr		Temp.	PVTempAverage	Panel back temp. ave.	
33			Schedule C	1 day	Channel 5	Voltage	PVArrayVoltCh5	PV Array Voltage	
34			Schedule	1 day	Channel 6	Current	PVArrayCurrCh6	PV Array	

			C					Current	
35			Schedule C	1 day		Power	PVArrayPower	PV Array Power	
36			Schedule C	1 day	Channel 3	Temp.	PVTemp1TtypeCh3	Panel back temp.	Not logged
37			Schedule C	1 day	Channel 9	Temp.	PVTemp2TtypeCh9	Panel back temp.	Not logged
38			Schedule C	1 day		Temp.	PVTempAverage	Panel back temp. ave.	
39			Schedule D	30 days	Channel 5	Voltage	PVArrayVoltCh5	PV Array Voltage	
40			Schedule D	30 days	Channel 6	Current	PVArrayCurrCh6	PV Array Current	
41			Schedule D	30 days		Power	PVArrayPower	PV Array Power	
	Session 3	BattIn data							
42			Schedule A	1min.	Channel 10	Voltage	BattVoltCh10	Battery voltage	
43			Schedule A	1min.	Channel 6	Current	BattAmpInCh6	Battery current in	
44			Schedule A	1min.		Power	BattPowerIn	Battery power in	
45			Schedule A	1min.	Channel 4	Temp.	BattTempCh4	Battery temp.	
46			Schedule B	1 hr	Channel 10	Voltage	BattVoltCh10	Battery voltage	
47			Schedule B	1 hr	Channel 6	Current	BattAmpInCh6	Battery current in	
48			Schedule B	1 hr		Power	BattPowerIn	Battery power in	
49			Schedule B	1 hr	Channel 4	Temp.	BattTempCh4	Battery temp.	
50			Schedule C	1 day	Channel 10	Voltage	BattVoltCh10	Battery voltage	
51			Schedule C	1 day	Channel 6	Current	BattAmpInCh6	Battery current in	
52			Schedule C	1 day		Power	BattPowerIn	Battery power in	
53			Schedule C	1 day	Channel 4	Temp.	BattTempCh4	Battery temp.	
	Session 4	BattOut data							
54			Schedule A	1min.	Channel 10	Voltage	BattVoltCh10	Battery voltage	
55			Schedule A	1min.	Channel 6	Current	BattAmpOutCh6	Battery current out	
56			Schedule A	1min.		Power	BattPowerOut	Battery power out	
57			Schedule A	1min.	Channel 4	Temp.	BattTempCh4	Battery temp.	
58			Schedule B	1 hr	Channel 10	Voltage	BattVoltCh10	Battery voltage	
59			Schedule B	1 hr	Channel 6	Current	BattAmpOutCh6	Battery current out	
60			Schedule B	1 hr		Power	BattPowerOut	Battery power out	
61			Schedule B	1 hr	Channel 4	Temp.	BattTempCh4	Battery temp.	
62			Schedule C	1 day	Channel 10	Voltage	BattVoltCh10	Battery voltage	
63			Schedule C	1 day	Channel 6	Current	BattAmpOutCh6	Battery current out	
64			Schedule C	1 day		Power	BattPowerOut	Battery power out	
65			Schedule C	1 day	Channel 4	Temp.	BattTempCh4	Battery temp.	
	Session 5	Inverter data							
66			Schedule A	1 min.	Channel 8	Power	InverterPowerCh8	Inverter Power	
67			Schedule B	1 hr	Channel 8	Power	InverterPowerCh8	Inverter Power	
68			Schedule C	1 day	Channel 8	Power	InverterPowerCh8	Inverter Power	

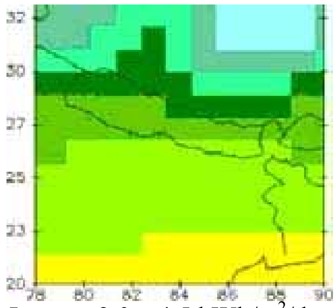
	Session 6	SWH data							
69			Schedule A		CEM Channel 1	Temp.	SWHTabs1CEMCh1	Absorber Temp.	
70			Schedule A	1 min.	CEM Channel 2	Temp.	SWHTabs2CEMCh2	Absorber Temp.	
71			Schedule A	1 min.	CEM Channel 3	Temp.	SWHTabs3CEMCh3	Absorber Temp.	
72			Schedule A	1 min.	CEM Channel 4	Temp.	SWHTabs4CEMCh4	Absorber Temp.	
73			Schedule A	1 min.	CEM Channel 5	Temp.	SWHTinCEMCh5	Inlet Temp.	
74			Schedule A	1 min.	CEM Channel 6	Temp.	SWHToutCEMCh6	Outlet Temp.	
75			Schedule A	1 min.	CEM Channel 7	Temp.	SWHTinsulCEMCh7	Storage Tank Insulation Temp.	
76			Schedule B	1 hr	CEM Channel 1	Temp.	SWHTabs1CEMCh1	Absorber Temp.	
77			Schedule B	1 hr	CEM Channel 2	Temp.	SWHTabs2CEMCh2	Absorber Temp.	
78			Schedule B	1 hr	CEM Channel 3	Temp.	SWHTabs3CEMCh3	Absorber Temp.	
79			Schedule B	1 hr	CEM Channel 4	Temp.	SWHTabs4CEMCh4	Absorber Temp.	
80			Schedule B	1 hr	CEM Channel 5	Temp.	SWHTinCEMCh5	Inlet Temp.	
81			Schedule B	1 hr	CEM Channel 6	Temp.	SWHToutCEMCh6	Outlet Temp.	
82			Schedule B	1 hr	CEM Channel 7	Temp.	SWHTinsulCEMCh7	Storage Tank Insulation Temp.	
	Session 7	Solar cooker data							
83			Schedule A	1 min.	CEM Channel 8	Temp.	SCTfocusCEMCh8	Focal Temp.	
84			Schedule A	1 min.	CEM Channel 9	Temp.	SCTupCEMCh9	Pressure cooker inside temp.(bottom)	
85			Schedule A	1 min.	CEM Channel 10	Temp.	SCTlowCEMCh10	Pressure cooker inside temp.(top)	
	Session 8	Ambient Temp data							
86			Schedule A	1 min.	Channel 1	Temp.	TaEastTtypeCh1	East side ambient temp.	
87			Schedule A	1 min.	Channell 5	Temp.	TaWestTtypeCh5	West side ambient temp.	
88			Schedule A	1 min.		Temp.	TaAverage	Ave. ambient temp.	
89			Schedule B	1 hr	Channel 1	Temp.	TaEastTtypeCh1	East side ambient temp.	
90			Schedule B	1 hr	Channell 5	Temp.	TaWestTtypeCh5	West side ambient temp.	
91			Schedule B	1 hr		Temp.	TaAverage	Ave. ambient temp.	
92			Schedule C	1 day	Channel 1	Temp.	TaEastTtypeCh1	East side ambient temp.	Not logged
93			Schedule C	1 day	Channell 5	Temp.	TaWestTtypeCh5	West side ambient temp.	Not logged
94			Schedule C	1 day		Temp.	TaAverage	Ave. ambient temp.	
	Session 9	PV System Power data							
95			Schedule A	1 min.			PVArrayPower	PV Array Power	
96			Schedule A	1 min.			BattPowerIn	Battery power in	
97			Schedule A	1 min.			BattPowerOut	Battery power out	
98			Schedule A	1 min.	Channel 8		InverterPowerCh8	Inverter Power	
99			Schedule B	1 hr			PVArrayPower	PV Array Power	

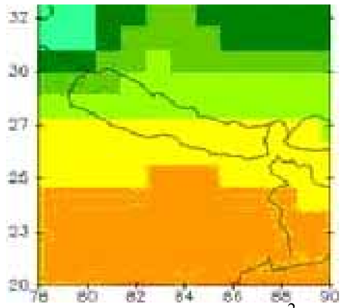
100			Schedule B	1 hr			BattPowerIn	Battery power in	
101			Schedule B	1 hr			BattPowerOut	Battery power out	
102			Schedule B	1 hr	Channel 8		InverterPowerCh8	Inverter Power	
103			Schedule C	1 day			PVArrayPower	PV Array Power	
104			Schedule C	1 day			BattPowerIn	Battery power in	
105			Schedule C	1 day			BattPowerOut	Battery power out	
106			Schedule C	1 day	Channel 8		InverterPowerCh8	Inverter Power	
107			Schedule D	30 days			PVArrayPower	PV Array Power	
	Session 10	WLED data							
108			Schedule A	1 min.	Channel 4	Voltage	WLEDLuxeonVoltCh4	Voltage	
109			Schedule A	1 min.	Channel 3	Current	WLEDLuxeonAmpCh3	Current	
110			Schedule A	1 min.		Power	WLEDLuxeonPower	Power	
111			Schedule A	1 min.	Channel 7	Voltage	WLEDNichiaVoltCh7	Voltage	
112			Schedule A	1 min.	Channel 7	Current	WLEDNichiaAmpCh7	Current	
113			Schedule A	1 min.		Power	WLEDNichiaPower	Power	
114			Schedule B	1 hr	Channel 4	Voltage	WLEDLuxeonVoltCh4	Voltage	
115			Schedule B	1 hr	Channel 3	Current	WLEDLuxeonAmpCh3	Current	
116			Schedule B	1 hr		Power	WLEDLuxeonPower	Power	
117			Schedule B	1 hr	Channel 7	Voltage	WLEDNichiaVoltCh7	Voltage	
118			Schedule B	1 hr	Channel 7	Current	WLEDNichiaAmpCh7	Current	
119			Schedule B	1 hr		Power	WLEDNichiaPower	Power	
120			Schedule C	1 day	Channel 4	Voltage	WLEDLuxeonVoltCh4	Voltage	
121			Schedule C	1 day	Channel 3	Current	WLEDLuxeonAmpCh3	Current	
122			Schedule C	1 day		Power	WLEDLuxeonPower	Power	
123			Schedule C	1 day	Channel 7	Voltage	WLEDNichiaVoltCh7	Voltage	
124			Schedule C	1 day	Channel 7	Current	WLEDNichiaAmpCh7	Current	
125			Schedule C	1 day		Power	WLEDNichiaPower	Power	

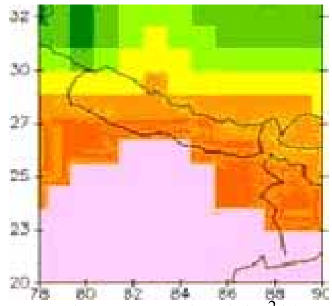
Table 7-13: Monitoring Schemata for the Datataker DT605 according to the Sessions

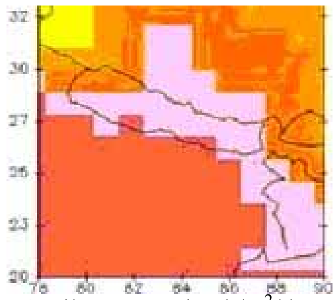
18.4. Appendix to Chapter 8 Solar Irradiation from the NASA Web Site

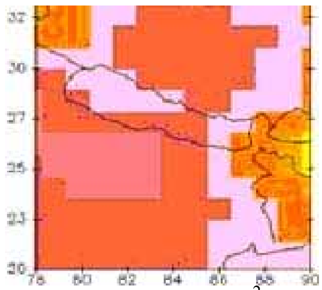
18.4.1. Monthly Average Horizontal Solar Irradiation from 1983 – 1993 for Nepal

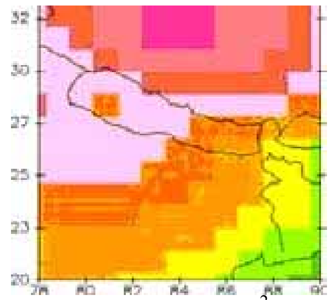

January 3.0 – 4.5 kWh/m^2/day

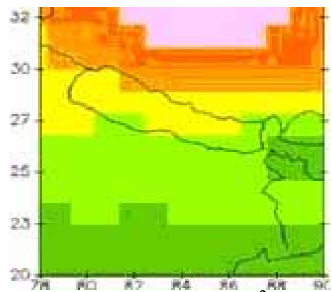

February 3.5 – 5.0 kWh/m^2/day

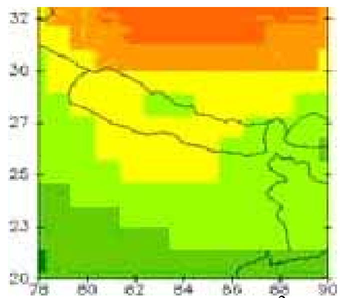

March 4.5 - 6.0 kWh/m^2/day

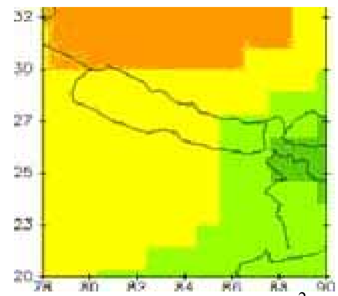

April 5.0 – 7.0 kWh/m^2/day

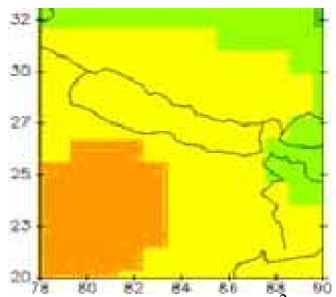

May 6.0 – 7.0 kWh/m^2/day

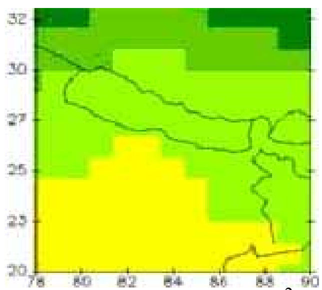

June 5.5 – 6.5 kWh/m^2/day


July 4.0 – 5.5 kWh/m^2/day


August 4.0 – 5.0 kWh/m^2/day


September 4.0 – 5.0 kWh/m^2/day


October 4.5 – 5.0 kWh/m^2/day


November 4.0 – 4.5 kWh/m^2/day

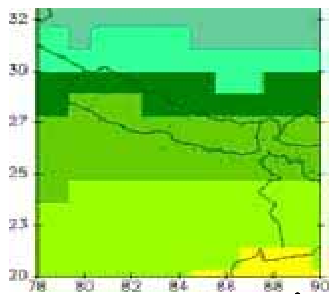

December 3.0 – 4.0. kWh/m^2/day

Figure 8-3: Monthly Average Horizontal Solar Irradiation from 1983 – 1993 for Nepal

The Simikot HARS Solar PV System (Lat. 29.967ºN/Long. 81.817ºE), & Chauganphaya Village Solar PV System (Lat. 30.000ºN/Long. 81.774ºE) in Humla, the following monthly horizontal solar irradiation (kWh/m^2/day) are applicable:

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Aver.
Simikot	3	3.5	4.5	5	6	6	5	5	5	5	4	3	4.6
Chauganphaya	3	3.5	4.5	5	6	6	5	5	5	5	4	3	4.6

Table 8-2: Simikot and Chauganphaya NASA Graphical Monthly Horizontal Solar Irradiation.

These solar irradiation maps are from the NASA web site: http://eosweb.larc.nasa.gov/

18.4.2. Average Surface Albedo from 1983 –1993 for Nepal

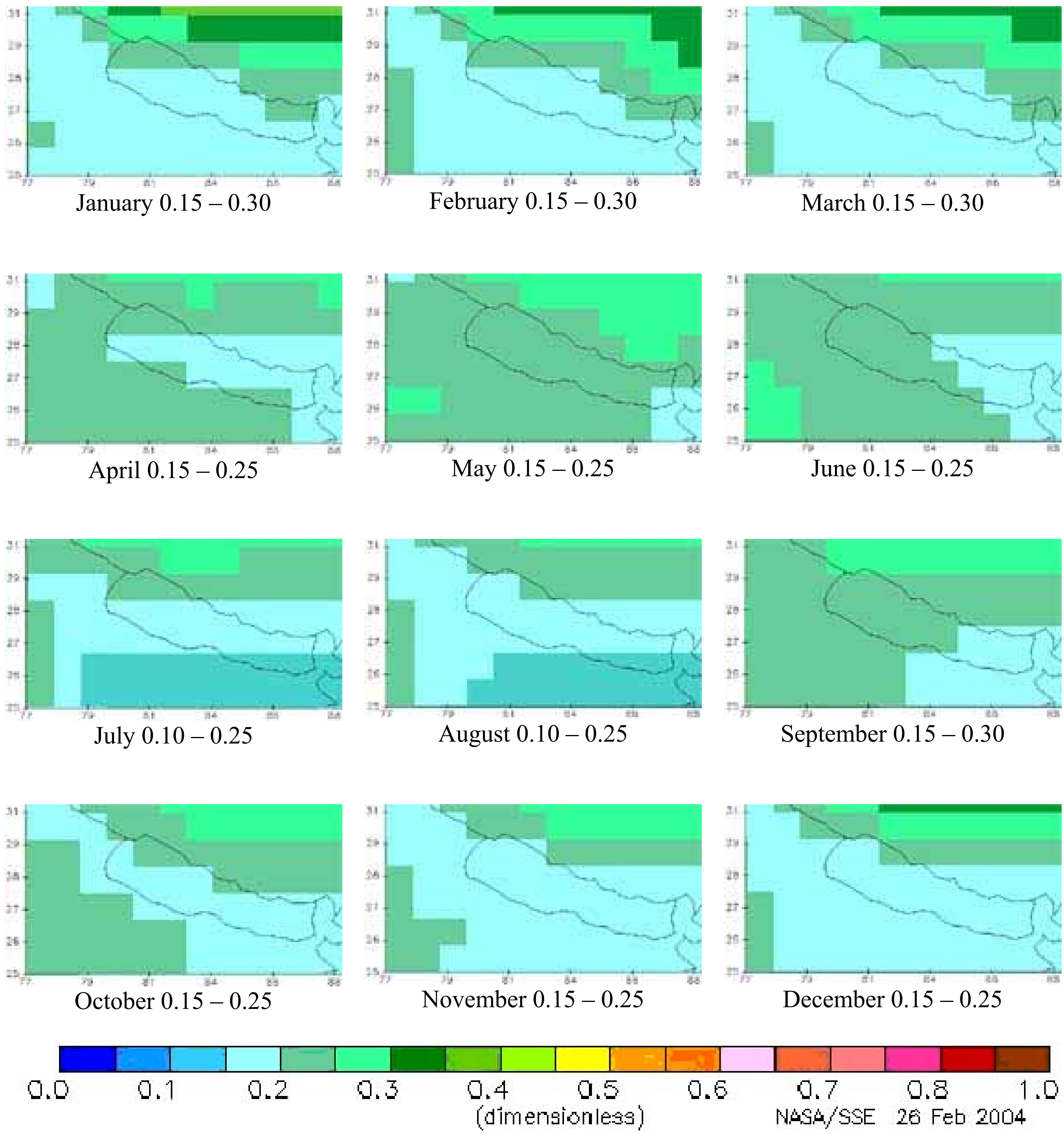


Figure 8-4: Average Surface Albedo from 1983 –1993 for Nepal

For the Simikot HARS Solar PV System (Lat. 29.967º N / Long. 81.817º E, at 3,000 m.a.s.l.), and the Chauganphaya Village Solar PV System (Lat. 30.000º N / Long. 81.774º E, at 2,643 m.a.s.l.) in Humla, Nepal, the following monthly Surface Albedo values are applicable:

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Aver.
Simikot	0.3	0.3	0.3	0.25	0.25	0.25	0.25	0.25	0.3	0.25	0.25	0.25	0.27
Chauganphaya	0.3	0.3	0.3	0.25	0.25	0.25	0.25	0.25	0.3	0.25	0.25	0.25	0.27

Table 8-3: Simikot and Chauganphaya NASA Graphical Monthly Surface Albedo.

These surface albedo data are from the NASA web site: http://eosweb.larc.nasa.gov/

18.4.3. Maximum Monthly NO - SUN Days from 1983 –1993 for Nepal

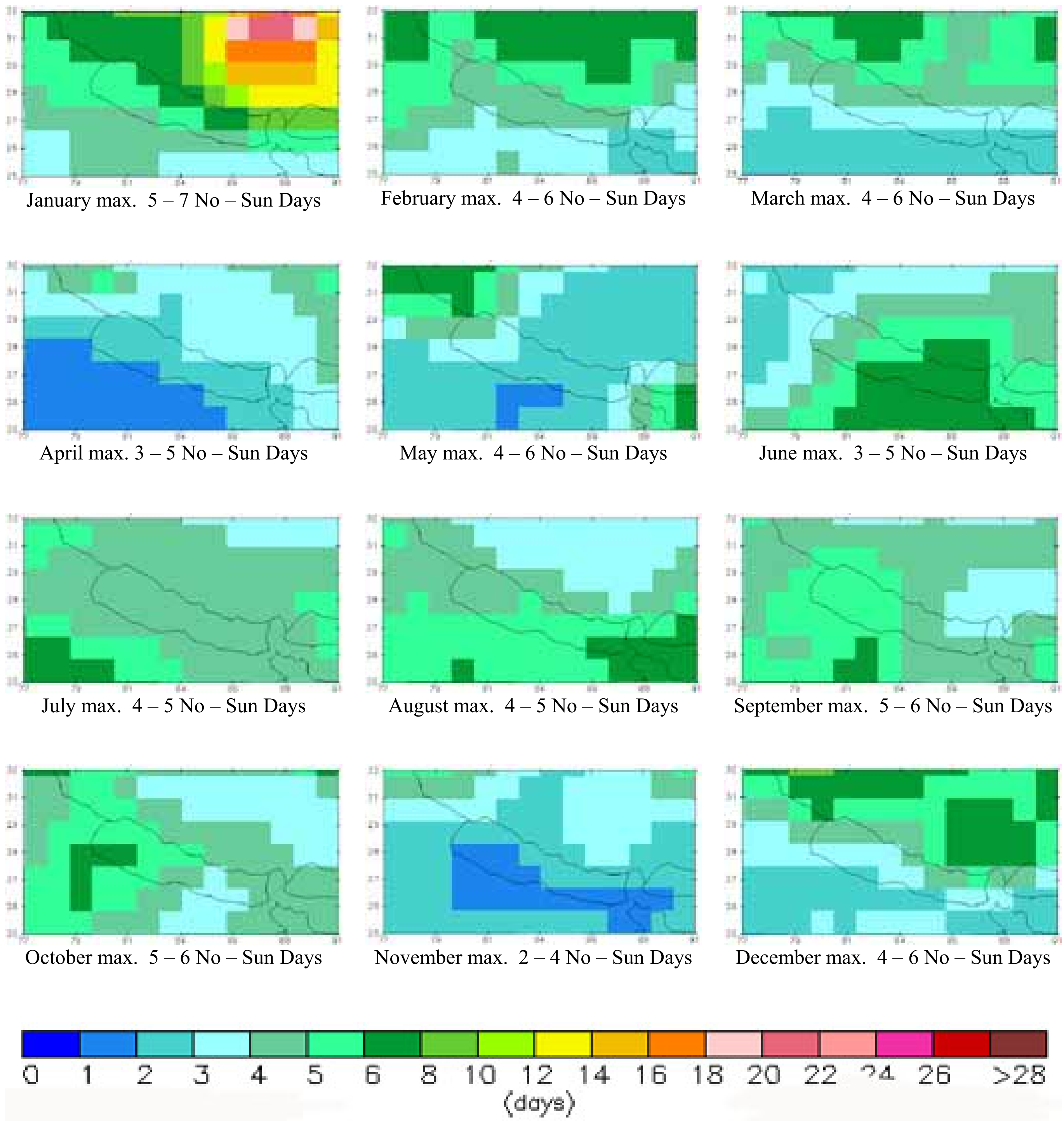


Figure 8-5: Maximum Monthly NO - SUN Days from 1983 –1993 for Nepal

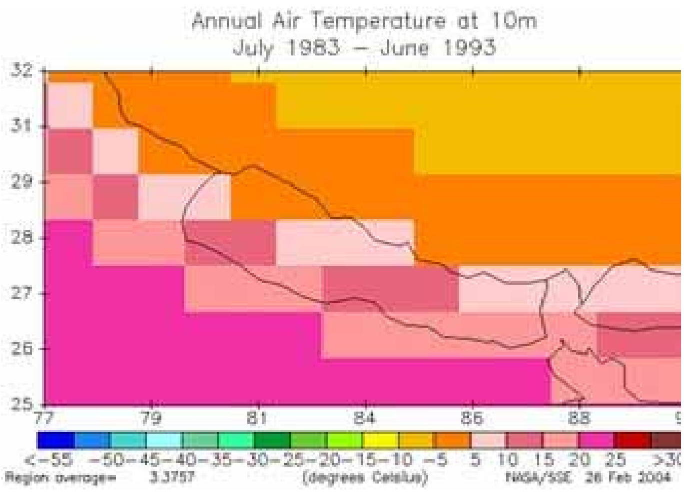
For the Simikot HARS Solar PV System (Lat. 29.967º N / Long. 81.817º E, at 3,000 m.a.s.l.), and the Chauganphaya Village Solar PV System (Lat. 30.000º N / Long. 81.774º E, at 2,643 m.a.s.l.) in Humla, Nepal, the following averaged Maximum Monthly NO – Sun Days values are applicable:

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Aver.
Simikot	6	5	5	4	5	4	4.5	4.5	5.5	5.5	3	5	4.75
Chauganphaya	6	5	5	4	5	4	4.5	4.5	5.5	5.5	3	5	4.75

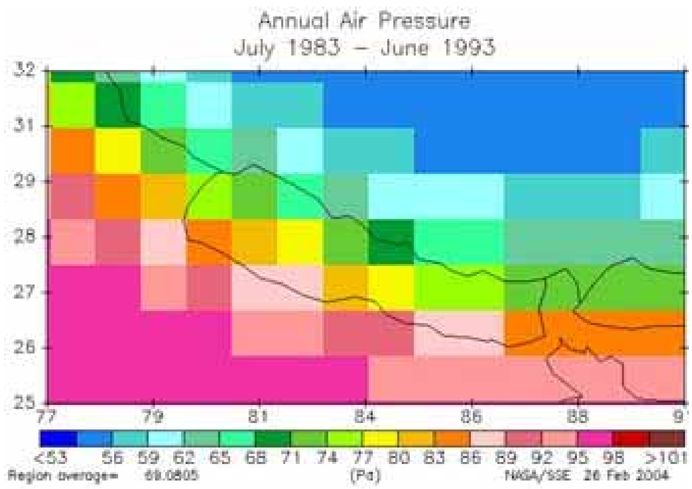
Table 8-4: Simikot and Chauganphaya NASA Graphical Maximum Monthly NO - SUN Days.

