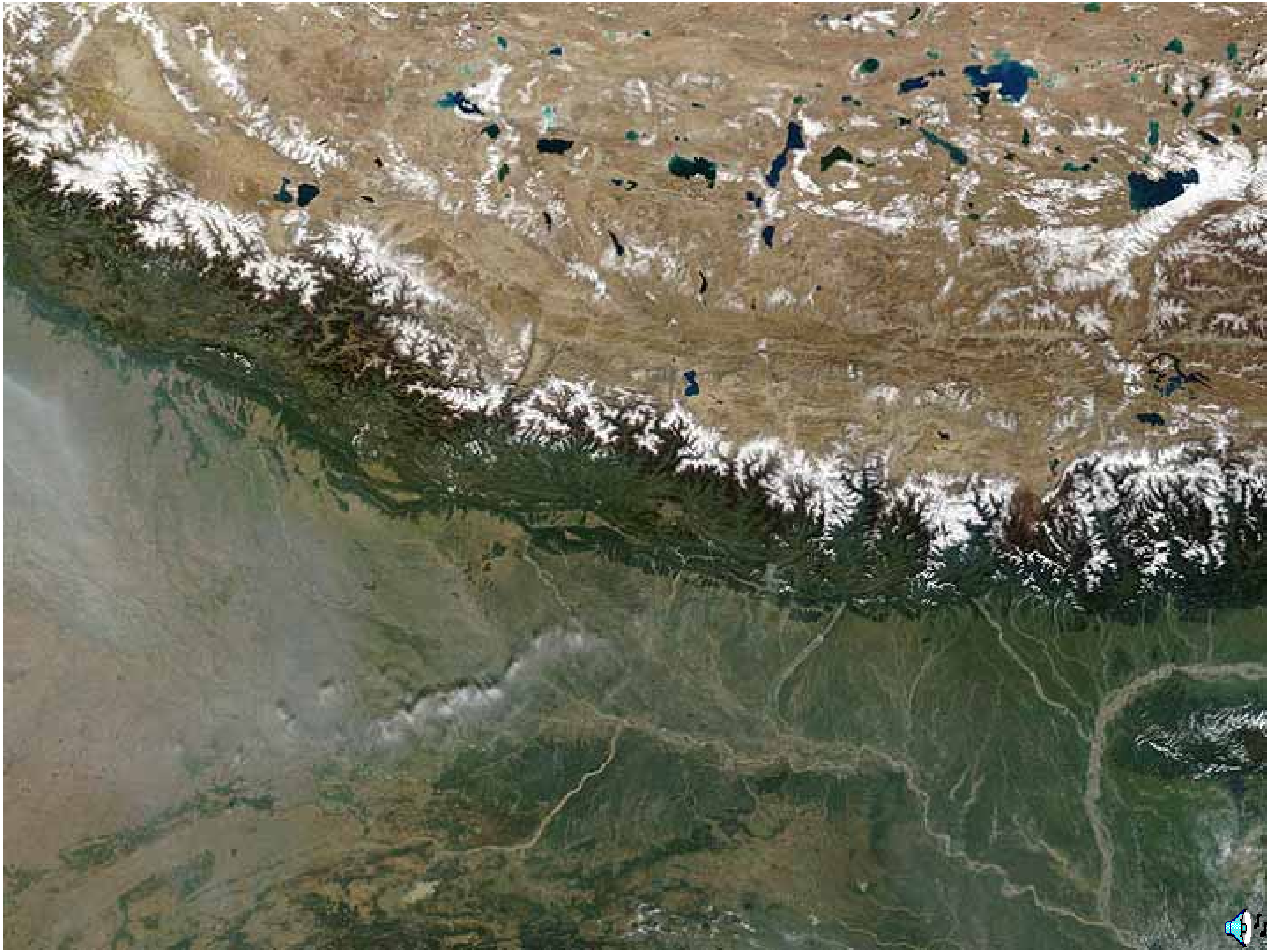
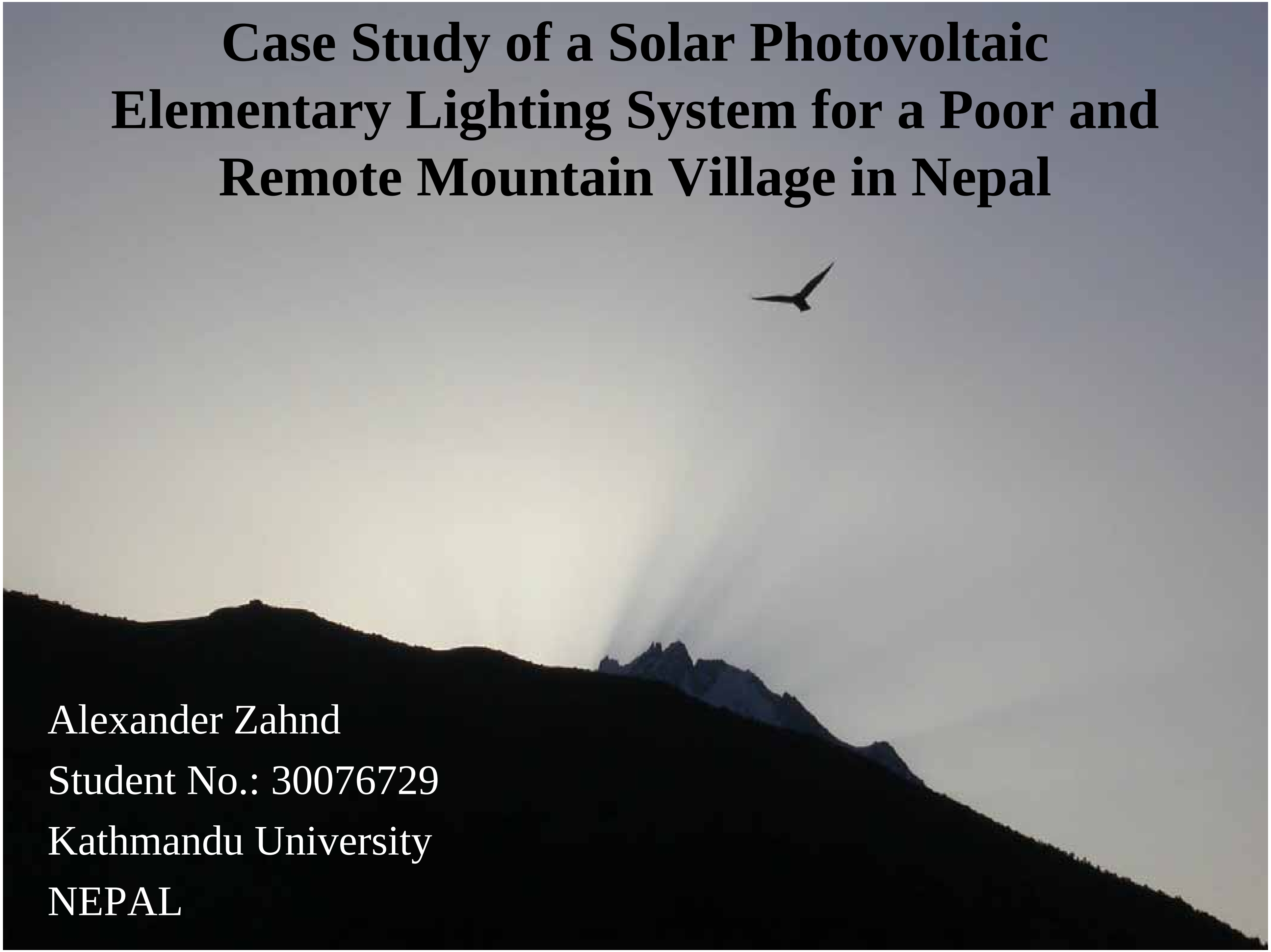

NEPAL



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



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Kathmandu University
NEPAL

Nepal's Stage of Development

1. **Nepal opened its doors for the world only in 1953**
2. **Nepal still counts among the least developed countries.**
3. **Population: 26 Mio., 88 % in rural, remote mountain areas.**
4. **Average annual population growth 2.6%.**
5. **Overall literacy rates: 40% - 60% in cities, but in the remote mountain areas 4% - 20% for both, women and men.**

Nepal's Stage of Development

6. **The average income per head per year is 30 US$ - 260 US$.**
7. **85% of Nepal's people have no access to electricity.**
8. **Annual per capita electricity consumption (2001) 66.7 kWh.**
9. **There is a clear relationship between poverty and access to electricity, and poverty levels increase the more remote and difficult to access the communities live.**

Nepal's Stage of Development

10. **Nepal's technical feasible potential hydroelectric power capacity is estimated 83,290 MW, with 42,133 MW estimated to be technical economical.**
11. **Nepal's installed total electric generating capacity (2003) is 590 MW, of which 90%, or 533 MW is hydroelectric, representing 1.26 % of Nepal's technical feasible potential,** (with 57 MW from 3 diesel generator mini-grids).
12. **Average of 300 sunshine days a year, and daily average solar insulation of 4.5 – 5.5 kWh/m^2.**

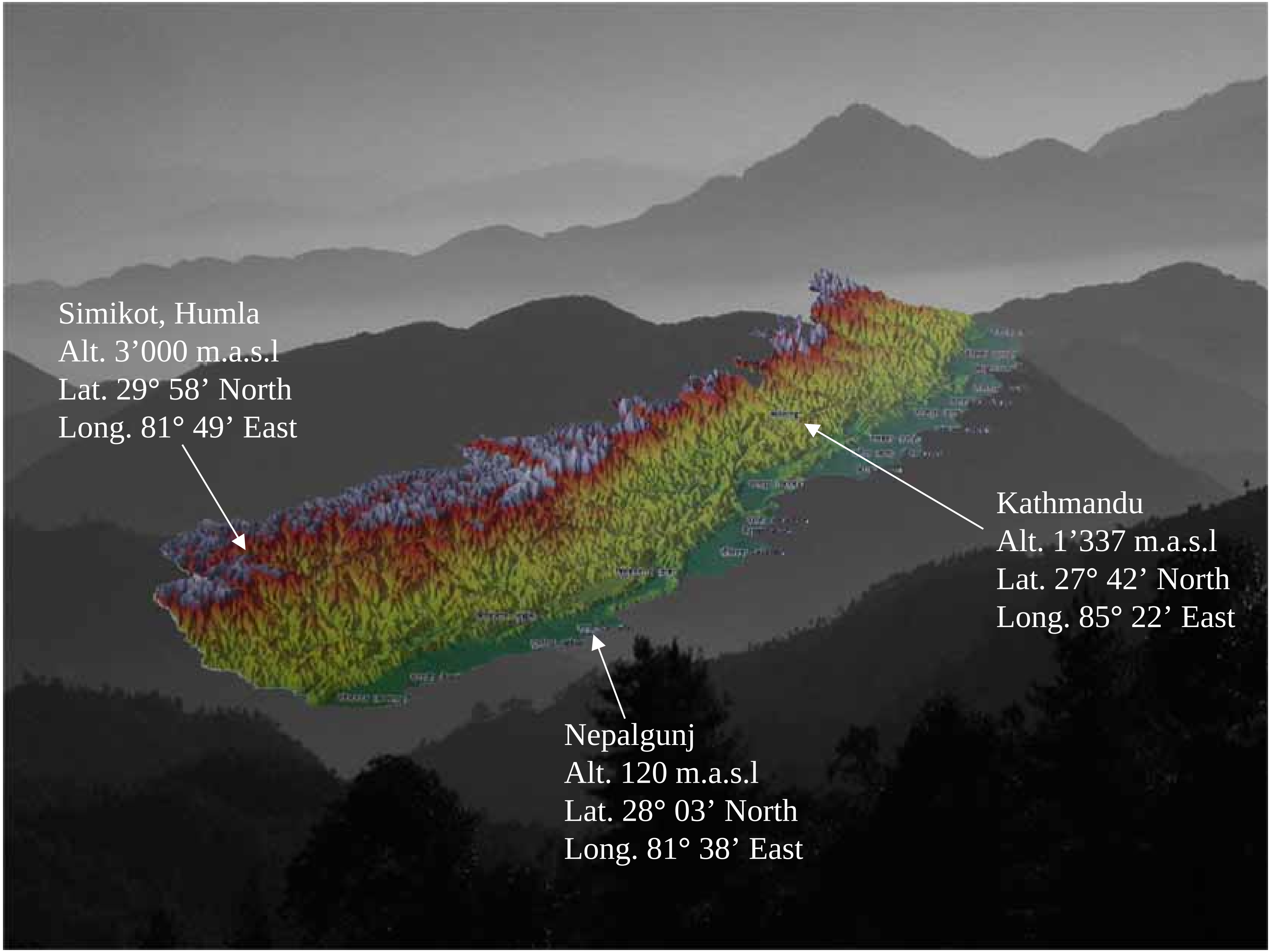
Nepal's Stage of Development

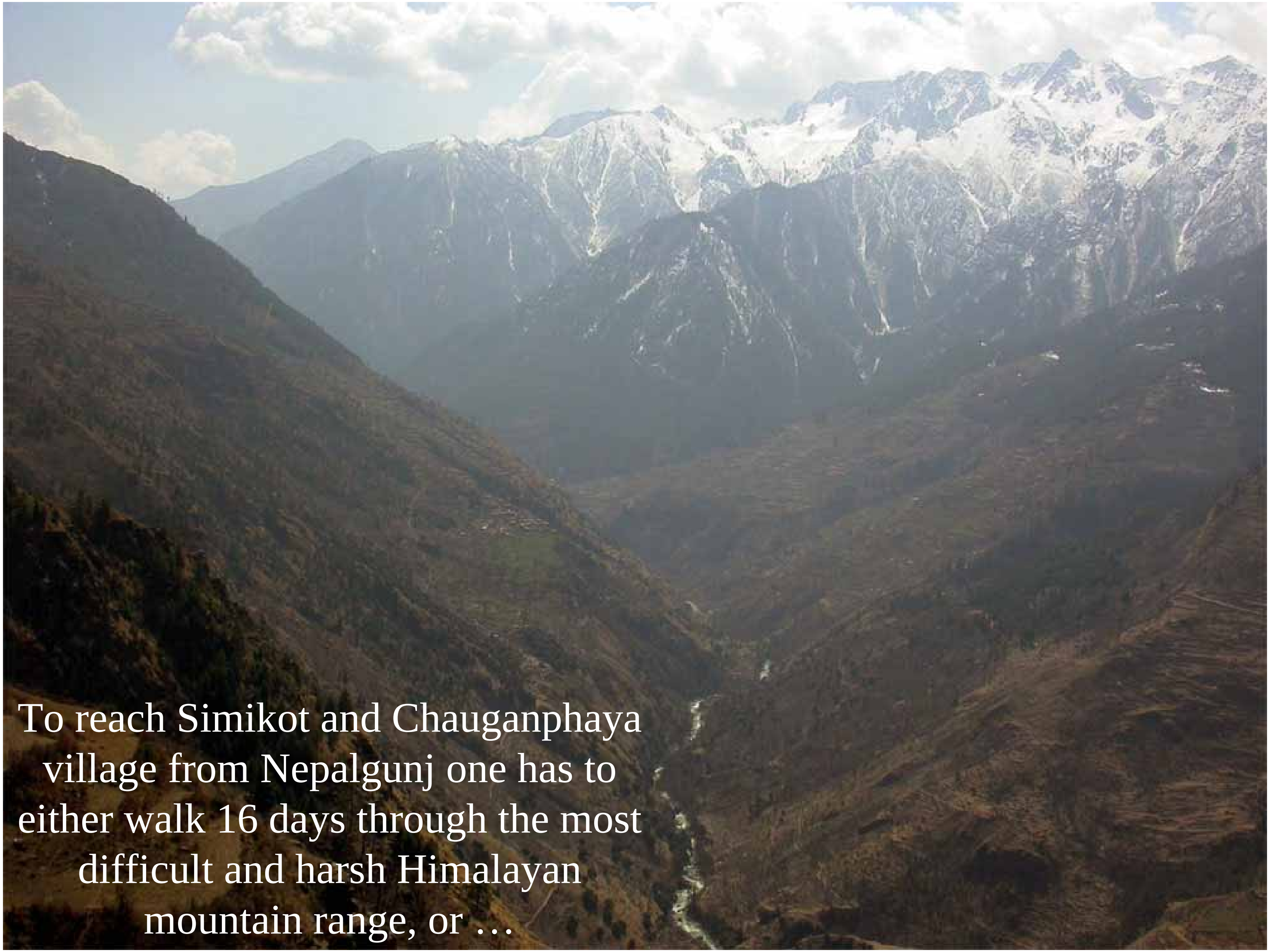
Demands a Holistic working approach, addressing the

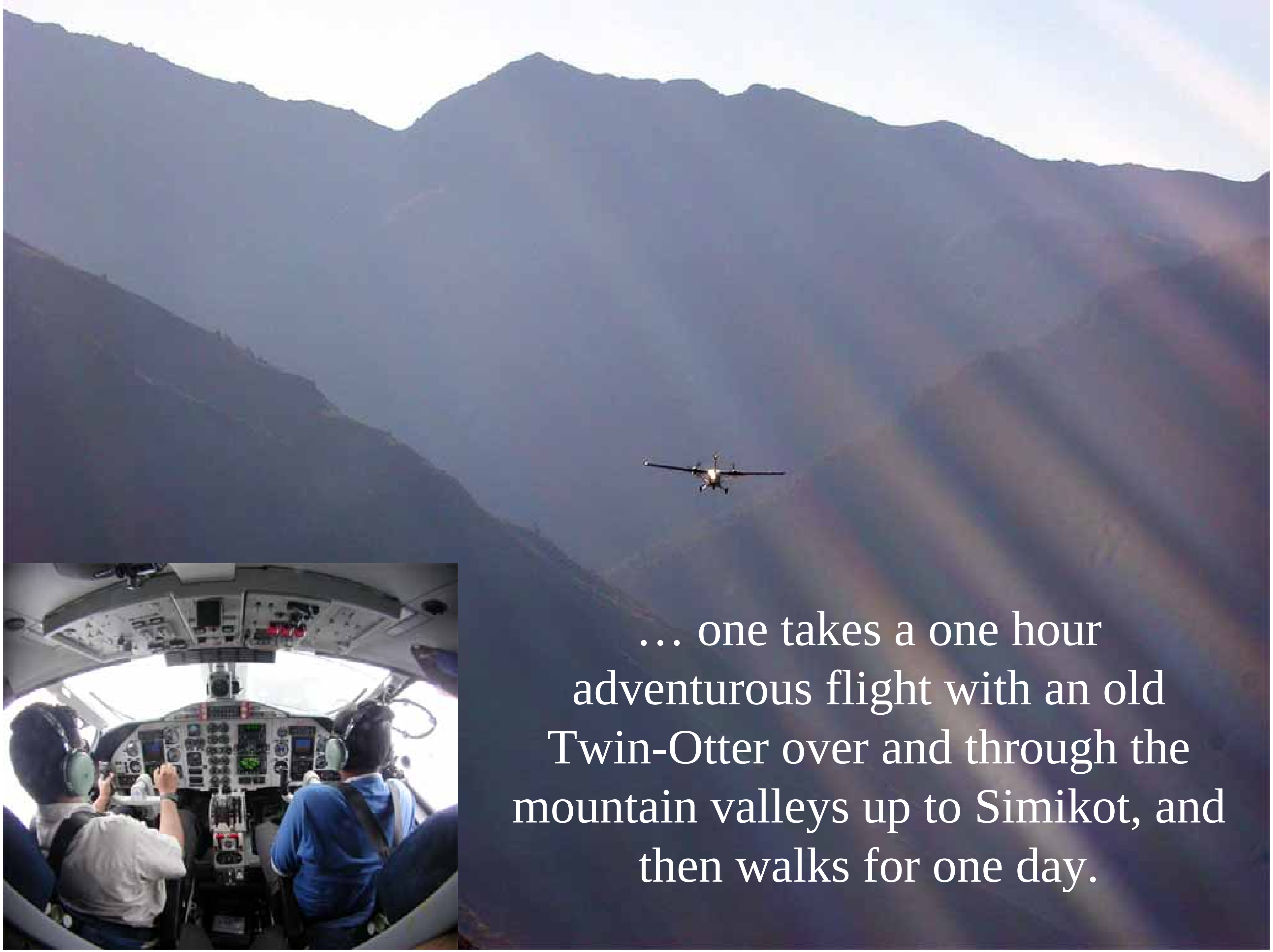
- Social
- Physical
- Mental
- Spiritual

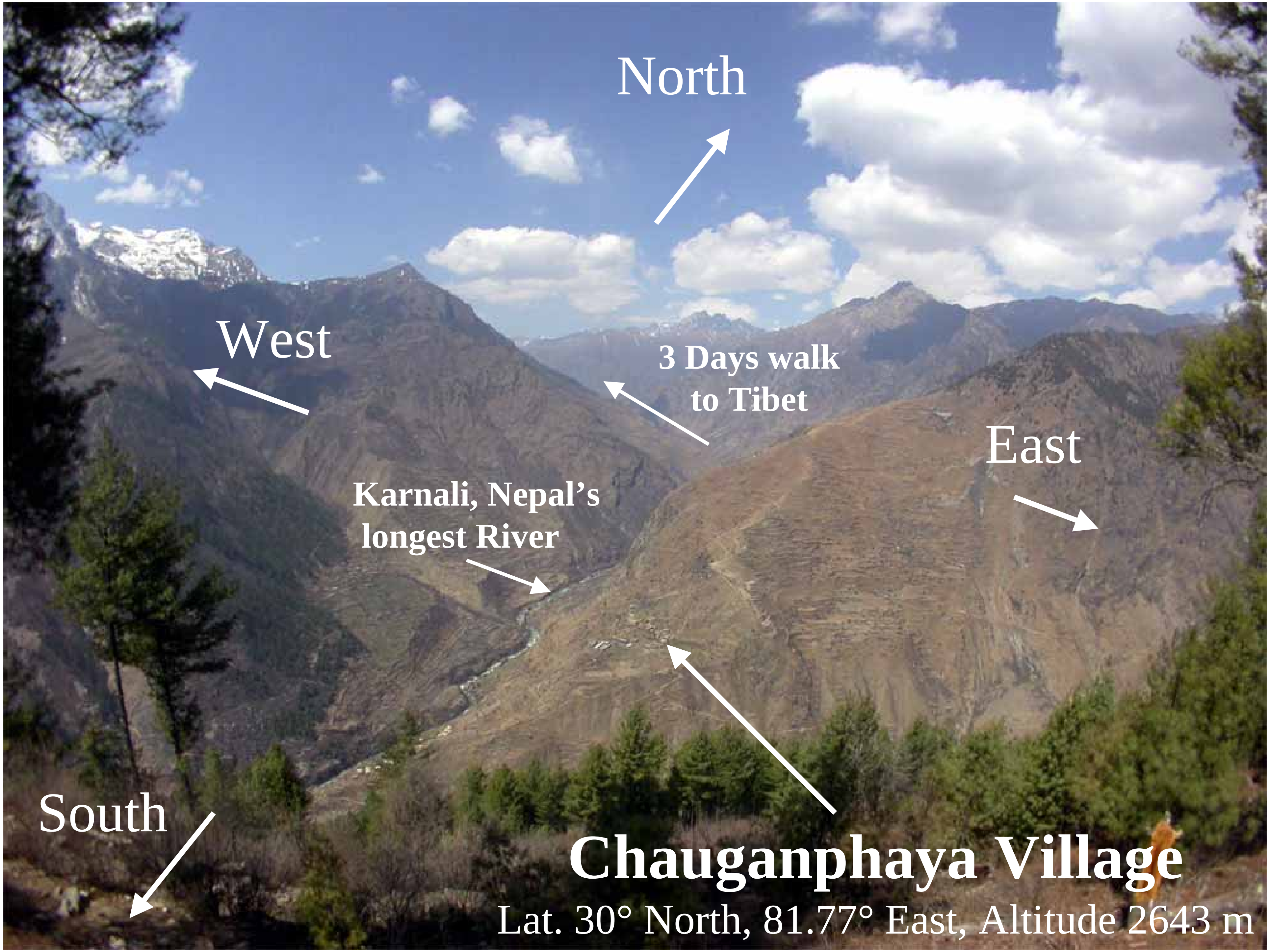
Needs of the people in sustainable ways

- Social : We are created as individual beings, in fellowship with others
- Physical : We have a body which needs food, health care, rest
- Mental : Being able to think clearly and make rational decisions
- Spiritual : To strive for fellowship with our Creator