These maximum monthly NO – SUN Days data are from the NASA web site: http://eosweb.larc.nasa.gov/

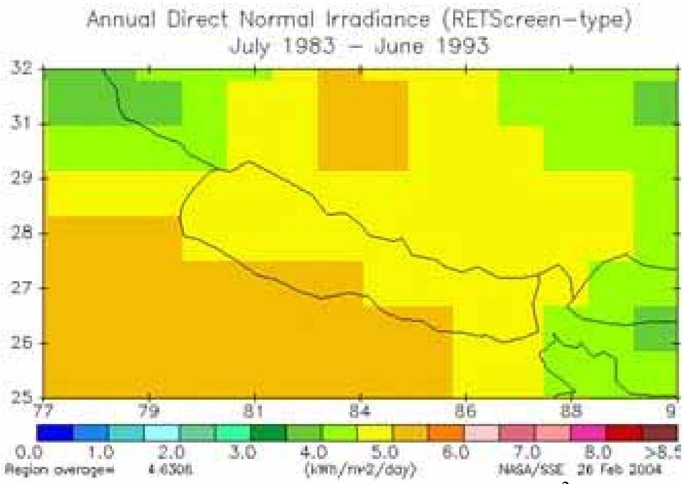
18.4.4. Various Average Annual NASA Data from 1983 –1993 for Nepal



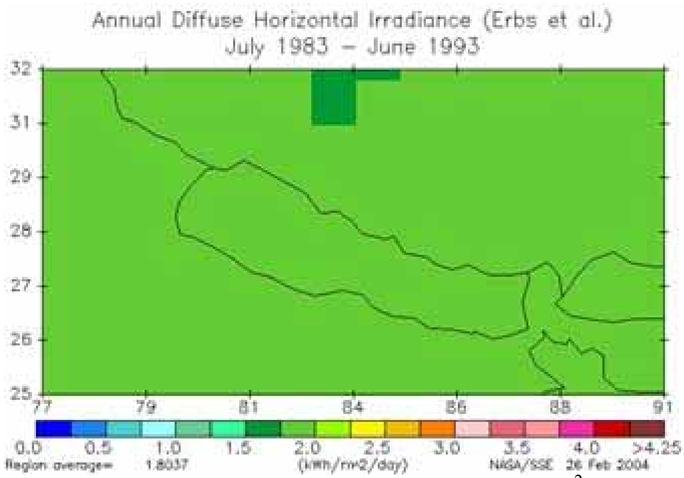
Annual Air Temp. Simikot & Chauganphaya –5º to + 5º C



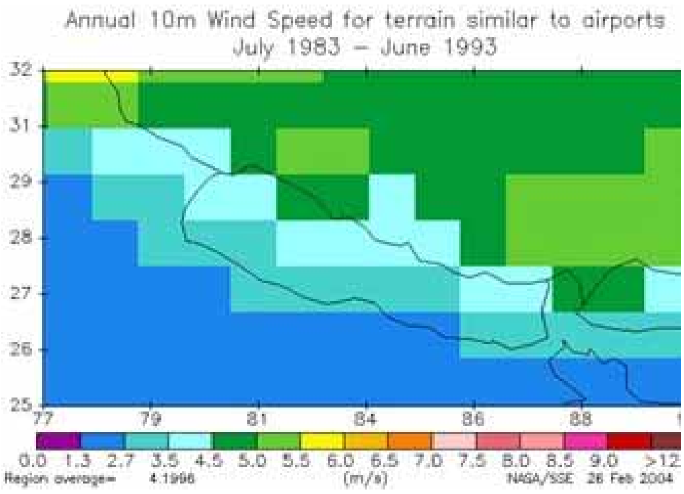
Annual Air Pressure Simikot & Chauganphaya 71 – 74 kPa



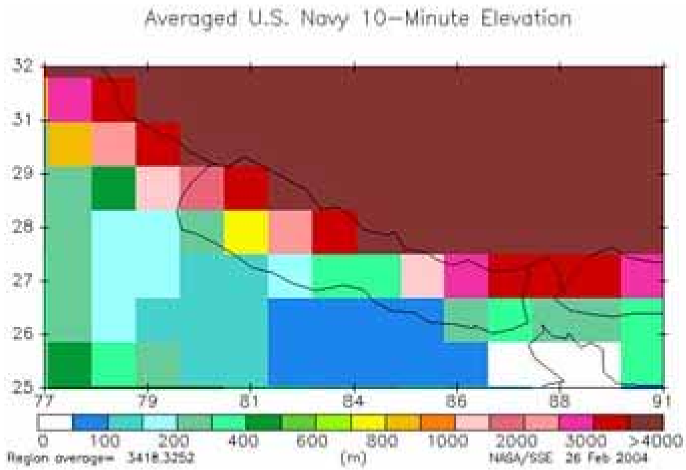
For Simikot & Chauganphaya 4.5 – 5.0 kWh/m^2/day



For Simikot & Chauganphaya 1.75 – 2.0 kWh/m^2/day



Annual 10 Wind Speed Simikot & Chauganphaya 4.5 – 5 m/s



Simikot Elevation 3,000 m; Chauganphaya Elevation 2643 m

Figure 8-6: Various Average Annual NASA Data from 1983 –1993 for Nepal

The above Data are for the Simikot HARS Solar PV System (Lat. 29.967º N / Long. 81.817º E), and the Chauganphaya Village Solar PV System (Lat. 30.000º N / Long. 81.774º E) in Humla, Nepal.

These surface albedo data are from the NASA web site: http://eosweb.larc.nasa.gov/

18.4.5. Various NASA Data for the Simikot HARS Solar PV System (Lat. 29.967º N / Long. 81.817º E / 3,000 m.a.s.l.) and the Chauganphaya Village Solar PV System (Lat. 30.000º N / Long. 81.774º E / 2,643 m.a.s.l.), in Humla, Nepal

Geometry Information of NASA satellite data recording:

Northern boundary
30

Western boundary
81

CENTER
Latitude 29.5
Longitude 81.5

Eastern boundary
82

Southern boundary
29

Irradiation on horizontal surface (kWh/m²/day)													
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10 Year Average	3.36	3.94	4.75	5.73	6.30	6.20	4.90	4.74	4.74	4.70	4.09	3.28	4.72

The irradiation on a horizontal surface is the amount of electromagnetic energy (solar radiation) incident on the surface of the earth. The above values provide an average horizontal irradiation of 4.72 kWh/m^2/day. That matches with the value read out of the horizontal irradiation maps of 4.6 kWh/m^2/day rather well (see "Average Horizontal Solar Irradiation from 1983 – 1993 for Nepal for each Month")

Difference from average irradiation (%)												
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	-20	-13	-11	-6	-11	-16	-11	-8	-17	-17	-5	-8
Maximum	8	13	20	9	10	13	13	11	8	15	5	10

Diffuse irradiance on horizontal surface Erbs et al. method (kWh/m²/day)													
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10 Year Average	1.11	1.54	1.89	2.15	2.31	2.40	2.41	2.26	2.00	1.57	1.05	1.01	1.81
Minimum	1.06	1.47	1.73	2.07	2.20	2.27	2.40	2.25	1.96	1.39	0.98	0.93	1.73
Maximum	1.19	1.57	1.92	2.19	2.38	2.45	2.38	2.25	2.00	1.67	1.10	1.05	1.85
Average K	0.55	0.53	0.53	0.55	0.56	0.54	0.43	0.45	0.50	0.60	0.64	0.58	0.54
Minimum K	0.44	0.46	0.47	0.52	0.50	0.45	0.39	0.41	0.41	0.50	0.61	0.53	0.47
Maximum K	0.60	0.61	0.63	0.60	0.62	0.61	0.49	0.49	0.54	0.69	0.68	0.64	0.60

Diffuse irradiance on a horizontal surface is the amount of electromagnetic energy (solar radiation) incident on the surface of the earth under all-sky conditions with direct radiation from the sun's beam blocked by a shadow band or tracking disk at the earth's surface. The minimum diffuse irradiance is when the horizontal irradiation and clearness index K are maximum.

Irradiation clearness index K (0 to 1.0)													
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Average K	0.55	0.53	0.53	0.55	0.56	0.54	0.43	0.45	0.50	0.60	0.64	0.58	0.54
Minimum K	0.44	0.46	0.47	0.52	0.50	0.45	0.39	0.41	0.41	0.50	0.61	0.53	0.47
Maximum K	0.60	0.61	0.63	0.60	0.62	0.61	0.49	0.49	0.54	0.69	0.68	0.64	0.60

The clearness index K is the fraction of irradiation at the top of the atmosphere which reaches the surface of the earth.

Minimum available irradiation as % of average values over consecutive-day period (%)												
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min/1 day	5.35	22.8	27.3	31.0	21.5	31.6	20.4	24.0	18.9	12.1	27.8	7.92
Min/3 day	23.0	47.2	41.2	55.2	43.3	50.3	42.8	48.1	37.4	34.6	52.6	34.7
Min/7 day	41.6	65.5	60.3	69.6	62.7	61.6	57.6	58.8	52.5	46.5	70.9	61.5
Min/14 day	67.6	72.1	68.0	79.8	70.4	77.6	73.0	70.4	64.9	61.0	84.7	73.0
Min/21 day	71.9	77.7	76.4	88.3	78.1	79.5	78.2	78.7	73.8	72.3	90.5	78.5
Min/Month	80.3	86.5	89.4	93.7	89.2	84.3	89.1	91.9	82.7	83.1	95.3	92.3

The time-integrated, consecutive-day kWh/m^2 values are obtained from sequential-day satellite data. E.g. the above results suggest that 61% of the expected irradiation is available for the worst-case, 14-day period within October over the period of the data set. The worst one day produces only 5.35% of the expected irradiation, and that is min January.

Available surplus as % of average values over consecutive-day period (%)												
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max/1 day	147	151	147	136	138	137	161	154	143	136	128	139
Max/3 day	145	147	138	131	134	132	156	148	141	132	125	138
Max/7 day	136	138	132	121	129	128	145	136	133	126	119	131
Max/14 day	124	126	124	117	121	121	131	121	127	123	115	124
Max/21 day	119	122	123	112	117	118	124	116	117	121	111	120
Max/Month	108	113	120	109	110	113	113	111	108	115	105	110

That is the available surplus as % of average monthly values over consecutive-day period. The time-integrated, consecutive-day kWh/m^2 values are obtained from sequential-day satellite data. E.g. the above value for Max/1 day in January suggests that a storage capacity of 47 % larger than expected average requirements may be desirable if all the best-case, 1-day product is to be saved.

Horizontal surface deficits below expected values over consecutive-day period (kWh/m^2)												
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 day	3.18	3.04	3.45	3.95	4.94	4.24	3.90	3.60	3.84	4.13	2.96	3.02
3 day	7.76	6.23	8.37	7.69	10.7	9.23	8.40	7.37	8.90	9.21	5.82	6.42
7 day	13.7	9.50	13.1	12.1	16.4	16.6	14.5	13.6	15.7	17.5	8.32	8.83
14 day	15.2	15.3	21.2	16.2	26.0	19.3	18.4	19.6	23.2	25.6	8.77	12.3
21 day	19.7	18.3	23.5	14.0	28.9	26.6	22.3	21.2	26.0	27.2	8.10	14.7
Month	20.4	14.8	15.5	10.8	21.0	29.1	16.4	11.7	24.6	24.4	5.69	7.75

As an example, these values suggest that the worst consecutive-day deficit of 29.1 kWh/m^2 in Chauganphaya Village is for a period of one month. This deficit is relative to the June average expected irradiation.

Equivalent number of NO-SUN days (days)												
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 day	0.94	0.77	0.72	0.68	0.78	0.68	0.79	0.75	0.81	0.87	0.72	0.92
3 day	2.30	1.58	1.76	1.34	1.69	1.48	1.71	1.55	1.87	1.95	1.41	1.95
7 day	4.08	2.41	2.77	2.12	2.60	2.68	2.96	2.88	3.32	3.73	2.03	2.69
14 day	4.52	3.89	4.47	2.82	4.13	3.12	3.76	4.14	4.90	5.45	2.13	3.77
21 day	5.88	4.66	4.95	2.45	4.59	4.30	4.55	4.47	5.48	5.79	1.97	4.50
Month	6.08	3.76	3.26	1.88	3.34	4.69	3.35	2.48	5.18	5.21	1.39	2.36

As an example for the month of January, the data suggests that the maximum number of NO-SUN days is slightly higher than 6 days over a period of the month January.

Daylight cloud amount (%)												
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10 Year Average	50.2	59.7	62.7	61.7	62.8	68.0	81.8	79.4	65.8	41.9	35.6	48.9

Percent of cloud amount during daylight within a region.

Air temperature at 10m (° C)													
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10 Year Average	-3.72	-2.71	-0.16	4.28	10.8	12.1	11.5	11.9	9.28	2.52	-1.1	-2.67	4.35

Daily temperature range at 10m (° C)												
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10 Year Average	13.0	13.4	14.0	14.9	15.1	12.3 *	8.40	7.75	8.55	11.6	13.0	12.5

* Warmest month
Difference between the average daily maximum and average daily minimum, calculated from air temperature at 10 meters.

Daily mean earth temperature minimum, maximum and amplitude (° C)													
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Amplitude
10 Year Average Min	-11.5	-9.77	-7.55	-4.9	9.05	8.27	3.14	9.30	4.76	-7.71	-7.63	-9.9	
10 Year Average Max	-2.96	-1.66	-0.26	13.4	19.0	20.3	14.0	13.6	12.1	7.11	-1.12	-2.29	
10 Year Average Amp	4.28	4.05	3.64	9.16	5.00	6.04	5.45	2.16	3.70	7.41	3.25	3.80	15.9

Minimum daily mean earth temperature for each month is averaged for 10 years.
Maximum daily mean earth temperature for each month is averaged for 10 years.
Amplitude is one half of the difference between the average daily earth temperature minimum and maximum.
These values are calculated from earth skin temperature. These values are good to know because of the underground cabling has to be buried deeper than the frost depth, to prevent any condensation inside the pipes or cables.

Frost days (days)													
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Sum
10 Year Average	29	25	25	21	12	6	1	0	5	22	25	28	199

The number of days for which the temperature falls below 0 degrees Celcius. These values are calculated from air temperature at 10 meters. This data is good to know for as it shows that the solar PV modules will not get as hot as otherwise in a warmer climate. That means that higher efficiencies of the PV modules can be expected on an annual average.

Relative humidity (%)												
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10 Year Average	62.6	63.4	61.8	55.7	49.2	63.7	81.1	83.3	80.7	71.9	66.4	64.2

The relative humidity is calculated from air temperature and humidity ratio at 10 meters and surface pressure with an estimated uncertainty of 9%. These values are interesting to know, as the more humid a place is the better the various cable and wiring insulations have to be in regard to safty e.g. against short curcuits because of high humidity.

Humidity ratio (kg/kg)												
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10 Year Average	0.0030	0.0033	0.0039	0.0050	0.0072	0.0095	0.0111	0.0116	0.0096	0.0056	0.0039	0.0033

The humidity ratio (also referred to as Specific Humidity) measured 10 meters above the earth's surface.

Declination (degrees)												
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	-20.7	-12.3	-1.79	9.71	18.8	23.0	21.2	13.7	3.08	-8.46	-18.1	-22.8

Declination is the angular distance of the sun north (positive) or south (negative) of the equator. Declination varies through the year from 23.45° north to 23.45° south and reaches the minimum/maximum at the southern/northern summer solstices.

Sunset hour angle (degrees)												
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	77.3	82.7	88.9	95.6	101	104	102	98.1	91.7	85.0	79.0	75.8

The sunset hour angle is the angle that the earth has rotated between the time of solar noon and sunset. The earth rotates 15° with respect to the sun each hour.

Maximum solar angle from horizon (degrees)												
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	39.2	47.6	58.2	69.7	78.8	83.0	81.2	73.7	63.0	51.5	41.8	37.1

The maximum solar angle from the horizon is the maximum vertical angle of the sun above the horizon.

Irradiation on equator-pointed tilted surfaces, Perez/Erbs et al. method (kWh/m²/day)													
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
SSE HRZ	3.36	3.94	4.75	5.73	6.30	6.20	4.90	4.74	4.74	4.70	4.09	3.28	4.72
K	0.55	0.53	0.53	0.55	0.56	0.54	0.43	0.45	0.50	0.60	0.64	0.58	0.54
Erbs DIF	1.11	1.54	1.89	2.15	2.31	2.40	2.41	2.26	2.00	1.57	1.05	1.01	1.81
RET DNR	4.57	4.51	4.51	4.92	5.66	5.26	3.41	3.54	4.05	5.59	5.91	4.91	4.74
Tilt 0	3.29	3.91	4.70	5.61	6.27	6.17	4.88	4.71	4.67	4.66	4.00	3.22	4.67
Tilt 14	4.28	4.72	5.29	5.97	6.33	6.09	4.88	4.88	5.14	5.58	5.15	4.31	5.22
Tilt 29	5.10	5.34	5.64	6.02	6.04	5.67	4.63	4.80	5.36	6.23	6.07	5.22	5.51
Tilt 44	5.61	5.64	5.66	5.72	5.41	4.95	4.14	4.46	5.28	6.52	6.62	5.81	5.49
Tilt 90	4.98	4.52	3.79	2.98	2.22	1.87	1.76	2.20	3.33	4.99	5.70	5.32	3.64
OPT	5.77	5.66	5.69	6.04	6.35	6.18	4.91	4.88	5.37	6.53	6.76	6.04	5.85
OPT ANG	58.0	50.0	37.0	24.0	10.0	4.00	7.00	17.0	33.0	47.0	56.0	60.0	33.5

The optimum angle provides the monthly averaged maximum irradiation.

Equivalent Sun Hours irradiation for equator-pointed tilted surfaces, Perez/Erbs et al. method (kWh/m²/day)													
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
SSE MIN	2.70	3.41	4.25	5.37	5.62	5.23	4.37	4.36	3.92	3.91	3.91	3.03	4.17
K	0.44	0.46	0.47	0.52	0.50	0.45	0.39	0.41	0.41	0.50	0.61	0.53	0.47
Erbs DIF	1.19	1.57	1.92	2.19	2.38	2.45	2.38	2.25	2.00	1.67	1.10	1.05	1.85
RET DNR	3.31	3.63	3.96	4.54	4.83	4.06	2.65	2.97	2.85	4.49	5.68	4.54	3.96
Tilt 0	2.64	3.38	4.20	5.25	5.59	5.20	4.35	4.34	3.86	3.88	3.81	2.98	4.12
Tilt 14	3.34	4.02	4.71	5.57	5.64	5.16	4.34	4.48	4.21	4.56	4.90	3.92	4.57
Tilt 29	3.91	4.49	5.00	5.61	5.39	4.84	4.12	4.41	4.37	5.04	5.78	4.70	4.80
Tilt 44	4.25	4.70	5.00	5.33	4.85	4.27	3.70	4.10	4.29	5.24	6.30	5.20	4.77
Tilt 90	3.72	3.72	3.36	2.81	2.09	1.75	1.64	2.06	2.73	3.98	5.43	4.71	3.17
OPT	4.34	4.71	5.04	5.63	5.65	5.21	4.37	4.49	4.37	5.24	6.43	5.38	5.07
OPT ANG	57.0	48.0	37.0	23.0	9.00	5.00	7.00	17.0	32.0	46.0	56.0	60.0	33.0

Equivalent Sun Hours irradiation is based on the minimum monthly SSE horizontal irradiation for the 10-year time period from July 1983 through June 1993.

Peak Sun Hours irradiation for equator-pointed tilted surfaces, Perez/Erbs et al. method ($kWh/m^2/day$)													
Lat 30.000 Lon 81.774	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
SSE MAX	3.64	4.47	5.68	6.25	6.91	7.00	5.55	5.25	5.13	5.39	4.32	3.62	5.26
K	0.60	0.61	0.63	0.60	0.62	0.61	0.49	0.49	0.54	0.69	0.68	0.64	0.60
Erbs DIF	1.06	1.47	1.73	2.07	2.20	2.27	2.40	2.25	1.96	1.39	0.98	0.93	1.73
RET DNR	4.99	5.50	5.98	5.60	6.45	6.33	4.39	4.34	4.64	6.68	6.24	5.56	5.56
Tilt 0	3.56	4.44	5.62	6.12	6.88	6.96	5.52	5.22	5.05	5.35	4.21	3.56	5.21
Tilt 14	4.67	5.44	6.41	6.51	6.92	6.85	5.51	5.40	5.57	6.43	5.43	4.77	5.83
Tilt 29	5.58	6.21	6.90	6.57	6.58	6.35	5.20	5.30	5.81	7.22	6.40	5.79	6.16
Tilt 44	6.15	6.60	6.96	6.24	5.87	5.50	4.61	4.92	5.73	7.56	6.98	6.45	6.13
Tilt 90	5.48	5.33	4.65	3.19	2.32	1.95	1.87	2.36	3.58	5.78	6.01	5.90	4.03
OPT	6.33	6.65	6.98	6.59	6.95	6.97	5.55	5.41	5.82	7.57	7.13	6.71	6.56
OPT ANG	58.0	51.0	39.0	24.0	9.00	3.00	6.00	17.0	33.0	48.0	56.0	60.0	33.6

All the above data are generated from the NASA web site: http://eosweb.larc.nasa.gov/

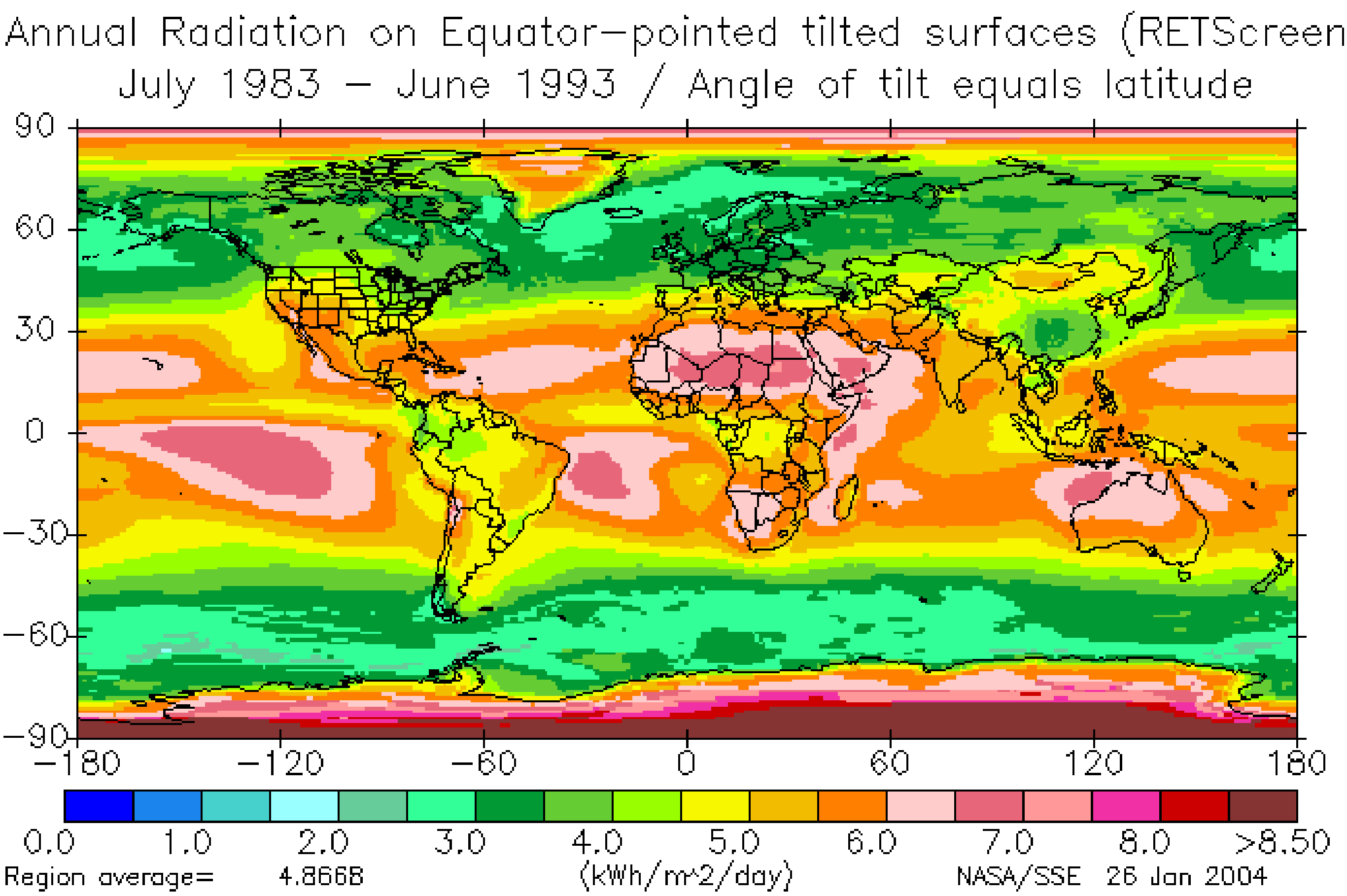


Figure 8-7: World Annual Average Irradiation on Equator-Pointed Tilted Surface July 1983 – June 1993

18.4.6. Extrapolated NASA Surface Meteorology and Solar Energy Data

The various data are calculated through interpolation for Simikot HARS Solar PV System (Lat. 29.967º N / Long. 81.817º E), and the Chauganphaya Village Solar PV System (Lat. 30.000º N / Long. 81.774º E) in Humla, Nepal. The Simikot HARS Solar PV system, at a Latitude of 29.967º N is considered with a Latitude of 30 º North values. The data are from the NASA web site: http://eosweb.larc.nasa.gov/

Monthly average Clear Sky Irradiation (kWh/m^2/day) for July 1983 - June 1993

Amount of electromagnetic energy (solar radiation) incident on the surface of the earth during clear sky days (cloud fraction < 10%).

Lat.	Long.	January	February	March	April	May	June	July	August	Sept.	October	Nov.	Dec.	Annual Av.	Remark
30	81	4.47	5.66	6.93	8.26	8.82	9.05	8.46	7.73	6.91	5.82	4.75	4.06	6.74	
30	82	4.39	5.63	6.87	8.31	8.82	9.18	8.47	7.73	6.81	5.69	4.72	3.88	6.71	
29.967	81.817	4.41	5.64	6.88	8.30	8.82	9.16	8.47	7.73	6.83	5.71	4.73	3.91	6.72	Simikot HARS
30.000	81.774	4.41	5.64	6.88	8.30	8.82	9.15	8.47	7.73	6.83	5.72	4.73	3.92	6.72	Chauganphaya

Monthly average Irradiation on horizontal surface (kWh/m^2/day) for July 1983 - June 1993

The irradiation on a horizontal surface is the amount of electromagnetic energy (solar radiation) incident on the surface of the earth.

Lat.	Long.	January	February	March	April	May	June	July	August	Sept.	October	Nov.	Dec.	Annual Av.	Remark
30	81	2.94	3.59	4.28	5.39	6.25	6.69	5.32	5.01	5.07	4.68	3.93	2.89	4.67	
30	82	3.13	3.86	4.63	5.80	6.53	7.01	5.54	5.17	5.10	4.64	4.01	2.90	4.86	
29.967	81.817	3.10	3.81	4.57	5.72	6.48	6.95	5.50	5.14	5.09	4.65	4.00	2.90	4.83	Simikot HARS
30.000	81.774	3.09	3.80	4.56	5.71	6.47	6.94	5.50	5.13	5.09	4.65	4.00	2.90	4.82	Chauganphaya

Monthly average Irradiation Clearness Index K (0 to 1.0) for July 1983 - June 1993

Fraction of irradiation at the top of the atmosphere which reaches the surface of the earth.

Lat.	Long.	January	February	March	April	May	June	July	August	Sept.	October	Nov.	Dec.	Annual Av.	Remark
30	81	0.50	0.50	0.49	0.53	0.56	0.59	0.47	0.48	0.55	0.61	0.63	0.53	0.54	
30	82	0.53	0.54	0.52	0.57	0.59	0.61	0.49	0.49	0.55	0.60	0.65	0.53	0.56	
29.967	81.817	0.52	0.53	0.51	0.56	0.58	0.61	0.49	0.49	0.55	0.60	0.65	0.53	0.55	Simikot HARS
30.000	81.774	0.52	0.53	0.51	0.56	0.58	0.61	0.49	0.49	0.55	0.60	0.65	0.53	0.55	Chauganphaya

18.5. Appendix to Chapter 9 Solar Irradiation Simulation with METEONORM V5 for Humla

18.5.1. Accuracy of METEONORM[14]

Quality of basis data: The error in interpolating the monthly radiation values is 15%, and for temperatures 1.3°C.

Climatic variations: The METEONORM radiation database is based on 10 year measurement periods, the other parameters mainly on 1961-90 means. Comparisons with longer term measurements show that the discrepancy in average total radiation due to choice of time period is less than 2% for all weather stations.

Computational models: The models used in METEONORM are designed to calculate radiation on inclined surfaces and additional parameters. One or more models are used depending on data basis. If the results are to be passed on for further processing, the data basis and models used should be specified to ensure that the results are correctly interpreted.

The hourly model in general, tends to overestimate slightly the total radiation on inclined surfaces by 1%. The discrepancy compared to measured values is ±6% for individual months and ±3% for yearly sums.

It is important for users of METEONORM to be aware that the data basis and computational models only approximate the real situation. Notwithstanding this, the variation in measured total radiation between one year and another is greater than the inaccuracy in the models.

18.5.2. Data Input for Simikot

As Simikot is a very remote place, with no meteorological station, the software has to extrapolate the data from either other stations or satellite data. For the extrapolation for Simikot though only 1-3 stations, according to Figure 8-1, are available. To generate the Simikot related global horizontal solar irradiation values not even one meteorological station is available, but it can only be extrapolated through satellite data, as is indicated in the pop-up METEONORM menu, as depicted in Figure 9-5.

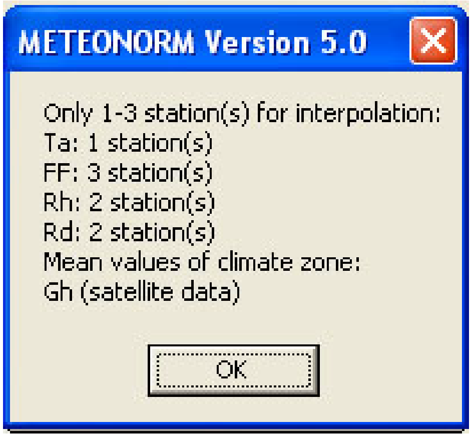


Figure 9-5: METEONORM V5 pop-up menu for the meteorological data extrapolation. The pop-up menu for the extrapolation of the Simikot meteorological data indicates, that only very few, maximum 1-3 meteorological stations are available for the extrapolation of the identified meteorological data for Simikot.
That has of course a direct influence on the quality of the extrapolated data, and thus the calculated data has to be taken with the appropriate caution.

Ta: Ambient temperature
FF: Wind Speed
Rh: Relative humidity
Rd: days per month with precipitation
Gh: Global horizontal solar irradiation

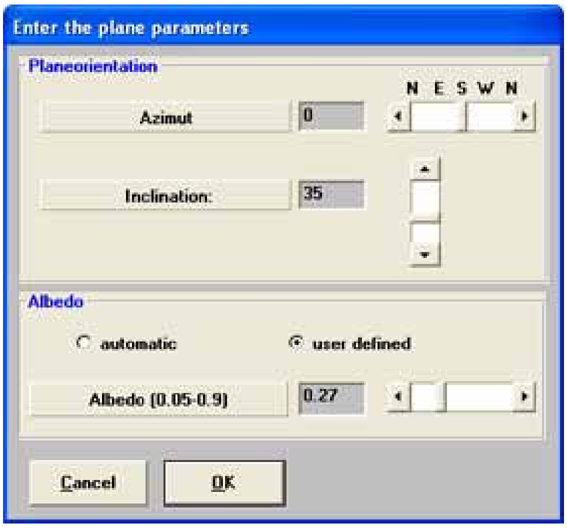


Figure 9-6 METEONORM V5 plane parameters input menu for Simikot.
In the plane parameters input menu the fixed inclination, 35° due south, azimuth 0°, (as there is no option in METEONORM for tracking), and the Albedo value of 0.27 according to the NASA annual average value resulting from the graphics in 18.4.2. are defined for the generation of the defined meteorological data for Simikot HARS.

18.5.3. Simulation for the Simikot HARS Solar PV System

Two sub menus, Meteo and Hourly values, are available in the METEONORM V5 software packet to generate the meteorological data for a defined geographical location. Meteo (only available from version 5 on) gives an oversight of all meteorological parameters (monthly means). Hourly values starts the calculation process for the generation of hourly values and is guided by the needs of the different output formats. If hourly values are to be calculated, the desired format for the output files can be specified among 15 possible formats[15] for the further data processing. For the monthly model (Meteo), a standard format must be used.

In the following both, the Hourly and the Meteo simulation values are presented for the Simikot HARS location, according to the defined input parameters as presented in 9.3.

18.5.4. Hourly Simulation Data for the Simikot HARS

The METEONORM simulation, generated with the hourly values in the standard format (to have more detailed output results parameters compared to the PVSyst. format) resulted in the following data:

Calculation (hour) 09. 07. 2004 / 11:53

METEONORM Version 5.0

Site:	Simikot KU HARS		
Situation:	open		
Horizon:	vh29.967081.8170.hor		
Azimuth:	0	Inclination:	35
Type	Userdefined site	Format	Standard

All radiation datas are influenced by a high horizon!
The ending "hor" means with high horizon
Albedo = 0.27

Jan	H_Gh	H_Dh	H_Gkhor	H_Dkhor	H_Bnhor	Ta
Jan	138	31	230	56	223	3.0
Feb	81	47	98	50	61	3.7
Mar	130	66	147	70	105	7.5
Apr	135	79	131	76	84	12.0
May	159	78	141	73	116	14.3
Jun	136	79	115	70	80	14.9
Jul	140	85	121	77	80	13.8
Aug	125	70	117	66	79	13.5
Sep	112	68	115	67	70	12.7
Oct	211	41	275	61	279	10.9
Nov	148	31	232	52	228	7.8
Dec	118	33	197	53	182	5.0
Year	1626	709	1918	772	1587	9.9

Legend:

H_Gh: Irradiation of global radiation horizontal
H_Dh: Irradiation of diffuse radiation horizontal
H_Gkhor: Irradiation of global rad., tilted plane, with high horizon
H_Dkhor: Irradiation of diffuse rad., tilted plane, with high horizon
H_Bnhor: Irradiation of beam, with high horizon
Ta: Air temperature

Radiation in [kWh/m²]
Temperature in [°C]
Gh: Mean values of climate zone
Ta: Only 1 station(s) for interpolation

Figure 9-7 Tabled Monthly Solar Irradiation Data for the Simikot HARS. 35° South Tilted Horizontal, presented as H_Gh, and 35° south inclined position, presented as H_Gkhor, values.

The global irradiation on the 35° south inclined surface, which represents an annual average of the solar PV modules installed at the HARS, amounts to 1,918 kWh/m^2 per year. The lowest irradiation is received in February, with just under 100 kWh/m^2 per month, while the maximum solar energy per month is received in October with 275 kWh/m^2 per month. To have the solar PV modules already at a fixed inclined position of 35° means 18% more annual energy output per m^2 in comparison to the horizontal position. But the HARS solar PV modules are tracking the sun, automatically from the East in the morning to the West in the evening, and either once a week or twice a month, the North – South axis is manually adjusted according to the changing declination, from 5° (during later June) - 60° (during later December). Thus significantly higher daily irradiation values are expected throughout the year from the actual solar irradiation data recording from the 2-axis self-tracking frame values.

The average daily ambient temperature is just under 10° C, with January being the coldest month with 3° C, and June being the warmest month with just under 15° C. While these temperature values are indicative for the average mean ambient temperature, the daily minimum and maximum vary extremely (as can be seen in more detail in Figure 9-10), especially during the 4 winter months from November through to February.

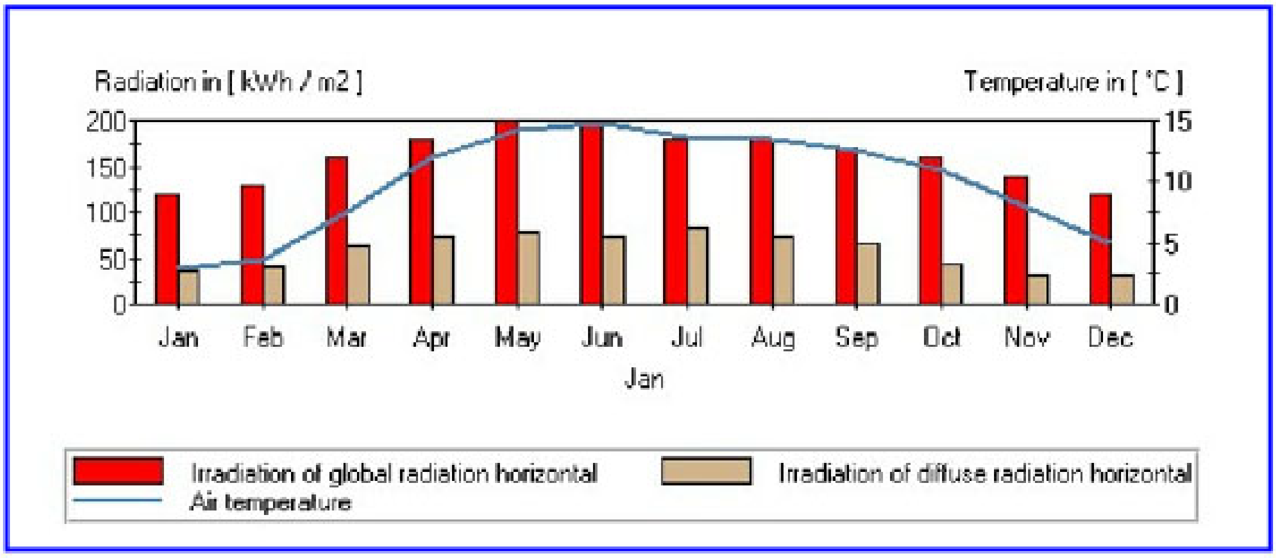


Figure 9-8: Monthly Mean Global and Diffuse Radiation in W / m^2 on a Horizontal Surface and Ambient Temperature. Diffuse radiation on a horizontal surface, and monthly mean ambient air temperature in ° C for the HARS in Simikot. (The "Jan" inbetween June and July is a METEONORM software problem occurring in several of its graphs, and cannot be changed by the user).

Daily means of global radiation

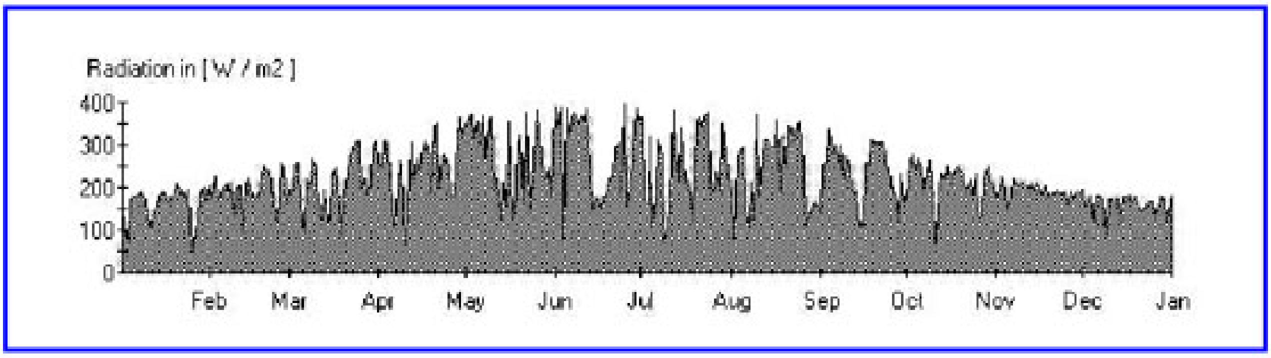


Figure 9-9: Daily Means Global Radiation in W / m^2 on a Horizontal Surface

From this simulated graph one can say that an average of around 200 W/m^2 (over a 24 hours period) over the course of a year is realistic. The simulation though generated an annual value of 1,626 W/m^2, which results in an average solar radiation of 186 W/m^2 per hour (on a 24 hour basis). Interesting now is to compare the data provided from Figure 7-2: "Average Yearly Solar Irradiation", presenting the annual global irradiation according to a large area of the earth's surface. In Figure 7-2, Nepal is depicted as having an average annual global solar irradiation of 1,950 kWh/m^2 – 2,200 kWh/m^2. That results in an average global irradiation of 223 W/m^2 – 251 W/m^2 (over a 24 hours period), which is 27% more (if the average value of Figure 7.2 is taken). These differences shows how important it is to monitor and measure the available solar energy at the geographical location in question, as the local prevailing conditions can be so different from the more "overall" conditions of an area, especially in a country like Nepal, with 5 climate zones due to the enormous changes occurring within the Himalayas.

Daily values of temperature (mean, min, and max.)

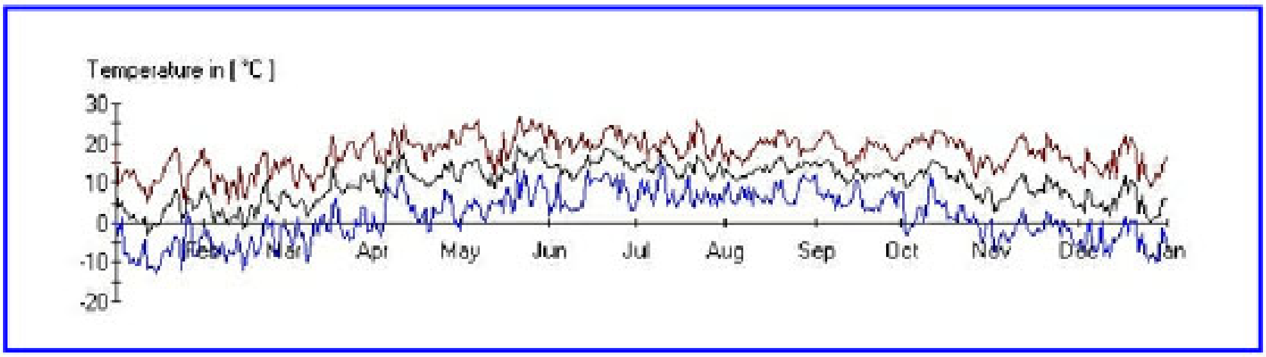


Figure 9-10: Daily Values of Mean (middle), Minimum (lower) and Maximum (upper) Temperature Variations.

Throughout the year, the ambient temperature in Simikot varies enormously, as these graphs clearly indicate. The experience of living there shows, that it is not unusual to have freezing nights with temperatures around - 10° C, though during the day the sun heats the air up to + 20° C, resulting in a daily temperature difference of 30° C, especially during the 4 winter months from November to February.

18.5.5. METEO Simulation Data for the Simikot HARS

The METEONORM simulation, generated with the METEO values in the standard format resulted the following data:

With an average daily 7.4 hours of sunshine, or 2,705 hours sunshine per year, Simikot is a very sunny place. That includes the high horizon due to the surrounding mountain ranges (see Figure 9-11). Clearly can be seen the 4 months, from June to September, during which the monsoon brings over 72% of the annual precipitation, and over 73% of the rainy days are accounted for during this time period.

One can clearly say that Simikot is not a windy place per se, never even touching a monthly average of 3 m/s, which is about the minimum cut-in wind speed for most of the wind turbines. The 4 months after the winter, when the sun starts to be strong, the snow is melting and strong thermal winds occur, are the windiest months. Again the average is not very indicative of the strong gusts, which occur at times in Simikot during that time.

Calculation (hour) 09. 07. 2004 / 12:56

METEO Values

METEONORM Version 5.0

Site:	Simikot KU HARS		
Situation:	open		
Horizon:	vh29.967081.8170.hor		
Type	Userdefined site	Format	METEO

All radiation datas are influenced by a high horizon!
The ending "hor" means with high horizon
Albedo = 0.27

Jan	Ta	Ta min	Ta dmin	Ta dmax	Ta max	RH
Jan	3.0	-12.9	-6.8	12.3	18.7	96
Feb	3.7	-12.7	-5.0	11.5	17.8	97
Mar	7.5	-9.9	-1.3	15.8	23.1	97
Apr	12.0	-4.3	3.6	19.1	24.3	96
May	14.3	-0.2	6.2	21.2	26.9	97
Jun	14.9	2.9	8.0	20.5	25.9	97
Jul	13.8	3.4	7.8	19.1	24.5	97
Aug	13.5	4.3	8.1	18.7	24.3	97
Sep	12.7	2.2	6.1	18.3	23.6	97
Oct	10.9	-4.1	2.1	18.9	23.4	97
Nov	7.8	-7.8	-2.1	17.1	22.4	97
Dec	5.0	-10.3	-4.8	14.9	21.5	97
Year	9.9					97

Jan	H_Ghhor	SDmhor	SDdhor	SD astr.	RR	RD	FF	DD
Jan	141	230	7.4	10.3	44	3	1.8	270
Feb	78	211	7.5	11.0	57	5	2.3	270
Mar	127	235	7.6	11.9	66	6	2.9	270
Apr	130	249	8.3	12.8	40	4	2.7	270
May	156	261	8.4	13.5	70	9	2.3	270
Jun	131	204	6.8	13.9	151	21	1.9	270
Jul	134	173	5.6	13.7	312	27	1.6	270
Aug	120	182	5.9	13.1	280	27	1.5	270
Sep	107	214	7.1	12.2	196	26	1.5	270
Oct	206	267	8.6	11.3	43	6	1.6	270
Nov	149	254	8.5	10.5	10	1	1.5	270
Dec	118	228	7.4	10.1	29	3	1.5	270
Year	1597	2705	7.4		1297	138	1.9	270

Legend:

Ta:	Air temperature	RH:	Relative humidity
Ta min:	10 y minimum (approx.)	Ta max:	10 y maximum (approx.)
Ta dmin:	Mean daily minimum Ta	Ta dmax:	Mean daily maximum Ta
SD:	Sunshine duration	RR:	Precipitation
RD:	Days with precipitation	FF:	Wind speed
SD astr.:	Sunshine duration, astronomic	DD:	Wind direction
Gh:	Irradiation of global radiation horizontal		

Temperature in [°C]
Wind speed in [m/s]
Sunshine duration in [h/day]
Radiation in [kWh/m²]

Gh:	Mean values of climate zone
Ta:	Only 1 station(s) for interpolation
Rh:	Only 2 station(s) for interpolation
FF:	Only 3 station(s) for interpolation

Figure 9-11: Tabled Monthly METEO Format Data for the Simikot HARS

H_Ghhor values, the monthly sunshine duration in hours on a horizontal plane (SDmhor), and the daily sunshine duration in hours on a horizontal plane (SDdhor) values. The global horizontal irradiation simulated with the METEO simulation is compared to the hourly value simulation just 1.8 % lower over the course of one year. That lies within an acceptable tolerance.

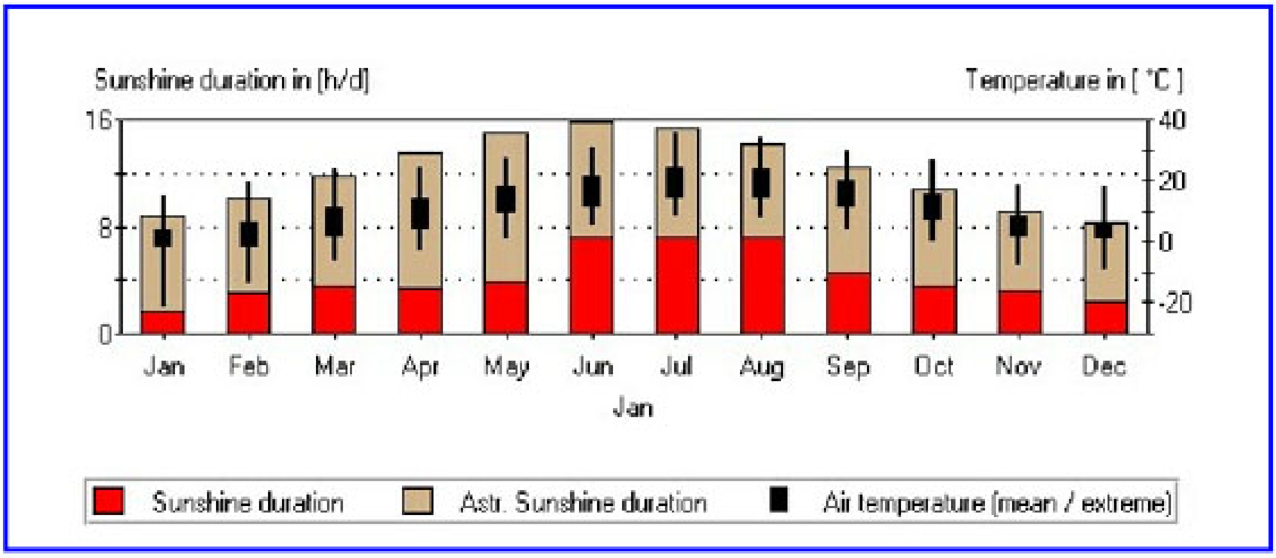


Figure 9-12: Daily Sunshine Hours and Ambient Temperature according to the Month in Simikot.