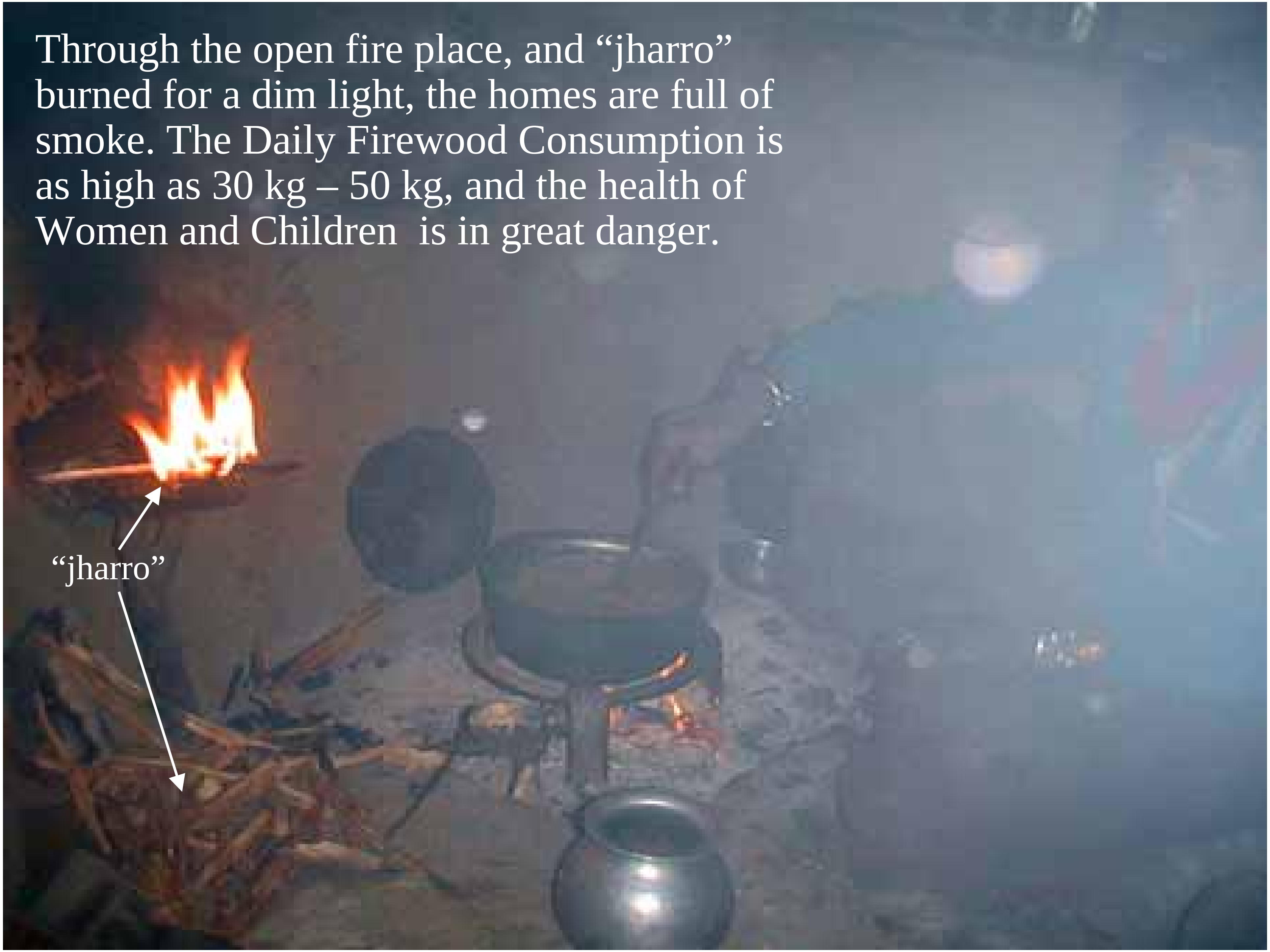

Simikot, Humla
Alt. 3’000 m.a.s.l
Lat. 29° 58’ North
Long. 81° 49’ East
Kathmandu
Alt. 1’337 m.a.s.l
Lat. 27° 42’ North
Long. 85° 22’ East
Nepalgunj
Alt. 120 m.a.s.l
Lat. 28° 03’ North
Long. 81° 38’ East


To reach Simikot and Chauganphaya village from Nepalgunj one has to either walk 16 days through the most difficult and harsh Himalayan mountain range, or …


… one takes a one hour adventurous flight with an old Twin-Otter over and through the mountain valleys up to Simikot, and then walks for one day.


North
West
3 Days walk
to Tibet
East
Karnali, Nepal's
longest River
South
Chauganphaya Village
Lat. 30° North, 81.77° East, Altitude 2643 m


The remote and impoverished mountain community of Chauganphaya in Humla, Nepal, has requested light in their homes through a Solar PV Village System.


Through the open fire place, and “jharro” burned for a dim light, the homes are full of smoke. The Daily Firewood Consumption is as high as 30 kg – 50 kg, and the health of Women and Children is in great danger.
“jharro”


In all projects
the people are in the center
of interest, and the applied technologies
are to serve them.

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

Some of the 44 questions of the Chauganphaya Village Survey

1. Housing Material:
Stone / Mud
Stone / Dry Masonry
Stone Plaster
Other :

2. Cooking Method:
Open fire with stone support
Open fire with metal/steel frame
Open fire with *odhan* (three legged steel frame)
Metal stove door YES/NO, with hot tank YES/NO, chapatti baking facility YES/NO
"Jumla" design smokeless metal stove
Other:

3. Heating Method:
Open fire
Smokeless metal Stove (defined kind)
"Jumla" design smokeless metal stove

4. Lighting Method:
Jharro (resin soaked pine wood stick)
Matitel (tupi) (kerosene light)
Candle
Hydro power
Solar

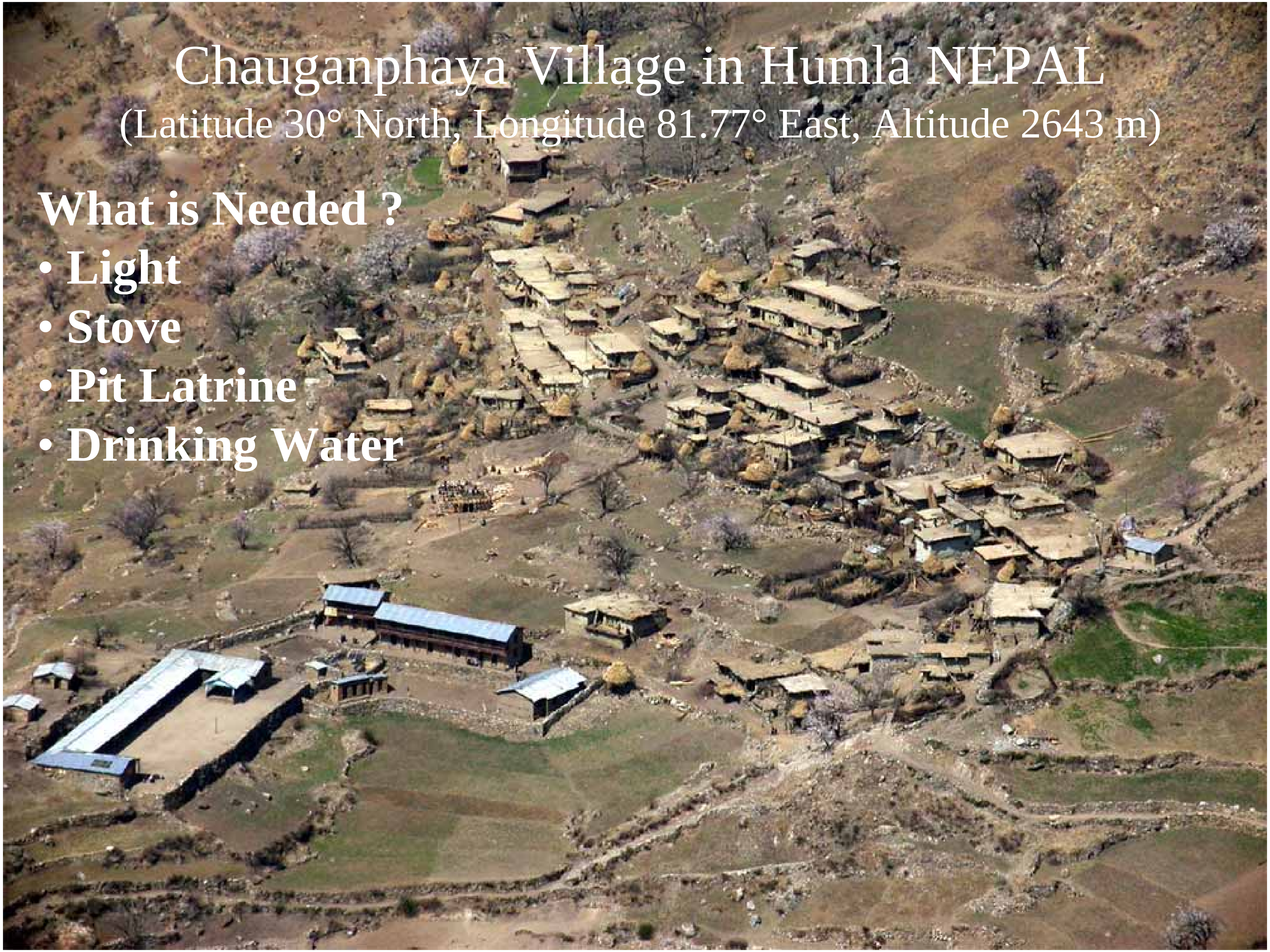
Does this household have a latrine? How far away is it?

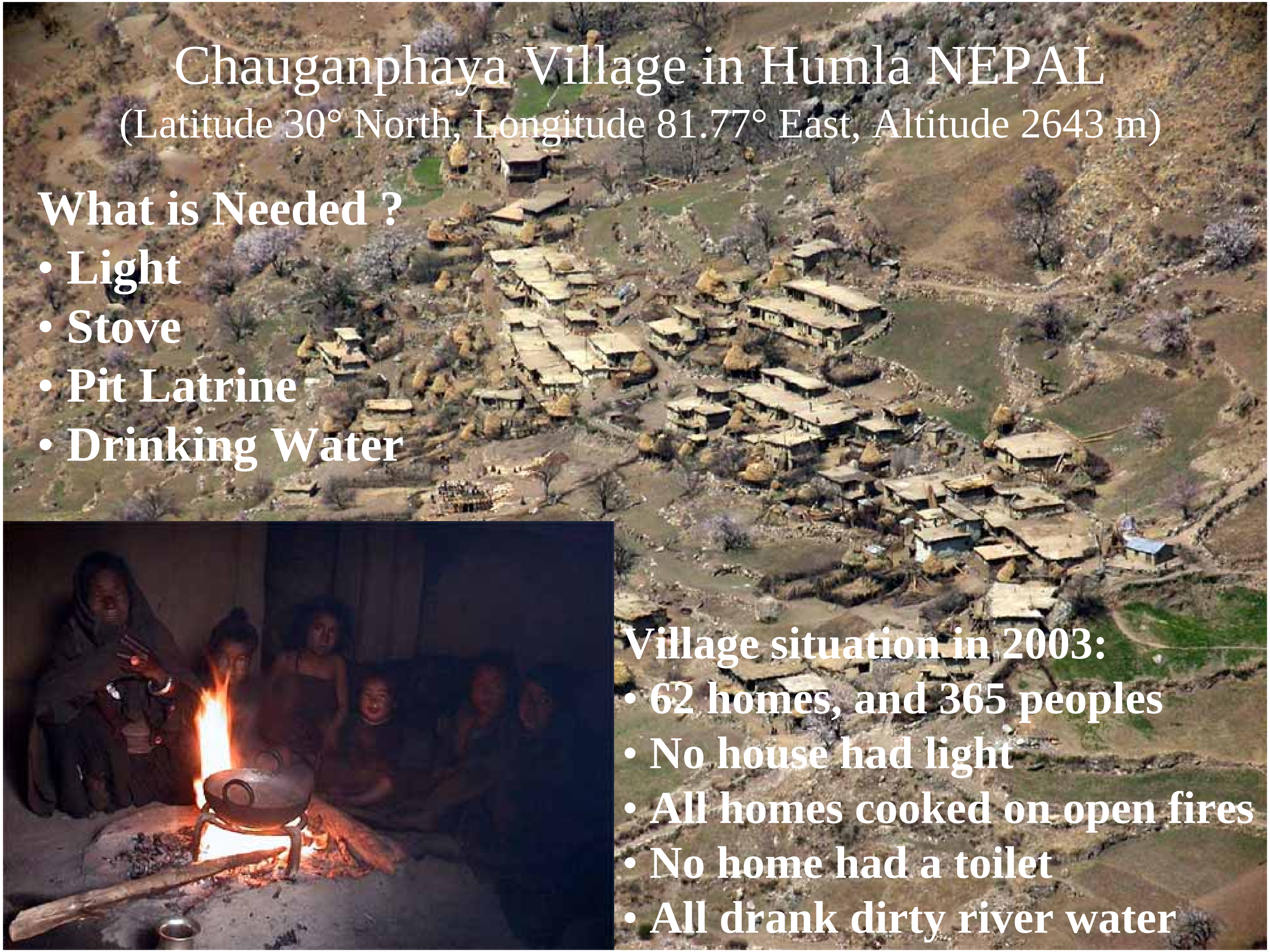
What is their Lighting Method before Solar Energy powered WLED Lights

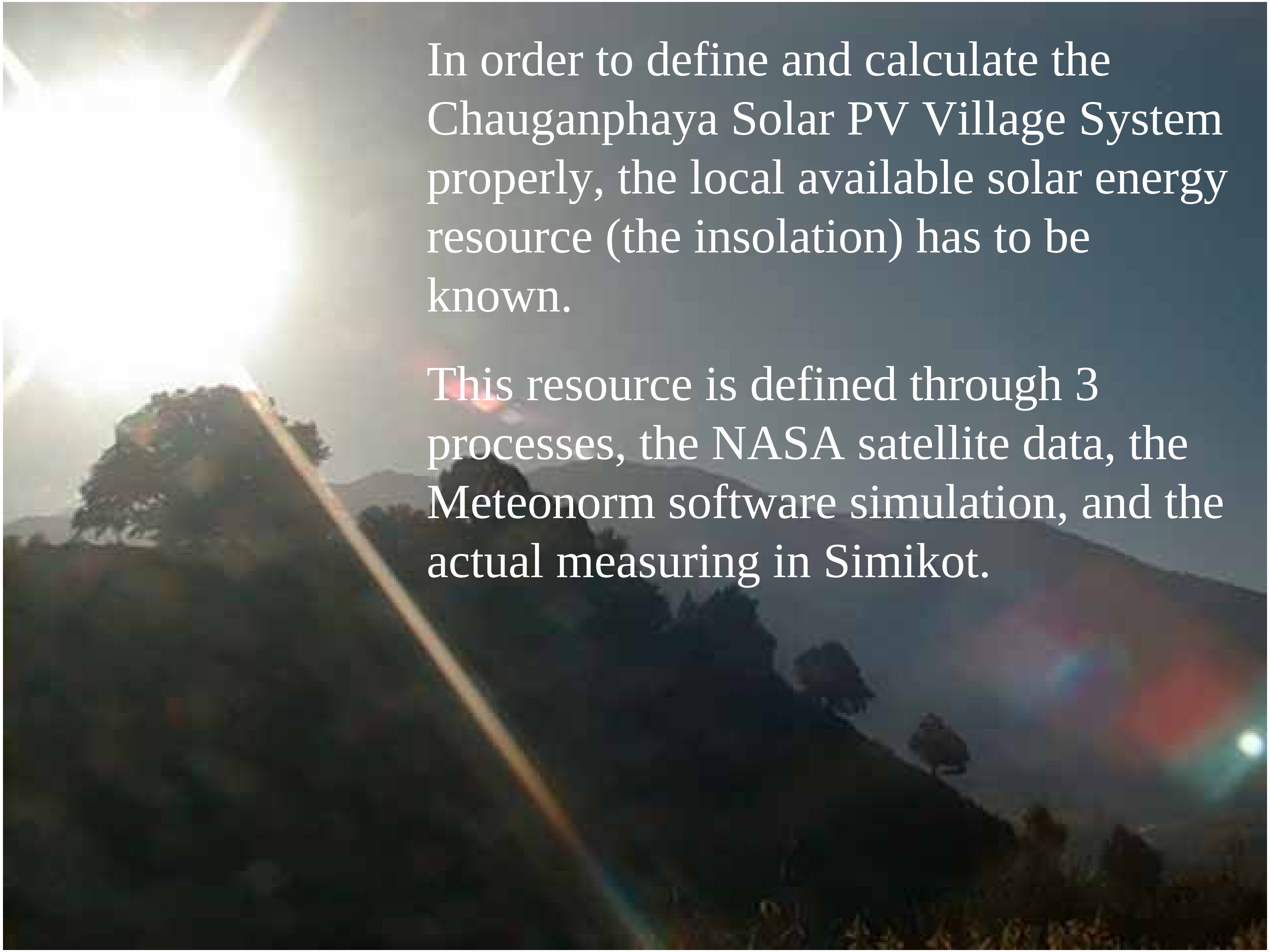
Answers	***Households***	***Percent***	***Remarks***
“Jharro”	113	99.1	Resin soaked pine wood sticks
Solar	1	0.9	Solar PV panel power fluorescent tube ~10 W
Total	114	100	

Expected Changes from Light through the Solar PV Village System

Answer	***Households***	***Percent***	***Remarks***
Bright inside the home	25	21.9	
More activities in the evening	9	7.9	For housework and income generation possibilities
Children can study in the evening	3	2.6	
Cleaner air	2	1.8	No “jharro” to burn
Cleaner home	5	35.1	The dirt can be seen more clear
Healthier inside environment	18	15.8	
“Jharro” free	15	13.2	
Less firewood is used	1	0.9	
Missing	1	0.9	


Chauganphaya Village in Humla NEPAL
(Latitude 30° North, Longitude 81.77° East, Altitude 2643 m)
What is Needed ?
• Light
• Stove
• Pit Latrine
• Drinking Water

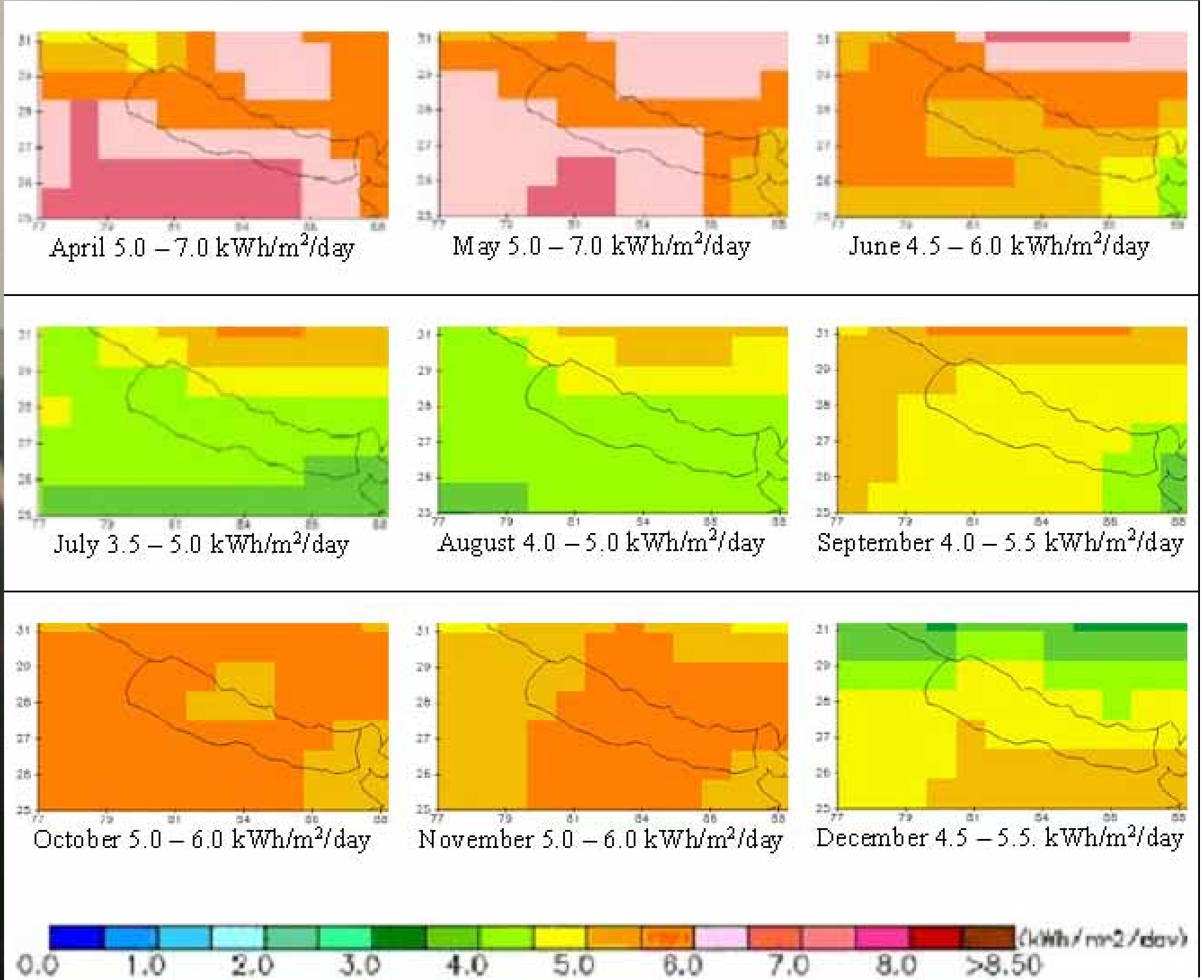

Chauganphaya Village in Humla NEPAL
(Latitude 30° North, Longitude 81.77° East, Altitude 2643 m)
What is Needed ?
• Light
• Stove
• Pit Latrine
• Drinking Water
Village situation in 2003:
• 62 homes, and 365 peoples
• No house had light
• All homes cooked on open fires
• No home had a toilet
• All drank dirty river water



In order to define and calculate the Chauganphaya Solar PV Village System properly, the local available solar energy resource (the insolation) has to be known.

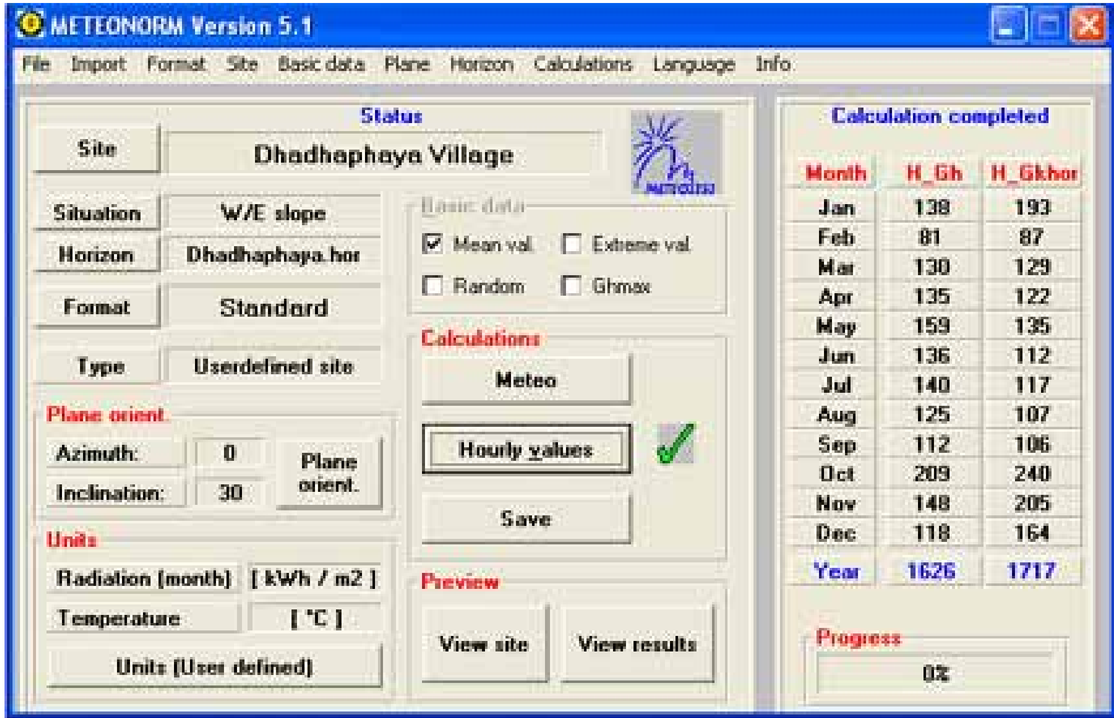
This resource is defined through 3 processes, the NASA satellite data, the Meteonorm software simulation, and the actual measuring in Simikot.