Throughout the year Simikot experiences a high temperature difference. That is not unusual when considered the altitude is 3,000 m, and that Simikot is surrounded by 4,000 – 6,000 m high mountain ranges. The daily sunshine duration (SD) graphically presented in Figure 9-12, does not really match with the figures in the table in Figure 9-11, especially not for the months April, May, October and November, during which the sunshine hours each day exceed 8 hours in the METEO simulation, though in Figure 9-12 the values are just about half.

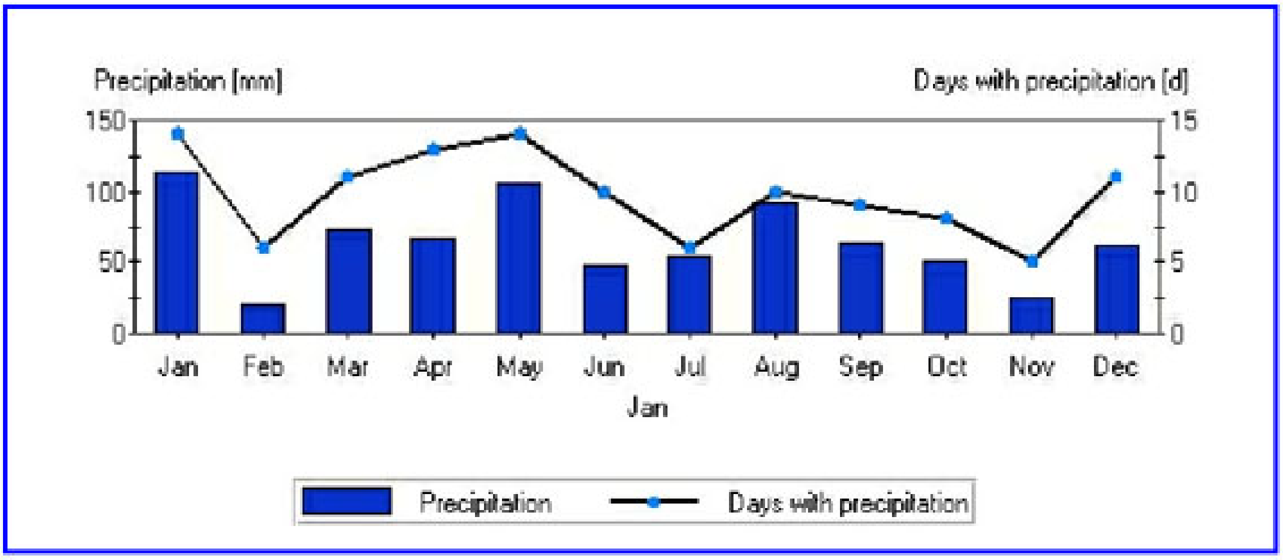


Figure 9-13: The Amount of Days per Months it Rains and the Precipitation (in mm) during that Month.

Also the graph in Figure 9-13 shows very clear differences, which cannot be justified with the results generated and tabled in Figure 9-11. While the numbers show the clear signs of the Asian monsoon during the months June – September, with over 72% of the annual amount of precipitation, and very dry months the rest of the year, the graph shows a totally different trend, with no relationship at all. Thus obviously METEONORM V5 has a problem with the two graphs presented in Figures 9-12 and 9-13, as they do not represent or match exact enough the generated data in Figure 9-11.

In the following Excel graph is presented the average monthly precipitation and average number of days of precipitation with the actual METEO simulation results.

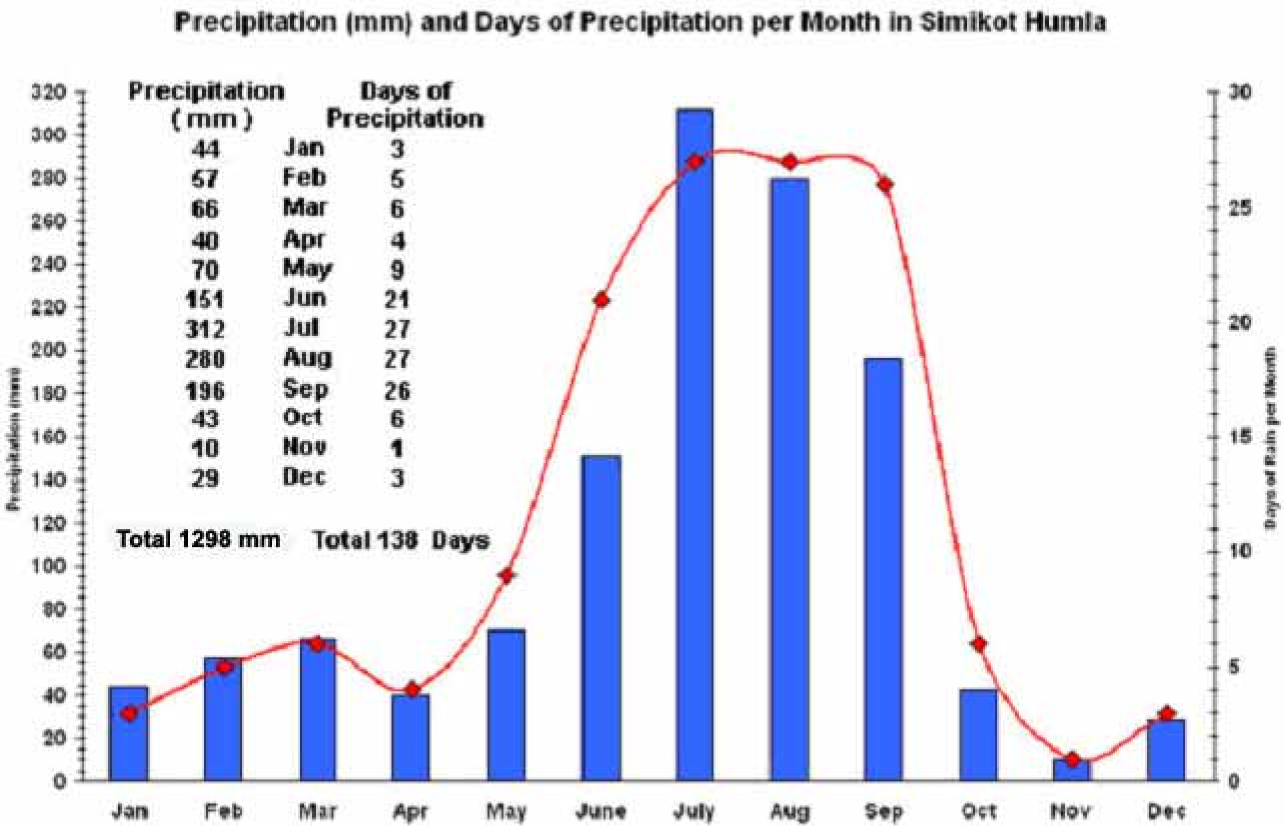


Figure 9-14: Excel graph for the average monthly precipitation and average monthly days of precipitation in Simikot. According to the METEO simulation generated results of Figure 9-11.

The precipitation graph is presented to show in particular the correlation between the solar irradiation and the precipitation during the monsoon months June - September.

While the average monthly sunshine duration during the long summer days for the 4 monsoon months (June - September) is 193 hours, with an average monthly solar irradiation of 117 kWh/m^2, the sun shines during the shorter winter days, for the 4 months October – January, on an average 245 hours per month (or 27% more), with an average monthly solar irradiation of 234 kWh/m^2 (or 100 % more).

18.5.6. Simulation for the Chauganphaya Village Solar PV System

As again there is no meteorological station, the METEONORM V5 software has to extrapolate the data from either other stations or satellite data. For the extrapolation of the global horizontal solar irradiation values for the Chauganphaya village not even one meteorological station is available, so that the data have to be extrapolated only from available satellite data, as is indicated in the pop-up menu (Figure 9-15). Further, the inclination of 35°, and annual average Albedo value of 0.27 are additional parameters for the input.

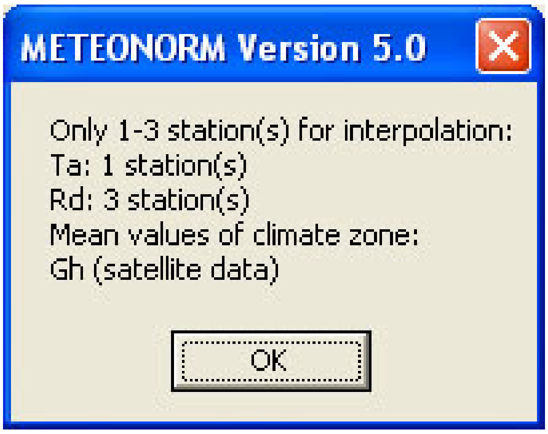


Figure 9-15: METEONORM Pop-Up Menu for the Extrapolation of the Chauganphaya Village Meteorological Data.
It indicates, that only very few, 1 station for the ambient temperature and 3 meteorological stations for the average monthly days of precipitation are available for the extrapolation of the data. That has a direct influence on the quality of the extrapolated data, and thus the simulated data has to be taken with the appropriate caution.

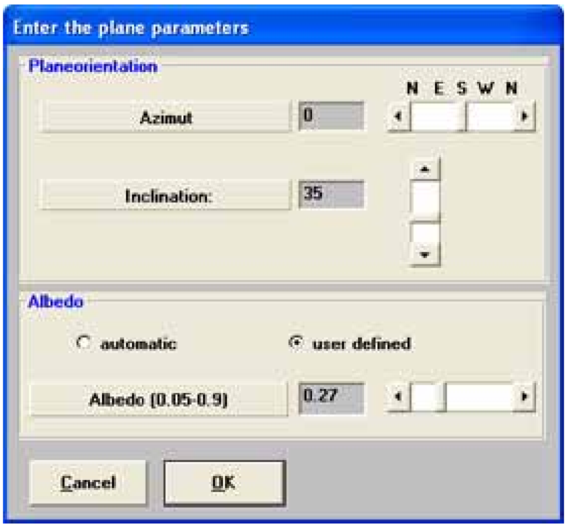


Figure 9-16: METEONORM Plane Parameters Input Menu for Chauganphaya.
The fixed inclination, 35° due south, azimuth 0°, and the Albedo value of 0.27 according to the NASA annual average value resulting from the graphics in 18.4.2., are also input.

18.5.7. Hourly Simulation Data for the Chauganphaya Village

The METEONORM simulation, generated with the hourly values in the standard format resulted in the following data:

Calculation (hour) 10. 07. 2004 / 05:31

METEONORM Version 5.0

Site:	Chaughanphaya Village		
Situation:	open		
Horizon:	vh29.967081.8170.hor		
Azimuth:	0	Inclination:	35
Type	Userdefined site	Format	Standard

All radiation datas are influenced by a high horizon!
The ending "hor" means with high horizon
Albedo = 0.27

Jan	H_Gh	H_Dh	H_Gkhor	H_Dkhor	H_Bnhor	Ta
Jan	103	43	157	59	126	4.7
Feb	81	44	100	48	68	5.4
Mar	130	66	145	69	106	9.2
Apr	84	59	78	53	39	13.7
May	129	82	113	74	67	16.0
Jun	138	80	116	72	81	16.6
Jul	143	73	124	67	96	15.5
Aug	126	72	118	67	78	15.2
Sep	107	69	110	67	61	14.4
Oct	173	39	231	54	230	12.6
Nov	125	35	193	52	180	9.5
Dec	93	41	143	54	113	6.7
Year	1428	703	1627	736	1245	11.7

Legend:

H_Gh: Irradiation of global radiation horizontal
H_Dh: Irradiation of diffuse radiation horizontal
H_Gkhor: Irradiation of global rad., tilted plane, with high horizon
H_Dkhor: Irradiation of diffuse rad., tilted plane, with high horizon
H_Bnhor: Irradiation of beam, with high horizon
Ta: Air temperature

Radiation in [kWh/m²]
Temperature in [°C]
Gh: Mean values of climate zone
Ta: Only 1 station(s) for interpolation

Figure 9-17: Tabled monthly Solar Irradiation Data for the Chauganphaya.
Horizontal, presented as H-Gh values, and 35° south inclined position, presented as H_Gkhor values .

The global irradiation on the 35° south inclined surface, which represents an annual average of the solar PV modules installed in Chauganphaya, amounts to 1,627 kWh/m^2 per year. The lowest irradiation is received in April, with just under 78 kWh/m^2 per month, while the maximum solar energy per month is received in October with 231 kWh/m^2 per month. To have the solar PV modules already at a fixed inclined position of 35° means 14% more annual energy output per m^2 compared to the horizontal position. But the four Chauganphaya solar PV modules are tracking the sun, automatically from the East in the morning to the West in the evening, and once a week, or twice a month, the North – South axis is manually adjusted according to the changing declination, from 5° (during later June) - 60° (during later December). Thus significant higher daily irradiation values are expected throughout the year from the actual solar irradiation data recording from the 2-axis self-tracking frame values. The average daily ambient temperature is just under 12° C, with January being the coldest month with 4.7° C, and June being the warmest month with just under 16.6° C. While these temperature values are indicative for the average mean ambient temperature, the daily minimum and maximum vary extremely (as can be seen in more detail in Figure 9-18), especially during the 4 winter months from November through to February.

18.5.8. METEO Simulation Data for the Chauganphaya Village

The METEONORM simulation, generated with the METEO values in the standard format resulted in the following data:

With an average daily 7.2 hours of sunshine, or 2,624 hours sunshine per year, Chauganphaya is also a very sunny place. That includes the high horizon due to the surrounding mountain ranges (see Figure 9-3). Clearly can be seen the 4 months, from June to September, during which the monsoon brings over 72.5% of the annual precipitation, and over 73% of the rainy days are accounted for during this time period. Chauganphaya also is not a windy place with 2.4. m/s average annual wind speed, and maximum monthly average of 3.4. m/s in March. The 4 months after the winter (May - June), when the sun starts to be strong, the snow is melting and strong thermal winds occur, indicate the most windy months.

Calculation (hour) 10. 07. 2004 / 06:23

METEONORM Version 5.0

Site:	Chaughanphaya Village		
Situation:	open		
Horizon:	vh29.967081.8170.hor		
Type	Userdefined site	Format	METEO

All radiation datas are influenced by a high horizon!
The ending "hor" means with high horizon
Albedo = 0.27

Jan	Ta	Ta min	Ta dmin	Ta dmax	Ta max	RH
Jan	4.7	-8.0	-3.1	12.5	18.6	97
Feb	5.4	-7.0	-1.6	11.7	19.5	97
Mar	9.2	-3.7	2.1	15.9	23.3	97
Apr	13.7	1.0	7.2	19.3	25.5	97
May	16.0	2.8	8.9	21.9	29.3	97
Jun	16.6	3.9	9.7	22.2	29.0	97
Jul	15.5	5.2	9.6	20.9	27.9	97
Aug	15.2	4.9	9.8	20.3	26.1	97
Sep	14.4	3.5	8.5	19.9	24.1	97
Oct	12.6	0.9	5.2	19.5	24.2	97
Nov	9.5	-2.6	1.5	17.1	21.2	97
Dec	6.7	-4.6	-0.7	14.6	20.8	97
Year	11.7					97

Jan	H_Ghhor	SDmhor	SDdhor	SD astr.	RR	RD	FF	DD
Jan	101	214	6.9	10.3	44	3	2.2	270
Feb	78	208	7.4	11.0	57	5	2.6	270
Mar	127	233	7.5	11.9	66	6	3.4	270
Apr	78	243	8.1	12.8	40	4	3.0	270
May	123	252	8.1	13.5	70	9	2.9	270
Jun	132	192	6.4	13.9	151	21	2.5	270
Jul	139	164	5.3	13.7	313	27	2.4	270
Aug	122	173	5.6	13.1	281	27	2.0	270
Sep	102	209	7.0	12.2	197	26	2.0	270
Oct	175	273	8.8	11.3	43	6	2.3	270
Nov	125	248	8.3	10.5	10	1	2.0	270
Dec	91	214	6.9	10.1	29	3	2.0	270
Year	1394	2624	7.3		1299	138	2.4	270

Legend:

Ta:	Air temperature	RH:	Relative humidity
Ta min:	10 y minimum (approx.)	Ta max:	10 y maximum (approx.)
Ta dmin:	Mean daily minimum Ta	Ta dmax:	Mean daily maximum Ta
SD:	Sunshine duration	RR:	Precipitation
RD:	Days with precipitation	FF:	Wind speed
SD astr.:	Sunshine duration, astronomic		
Gh:	Irradiation of global radiation horizontal		

Temperature in [°C]
Wind speed in [m/s]
Sunshine duration in [h/day]
Radiation in [kWh/m²]
Gh: Mean values of climate zone
Ta: Only 1 station(s) for interpolation

Figure 9-18: Tabled Monthly METEO Format Data for the Chauganphaya.

Tabled monthly Horizontal Solar Irradiation Data for the Chauganphaya Village, (H_Ghhor) values, the monthly sunshine duration in hours on a horizontal plane (SDmhor), and the daily sunshine duration in hours on a horizontal plane (SDdhor) values. The global horizontal irradiation simulated with the METEO simulation is compared to the hourly value simulation 2.4 % lower over the course of one year, which is still within an acceptable tolerance. The higher horizon due to the high mountain ranges all around Chauganphaya results in a slightly lower average daily sunshine duration of 0.1 hour or 6 minutes per day. Though while that is within an acceptable tolerance for a simulation, it indicates the right tendency due to the local prevailing geographical conditions.

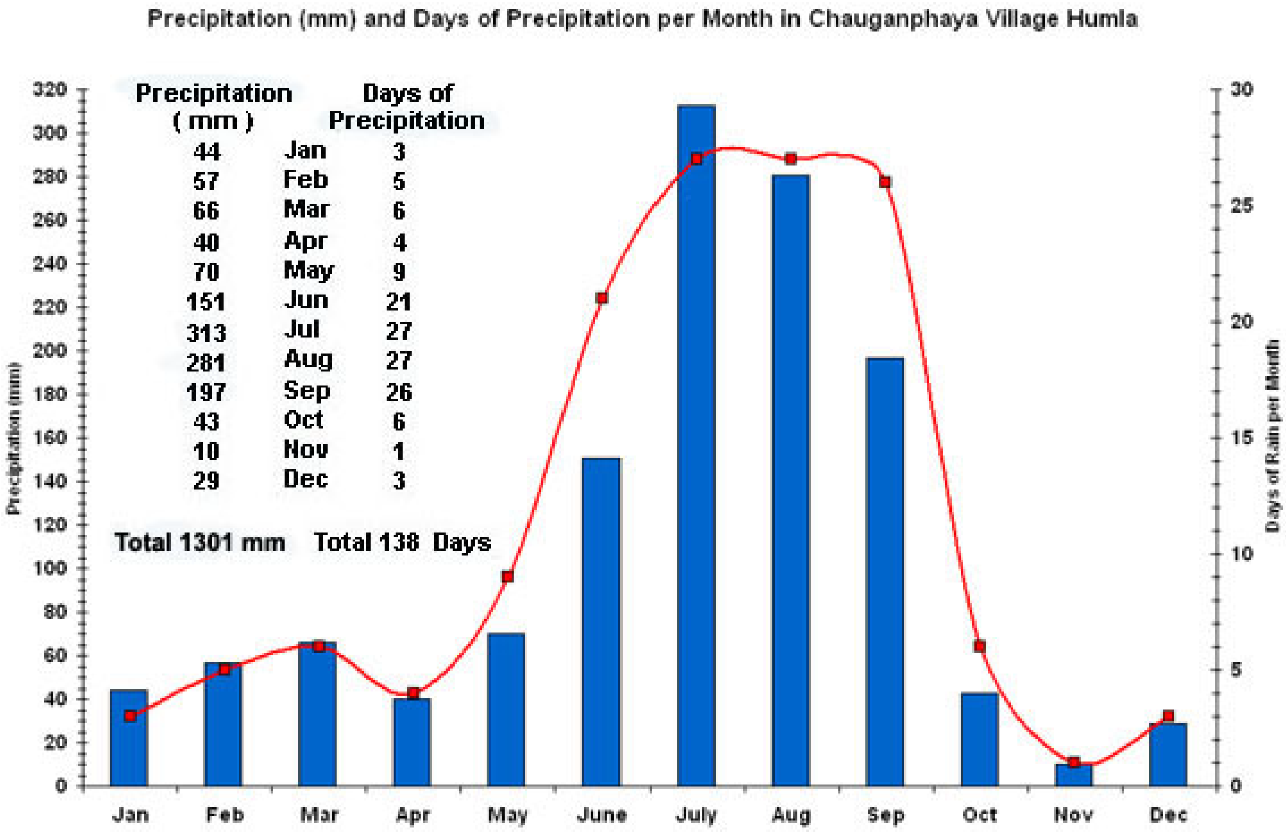


Figure 9-19: Excel graph for the average monthly precipitation and average monthly days of precipitation in Chauganphaya.

Again, the METEONORM generated graph for the precipitation are not corresponding with the data generated in METEO. Thus an Excel graph for the average monthly precipitation and average monthly days of precipitation in Chauganphaya according to the METEO simulation generated results (Figure 9-18) is plotted. This graph varies only in the three month of July – September by each 1 mm more rain, with the same amount of rainy days per month compared to the Excel graph in Figure 9-14. That shows the close proximity of the geographical area.