Average 30º towards Equator Tilted Solar Irradiation from 1983 –1993 for Nepal from NASA (http://eosweb.larc.nasa.gov/)



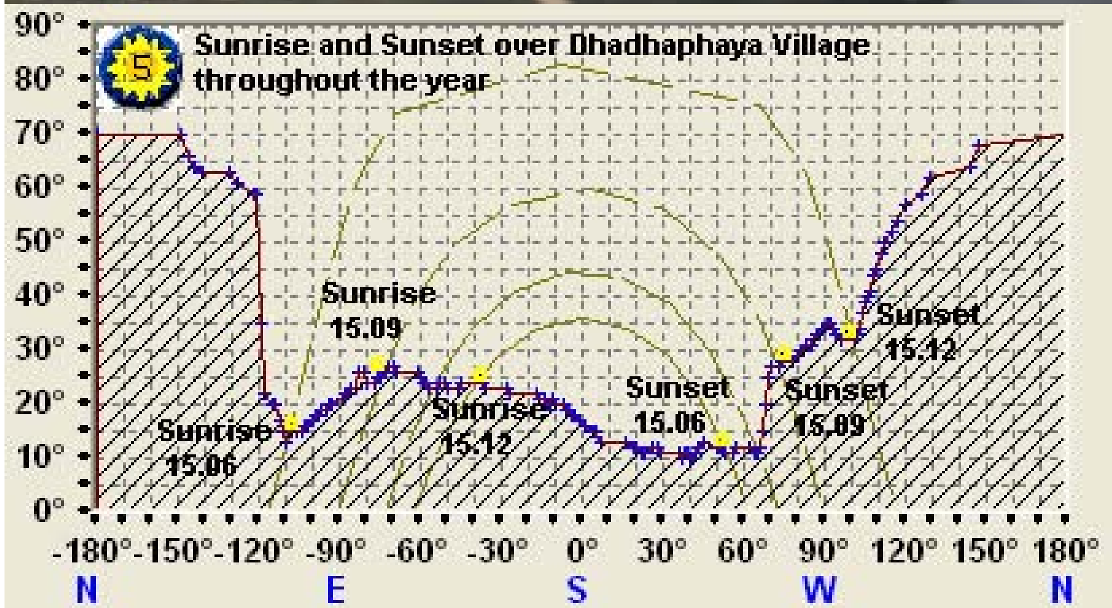
Average Annual Daily Solar Insolation for Chauganphaya Village, at 30° North, and 2’643 m.a.s.l. is ~ 5.2 kWh/m^2 on a 30 ° south tilted surface

METEONORM Solar Insolation Simulation Software



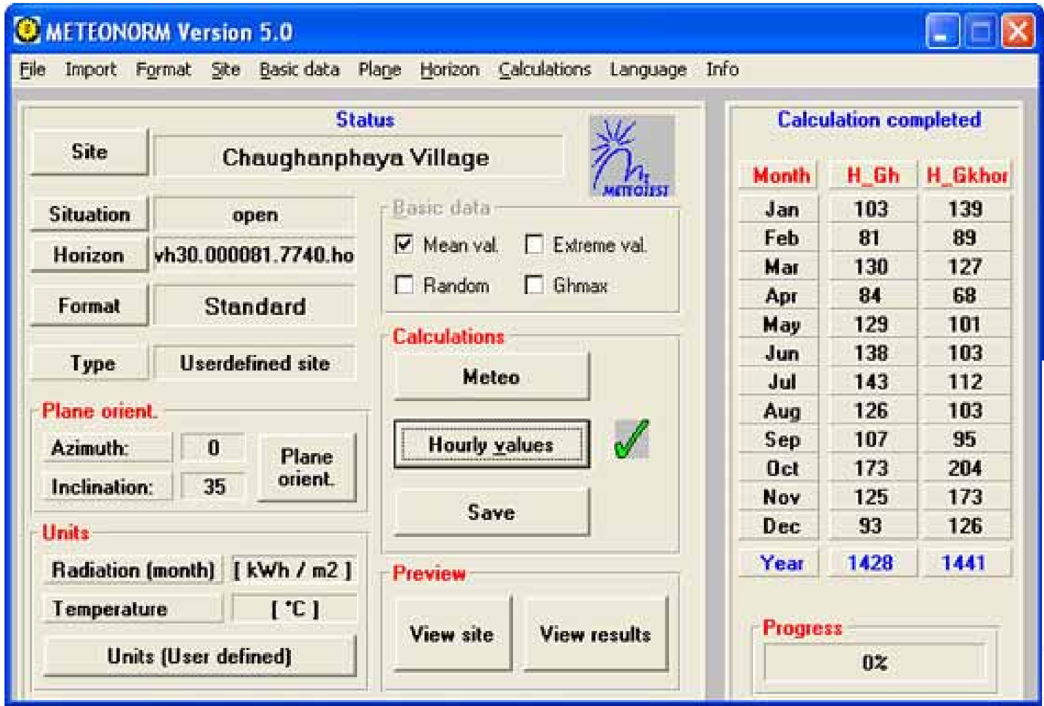
Month	H_Gh	H_Gkhor
Jan	138	193
Feb	81	87
Mar	130	129
Apr	135	122
May	159	135
Jun	136	112
Jul	140	117
Aug	125	107
Sep	112	106
Oct	209	240
Nov	148	205
Dec	118	164
Year	1626	1717

For the Dhadhaphaya Village



Included in the Simulation is the 360 ° Horizon around Dhadhaphaya

Simulated Chauganphaya Solar Insolation Data with Horizon, on a 35° South Tilted Surface



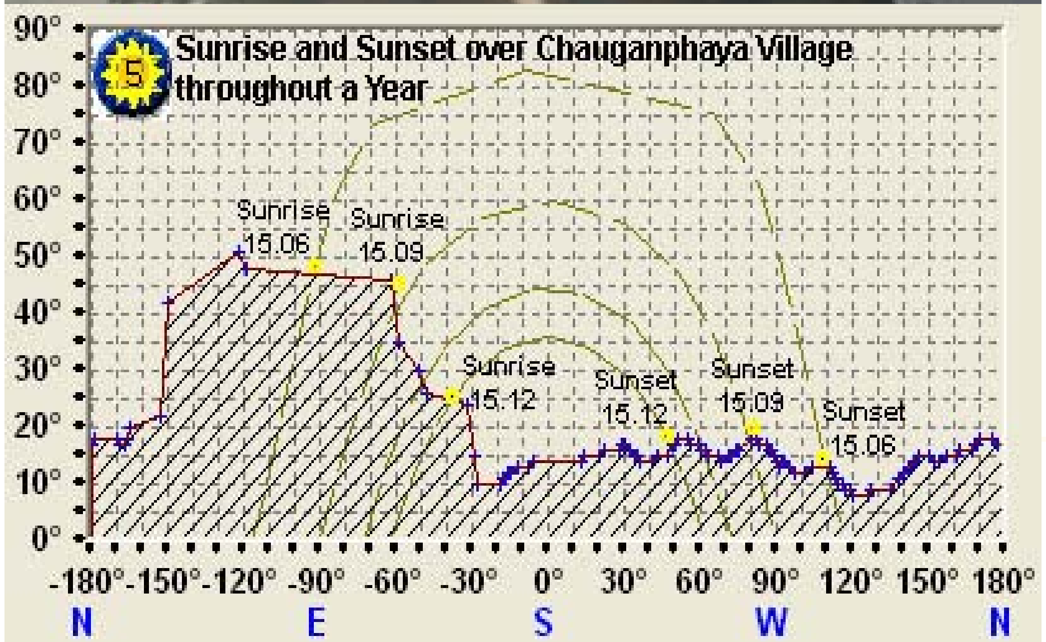
Site:	Chaughanphaya Village
Situation:	open
Horizon:	vh29.967081.8170.hor
Type	Userdefined site

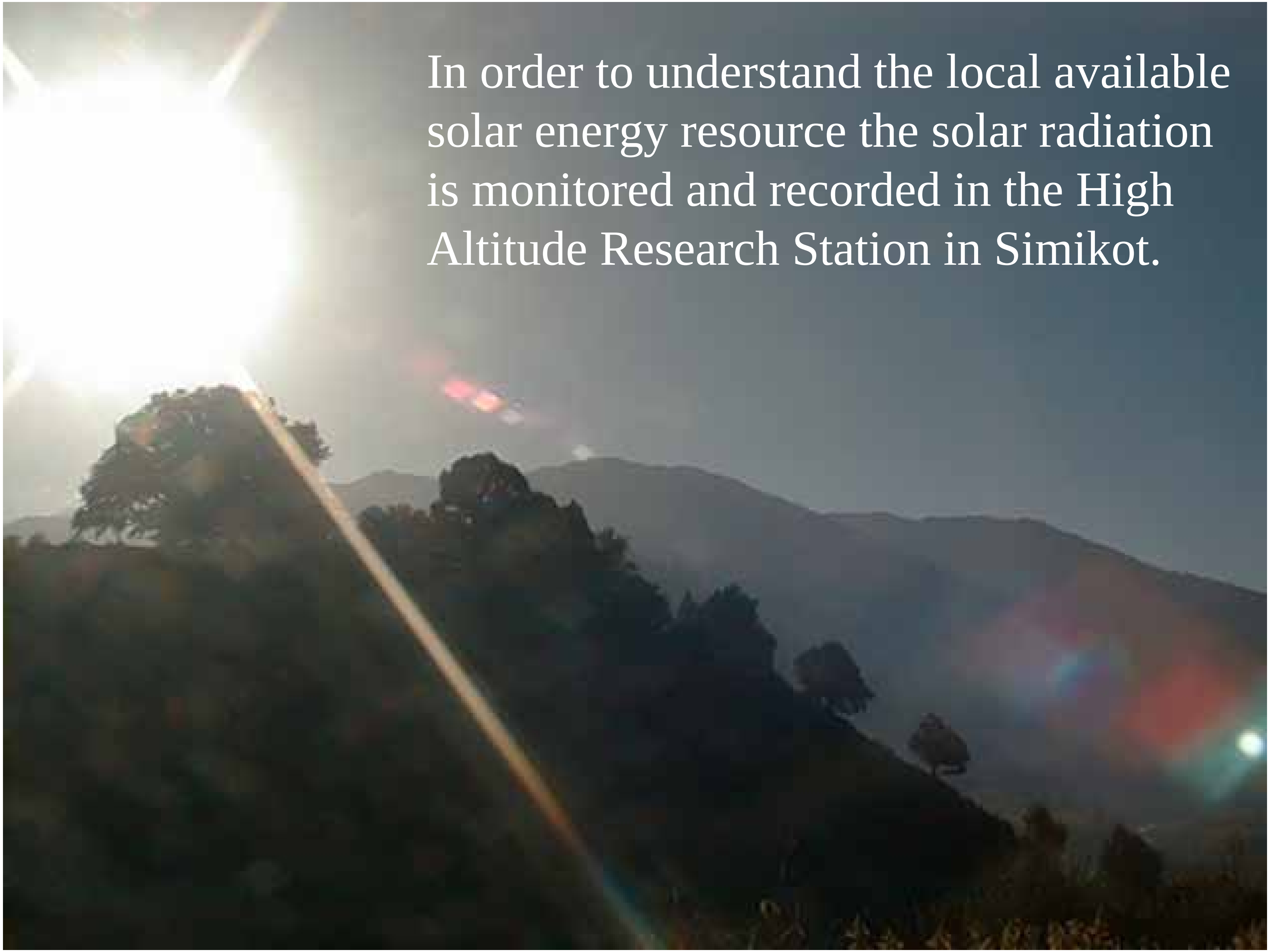
All radiation datas are influenced by a high horizon!
The ending "hor" means with high horizon
Albedo = 0.27

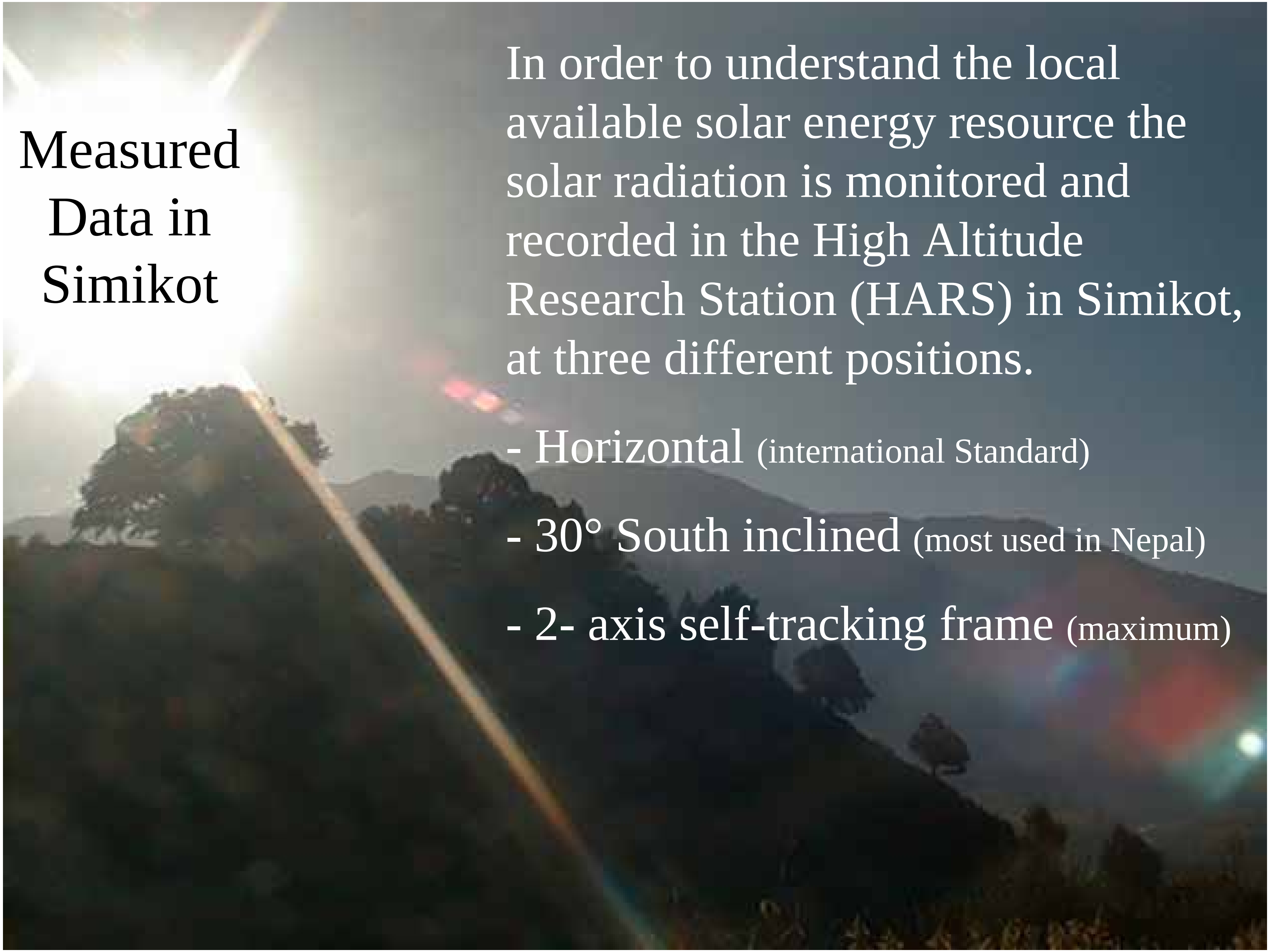
Jan	H_Gh	H_Dh	H_Gkhor	H_Dkhor	H_Bnhor
Jan	103	43	157	59	126
Feb	81	44	100	48	68
Mar	130	66	145	69	106
Apr	84	59	78	53	39
May	129	82	113	74	67
Jun	138	80	116	72	81
Jul	143	73	124	67	90
Aug	126	72	118	67	78
Sep	107	68	110	67	61
Oct	173	39	231	54	230
Nov	125	35	193	52	180
Dec	93	41	143	54	113
Year	1428	703	1627	736	1245

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

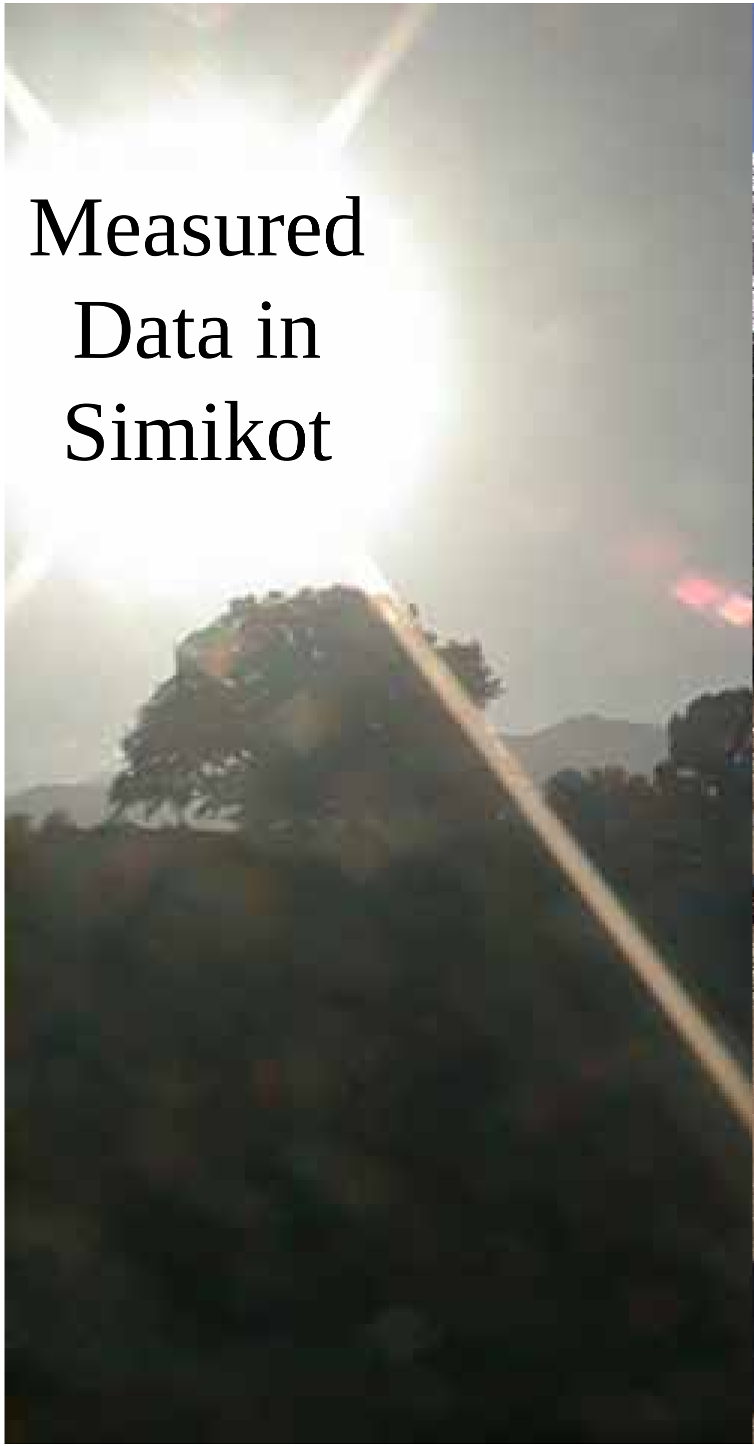
For the Chauganphaya Village

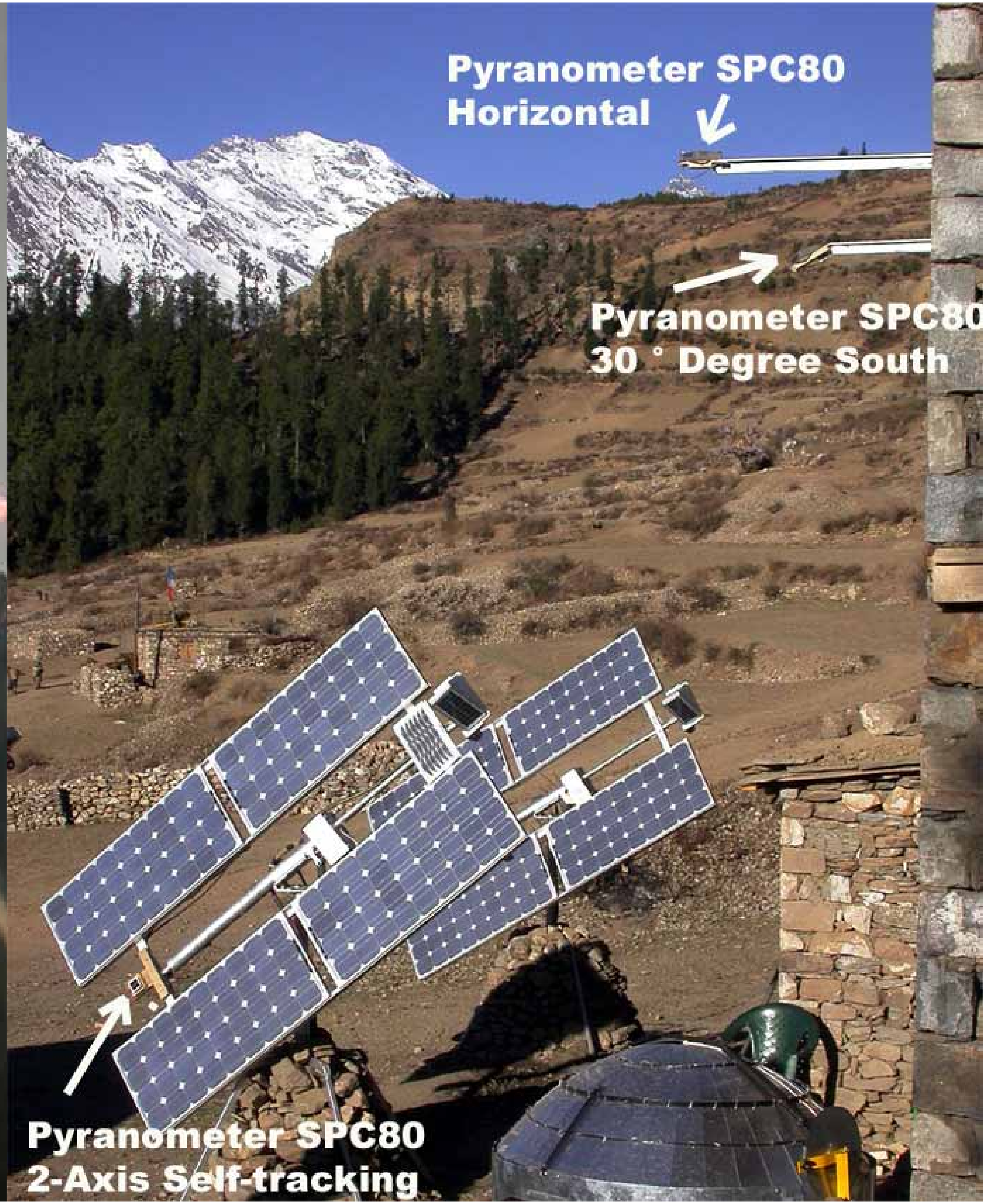



In order to understand the local available solar energy resource the solar radiation is monitored and recorded in the High Altitude Research Station in Simikot.