18.6. Appendix to Chapter 10 Solar PV System Simulation with PVSyst3.31

18.6.1. HARS Simikot Solar PV System Simulation Report

PVSYST V3.31	KU-ISIS HARS Simikot Solar PV System Simulation	23/04/04 09h18	Page 1/5

Stand alone PV system: Simulation parameters

Project : **Simikot**

Geographical site : **Simikot** — **Country** **Nepal**

Situation : Latitude 29.6°N — Longitude 81.5°E
Time defined as : Legal time Time zone = 5 — Altitude 3000 m
Monthly albedo values :

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Albedo	0.30	0.30	0.30	0.25	0.25	0.25	0.25	0.25	0.30	0.25	0.25	0.25

Meteo data : Simikot HARS Meteonorm SYN File

Simulation variant : **Simulation variant**
Simulation date 23/04/04 09h02

Simulation parameters :

Tracking plane, two axis	Minimum tilt	5°	Maximum tilt	60°
Rotation limitations	Minimum Azimuth	-10°	Maximum Azimuth	10°
Horizon	Average horizon height	12.9°		
Near shadings	No Shadings			

PV array characteristics :

PV module: Si-mono	Module name	**BP275F**		
	Manufacturer	BP Solar		
Number of PV modules :	in serie	2 modules	in parallel	6 strings
Total number of PV modules :	Nb. modules	12	unit nom. power	75 Wp
Array global power	Nominal (STC)	**900 Wp**	At oper. cond.	809 Wp (50°C)
Array operating characteristics (50°C)	U mpp	31 V	I mpp	26 A
Total area	Module area	**7.6 m²**	Cell area	6.7 m²

PV array loss factors :

Heat Loss Factor	k (const)	20.7 W/m²K	k (wind)	6.0 W/m²K / m/s
=> Nominal Oper. Coll. Temp. (800 W/m², Tamb=20°C,		wind 1 m/s)	NOCT	47 °C
Wiring ohmic losses	Global field res.	56.8 mOhm	Loss fraction	4.6 % at STC
Serie diode loss	Voltage drop	0.4 V	Loss fraction	1.2 % at STC
Module quality losses			Loss fraction	3.0 %
Module mismatch losses			Loss fraction	4.0 % (fixed Voltage)
Incidence effect: "Ashrae" parametrization	IAM =	1-bo (1/cos i - 1)	bo	0.05

System parameter:	System type	**Stand alone**		
Battery	Model	**Volta 6SB100**		
	Manufacturer	VOLTA Bangladesh		
Battery pack characteristics	Voltage	24 V	Nominal capacity	800 Ah
	Number of units (serie x parall)	2 x 8		
	Temperature	Fixed (20°C)		
Regulator	Model	JokerS802-30A		
	Manufacturer	Studer Lausanne Switzerland		
	Technology	Shunt transistor	Temp. coeff.	-5.0 mV/°C/elem.
Battery management Thresholds	Charging	28.8/27.0 V	Discharging	21.0/24.8 V
	Back-up gen. command	22.2/25.8 V		
User's needs :	Daily profiles	Constant over the year		
	Average	2.5 kWh/day		

Figure 10–5: PVSyst3.31 Simikot Simulation Report page 1

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Stand alone PV system: Horizon definition

Project : **Simikot**

Simulation variant : **Simulation variant**

Main system parameters	System type	**Stand alone**		
Horizon	Average horizon height	12.9°		
PV field orientation	Tracking, two axes			
PV modules	Model	BP275F	Pnom	75 Wp
PV array	Nb of modules	12	Pnom total	**900 Wp**
Battery	Model	Volta 6SB100	Technology	vented, plates
Battery pack	Nb of units	16	Voltage / Capacity	**24 V / 800 Ah**
User's needs	Daily profiles	Constant over the year	Global	913 kWh/year

Horizon :	Average height	12.9 °	Diffuse factor	0.93
	Albedo fraction	80 %	Albedo factor	0.36

Height [°]	21.0	21.0	19.0	18.0	18.0	17.0	18.0	17.0	17.0	15.0	13.0	13.0	12.0
Azimuth [°]	-180.0	-166.0	-159.0	-157.0	-155.0	-154.0	-152.0	-150.0	-144.0	-141.0	-137.0	-134.0	-132.0
Height [°]	11.0	11.0	12.0	12.0	11.0	10.0	10.0	9.0	9.0	8.0	9.0	9.0	8.0
Azimuth [°]	-121.0	-120.0	-118.0	-117.0	-115.0	-113.0	-111.0	-108.0	-106.0	-105.0	-102.0	-100.0	-99.0
Height [°]	8.0	7.0	7.0	6.0	6.0	5.0	4.0	4.0	3.0	3.0	2.0	1.0	1.0
Azimuth [°]	-98.0	-97.0	-92.0	-91.0	-90.0	-89.0	-88.0	-84.0	-83.0	-82.0	-81.0	-80.0	-79.0
Height [°]	3.0	4.0	5.0	6.0	6.0	5.0	5.0	4.0	4.0	3.0	3.0	4.0	5.0
Azimuth [°]	-76.0	-75.0	-74.0	-70.0	-68.0	-64.0	-61.0	-56.0	-51.0	-42.0	-40.0	-37.0	-36.0
Height [°]	5.0	6.0	6.0	7.0	10.0	11.0	11.0	10.0	11.0	11.0	12.0	12.0	13.0
Azimuth [°]	-35.0	-34.0	-33.0	-30.0	-23.0	-22.0	-19.0	-18.0	-16.0	-9.0	-8.0	-7.0	-6.0
Height [°]	13.0	14.0	15.0	14.0	14.0	13.0	13.0	14.0	14.0	15.0	15.0	14.0	14.0
Azimuth [°]	-3.0	-1.0	1.0	6.0	9.0	12.0	17.0	18.0	23.0	26.0	38.0	39.0	41.0
Height [°]	13.0	13.0	12.0	12.0	11.0	12.0	12.0	13.0	13.0	12.0	12.0	11.0	10.0
Azimuth [°]	42.0	51.0	54.0	64.0	65.0	67.0	80.0	83.0	95.0	97.0	98.0	100.0	106.0
Height [°]	10.0	11.0	12.0	12.0	13.0	13.0	14.0	14.0	16.0	16.0	20.0	20.0	21.0
Azimuth [°]	108.0	112.0	113.0	115.0	116.0	118.0	122.0	123.0	127.0	128.0	138.0	139.0	141.0
Height [°]	22.0	22.0	23.0	23.0	24.0	24.0	23.0	22.0	21.0	21.0			
Azimuth [°]	143.0	146.0	147.0	149.0	155.0	159.0	163.0	170.0	172.0	180.0			

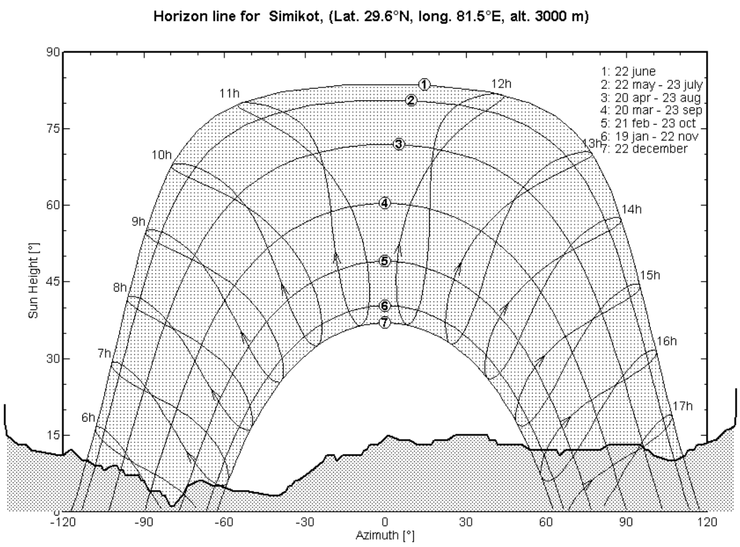

Figure 10–6: PVSyst3.31 Simikot Simulation Report page 2

Stand alone PV system: Detailed User's needs

Project : **Simikot**

Simulation variant : **Simulation variant**

Main system parameters	System type	**Stand alone**		
Horizon	Average horizon height	12.9°		
PV field orientation	Tracking, two axes			
PV modules	Model	BP275F	Pnom	75 Wp
PV array	Nb of modules	12	Pnom total	**900 Wp**
Battery	Model	Volta 6SB100	Technology	vented, plates
Battery pack	Nb of units	16	Voltage / Capacity	**24 V / 800 Ah**
User's needs	Daily profiles	Constant over the year	Global	913 kWh/year

Daily profiles, Constant over the year, average = 2.5 kWh/day

	0 h	1 h	2 h	3 h	4 h	5 h	6 h	7 h	8 h	9 h	10 h	11 h	
	12 h	13 h	14 h	15 h	16 h	17 h	18 h	19 h	20 h	21 h	22 h	23 h	
Hourly load	15.0	15.0	15.0	15.0	15.0	30.0	50.0	50.0	80.0	150.0	250.0	250.0	W
	150.0	150.0	200.0	200.0	200.0	200.0	100.0	120.0	100.0	100.0	30.0	15.0	W

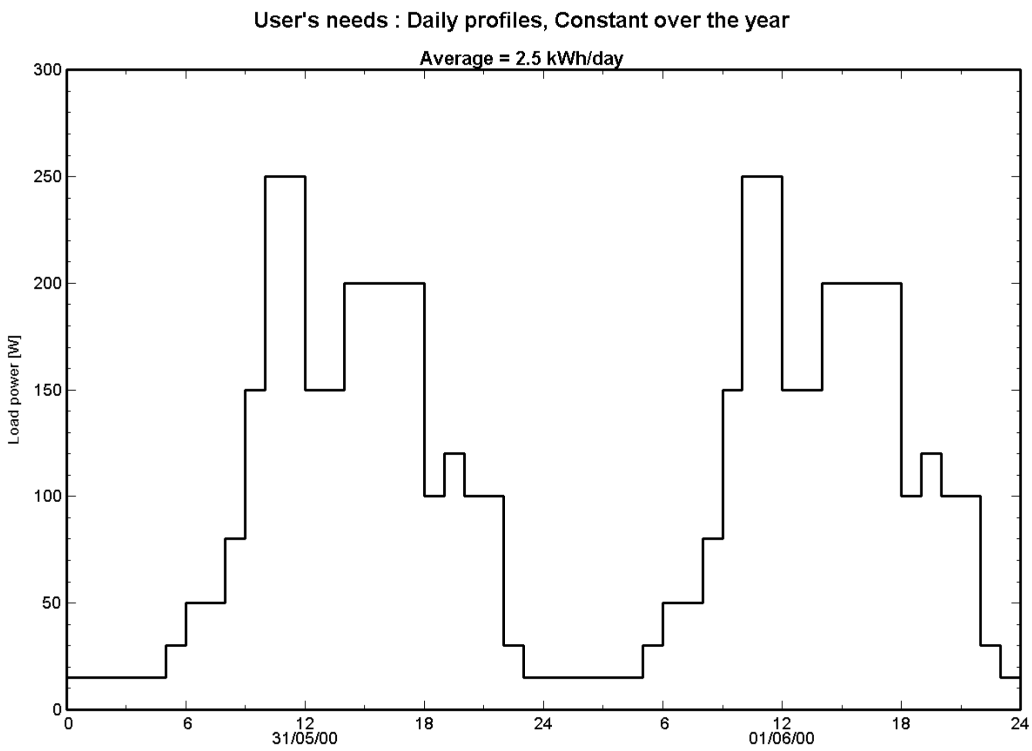

Figure 10–7: PVSyst3.31 Simikot Simulation Report page 3

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Stand alone PV system: Main results

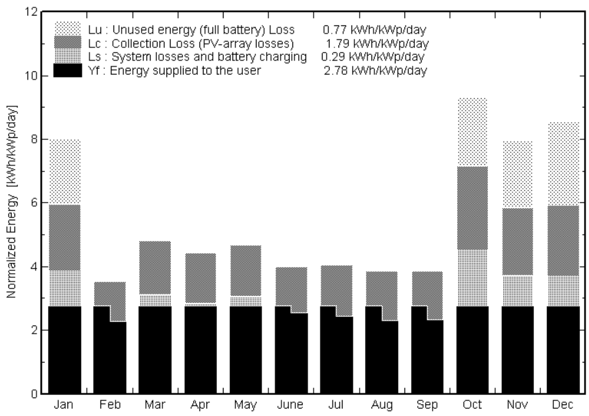
Project : **Simikot**

Simulation variant : **Simulation variant**

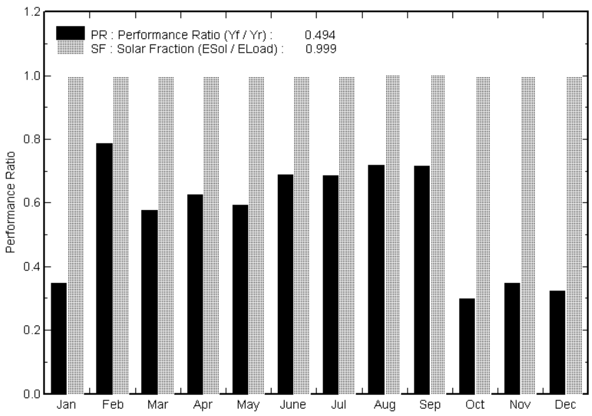
Main system parameters	System type	**Stand alone**		
Horizon	Average horizon height	12.9°		
PV field orientation	Tracking, two axes			
PV modules	Model	BP275F	Pnom	75 Wp
PV array	Nb of modules	12	Pnom total	**900 Wp**
Battery	Model	Volta 6SB100	Technology	vented, plates
Battery pack	Nb of units	16	Voltage / Capacity	**24 V / 800 Ah**
User's needs	Daily profiles	Constant over the year	Global	915 kWh/year

Main simulation results				
System production	Total	912 kWh/year	Specific	1013 kWh/kWp/year
	Performance ratio PR	49.4 %	Solar fraction SF	99.9 %
Loss of load	Time fraction	0.0 %	Missing energy	0.6 kWh
Investment	Global incl. taxes	817000 NRp	Specific	908 NRp/Wp
Yearly cost	Annuities (loan 0.0%, 20 years)	40850 NRp/yr	Running costs	19260 NRp/yr
Energy cost		**65.9 NRp/kWh**		

Normalized productions (per installed kWp): Nominal power 900 Wp



Performance Ratio and solar fraction



	GlobHor	GlobInc	E Avail	EUnused	E Miss	E User	E Load	SolFrac
	kWh/m²	kWh/m²	kWh	kWh	kWh	kWh	kWh	
January	137.3	248.0	77.31	56.85	0.189	77.31	77.50	0.998
February	80.5	99.0	70.00	0.13	0.003	70.00	70.00	1.000
March	130.1	149.6	77.49	0.14	0.012	77.49	77.50	1.000
April	134.4	133.0	75.00	0.19	0.001	75.00	75.00	1.000
May	158.6	145.2	77.47	0.32	0.025	77.47	77.50	1.000
June	135.6	120.9	74.98	1.29	0.020	74.98	75.00	1.000
July	139.4	125.7	77.53	0.11	-0.026	77.53	77.50	1.000
August	124.7	120.0	77.54	0.30	-0.040	77.54	77.50	1.001
September	111.5	116.3	75.03	0.16	-0.033	75.03	75.00	1.000
October	202.6	289.2	77.37	60.48	0.126	77.37	77.50	0.998
November	140.3	239.2	74.84	57.68	0.163	74.84	75.00	0.998
December	139.6	265.6	77.32	73.67	0.181	77.32	77.50	0.998
Yearly sum	1634.8	2051.7	911.88	251.32	0.622	911.88	912.50	0.999

Legends:				
	GlobHor	Horizontal global irradiation	E Miss	Missing energy
	GlobInc	Global incident in coll. plane	E User	Energy supplied to the user
	E Avail	Produced (available) Solar Energy	E Load	Energy need of the user (Load)
	EUnused	Unused energy (full battery) loss	SolFrac	Solar fraction (EUsed / ELoad)

Figure 10–8: PVSyst3.31 Simikot Simulation Report page 4

PVSYST V3.31	KU-ISIS HARS Simikot Solar PV System Simulation	23/04/04 09h20	Page 5/5

Stand alone PV system: Economic evaluation

Project : **Simikot**

Simulation variant : **Simulation variant**

Main system parameters	System type	**Stand alone**		
Horizon	Average horizon height	12.9°		
PV field orientation	Tracking, two axes			
PV modules	Model	BP275F	Pnom	75 Wp
PV array	Nb of modules	12	Pnom total	**900 Wp**
Battery	Model	Volta 6SB100	Technology	vented, plates
Battery pack	Nb of units	16	Voltage / Capacity	**24 V / 800 Ah**
User's needs	Daily profiles	Constant over the year	Global	913 kWh/year

Investment

PV modules (Pnom = 75 Wp)	12 units	30000 NRp / unit	360000 NRp
Supports / integration		10000 NRp / module	120000 NRp
Batteries (12 V / 100 Ah)	16 units	7000 NRp / unit	112000 NRp
Setting, wiring, regulator...			10000 NRp
3 Self-Tracking PV Module Fram			90000 NRp
Joker Sine wave 800 W + charge			80000 NRp
Battery Bank Box, Volt, Amp.			15000 NRp
Transport by bus, air and port			15000 NRp
Engineering			15000 NRp
Substitution underworth			-0 NRp
Gross investment (without taxes)			**817000 NRp**

Financing

Gross investment (without taxes)		817000 NRp
Taxes on investment (VAT)	Rate 0.0 %	0 NRp
Gross investment (including VAT)		817000 NRp
Subsidies		-0 NRp
Net investment (all taxes included)		**817000 NRp**
Annuities	(Loan 0.0 % over 20 years)	40850 NRp/year
Maintenance		5000 NRp/year
Insurance, annual taxes, ...		0 NRp/year
Provision for battery replacement	(Lifetime 7.4 years)	14260 NRp/year
Total yearly cost		**60110 NRp/year**

Energy cost

Used Solar Energy	912 kWh / year
Excess energy (battery full)	251 kWh / year
Used energy cost	**65.9 NRp / kWh**

Figure 10–9: PVSyst3.31 Simikot Simulation Report page 5

18.7. Appendix to Chapter 11 Social Village Survey

18.7.1. Household and Health Improvement with Solar Lights, Smokeless Stoves, Pit Latrines and Drinking Water

Household and Health Improvement with Solar Lights & Smokeless Stoves:
Baseline Questionnaire: Year 1 (2004)
The ISIS Foundation

General

1. VDC:
2. Village:
3. Name of household head:
4. Household head is (circle one): male female
5. Marital type (circle one): monogamous polygynous polyandrous
6. Self-described socio-economic status (circle one): Low Middle High
7. Group-described socio-economic status (circle one): Low Middle High
8. Kind and numbers of livestock

Type:	**Number:**
Cattle	
Yaks/Naks	
Dzopa/Dzoma	
Goats	
Sheep	
Horses	

9. Size and kind of land:

Type:	**Days work**
Ri-shing	
Nga-shing	

10. # rooms in house:
11. Housing material:
    a. Stone/Mud
    b. Stone/Dry masonry
    c. Stone/Plaster
    d. Other:
12. Cooking method:
    a. Open fire with stone support
    b. Open fire with metal/steel frame (that strong expensive ~6,000 NRp metal frame)
    c. Open fire with *odhan* (three legged steel frame)
    d. Metal stove door YES/NO, with hot tank YES/NO, chapatti baking facility YES/NO
    e. "Jumla" design smokeless metal stove
    f. Other:
13. Heating method:
    a) open fire
    b) smokeless metal stove (define the kind)
    c) "Jumla" design smokeless metal stove
14. Lighting method:
    a) jharro
    b) matitel (tupi)
    c) candle
    d) hydro power
    e) solar

15. Does this household have a latrine? How far away is it?

16. If the household has a latrine, who uses it?

17. If the household has no latrine, where do people *pisab garnu/disaa garnu*?

18. Source and distance of drinking/cooking water:

19. Is drinking water boiled before it is consumed?

20. If water is boiled for drinking, is it then covered when left in the house (before consumption)?

Demographic

21. Describe household composition (family members and other residents):

22. Residents of house--fill in this table:

Age group	**# Female**	**#Male**
0-4		
5-14		
15-49		
50+		

23. List name/age/sex of smokers in household.

24. List name, sex and years of education for any educated adults in household:

25. # current students in family:

Primary School	Secondary School
Female:	
Male:	

Social /Attitudinal Data

26. Average hour of rising males/females:

27. Average hour to bed males/females:

28. Describe evening activities for males and females (after dark):
    a. Female:

    b. Male:

29. Describe morning activities for males and females (before light):
    a. Female:

    b. Male:

30. Why do you want solar lighting? What changes do you think solar lighting will bring to your house?
    a. (male response:)

    b. (female response:)

31. Why do you want a smokeless stove? What changes do you think a smokeless stove will bring to your house?
    a. (male response:)

    b. (female response:)

32. What do you like about your current heating/cooking method?
    a. (male response:)

    b. (female response:)

33. What disadvantages do you anticipate to having a smokeless stove?
    a. (male response:)

b. (female response:)

34. # of *bari* and # of hours per week spent gathering wood (estimate)
    a. (male response:)

    b. (female response:)

35. What would you do with that time if you used ½ as much wood in a smokeless metal stove?

36. How many *bari* of wood a week do you think you will save? How many hours will you save?

Health Data (for nurse to collect)

37. # of residents with acute upper respiratory infection (AURI):

Age group	**Names of females with infection**	**Names of males with infection**
0-4		
5-14		
15-49		
50+		

38. # of residents with acute lower respiratory infection (ALRI):

Age group	**Names of females with infection**	**Names of males with infection**
0-4		
5-14		
15-49		
50+		

39. # of adults with diarrhea currently:

Age group	**Females—name and blood present y/n**	**Males—name and blood present y/n**
0-4		
5-14		
15-49		
50+		

40. # of adults with diarrhea within last 3 months:

Age group	**Females—name and blood present y/n**	**Males—name and blood present y/n**
0-4		
5-14		
15-49		
50+		

41. # of adults with intestinal worms currently:

Age group	**Names of females with infection**	**Names of males with infection**
0-4		
5-14		
15-49		
50+		

42. # adults with intestinal worms within last 3 months:

Age group	**Names of females with infection**	**Names of males with infection**
0-4		
5-14		
15-49		
50+		

43. For each child (under age 5) in the household, record the following information:

Measurement	Name	Name	Name	Name	Name	Name	Name	Name
Age in months								
BCG Scar Y/N								
Mid-upper arm circumference (cm)								
Weight								
Height/length (cm)								
Diarrhea Y/N								
Blood in diarrhea Y/N								
Dehydrated Y/N								
Worms Y/N								
Palmar pallor								

44. For each woman of childbearing age in the household, record the following information:

Measurement	Name	Name	Name	Name
Age				
Weight				
Height (cm)				
Palmar pallor				
Do you have to stop to catch your breath when walking at a moderate speed (do you stop more than normal)				
Do you walk more slowly than persons as old as you because of difficulty breathing?				

18.7.2. Additional Village Survey Data

Social status of the community

Social Economic Status of the Chauganphaya Village			
Social Status	*Households*	*Percent*	*Remark*
High	2	1.8	According to their own evaluation
Middle	58	50.9	
Low	50	43.9	
Missing	4	3.5	They could not evaluate themselves
Total	114	100	

Table 11-12: Social Economic Status of the Chauganphaya Village

Morning and evening activities according to the sex

Morning Activities of the Women			
Activities	*Households*	*Percent*	*Remark*
Clean the house	3	2.6	
Collect firewood	1	0.9	
Cook food	12	10.6	
Fetch water	13	11.4	
Field work	1	0.9	
Prepare/cook tea	74	64.9	
Spin wool	1	0.9	
Missing	9	7.9	
Total	114	100	

Table 11-13: Morning Activities of the Women

Morning Activities of the Men			
Activities	*Households*	*Percent*	*Remark*
Arrange for work	1	0.9	
Child care	1	0.9	
Collect “jharro”	1	0.9	
Drink tea	73	64.0	
Eat breakfast	1	0.9	
Fetch water	3	2.6	
Field work	3	2.6	
Light fire	1	0.9	
Prepare tea	6	5.3	
Smoke	1	0.9	
Spin wool	5	4.4	
Wake up children	5	4.4	
Washing the face	1	0.9	
Missing	12	10.5	
Total	114	100	

Table 11-14: Morning Activities of the Men

Evening Activities of the Women			
Activities	*Households*	*Percent*	*Remark*
Cleaning the house	1	0.9	
Cooking food	72	63.2	
Drink tea	1	0.9	
Eat meal	27	23.7	
Spin wool	1	0.9	
Wash dishes	3	2.6	
Missing	9	7.9	
Total	114	100	

Table 11-15: Evening Activities of the Women

Evening Activities of the Men			
Activities	*Households*	*Percent*	*Remark*
Child care	2	1.8	
Cooking dinner	5	4.4	
Eat meal	47	41.2	
Drink tea	1	0.9	
Fetch water	1	0.9	
Smoke	5	4.4	
Spin wool	41	36.0	
Wash dishes	1	0.9	
Missing	11	9.6	
Total	114	100	

Table 11-16: Evening Activities of the Men

Education level from 114 families

The average education level for men:

53 men with an average of 4.8 years of primary school education.

The average education level for women:

8 women with an average of 10.25 years of school education. This figures is confusing because out of all the 114 families, only 8 women have ever gone to school, and out of these 8 women, one young woman has 13 years of education, therefore the average seems rather high.

Average Animals per Family

Cattle: 2.3

Yak: 1.3

Dzopa (Yak-horse bread): 1.7

Goats: 12.6

Sheep: 12.6

Horses: 1.4

18.8. Appendix to Chapter 12 Chauganphaya Village Solar PV System

18.8.1. Formal initial Meeting with the Community's Eldership / Representatives

In this meeting the total number of households of the village, family names, population (back tracked over the last decade if possible to calculate the approximate annual growth rate) and age distribution is assessed. The local people share their experience with the light technology so far used (which is the tree resin lamps, called "jharro", for night lighting and any indoor work). Questions of income and social status can be asked, though with great care and in culturally appropriate ways. The Hindu caste system is very strong and families are clearly distinguished in castes, which mostly define the people's work, life style and opportunities.

Appropriate questions and language has to be used in order to get the right answers without offending the people in any way. The village eldership is advised (and helped if needed) to write a formal request letter for an elementary solar PV electrification project for their village, and sign it with thumb prints from each house owner. That is in done, so that the leadership shares the project idea with the whole community, and in order to have the backing of the whole community. From the beginning it creates a strong ownership feeling for the project among the local people. A demonstration is given, of the lights and the equipment to be installed, thus helping the people to have realistic expectations. Additional discussions and mutual sharing brings out various other information and data, which are not crucial but useful to know before designing stage of the project.

A useful, though not compulsory step is to undertake a detailed village survey, as mentioned in more detail in chapter 11. It provides valuable baseline data of a village in regard to their status of development, social structure, health and education level. These data can be compared with the data collected repeatedly at defined intervals, e.g. yearly, with the same survey being conducted after the project implementation. That enables the implementer to understand the actual impact a solar PV system has had on the community in the context of their life circumstances, and strive to develop their living conditions on an ongoing basis.

18.8.2. Geographical Conditions and Solar Irradiation Data

A solar PV system can be designed in various ways. Either with a back of the envelope calculation (as demonstrated in 12.6), or with the support of a professional solar PV simulation software tool, such as PVSyst3.31 (chapter 10).

In order to input geographical data for the calculation and design of a solar PV system with a software tool, various geographical and meteorological parameters have to be known. They can be acquired from various sources.