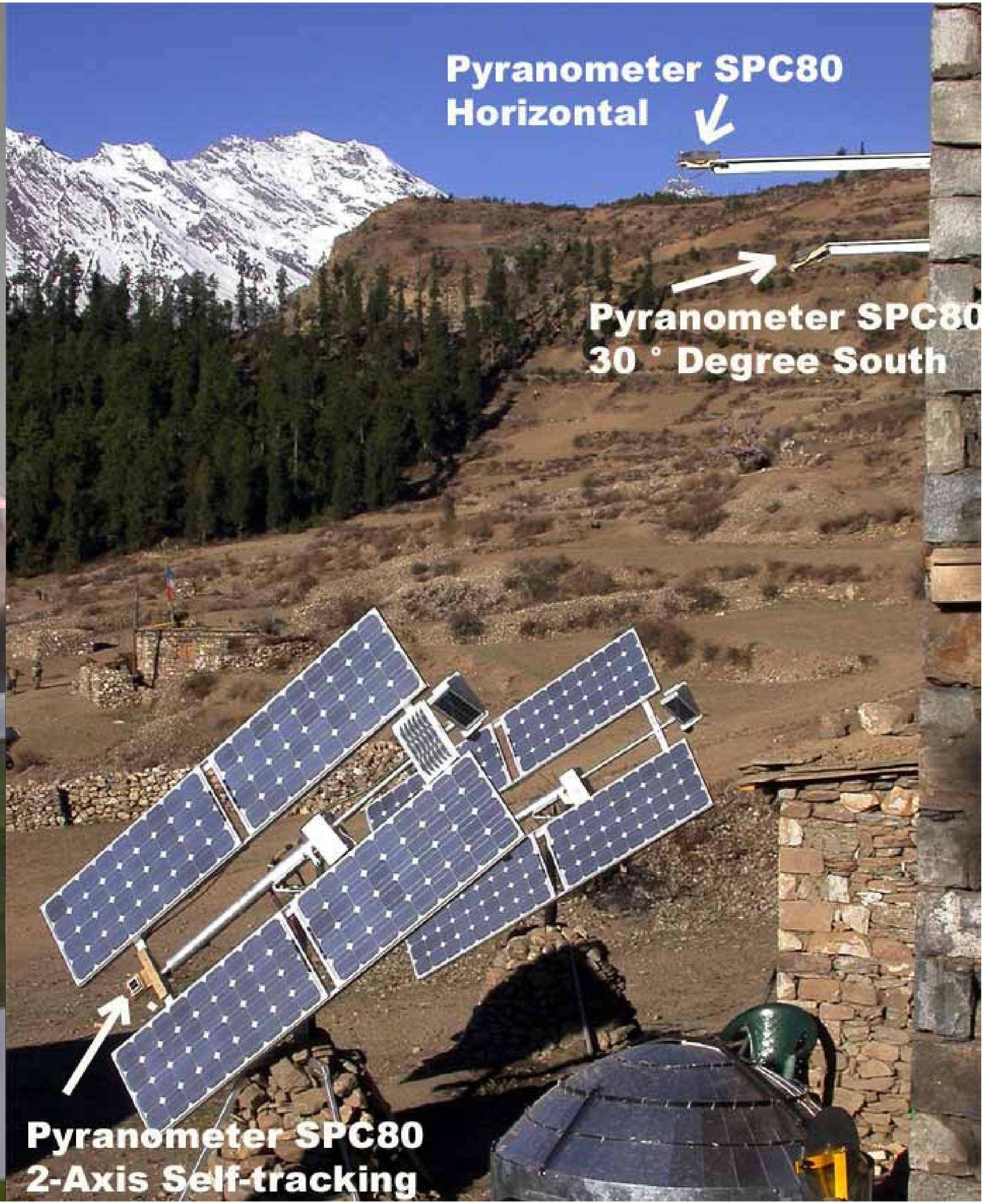

Measured Data in Simikot
In order to understand the local available solar energy resource the solar radiation is monitored and recorded in the High Altitude Research Station (HARS) in Simikot, at three different positions.
- Horizontal (international Standard)
- 30° South inclined (most used in Nepal)
- 2- axis self-tracking frame (maximum)

Measured Data in Simikot

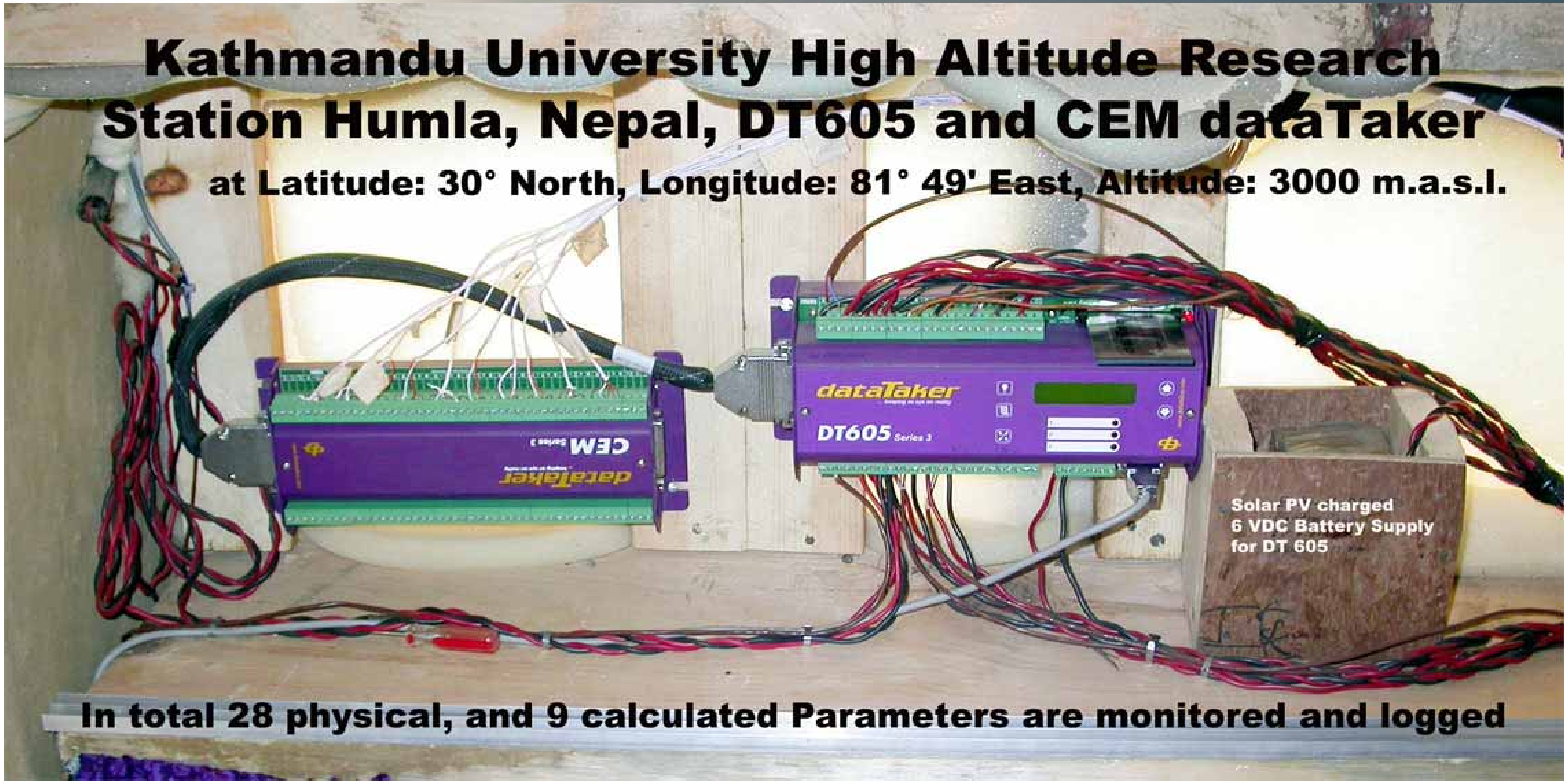


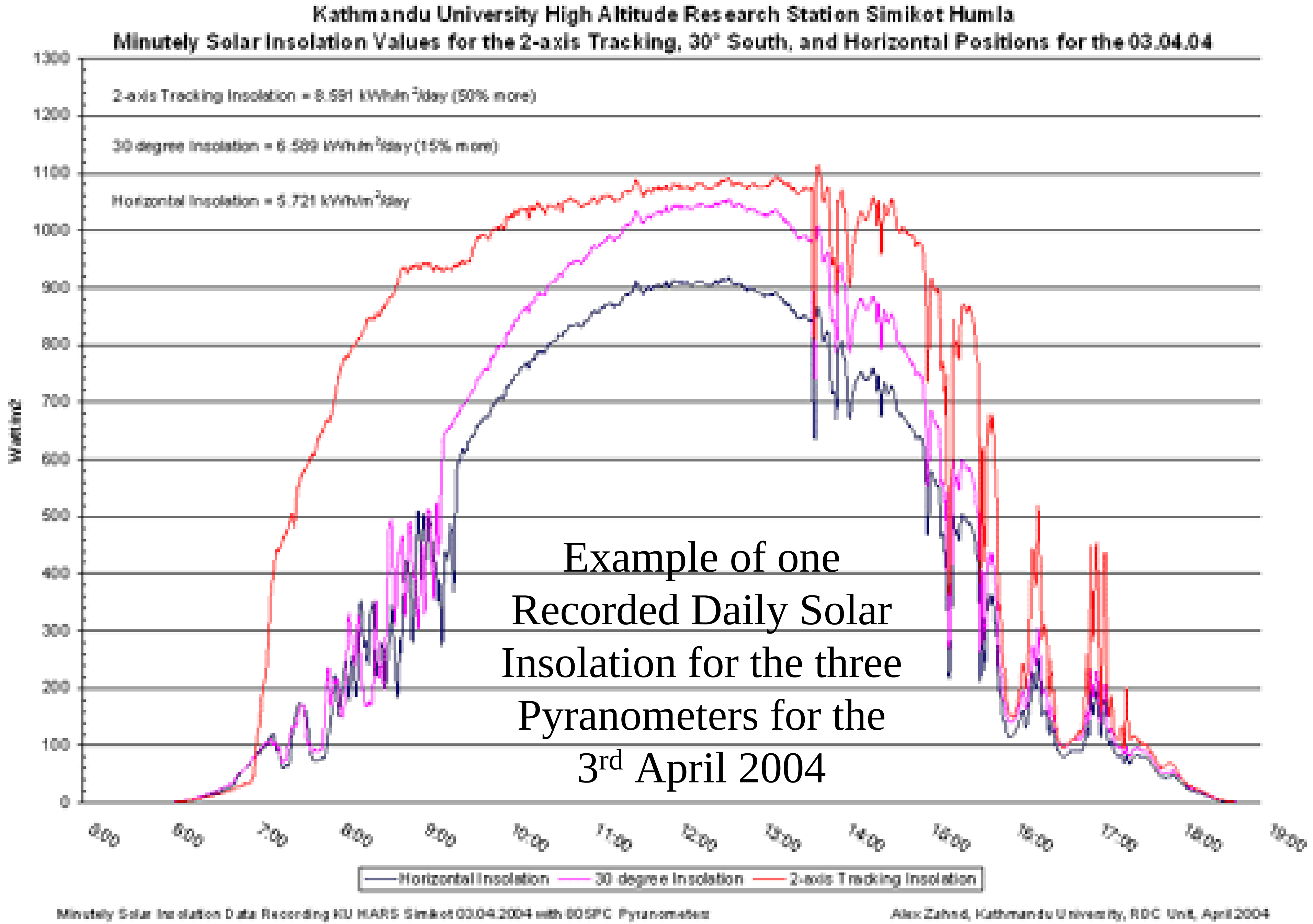



SPC 80 Pyranometer
from SolData Denmark
435: 152mV/(kW/m²)