The geographical parameters:

- The village's latitude, longitude and altitude, can be read out from a good map within 15' accuracy. The exact location's latitude and longitude can be interpolated accordingly. The altitude is mostly given in maps for villages or clearly indicated spots. In the case of the Chauganphaya village, first an approximate extrapolation from the best available map of the area was carried out. Second a local altimeter measurement was taken, calibrated according to the Simikot airport altitude (2,946 m). Third, through the help of Mr. Remund from METEONORM[16], a satellite data measurement was taken as part of the "NASA-90m-horizon model", modeling the horizon around Chauganphaya, as significant high mountain ranges encircle the village. The altitude readings from the map and the altimeter have been both within 50 meters of the provided satellite data, which was taken as the most reliable.

- The village's local geographical conditions, such as the surrounding mountain range, can be included either through multiple joined pictures, a fish-eye picture, or a horizon angle calculation/estimation 360° (or at least 135° either side of direct south, as Chauganphaya lies in the northern hemisphere) around the village. NASA has developed a new model, called the "NASA-90m-horizon-model", which enables to create a 360° plot of the surrounding geographical conditions (thus ideal for mountainous areas) through satellite data.

  This plot can be imported into software packages such as PVSyst3.31 and METEONORM V.5, as used for the present project. That enables to simulate a rather accurate (360° within 90 meter height) horizon Figure of the local geographical location. This improves the accuracy of the simulation in particular in such a case as the Chauganphaya village, which lies at 2,643 meters altitude, fully surrounded by high mountains with heights of 4,000 – 6,000 meters. In case of Chauganphaya, that would mean, that if one looks around, the horizon is rather high (at an average straight angle of 23.9°). That limits naturally the length of sun hours per day, which has to be integrated into the solar PV system size calculation.

  The "NASA-90m- horizon-model" is still very new and thus not available as a software packet in the open market. Through a formal request and the provision of the detailed local conditions by the writer (through Figures, such as e.g. in 12-1) and geographical data from the map reading, it was possible that the software designer (notable Mr. Jan Remund) from METEONORM, calculated the detailed horizon conditions for the Chauganphaya village (as well as for the Simikot HARS conditions).

The meteorological parameters:

- The solar irradiation data (in kWh/m^2 per day$^)$ is the most important data for the solar PV system calculation and design. Again there are various ways to obtain these data. The best solution is to have long-term locally monitored and recorded data. Unfortunately that is often not possible, from a close by vicinity, in a developing country. A second approach is to extrapolate recorded solar irradiation data from a close by meteorological station, by taking the specific geographical conditions of the locality in mind into consideration. For the Chauganphaya village there has never been any solar irradiation data recorded, not even within the next few hundred kilometers. That is the major reason why the designing and starting of a solar irradiation data monitoring and recording programme has been part of this dissertation (see chapter 7). The third method to acquire solar irradiation data is through a database as e.g. NASA makes it available through the Internet. Over years ground data, where available, and satellite data, where no other data recording takes place, are collected according to regions of the globe. The major NASA Internet based meteorological database can be accessed by anyone under larc@eos.nasa.gov . For several examples of solar irradiation values under various angles and solar irradiation related data, such as the average monthly Albedo values, the monthly average Irradiation Clearness

Index K, or the Maximum NO-Sun days for each month for Nepal, see in the Appendix 1.4.1. – 18.4.5.

- Another way to create solar irradiation data for a defined location is through a solar PV software packet, which has an integrated solar irradiation database. Some of the software packets, which include such irradiation database, or have links included to the Internet to available solar irradiation database are PVSOL[17], Solar Design Studio[18], or RETScreen[19]. They provide long-term solar irradiation data for many international places (mostly cities), which are often close enough (within a range of 50 km) to be extrapolated for the particular place in question. But in order to create an acceptable solar irradiation database for a remote place, such as the village of Chauganphaya, without any possibility for an acceptable extrapolation of a close by city, no satisfactory solar irradiation data can be achieved.

  In the case of Chauganphaya village, the closest available data in these software packages are: New Delhi / Safdarjung, at a latitude of 28.58° North and a longitude of 77.20°, some 479.75 km air distance from Chauganphaya away in India[20]. Chengdu, a city just west of the Tibetan high plateau in China, is the other "closest" city. It lies at latitude of 36.67° North and a longitude of 104.02°[21]. With 22° more to the East, these data cannot be of relevance for the Chauganphaya village. Therefore in the case of the village of Chauganphaya the distance is one reason why the above meteorological stations cannot provide acceptable data.

  The other important reason for inappropriate data is their geographical differences. While New Delhi lies in the flat, open low altitude (100 – 200 m.a.s.l.) part of India, Chengdu lies to the West of the high altitude plateau of Tibet in central China. The vast difference in altitude, and geographical difference compared to the high altitude and extreme mountainous area of

Chauganphaya village, makes these meteorological data from New Delhi and Chengdu inappropriate.

- A third approach is to consult a meteorological software packets such as METEONORM from METEOTEST in Switzerland[22]. METEONORM is a valuable tool for solar energy applications (such as building design, heating and cooling), and renewable energy system designs. It is a computer program with a comprehensive climatological database for the calculation of solar energy data for any geographical location on the globe. With an easy to understand menu and platform, the user can specify a particular location on the globe for which meteorological data, such as the solar irradiation, are required. Drawing from an extensive database of over 7,000 meteorological stations around the world it generates solar irradiation data as well as other meteorological data in various formats required by solar PV system design software packets.

18.8.3. BP 275 F Solar PV Module

The reasons for choosing the BP275F solar PV module are:

1. More readily available in Nepal. This guarantees any future update possibilities, even for the village community.
2. It is a product from a well known international company with a good, solar PV module manufacturing reputation, established also in India now.
3. These PV modules are manufactured in, Bangalore, India, and thus can be considered as "locally" available (as Nepal imports 90% of its goods from its neighboring country India).
4. This PV module at 373 NRp/ W_R (5 US$ /Watt), has the best price/Watt ratio compared to other PV modules imported from abroad, which are between 400 – 440 NRp (5.46 – 6 US$/W).

5. The BP275F module's high technical quality and performance. The module is a Si-mono (silicon-mono-crystalline) module with an efficiency per cell area of 13.49 %, or efficiency per module area of 12.03 %[23]. Other comparable solar PV modules' efficiency per module area:

PV Module Brand	*Rated Power Output*	*Type*	*Efficiency*
PHOTOWATT PW 750	75 W	Si-poly	10.90%.
GVP 075	75 W	Si-poly	11.74%
Shell SP75	75 W	Si-mono	11.86%
ASTRO AP-75	75 W	Si-mono	11.74%

Table 12-1: Solar PV Module Efficiencies

The BP275F has a Temperature coefficient of –0.44%/ºC, while all above listed competitive modules have a slightly higher temperature coefficient of –0.45%/ºC – 0.47%/ºC. Further, the BP275F is with 7.5 kg/module 0.1 – 0.7 kg/module lighter than its competitors[24]. Though this does not seem to be so important, for our Chauganphaya Village solar PV system, which is so remote that all material has to be flown into Simikot by air plane and the carried by porters for one day, this results in slightly lower air plane costs and porter costs. This is important for the overall system costs calculation.

6. BP guarantees 12 years 90% and 25 years 80% rated power output on the BP275F solar PV module.

With the help of the Sandia Photovoltaic Performance model I-V Curve Tracer, included in the Solar Design Studio[25], a performance simulation with the four 75 W BP275F solar PV modules has been carried out. The following parameters were input:

- By choosing the BP275F PV module, the software inputs all the specific module parameters stored in its database.
- The altitude of Chauganphaya with 2,643 meters.

- The solar irradiation ratio of 900 W/m^2 beam radiation and 100 W/m^2 diffuse irradiation, totaling an irradiation of 1,000 W/m^2.
- The ambient temperature 20° C.
- The wind speed of 2 m/s.
- Sun elevation 30° over the horizon, and the solar PV modules are perpendicular to the sun.
- The 24 Volt system for the four modules (2 serial and 2 parallel connected).

The software calculates the maximum power output of the solar array (4 x 75Watt) of 265.32 W (at V_{mp} 30.18 V and I_{mp} 8.79 Amps), at a cell temperature of 47.45° C. With a fill factor FF of 0.711 the solar array generates power with 10.52% efficiency.

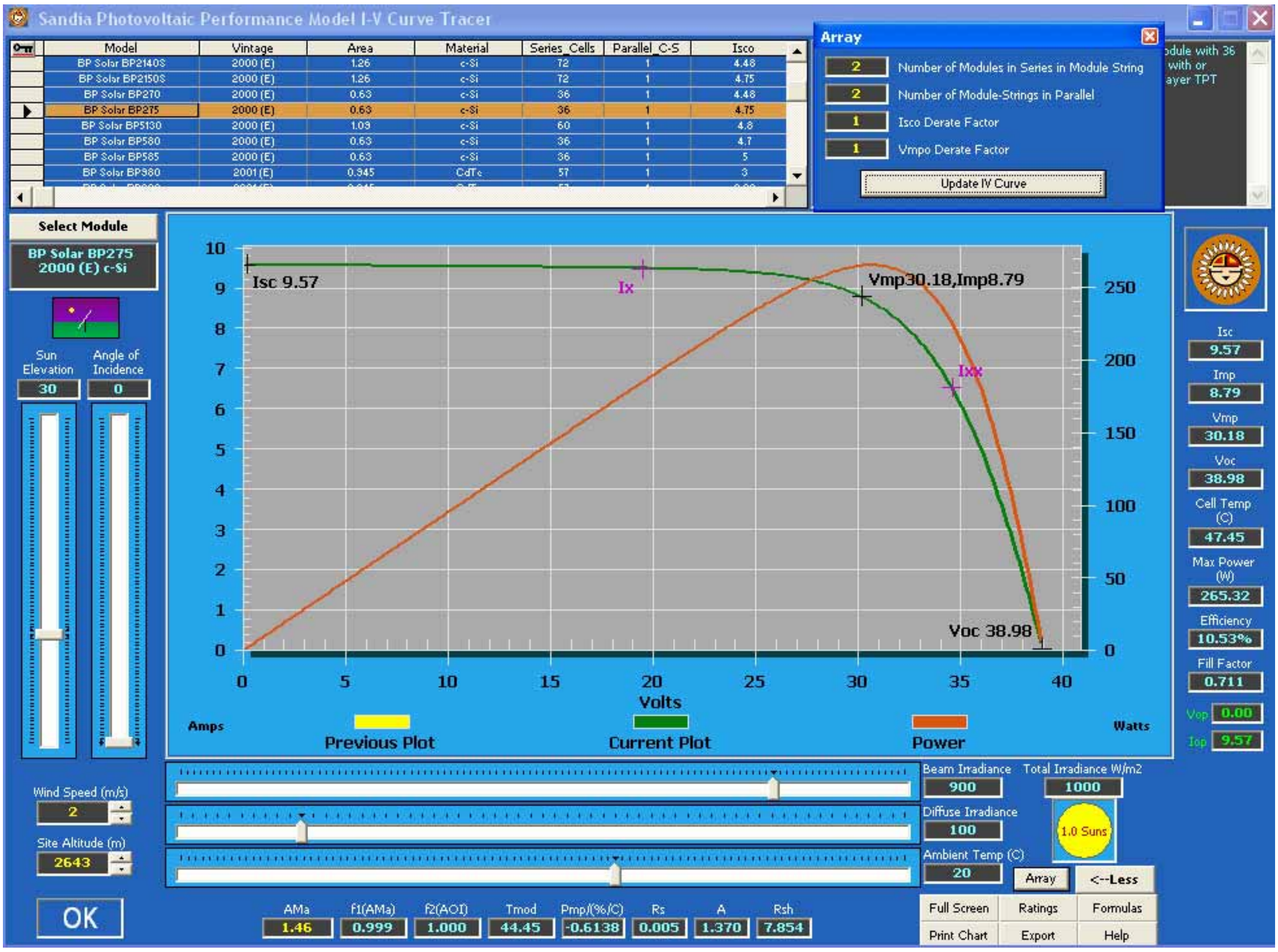


Figure 12-19: Sandia Photovoltaic Performance model I-V Curve Tracer software

Simulation of the four 75 Watt BP275F solar PV modules for the Chauganphaya village system.

Points which have been considered with regard to the solar PV modules installation and operation:

- Proper positioning of the solar PV module(s), surrounded and firmly tied to the self-tracking frame, able to bear the strong spring winds/gusts.
- PV modules are cleaned 2 - 3 times/week before sunrise or after sunset.
- The armored wires from the solar PV module(s) to the battery bank are UV stabilized, and thus properly protected for years to come.
- From 2 solar PV modules on a 24 Volt DC system voltage is chosen to minimise the current losses. Thus slightly thinner copper wires can be chosen, which in turn are cheaper to buy and with less transport costs.

18.8.4. 2-Axis Self-Tracking Solar PV Module Frame

A solar PV module generates the highest power output if it is under a perpendicular angle to the sun (as seen in the above Sandia I-V Curve Tracer Figure 12-19). In order to achieve that throughout the day, the solar PV modules have to be mounted on a 2-axis tracking frame, which changes its position continuously in 2 dimensions, as the sun moves along its daily sun path. This technology is not new, but so far it turned out that a solar PV array > 1 kW only could be considered to include a self-tracking frame, due to the high cost. The major costs are for the 2-axis self-tracking electronic controlled tracking device (with an integrated daily sun path program) and two-dimensional geared hydraulic cylinder system. In the course of the last 3 years an intensive development took place with regard to an appropriate, simple and affordable solar self-tracking frame for the context of Nepal, in order to utilise the high solar energy resource more appropriately. The following philosophy was pursued. The East to West sun tracking path has to be automatic, from the East at sunrise, to the West at sunset, and back in the morning. The sun's position in the sky according to the solar declination and the local latitude can be adjusted manually on a periodical basis. Tests have shown that weekly or even monthly adjustment of that angle are sufficient with minimal deviation (within 5%) of the maximum power output of a constantly adjustable 2-axis self-tracking frame (that data was measured by comparing the perfectly perpendicular position under the sun throughout the day with the 2-axis self-tracking frame as used in the Chauganphaya village solar PV system). Thus, the manual variable axis can be adjusted from 5° to 60° in the North-South axis (in the Figure 12-20, the manual changeable axis is at an angle of 40° during the second part of the month of March). Thus, while it is not a "perfect" 2-axis self-tracking frame, it tracks the sun automatically throughout the day from East to West, with the ability to manually adjust the North-South axis. After 3 stages of development and intensive tests, the following 2-axis self-tracking frame (Figures 12-4 and 12-20) is now installed in the Chauganphaya Village solar PV system.

Figure 12-20: 2-Axis Self-Tracking Frame 2
2-axis self-tracking frame right after sunset. The tracker has a minimum azimuth angle of -170° (fully East), and a maximum azimuth angle of 10° (fully West as in the Figure). Thus the tracker tracks the sun over an angle of 160° during the course of one full sunny day.
During the spring season (March – May) every year strong winds occur due to the intensive thermal movements of the upraising air from the ground. In order to hold the frame and solar PV modules secure, the tracking frame is constructed at its base in such a way that it can be filled with a pile of stones, once it is installed.

Figure 12-21: 2-Axis Self-Tracking Frame 3
Right after sunrise, the 3rd 2.5 Watt solar PV module (fixed at the top left of the frame) supports the initial start to move the frame towards East from the fully West position it reached the evening before. On top of the frame in the middle can be seen the two 2.5 Watt solar PV modules mounted with a 30° towards each other.
One 2.5 W PV panel's plus is connected with the other panel's minus, in order to power the gear box (fixed on the frame) in the direction perpendicular to the sun. In that position the two 2.5 Watt solar PV modules generated equal power and thus the gear box does not turn.

Points which have been considered with regard to the 2-axis self-tracking frame installation and operation:

- The self-tracking frame is installed on the flat mud roof of the powerhouse. The position has been chosen in such a way that throughout the year at no time of the day, can any shading occur due to other homes, trees or growing shrubs.
- The self-tracking frame foot stand has been designed with cross bars at the bottom, in order that a stone pile can be filled within the four legs of the stand (as cement is prohibitive in Humla and thus not appropriate). That provides the self-tracking frame with enough weight to keep it firm on the ground, during the harsh spring winds and gusts. Further, the cross bars at the bottom each have 4 holes through which long metal nails are driven, right into the wooden beams of the mud roof. That further assures a safe and strong installation.
- The gear box is protected with a cover, so that no rain or melted snow water can enter and take the grease away from the gear box wheels.
- There is a hole at all four ends of the self-tracking frame (two at the top and two at the bottom). This enables one to fix the self-tracking frame in a fixed position with four strong nylon ropes, in case a longer lasting storm occurs. In that position the motor which drives the gear box is disconnected through the installed plug.
- The self-tracking frame is adjusted twice a month in the North-South axis to make up the change of solar declination, according to a monthly angle list.

18.8.5. Solar Charge Controller

High sustainability, long life expectancy and appropriate lighting for the context, are part of the key aims for the design of the Chauganphaya elementary solar PV system electrification. The major responsibility of the solar battery charger is to manage the energy input into the battery bank which has been generated by the solar PV modules. The aim is, to store all the generated electricity in efficient ways in the battery bank. For the Chauganphaya village solar PV system a special charge controller, to charge lead-acid, vented plate batteries, has been built by the local company Pico Power Nepal (PPN) according the following demands:

- System voltage 12 VDC and 24 VDC possible.
- Voltage range input from the solar PV array: 0 - 40 VDC.
- Current range input from the solar PV array: 0 – 30 Amps (allowing any future doubling of the PV array size).
- Series transistor technology.
- Trickling charging, starting at 27.4 VDC.
- Over charge protection at a maximum Voltage of 28.8 VDC.
- Gassing Regulation: Monthly equalisation charge (up to 30.8VDC, which is around 2.57 VDC per battery cell for each 2V cell of the 12 cells serial connected to make up the 24 VDC battery bank).
- External temperature sensor with a reference temperature of 20° C.
- LED Indicators to display the battery bank charge condition.
- One maximum 12 VDC, 0.5 Amp (max. 6 Watt) output connection for WLED lights, and a battery charger for the rechargeable multimeter and torch battery (which are part of the maintenance tools), in the powerhouse.
- Lightning protection.
- Low parasitic power consumption.

- Reverse polarity protection.
- Life expectancy 8 – 10 years.
- Stand by unit (in case the installed one fails) immediately (on call) available.

Points which have been considered with regard to the Charge Controller technology, installation and operation:

- The charge controller is manufactured locally, in Nepal, and thus there is the ability to repair or even exchange it, in case of malfunction.
- To have it installed in a dry place where no rain water will drip (this is important as the roofs are mud roofs, and they will always leak for the first 2 - 3 years).
- To have it installed about 1 meter above the battery bank, in order to prevent any possibility of hydrogen gases from the boost charging to enter the charge controller (see Figure 12-8).
- To be able to have a good margin of oversizing in regard to solar PV array current input, even if the system is run on 12 VDC with one additional, a 5^{th} (and thus maximum 22.5 Amps input), or up to three additional, or 7 solar PV modules (and thus maximum 31.15 Amps (7 x 4.45 Amps) input with 12 VDC), or up to 8 solar PV modules (and thus maximum 18 Amps input with 24 VDC). In that way the solar PV system can be increased up to 100% in size according to the local community's budget, if the future load growth demands it.
- There are 5 spare fuses inside the charge controller.
- For any fuse exchange, the charge controller can be opened through screws, with the available tools that the trainees have been trained with.

18.8.6. Solar Discharge Controller

The battery bank discharger is an important part in guaranteeing the ability of the battery bank to provide the daily WLED load demand over a battery bank life expectancy of 8 - 10 years (and thus to change the battery bank only once throughout the solar system's, 20 years life expectancy). The battery bank discharger's major responsibility is to manage the energy output from the battery bank. The aim is, to efficiently provide all the energy demand for the initial 189 WLED lights up to 5 hours a day. Further, that energy demand should be able to be provided over a defined time period of at least 5 days without sunshine (which is according to the AUS RAPS system standard AS 4509.3, chapter 3.4.7.8 which demands typically 5 – 10 days independence for a RAPS solar PV system's battery bank without backup generator).

The following demands were defined for the solar discharge controller, before it was manufactured locally by PPN:

- System voltage 12 VDC.
- Minimum Battery Bank voltage threshold (after which the power is cut) of 11.8 VDC for the 12 VDC system voltage.
- Reconnection voltage of 12.6 VDC after the power has been cut.
- Battery Bank Voltage indication with red LEDs with 5 levels, from low to 15 VDC (see Figure 12-7).
- Output from two power lines with the capability of powering 140 one Watt WLED lights each. That enables a future load demand growth of households in Chauganphaya over the next 10 years.
- Two equal discharge controller are installed for different clusters of up to 20 homes each. That means that one single discharge controller can take the load of the whole village's light load demand in case one breaks down.

Points which have been considered with regard to the Discharge Controller technology, installation and operation:

- The discharge controller is manufactured locally, in Nepal, and thus there is the ability to repair or even exchange it, in case of mal function.
- To have it installed in a dry place where no rain water will drip on it.
- To have it installed about 1 meter above the battery bank, in order to prevent any possibility of hydrogen gases from the boost charging to enter the discharge controller (see Figure 12-8).
- There are 5 spare fuses inside the discharge controller.
- For any fuse exchange, the discharge controller can be opened through screws, with the available tools that the trainees have been trained with.

18.8.7. Battery Bank

In the following are the important conditions and parameters defined for the Chauganphaya Village solar system battery bank. The " = " sign indicates the condition to be fulfilled:

- High reliability, low maintenance, safe to use, high energy efficiency, appropriate cost. The VOLTA 6SB90 Solar Deep Cycle battery fulfills that.
- Battery Bank System Voltage = 24 VDC.
- Number of days of Independence of sunshine = 5 - 6 days.
- Battery Bank capacity = 400 Ah (defined according to the daily load demand and days of independence of sunshine), @ 24 VDC and @ C_{20} (discharge time 20 hours).
- Maximum Depth of Discharge (DoD) = 0.35. That means that the battery bank is never more discharged than 35% even after 5 days without sunshine.

- Battery electrolyte gravity 1,250 gr/liter.
- The battery bank is exposed to a High Altitude Himalayan climate, and therefore needs appropriate insulation to be kept between 15 °C and 20 °C throughout the year.
- A demanded life expectancy of 8 – 10 years. The life expectancy of a battery depends on the amount of DoD cycles (length of days without sunshine), the temperature changes (seasonal), the discharge current (different load demands), gravity of the sulfuric acid electrolyte, and ratio of day to night load.

Points which have been considered with regard to the Battery Bank size, installation and operation:

- The battery bank is installed in a locally made wooden box with a lid, and insulated with the original packing material (carton box and Styrofoam cover) within the powerhouse. Further, locally available insulation materials, such as silver perch tree bark and pine tree needles, have been used. The battery box has two holes on each longer side, one at the bottom end and one at the top end, in order to have a constant slow air flow to prevent any dangerous hydrogen concentration within the battery box. Ideally these two holes are connected to the outside air, though in this case, as the powerhouse is a stone masonry house with wooden beams and a flat mud roof, the house itself provides a satisfactory constant air draft to get rid of any hydrogen generated through the monthly boost charging of the battery bank. The insulated battery box keeps the battery bank at a constant temperature throughout the year between 15°C - 20°C, a good range for the battery bank's charging and discharging rates[26].

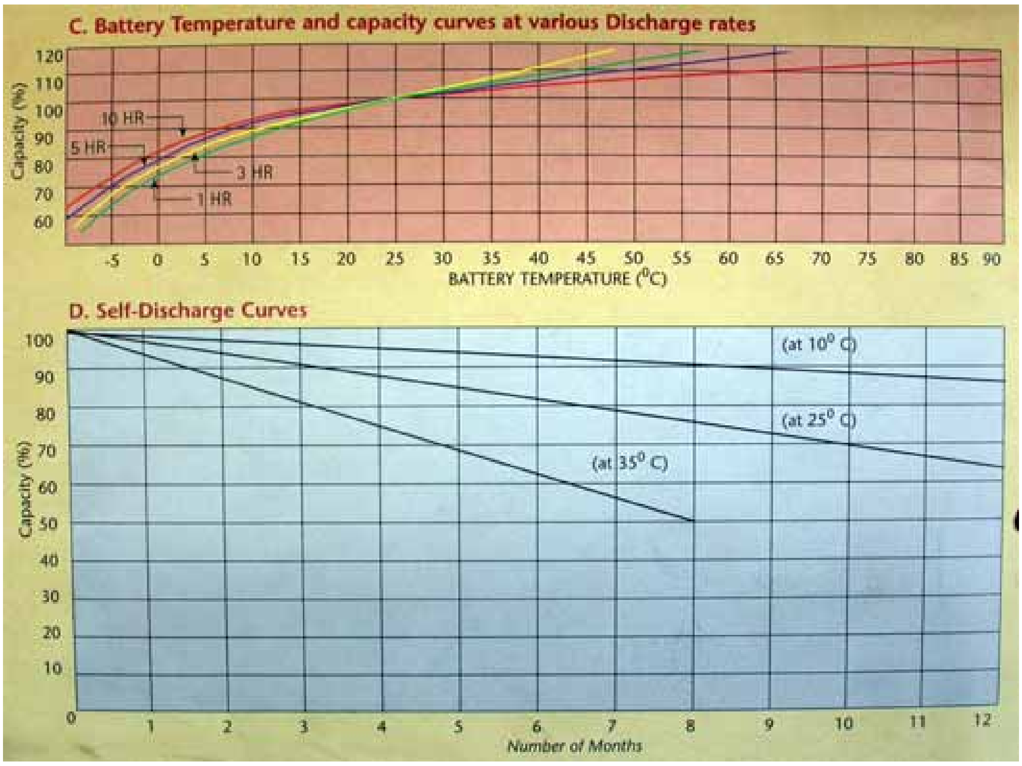


Figure 12-22 Battery Temperature and Capacity Curves
Volta Solar Deep Cycle Battery Temperature and Capacity Curves at various Discharge rates, and Self-Discharge Curves[27].

The measured average temperature in the insulated battery bank wooden box various between 15°C - 20°C throughout the year.

The Volta 6SB90 battery has a > 95% energy capacity at the 10 hour discharge rate. With a longer discharge rate, as that is the case in Chauganphaya, the capacity is close to 100%. Also the self-discharge rate is low at the temperature range of 15°C - 20°C.

- The battery bank size capacity is designed in such a way that it is never more discharged than 35% (or a DoD of maximum 0.35), even after 5 days without sunshine. True, that demands a rather big battery bank and high costs, but on the other hand the battery bank will last around 8 - 10 years. For such a remote and difficult to access area it is worth investing in an appropriate battery bank size from the beginning, as it is not advised to add any new batteries to a battery bank, which is already in use for more than 3 months.
- The 2 Chauganphaya solar PV system trainees have been trained, during the 1 week training to measure the battery bank's voltage four times a day and input the data into an Excel sheet table, that has been prepared and provided. The WLED lights in Chauganphaya are mainly in use during two time periods each day. In the morning for about 3 hours and in the evening for about 2 hours, with a total daily load of approx. 700 W/day (140 WLED lights @ 5 hours/day, or 75% of all 189 installed WLED lights). See for a

more detailed load profile page 3 of the PVSyst3.3.1 report in the Appendix Chapter 18.8.11. PVSyst3.31 Chauganphaya Village PV System Simulation Report. Thus the battery bank is measured before and after the morning light period, as well as before and after the evening light period. This detailed data collection over a long-term period will provide an understanding of the battery bank's daily state of charge, throughout the seasonal changes.

18.8.8. Underground Cables and House Wiring

The village has a centrally located solar PV system, in order to utilize the four 75W solar PV modules mounted on the self-tracking frame all day long at their highest power output under the prevailing solar radiation conditions. The solar PV system is designed for 63 homes, situated on a small elevated plateau, as can be seen from the Figures 12-1 and 12-16. There is a huge problem of deforestation throughout the Nepal Himalayas, and in particular in the high altitude areas, as trees grow much slower. Mainly one kind of tree grows here, the Himalayan pine tree, or locally called, "salla". Therefore in all of the construction endeavours, it is important to save trees. The strong spring winds (March - May), the sporadic heavy monsoon rains during the months of July - September, which turn little streams into dangerous rivers within hours, causing floods, landslides and huge soil erosion, as well as the snow fall during the month of January - February, are all nature's seasonal phases experienced in the Chauganphaya village. It is just not possible for a wooden pole made from a soft tree like the "salla", to withstand all these natural calamities for years. With an aim to building a sustainable elementary electrification system, these preconditions are not acceptable for a wooden pole transmission line connection from the central powerhouse to each of the consumers homes. Therefore underground cabling (90 cm deep buried), with armored cables of different copper sizes (see Figures 12-23 to 12-24) according to the load size, were chosen. The 63 homes are divided into 4 clusters with 15 – 20 homes each, according to their geographical location in regard to the powerhouse. For the underground transmission lines, 3 different sized armored copper cables are used. From the powerhouse to the cluster center, the thickest armored copper cable of $4mm^2$ size is used, as it is the longest distance (Figure 12-11). The $2.5mm^2$ thick armored cable, with 2 copper strings (Figure 12-23), is used from the cluster center to each individual home, if the distance is > 10 m, otherwise, where homes are very close, or < 10 m from each other (see in Figure 12-16 and 12-17 how close some of the homes are built together and on top of each other), the $1.5mm^2$, 2 copper lid armored cable (Figure 12-24), is installed.

The following table shows the 3 different installed armored copper cables' specification (provided by the Nepali cable manufacturer), load capability, WLED light load they carry, load ampere (allowing for ~ 20% additional DC current transmission losses), as well as future load growth ability:

Cable Size	Copper Strings	Max. Amps	WLED Lights	Power in Watt	Load Amps NOW	Volt DC	Installed for	Weight kg / m	Price NRp/m	Poss. Load Growth
$4mm^2$	2 @ 7	41	60	60 - 80	8	11–12.5	To Cluster	0.60	100	~ 5 times
$2.5mm^2$	2	32	3 - 60	5 - 80	0.5 - 8	11–12.5	In Cluster	0.47	80	~ 4 times
$1.5mm^2$	2	23	3 - 20	5 - 25	0.5 – 2.5	11–12.5	In Cluster	0.32	60	~ 10 times

Table 12-2: Armored Underground Cables used in the Chauganphaya Elementary Electrification Village Solar PV System

Figure 12-23: Armored cable 2.5.mm^2
$2.5mm^2$, 2 copper string armored cable, able to carry 32 Amp and 1,100 Volt, at up to 70° C conducting temperature.

Figure 12-24: Armored cable 1.5.mm^2
$1.5mm^2$, 2 copper string armored cable, able to carry 23 Amp and 1,100 Volt, at up to 70° C conducting temperature.

The armored cables are installed underground, right into the inside wall of each individual home. Inside the homes, the standard Nepali 40/60 house wiring cable (as can be seen in Figure 12-12 and 12-24with the WLED light) is used to install the 3 WLED lights, each with one off/on switch.

18.8.9. WLED Lights

Chapter 5 discussed in detail the whole issue of the various possible lighting technologies available in Nepal and those applicable for the Chauganphaya village context. In the following Figures the WLED (white light emitting diode) lights which have been developed and manufactured over the last 6 years in Nepal, and which now are also installed in the homes in Chauganphaya Village, are demonstrated and explained.

Figure 12-25: Installation WLED Light 2
The installation of the WLED light is important. House wires have to be installed at the bottom or at the side of the wooden beam to protect them from mice. Further the WLED lights are usually installed in the corners of the rooms, under a wooden beam, because they provide a more beam like light and therefore can easier be adjusted under a beam to the place they are intended to brighten up. Further, under the wooden beam they are to some extend protected from the dried up mud, which falls periodically down from the roof.

Figure 12-26: WLED Light On
Each of the 9 WLEDs consumes 20-25mA @ 3.6VDC. That amounts to ~800mW for a 9 WLED Nichia light as installed in the Chauganphaya village homes. Allowing some power transmission losses means that 1 Watt power consumption with about 23 lumens illuminance can be accounted for.

18.8.10. Holistic Project Approach

Smokeless Metal Stove

Families in the remote areas use precious firewood for cooking, room heating and light. These activities, especially the indoor cooking on open fire places, have a direct chronic impact on the health and the extremely low life expectancy for women and the high death rate of under 5 years of age children[28]. Deforestation has reached alarming conditions. An efficient smokeless metal stove, for cooking and heating, consuming only half the firewood, has been developed and designed for these remote and impoverished mountain communities. The smokeless metal stove takes the local people's eating habits and cooking culture into consideration. It provides 9 liter hot water in a stainless steel water tank attached to the stove, for drinking and washing purposes, improving drastically the hygiene and health conditions of the family. It enables a smoke free, safe environment in the home, especially for women and children. Each family is enabled to buy one smokeless metal stove for 2,500 NRp (35 US$), or at about 40 % of the actual manufacturing and transport cost. The other 60 % of the smokeless metal stove's are subsidised by the project.


Figure 12-27: Smokeless Metal Stove in Chetri Family
A Nepali Chetri (caste) family cooking a traditional Nepali dish "Dhal Bhat". That is rice, a vegetable dish (if the season allows it), and lentils. The hot water is welcome to wash the face, hands and dishes, improving the families hygiene and health conditions. On the top left side of the stove is a slot for their flat, unleavened bread, which is part of their daily diet.


Figure 12-28: Smokeless metal stove in Tibetan Family
A Nepali Tibetan family cooking their daily meal in a smoke free and pleasant environment. It is safe for small children, as they cannot fall into open fires and get burned. In high altitudes it is of benefit to cook with pressure cookers (those who can afford it). That helps beside the 50% lower fire wood consumption of the smokeless metal stove, to further limit the firewood consumption. That helps limiting the deforestation, and the time for the daily collecting of firewood.

Maintenance

Two people from each family were trained in the installation of the stove, which is needed as this stove has some special features such as a double chamber towards the bottom which needs to be filled with semi-liquid mud to fill the insulation chamber. These two members, usually a woman and the house owner, are trained in cutting the firewood down to the right size, so as to be able to cook with the front door of the stove closed tight. They are trained to cook all three dishes (rice, the vegetable dish and lentils) of their traditional meal at one time, as up until now they had to cook one dish at the time on an open fire place. The stove has a dynamic air flow regulation in the front door and a dumper in the exhaust pipe. And because of this, the air intake, and thus the fire, can be regulated. The training includes the proper use and needed adjustment to these air flows according to the use of the stove (either for cooking or heating). They learn that the stove has to be emptied of its ash, and that the exhaust pipe has to be cleaned, once a week.

Pit Latrine

In order to get a subsidy on the smokeless metal stove, each family has to build a pit latrine after completion of a 3 days training provided by the project staff on "how to build an appropriate pit latrine", in this area and for an average sized family. Each family has to provide all the locally available materials such as stones and wooden beams, beside digging the ~ 2 m deep and ~ 2 m diameter septic tank. The project provides a siphon, cement for the floor and the polyethylene pipes for the septic tank and for ventilation.

Figure 12-29: Ready Pit Latrine 1
Proud to have participated in the building of their own pit latrine. Cleaner villages, cleaner walking paths, cleaner fields and rivers, will result in long-term better and stronger health.

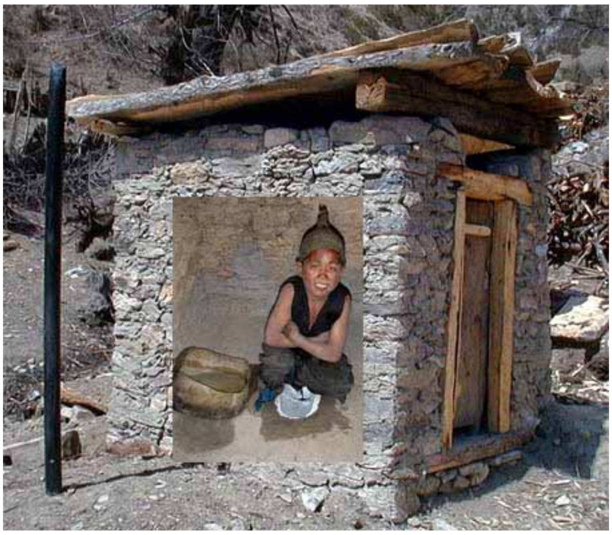


Figure 12-30: Ready Pit Latrine 2
The size of the septic tank is chosen according to the average family size of 7-11 people. The septic tank size is for up to 5 years. One ø 110 mm polyethylene pipe is into the septic tank, and one ø 55 mm polyethylene is for ventilation. The inside floor is laid out with cement.

Maintenance

As the pit latrine has a siphon, to keep the flies away, it needs a limited amount of water after each use. The training addresses issues such as how to keep the pit latrine clean and a way to teach children how to use it. It informs them of the approximate amount of years (~ 5 years for an average family size of ~ 7 people) until the septic tank is full, and needs emptying.

Drinking Water

Light, a smokeless metal stove, a pit latrine and clean, pure drinking water. Four basic needs for these high altitude communities in the Nepal Himalayas. These four issues address the most common sicknesses such as respiratory chest diseases, asthma, coughing, diarrhea, worms, and eye infections. The drinking water is tapped into at the spring, often way above the village, in the deep forests. The water source is protected with natural, thorny plants, such as the local "dhatello", in order to keep any wild, as well as domestic animals such as goats, away. If needed, a sand bed filter is built at the spring through which the water must first flow, before it is collected in a collection tank. From that tank, made out of stone masonry and a cement layer inside, the drinking water flows in polyethylene pipes of appropriate size (according to the spring's output), down to the village. If needed, every ~ 60 – 100 m altitude drop, a pressure break tank has to be built. From the last pressure break tank the water is led to the various tap stands in the village, from where the people collect it in their aluminum pots, the so called "kakro", as seen in the following two Figures 12-31 and 12-32. In the case of the Chauganphaya village, there has been a drinking water system built by the Government about 8 years ago. As it was never followed up and no one was trained to look after it and maintain it, it has been in a damaged state for the last several years. Thus it was part of the holistic project approach to repair that existing village drinking water system in partnership with the local people.

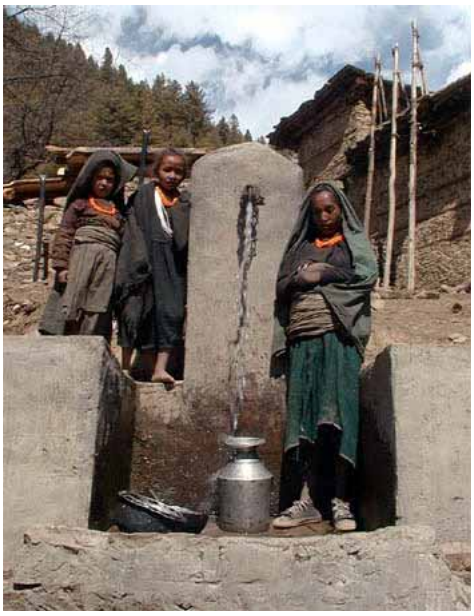


Figure 12-31: Drinking Water Tap Stand 1
Mostly girls and ladies collect the daily drinking water from the tap stands. Previously they had to walk far to the river and collect dirty river water for their daily drinking water, spending 2 hours a day for unclean water, causing sickness, such as worms and diarrhea. This time can now be spent in different, more profitable ways.

Figure 12-32: Drinking Water Tap Stand 2
The village drinking water systems are all gravity flow systems, with a water spring above the village. That enables a constant water flow, important to keep the system from freezing during the cold 4 winter months from November – February, with temperature down to – 25° C.

Maintenance

A drinking water committee is formed, in order to share the responsibility of maintaining the system. The following topics have been addressed:

- How to keep the spring intake clean and protected from any intruders.
- How to check the intake and pressure break tank(s).
- How to check the pipe connection points for leakage.
- How to keep the overflow at the tap stand clean and free of building up water, or form muddy puddles.

All these issues sound rather trivial and simple, but in order to have them taught to people for whom most of these issues are totally new, and thus often difficult to understand and grasp, demands total commitment, dedication and time and patience. But experience shows, that it is worthwhile investing in such trainings, as they build up a strong ownership feeling among the community for the newly implemented projetcs.

18.8.11. PVSyst3.31 Chauganphaya Village PV System Simulation Report

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Stand alone PV system: Simulation parameters

Project : **Chauganphaya Village Humla**

Geographical site : **Chaughanphaya Village** **Country** **Nepal**

Situation : Latitude 30.0°N Longitude 81.5°E
Time defined as : Legal time Time zone = 5 Altitude 2643 m
Monthly albedo values :

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Albedo	0.30	0.30	0.25	0.25	0.25	0.20	0.20	0.20	0.25	0.25	0.30	0.30

Meteo data : Chaughanphaya Village , synthetic hourly data

Simulation variant : **Simulation variant**
Simulation date 23/04/04 09h08

Simulation parameters :

Tracking plane, two axis Minimum tilt 5° Maximum tilt 60°
Rotation limitations Minimum Azimuth -10° Maximum Azimuth 10°

Horizon Average horizon height 23.9°

Near shadings No Shadings

PV array characteristics :

PV module: Si-mono Module name **BP275F**
Manufacturer BP Solar
Number of PV modules : in serie 2 modules in parallel 2 strings
Total number of PV modules : Nb. modules 4 unit nom. power 75 Wp
Array global power Nominal (STC) **300 Wp** At oper. cond. 270 Wp (50°C)
Array operating characteristics (50°C) U mpp 31 V I mpp 9 A
Total area Module area **2.5 m²** Cell area 2.2 m²

PV array loss factors :
Heat Loss Factor k (const) 20.7 W/m²K k (wind) 6.0 W/m²K / m/s
=> Nominal Oper. Coll. Temp. (800 W/m², Tamb=20°C, wind 1 m/s) NOCT 47 °C
Wiring ohmic losses Global field res. 33.0 mOhm Loss fraction 0.9 % at STC
Serie diode loss Voltage drop 0.7 V Loss fraction 2.1 % at STC
Module quality losses Loss fraction 3.0 %
Module mismatch losses Loss fraction 4.0 % (fixed Voltage)
Incidence effect: "Ashrae" parametrization IAM = 1-bo (1/cos i - 1) bo 0.05

System parameter: System type **Stand alone**

Battery Model **Volta 6SB100**
Manufacturer VOLTA
Battery pack characteristics Voltage 24 V Nominal capacity 400 Ah
Number of units (serie x parall) 2 x 4
Temperature Fixed (20°C)
Regulator Model PPN30/24
Manufacturer Pico Power Nepal
Technology uP, Series transistor Temp. coeff. -5.0 mV/°C/elem.
Battery management Thresholds Charging 27.4/25.2 V Discharging 23.8/24.5 V
Back-up gen. command 22.2/25.8 V

User's needs : Daily profiles Constant over the year
Average 0.7 kWh/day

Figure 12-33: PVSyst3.31 Chauganphaya Simulation Report page 1

Stand alone PV system: Horizon definition

Project : **Chauganphaya Village Humla**

Simulation variant : **Simulation variant**

Main system parameters	System type	**Stand alone**		
Horizon	Average horizon height	23.9°		
PV field orientation	Tracking, two axes			
PV modules	Model	BP275F	Pnom	75 Wp
PV array	Nb of modules	4	Pnom total	**300 Wp**
Battery	Model	Volta 6SB100	Technology	vented, plates
Battery pack	Nb of units	8	Voltage / Capacity	**24 V / 400 Ah**
User's needs	Daily profiles	Constant over the year	Global	255 kWh/year

Horizon :	Average height	23.9 °	Diffuse factor	0.77
	Albedo fraction	80 %	Albedo factor	0.20

Height [°]	17.0	18.0	18.0	17.0	17.0	18.0	20.0	22.0	42.0	51.0	48.0	46.0	35.0
Azimuth [°]	-180.0	-179.0	-170.0	-169.0	-167.0	-166.0	-165.0	-153.0	-150.0	-122.0	-119.0	-62.0	-59.0
Height [°]	30.0	28.0	24.0	15.0	10.0	10.0	11.0	11.0	12.0	12.0	13.0	13.0	14.0
Azimuth [°]	-51.0	-48.0	-32.0	-29.0	-28.0	-19.0	-18.0	-17.0	-16.0	-15.0	-12.0	-8.0	-6.0
Height [°]	14.0	15.0	11.7	15.0	16.0	16.0	17.0	17.0	16.0	15.0	15.0	14.0	14.0
Azimuth [°]	13.0	14.0	15.0	20.0	22.0	28.0	29.0	30.0	32.0	34.0	35.0	36.0	41.0
Height [°]	15.0	15.0	17.0	17.0	18.0	18.0	17.0	17.0	16.0	16.0	15.0	15.0	14.0
Azimuth [°]	43.0	47.0	49.0	50.0	51.0	55.0	56.0	59.0	60.0	62.0	63.0	67.0	68.0
Height [°]	15.0	15.0	16.0	16.0	18.0	18.0	17.0	17.0	16.0	16.0	15.0	14.0	13.0
Azimuth [°]	71.0	72.0	74.0	75.0	80.0	82.0	83.0	86.0	87.0	88.0	89.0	90.0	91.0
Height [°]	14.0	14.0	13.0	12.0	12.0	13.0	13.0	12.0	11.0	10.0	10.0	9.0	9.0
Azimuth [°]	92.0	93.0	95.0	97.0	101.0	104.0	111.0	112.0	113.0	114.0	116.0	117.0	119.0
Height [°]	8.0	8.0	9.0	11.0	12.0	13.0	13.0	14.0	14.0	15.0	15.0	14.0	14.0
Azimuth [°]	120.0	126.0	135.0	138.0	140.0	142.0	143.0	144.0	145.0	146.0	150.0	152.0	154.0
Height [°]	15.0	15.0	16.0	16.0	17.0	17.0	18.0	18.0	17.0	17.0			
Azimuth [°]	157.0	161.0	162.0	167.0	168.0	169.0	170.9	175.7	177.0	180.0			

Horizon line for Chaughanphaya Village , (Lat. 30.0°N, long. 81.5°E, alt. 2643 m)

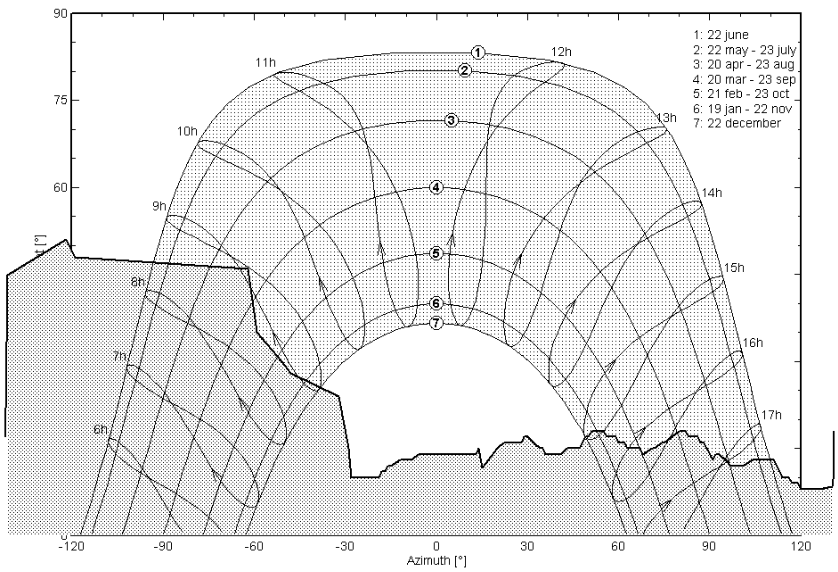

Figure 12-34: PVSyst3.31 Chauganphaya Simulation Report page 2

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Stand alone PV system: Detailed User's needs

Project : **Chauganphaya Village Humla**

Simulation variant : **Simulation variant**

Main system parameters	System type	**Stand alone**		
Horizon	Average horizon height	23.9°		
PV field orientation	Tracking, two axes			
PV modules	Model	BP275F	Pnom	75 Wp
PV array	Nb of modules	4	Pnom total	**300 Wp**
Battery	Model	Volta 6SB100	Technology	vented, plates
Battery pack	Nb of units	8	Voltage / Capacity	**24 V / 400 Ah**
User's needs	Daily profiles	Constant over the year	Global	255 kWh/year

Daily profiles, Constant over the year, average = 0.7 kWh/day

	0 h / 12 h	1 h / 13 h	2 h / 14 h	3 h / 15 h	4 h / 16 h	5 h / 17 h	6 h / 18 h	7 h / 19 h	8 h / 20 h	9 h / 21 h	10 h / 22 h	11 h / 23 h	
Hourly load	5.0	5.0	5.0	5.0	5.0	20.0	75.0	90.0	60.0	20.0	5.0	5.0	W
	5.0	5.0	5.0	5.0	5.0	20.0	75.0	90.0	80.0	60.0	40.0	10.0	W

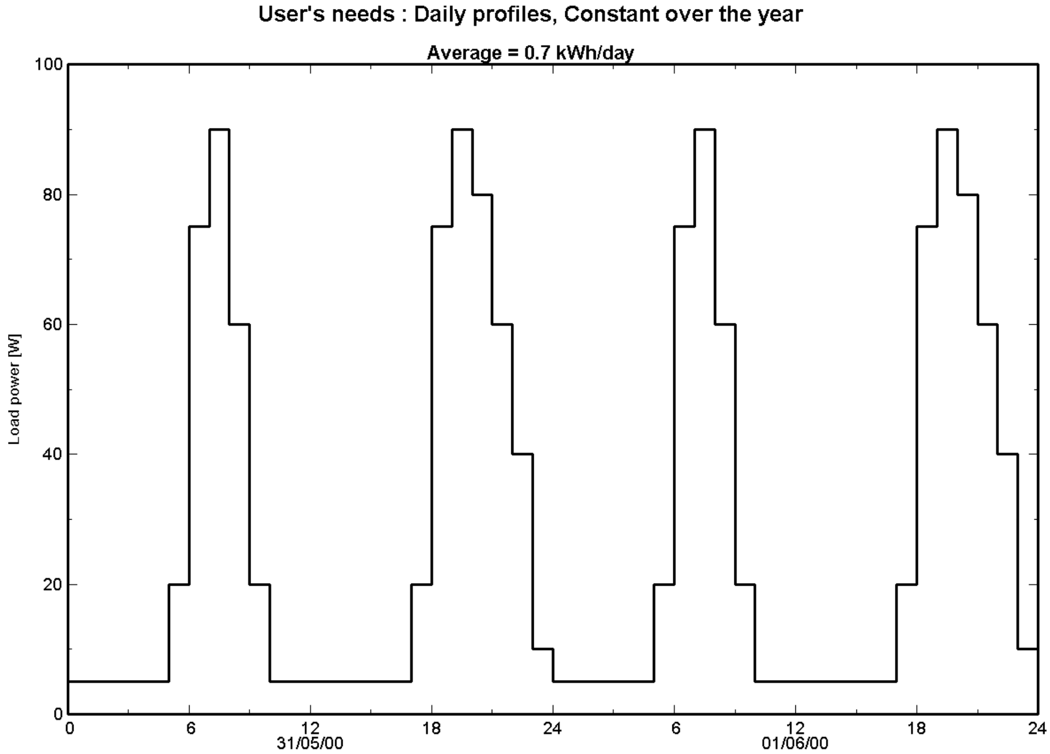


Figure 12-35: PVSyst3.31 Chauganphaya Simulation Report page 3

Stand alone PV system: Main results

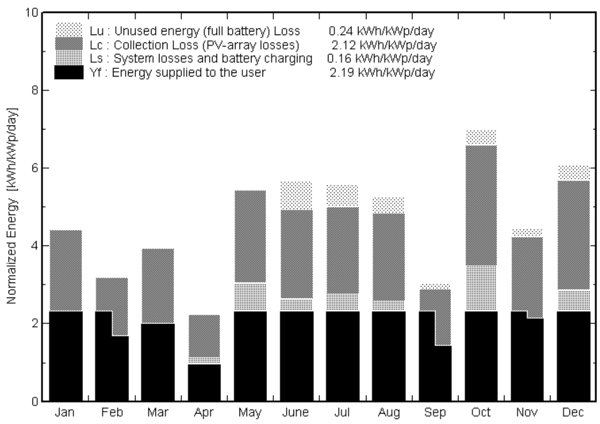
Project : **Chauganphaya Village Humla**

Simulation variant : **Simulation variant**

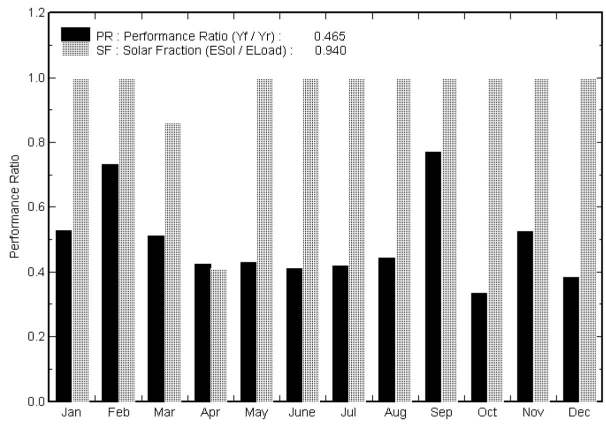
Main system parameters	System type	**Stand alone**		
Horizon	Average horizon height	23.9°		
PV field orientation	Tracking, two axes			
PV modules	Model	BP275F	Pnom	75 Wp
PV array	Nb of modules	4	Pnom total	**300 Wp**
Battery	Model	Volta 6SB100	Technology	vented, plates
Battery pack	Nb of units	8	Voltage / Capacity	**24 V / 400 Ah**
User's needs	Daily profiles	Constant over the year	Global	256 kWh/year

Main simulation results				
System production	Total	240 kWh/year	Specific	801 kWh/kWp/year
	Performance ratio PR	46.5 %	Solar fraction SF	94.0 %
Loss of load	Time fraction	6.0 %	Missing energy	15.3 kWh
Investment	Global incl. taxes	708000 NRp	Specific	2360 NRp/Wp
Yearly cost	Annuities (loan 0.0%, 20 years)	35400 NRp/yr	Running costs	12650 NRp/yr
Energy cost		**200 NRp/kWh**		

Normalized productions (per installed kWp): Nominal power 300 Wp



Performance Ratio and solar fraction



	GlobHor kWh/m²	GlobInc kWh/m²	E Avail kWh	EUnused kWh	E Miss kWh	E User kWh	E Load kWh	SolFrac
January	93.6	137.2	21.70	0.022	-0.00	21.70	21.70	1.000
February	74.5	89.4	19.60	0.064	-0.00	19.60	19.60	1.000
March	113.2	122.1	18.75	0.040	2.95	18.75	21.70	0.864
April	71.4	67.5	8.61	0.089	12.39	8.61	21.00	0.410
May	182.9	168.7	21.70	0.018	-0.00	21.70	21.70	1.000
June	193.8	170.8	21.00	6.678	-0.00	21.00	21.00	1.000
July	192.8	172.7	21.70	5.280	-0.00	21.70	21.70	1.000
August	170.5	163.4	21.70	3.909	-0.00	21.70	21.70	1.000
September	92.1	91.0	21.00	1.260	-0.00	21.00	21.00	1.000
October	156.2	216.3	21.70	3.518	-0.00	21.70	21.70	1.000
November	91.5	133.4	21.00	1.842	-0.00	21.00	21.00	1.000
December	104.8	188.4	21.70	3.641	-0.00	21.70	21.70	1.000
Yearly sum	1537.3	1720.9	240.18	26.360	15.32	240.18	255.50	0.940

Legends:				
	GlobHor	Horizontal global irradiation	E Miss	Missing energy
	GlobInc	Global incident in coll. plane	E User	Energy supplied to the user
	E Avail	Produced (available) Solar Energy	E Load	Energy need of the user (Load)
	EUnused	Unused energy (full battery) loss	SolFrac	Solar fraction (EUsed / ELoad)

Figure 12-36: PVSyst3.31 Chauganphaya Simulation Report page 4

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Stand alone PV system: Economic evaluation

Project : **Chauganphaya Village Humla**

Simulation variant : **Simulation variant**

Main system parameters	System type	**Stand alone**		
Horizon	Average horizon height	23.9°		
PV field orientation	Tracking, two axes			
PV modules	Model	BP275F	Pnom	75 Wp
PV array	Nb of modules	4	Pnom total	**300 Wp**
Battery	Model	Volta 6SB100	Technology	vented, plates
Battery pack	Nb of units	8	Voltage / Capacity	**24 V / 400 Ah**
User's needs	Daily profiles	Constant over the year	Global	255 kWh/year

Investment

PV modules (Pnom = 75 Wp)	4 units	34000 NRp / unit	136000 NRp
Supports / integration		8500 NRp / module	34000 NRp
Batteries (12 V / 100 Ah)	8 units	8000 NRp / unit	64000 NRp
Setting, wiring, regulator...			15000 NRp
Underground cabling armed wire			100000 NRp
Elelctronci fuses for 3 cluste			9000 NRp
3 load controller one per clus			15000 NRp
Transport by bus, air, porter			20000 NRp
Engineering + 200 WLED Lights			315000 NRp
Substitution underworth			-0 NRp
Gross investment (without taxes)			**708000 NRp**

Financing

Gross investment (without taxes)		708000 NRp
Taxes on investment (VAT)	Rate 0.0 %	0 NRp
Gross investment (including VAT)		708000 NRp
Subsidies		-0 NRp
Net investment (all taxes included)		**708000 NRp**
Annuities	(Loan 0.0 % over 20 years)	35400 NRp/year
Maintenance		5000 NRp/year
Insurance, annual taxes, ...		0 NRp/year
Provision for battery replacement	(Lifetime 9.6 years)	7650 NRp/year
Total yearly cost		**48050 NRp/year**

Energy cost

Used Solar Energy	240 kWh / year
Excess energy (battery full)	26.4 kWh / year
Used energy cost	**200 NRp / kWh**

Figure 12-37: PVSyst3.31 Chauganphaya Simulation Report page 5

18.8.12. Appendix to Chapter 12 Excel Spreadsheet Chauganphaya Village PV System Cost Simulation

Geographical Location:
Chauganphaya, Humla, Nepal. Latitude 30.000º North / Longitude 81. 774º East / Altitude: 2643 m.a.s.l.

System description: 300 W_R Stand-alone Solar PV System with a self-tracking frame

Parameters for the Life Cycle Cost (LCC) Calculation:

Period of Analysis (years):	20	Excess Inflation i (%):	2.0	Discount Rate (%):	5.0

Annualisation Factor $P_{a=}$ 14.959 (such as for annulised LCC or annual maintenance costs)
(according to the calculation of the net present worth of a recurring cost over the analysis period of
20 years with a discount factor of 10 % and an excess inflation rate i = 0%)

Present Worth Factor P_r =	0.467	(such as for battery replacement costs after 8 years)
Present Worth Factor Pr =	0.218	(such as for battery replacement costs after 16 years)
Present Worth Factor Pr =	0.386	(for charge controller/load controller replacement after 10 years)

Load:
Daily load: 63 Households, each 3 WLED lights = 189 WLED lights, @ 3.5 - 4 hours/day: **0.70 kWh/day**
(1 WLED light consist of 9 Nichia white LEDs, consuming total 1 Watt: Thus 189 Lights x 1W x 3.5h + ~40 Wh (wire losses or 5.7% of the daily load) = 701.5 Wh)

Solar PV System Parameter Definition:

Battery Bank Efficiency Factor: 0.80
PV Module Mismatch and Array Mismatch Factor: 0.90
Wire losses Factor: 0.90
Solar PV Array Energy Demand: 1.08 kWh/day
Annual Average Available Irradiation: 5 kWh/m^2 day (according to NASA data)
Solar PV Array size: 216 W of Solar PV Array needed size, resulting in 4 x 75 W solar PV modules
PV Module Size: 75 W_R or: 2.88 75.00 W_R PV Solar Modules
Because the Solar PV System is a 24 Volt System: **4** **75.00 W_R PV Solar Modules**

Sunshine independent energy storage: 7 days Max. DoD (Depth of Discharge): 0.30
Battery Bank size for 7 days Storage: 16 kWh

With a 24 Volt system that results in:		681 Ah	Battery Capacity:	100 Ah
Results in:	6.81 Batteries @12 Volt	Thus:	**8 Batteries**	**100 Ah capacity @ 24 V**

Solar PV System Price Calculation:

Solar PV Module Price:	6.00 US\$/W_R	450 NRp/W_R		75 NRp/US\$
Solar PV Array Price:	135,000 NRp	Lifespan:	20 years	
Solar PV Module Self-Tracking Frame:	30,000 NRp	Lifespan:	20 years	

(The Solar PV Module price per W_R is given in US\$ as all PV Modules are imported in Nepal)

Batterry Price:	100 US\$/Battery 100Ah	7,500 NRp/Battery		
Battery Bank Price:	60,000 NRp	Lifespan:	8 years	

(Battery price is given in US\$ as all Deep Cycle Batteries are imported in Nepal)

Solar Charge- and Load- Controller:	15,000 NRp	Lifespan:	10 years	

(Solar Charge- and Load- Controller are manufactured in Nepal these days)

Wiring:	Armed underground cable:	105,000 NRp	(for the all 63 households line distribution)	

(4mm^2 and 2.5 mm^2 armoured copper cable for underground cabling made in Nepal)

Lights:	1 WLED light costs:	1,550 NRp	total Lights:	200 cost:	310,000 NRp
Lifespan:	20 + years				
Switches, fuses:		15,000 NRp	Lifespan:	10 years	
Installation etc		15,000 NRp			
Transport (by bus, airplane and porters):		20,000 NRp			

TOTAL Installed Solar PV System Cost: 705,000 NRp

Annual Operation & Maintenance Cost, approx. 0.5% of total Installed cost: 3,525 NRp

Life -Cycle Operation & Maintenance Cost: 52,729 NRp

Recurring Costs:

Battery Bank:	41,048
Solar Charge- and Load- Controller:	5,783
Switches, fuses:	5,783
TOTAL Replacement Costs:	52,614

LIFE-CYCLE Cost:	**810,344 NRp**	Total Solar PV System Cost During the 20 years Lifetime
Annualised LIFE-CYCLE Cost:	**54,172 NRp**	Total Cost which for Each year of the Solar PV System's Lifetime has to be invested

Unit Electricity Cost: **212 NRp/kWh** kWh Cost During the 20 years Solar PV System's Lifetime

Price per Household per Month: **72 NRp** For each of the 63 Households in Chauganphaya Village, to keep the Solar PV System up and running and to have the budget after 20 years available for a new Solar PV Village System

Comparison with calculated costs with PVSyst 3.3: **200 NRp/kWh** compared to **212 NRp/kWh** in the LCC, or 6 % difference, which is an acceptable tolerance.

PVSyst 3.3 unit price:	**200 NRp/kWh**	
Life Cycle Costing:	***194 NRp/kWh***	***for Excess Inflation i of 2 % and Discount Rate of 4 %***
	212 NRp/kWh	***for Excess Inflation i of 2 % and Discount Rate of 5 % which is a realist assumption***
	213 NRp/kWh	***for Excess Inflation i of 0 % and Discount Rate of 3 %***
	229 NRp/kWh	***for Excess Inflation i of 4 % and Discount Rate of 8 %***
	240 NRp/kWh	***for Excess Inflation i of 2 % and Discount Rate of 6.5 %***
	247 NRp/kWh	***for Excess Inflation i of 5 % and Discount Rate of 10 %***
	249 NRp/kWh	***for Excess Inflation i of 3 % and Discount Rate of 8 %***
	252 NRp/kWh	***for Excess Inflation i of 0 % and Discount Rate of 5 %***

From the above unit prices it can be seen that the excess Inflation rate and the Discount Rate are a rather important information in the Life c ycle Cost analysis.

Thus it can be said that the Life Cycle Cost unit price calculation with a realistic Excess Inflation and Discount Rate (as above listed),
compared to the PVSyst3.3 unit price calculation differs mostly between -3 % and +20 %, which lies in the acceptable range of tolerance.

The exchange rate for NRp (Nepali Rupees) are: 1 US$ = 73.79 NRp, or 1 AUS $ = 53.95 NRp (26th March 2004 Kathmandu Post Newspaper)
That means, that 1 unit electricity (1 kWh) for light costs in Chauganphaya between US$ 2.63 or AUS$ 3.56 to US$ 3.41 or AUS$ 4.67

18.9. Appendix to Chapter 13 Case Study of the Tangin Solar PV Home System Project

18.9.1. Detailed Interview Questions and Answers provided by Mr. Lama from Tangin

A. Performance of the SHS

Question 1: What are the problems you faced over the last 1 ½ years? Any problems with the solar PV module, module fixation, module wiring, lights, light wiring, light switches, charge controller, fuse, or battery?

Answer to Question 1: "The experience with the equipment, and the problems we faced are:

- No actual problems with the solar PV modules or the module fixation.
- The wires from the PV modules to the battery are free falling, and hanging in the air. 10 SHS's wires' mantling are cracked at various places and the cooper wires are visible. Some families use the wires to hang up cloths for drying after they have been washed.
- Many homes, I am not sure of the exact number, had to exchange their tube lights. The average daily use of each of the two fluorescent tube lights per home is estimated to be around 3-4 hours, 1-2 hour in the morning and 2-3 hours in the evening. They turned black at the tube edges within weeks. To buy a spare tube, one has to walk a day to Simikot, and the price is NRp 150 just for the tube and NRp 700 for a whole new light, body and tube. The only shop that has spare tubes in Simikot is closed most of the time. Some homes have bought a third tube light, without consulting the installing company, before doing so. The tube's fuse mostly burns out, and as with the tube, the fuse is also available only in Simikot. Mice nibbled on the wires connected

to the light where the wires are not fixed underneath the wooden beam, but rather at the sides. I estimated that about 50% of the light switches are broken. They are installed too low, making it a new and interesting toy for children. Further, they seem to be of a poor quality. Many house owners changed the switches after the initial installation, as we were initially not asked where we would like the switches to be. But neither have we been provided with training on how to install, or fix switches or wires.

- 9, out of 38 charge controllers broke completely within the first 8 months and thus are not in operation anymore. No guarantee was provided, and a new charge controller costs NRp 2,500 – 3,000 (US$ 35 – 43), beside the difficulty of getting one, and installing it. In several charge controllers the fuse burnt out, which we solved through the installation of a metal strip instead of the glass fuse. Rain entered into several charge controllers and corroded various parts inside. Now in 9 SHS the solar PV module is directly hooked up to the battery, without any battery charge or discharge protection previously provided by the charge controller.
- Most of the light tubes and fuses burned out and no spare parts have been provided initially by the installer. As it is very difficult, time demanding and relatively expensive to get any spare fuse, most of the people have used metal strips, instead of proper glass fuses for the tube light fuse, as well as for the charge controller.
- Out of the 38 SHS batteries, one battery is totally "dead", not providing any energy." When Alex Zahnd asked how does he know when a battery is dead, as they do not have a multimeter, nor do they know what a multimeter is, Mr. Lama said: "We found out that when we put a piece of metal between the two metal poles of the battery and it sparks, the battery has power, if it

doesn't spark it is "dead". Most of the owners have experienced during the first year a drastic reduction in light output, and a shortening of the daily hours of running the lights." When asked where the batteries are stored, Mr. Lama confirmed Alex Zahnd's experience from the October 2002 visit to Tangin, that the batteries are installed on the top floor of the homes, to reduce the length between the solar PV module and the battery, thus saving wire length. Mr. Lama also confirmed that the top floors usually have no closed walls as they are used to dry the crops, and thus need air draft. During the 4 winter months, temperatures can drop down to – 25°C during the nights.

B. Maintenance and management of the SHS

Question 2: Who installed the SHSs?

Answer to Question 2: "A solar PV company from Kathmandu, who also established a sales office in Simikot, installed all the 38 SHSs in 10 days, with 2 staff, doing it all by themselves. Since the initial installation no one from the company, or from the Governmental institutions providing the subsidies, has again come to Tangin, in order to find out about the SHS performance, our experience, or to follow-up any difficulties we face".

Question 3: Who and how many from your village were trained to maintain and repair (in minor ways) the SHSs, and how many participated in the initial installation?

Answer to Question 3: "No one from the village was asked to participate in the installation of the SHSs as part of an "on the job training". Neither was anyone appointed for a basic training in maintaining the SHS, trained to recognizing any possible faults, or mal functioning of any equipment."

Question 4: Is there a "Solar Home System" village committee?

Answer to Question 4: "Initially there was a SHS interest committee formed, with the intended aim to have periodical meetings to discuss problems, maintenance needs etc. But since its formation this committee has not even met once".

Question 5: How much monthly fee is raised per family for maintenance and repair?

Answer to Question 5: "There is no fee raised or monthly payment towards a fund, in order to maintain, or repair the SHSs".

Question 6: What did the installing company say about the expected life of the SHS?

Answer to Question 6: "No information about the SHS, neither about the life expectancy, the maximum hours per day the lights can be used, nor the need for any maintenance, or possible repairs needed in the months to come, have been provided to us. No spare parts have been provided along with the new SHS, not even one spare fuse for the battery charge controller or any of the light tubes".

Question 7: How easy and at what price can you get spare parts, such as tubes, fuse, wires, battery or a charge controller?

Answer to Question 7: "As I mentioned already (answer to Q 2), for any spare parts someone has to walk to Simikot and back, which is a 2 days walk. And even then, most of the time the shop is closed and sometimes does not have the needed spare parts. Further, the prices are rather high. Thus it is very difficult to get spare parts".

C. Experience and suggestions

Question 8: How has your life changed since you have light in your home?

Answer to Question 8: "The evenings in particular have become much more meaningful. More group gatherings take place in which family and village issues are discussed and addressed. The ones going to school use the evening lights for reading and homework. More awareness about hygiene and health issues can be recognised."

Question 9: Are you satisfied overall with the SHS's performance?

Answer to Question 9: "Most of the people of the 38 homes with a SHS installed have had a different expectation of the energy services provided by the solar PV system. They imagined that the lights can be used much longer and that it will be much brighter. They also expected to be able to hook up a radio, and a battery charger. Thus I estimate that about 75% of the families with a SHS are not satisfied, and that about 25% are just about satisfied."

Question 10: What would you suggest to the company who installed the SHSs what could and should be different?

Answer to Question 10: "We would ask that we could be part in the initial decision about the SHS for our village. We would request to have at least a few people from our village trained in the basics of a SHS, in order to maintain and repair the most urgent needs. Further we would ask for a set or two of the most needed tools, such as a multimeter, screw drivers and spanners. We would like to suggest to them, that the SHSs should be periodically followed-up by a staff from the installing company, or project, and that these costs have to be covered, by the initial budget, and if possible, through periodical fees payments from each SHS owner.

We would urge them, to help us to form a committee which takes its task seriously, to raise fees for maintenance and main repairs. We are not at all aware of that, thus we need such initial input, guidance and encouragement."

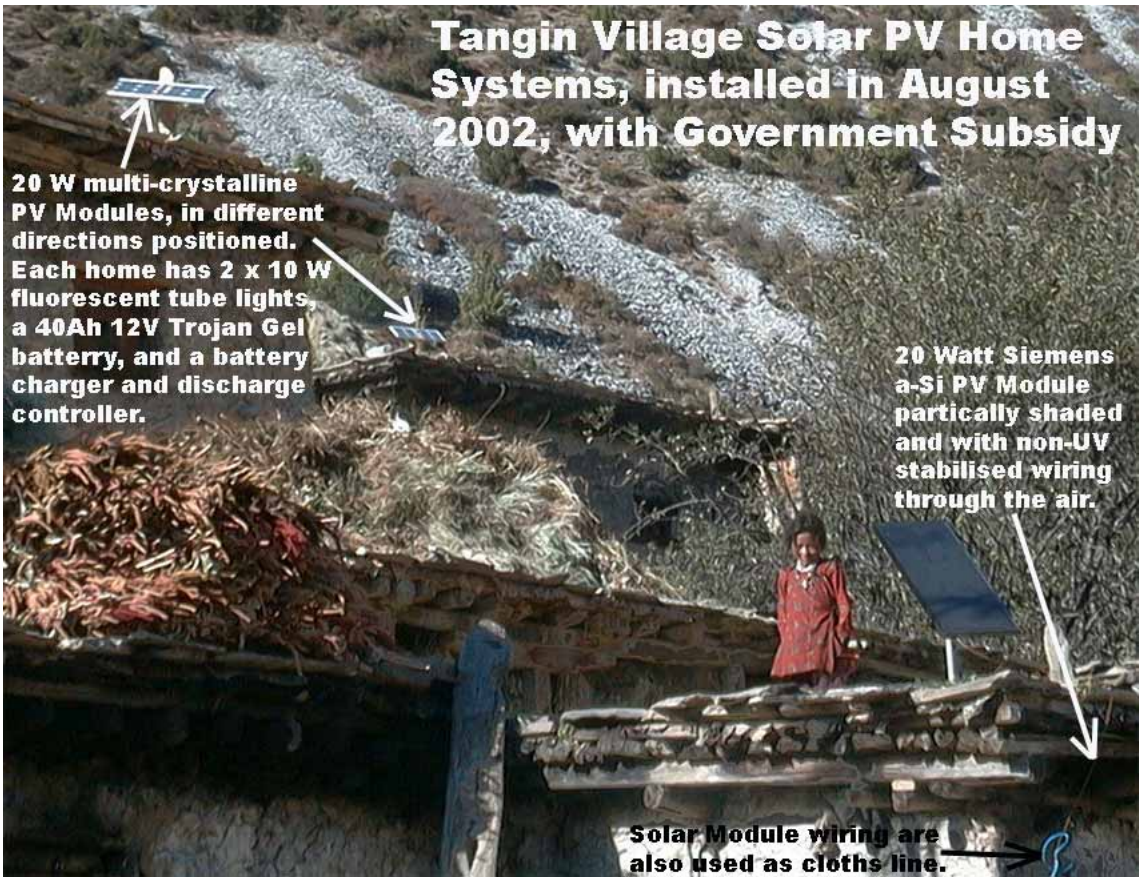

Figure 13-1: Tangin Village Solar Home System Project
Tangin Village, at 3,500 meter altitude, 30°North Latitude, 82°East Longitude, in Humla Nepal. In August 2002, a Solar PV Home System project, with Government subsidy, was implemented for 38 homes.

The Figure shows that one module is partially shaded, the solar PV modules are positioned at different angles, and in different directions. The wires, connecting the solar PV module with the battery charger (and in some cases the battery directly), are freely hanging in the air.

19. References

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[4] Luminous intensity (or candlepower) is the light density within a very small solid angle, in a specified direction. In other words, this is the total number of lumens from a surface emitted in a given direction. The unit of measure is candela. In modern standards, the candela is the basic of all measurements of light and all other units are derived from it. Candlepower measurements are often taken at various angles around the source and the results plotted to give a candlepower distribution curve. Such a curve shows luminous intensity (how "bright" the source seems) in any direction.
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[13] The inverter is a AJ802-S, 24 V with 30 Amps solar charge controller from the company Studer Innotec, Rue des Casernes 57 - CH - 1950 SION, Switzerland, Tel : +41 27 205 60 80 Fax : +41 27 205 60 88, info@studer-inno.com www.studer-inno.com
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