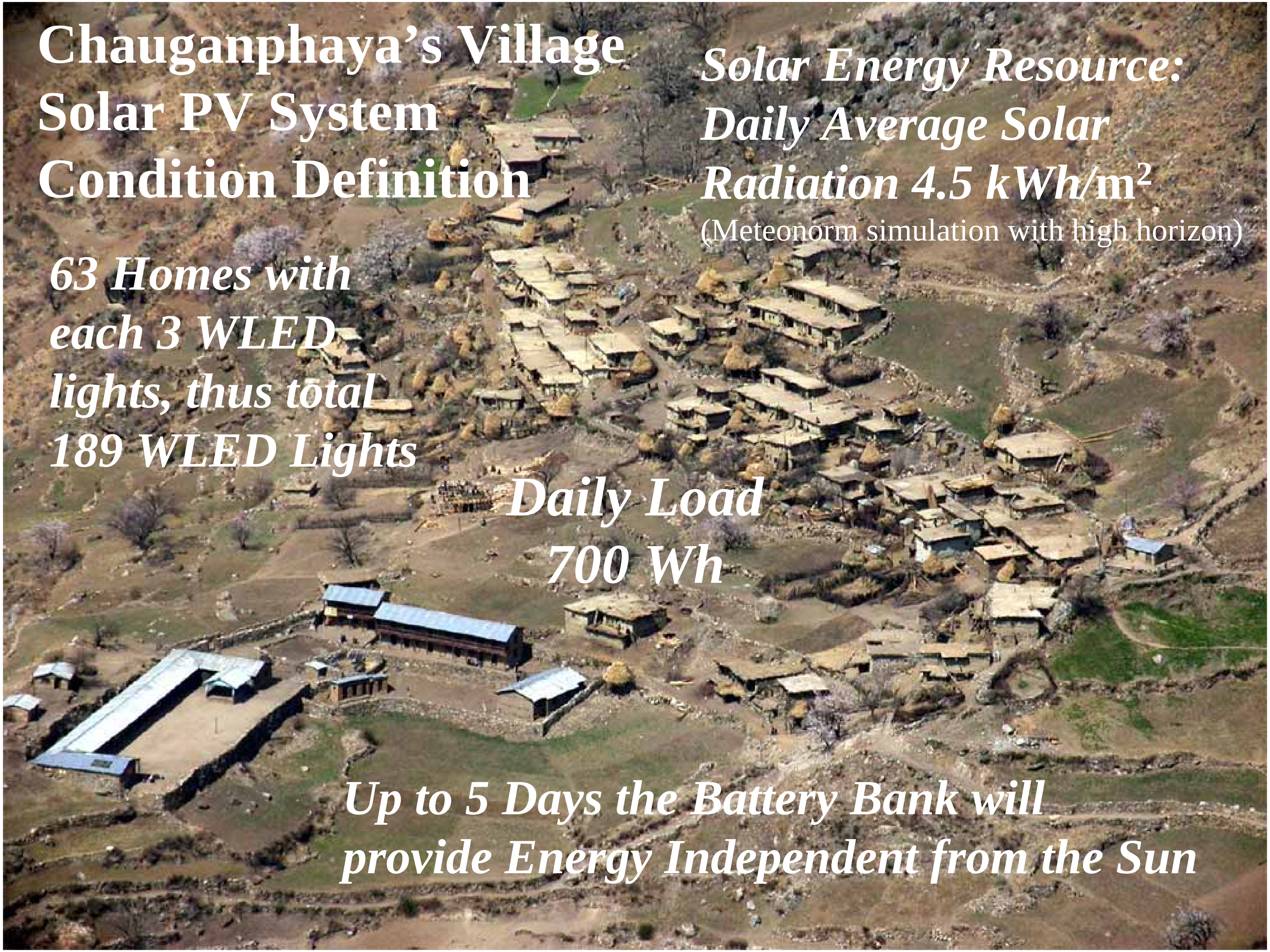

Pyranometer SPC80
Horizontal
Pyranometer SPC80
30 ° Degree South
Pyranometer SPC80
2-Axis Self-tracking

The recorded data in the dataTaker DT605 is downloaded on a weekly basis to the PC. A CD is written and sent to Kathmandu to be evaluated and to create the graphical display of the 3 different solar insolation values as well as the other data.





Example of one Recorded Daily Solar Insolation for the three Pyranometers for the 3rd April 2004


Chauganphaya’s Village
Solar PV System
Condition Definition
Solar Energy Resource:
Daily Average Solar
Radiation 4.5 kWh/m2
(Meteonorm simulation with high horizon)
63 Homes with
each 3 WLED
lights, thus total
189 WLED Lights
Daily Load
700 Wh
Up to 5 Days the Battery Bank will
provide Energy Independent from the Sun

Back of the Envelope Calculation of the Chauganphaya Solar PV Village System

Solar PV array Size:
700 Wh (daily load) / 0.8 (battery bank efficiency) = 875 Wh per day

Battery Bank size:
5 Days (Independency from the Sun) x 0.7 kWh (daily load) / 0.35 (DoD) = 10 kWh

Some Basic Input Data for the PVSyst3.31 Design Software Tool

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

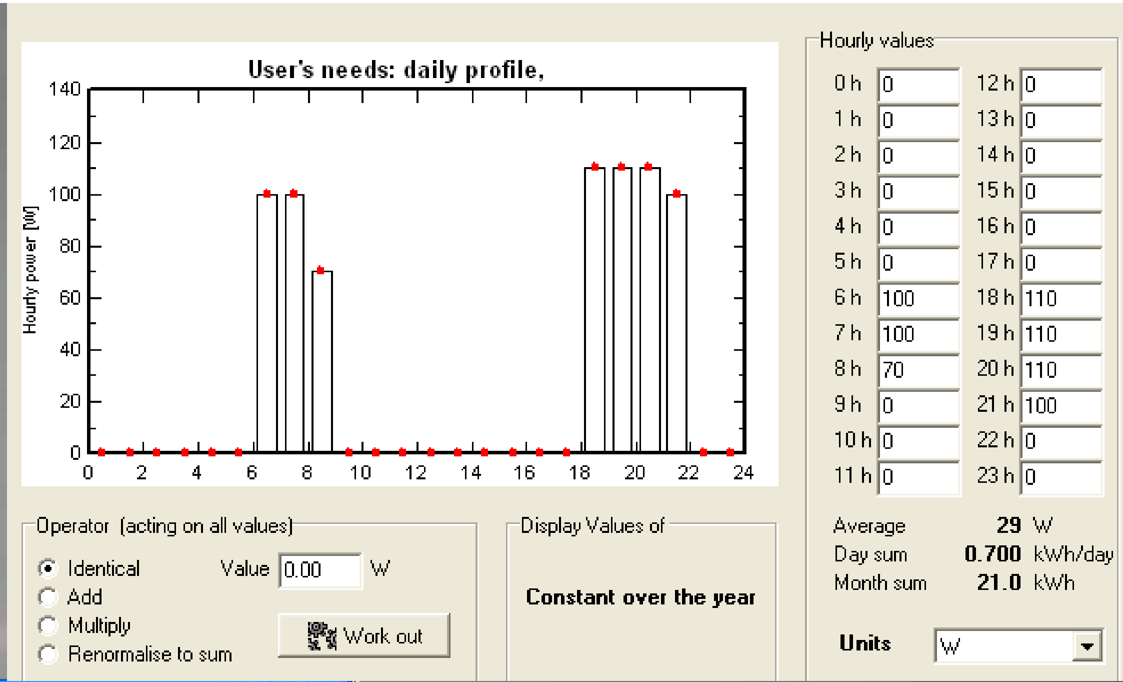
Total number of PV modules : Nb. modules 4 unit nom. power 75 Wp

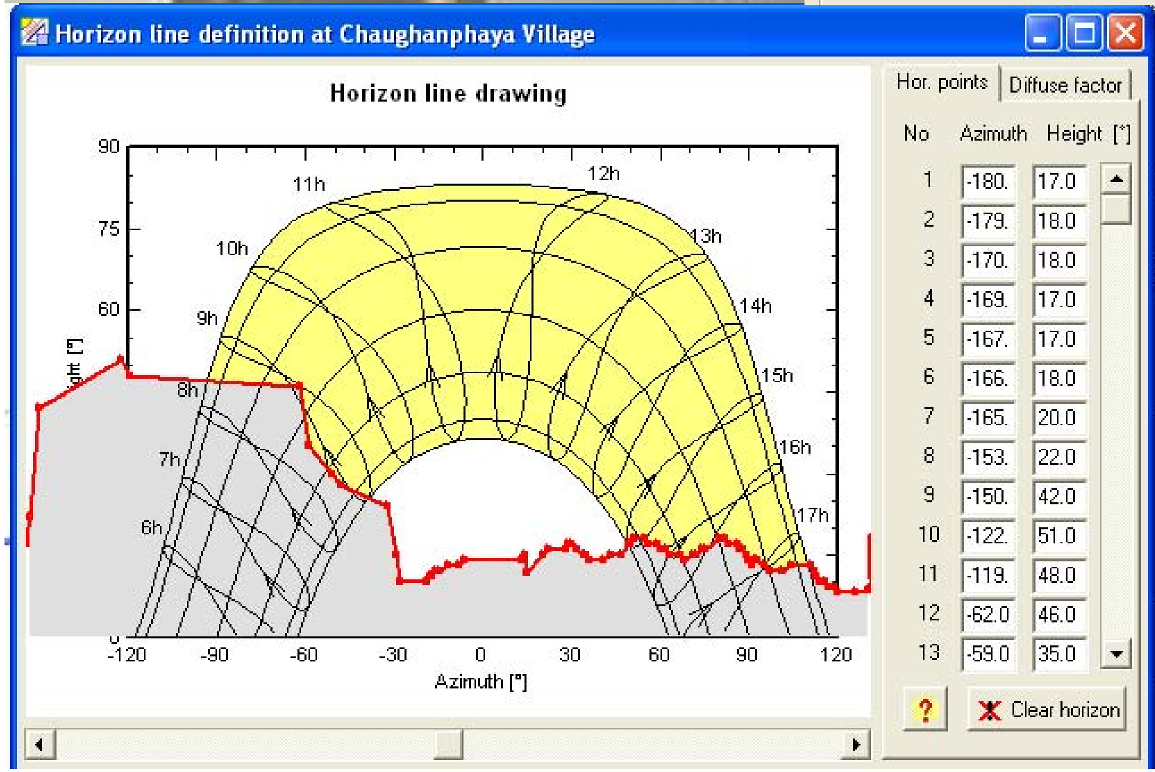
Array global power Nominal (STC) **300 Wp** At oper. cond. 270 Wp (50°C)

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

More Input Data for the PVSyst3.31 Software Tool





Daily Light Load Distribution Profile

Chauganphaya's Horizon line is included in the Design Simulation

Some of the Major PVSyst3.31 Design Simulation Output Results

PVSYST V3.31	Chauganphaya Elementary Solar PV Electrification Simulation	23/04/04 09h14	Page 4/5

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**	**[200 NRp = 2.85 US$ (1US$ = 70 NRp)]**	

The Following Equipment is used for the Chauganphaya Village Solar PV System

- Solar PV Modules
- 2-Axis Self-Tracking Frame
- Battery Bank Charger
- Battery Bank
- Battery Bank Discharger
- Underground Cables
- WLED Lights (white light emitting diodes)

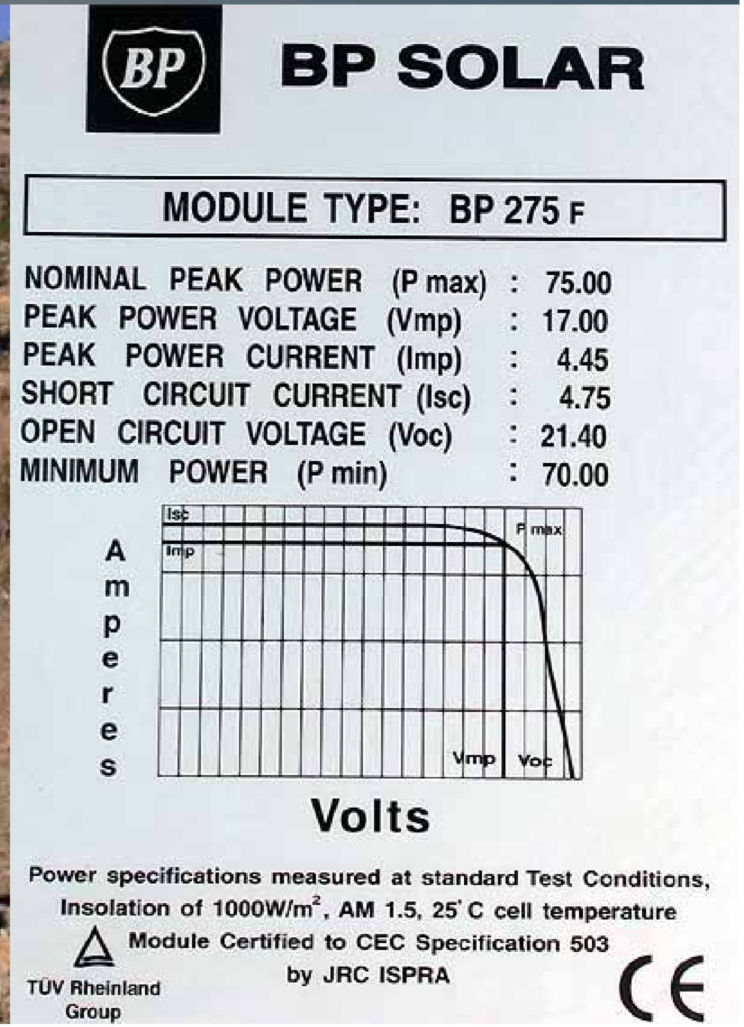
Solar PV Modules : BP 275 F with 75 W

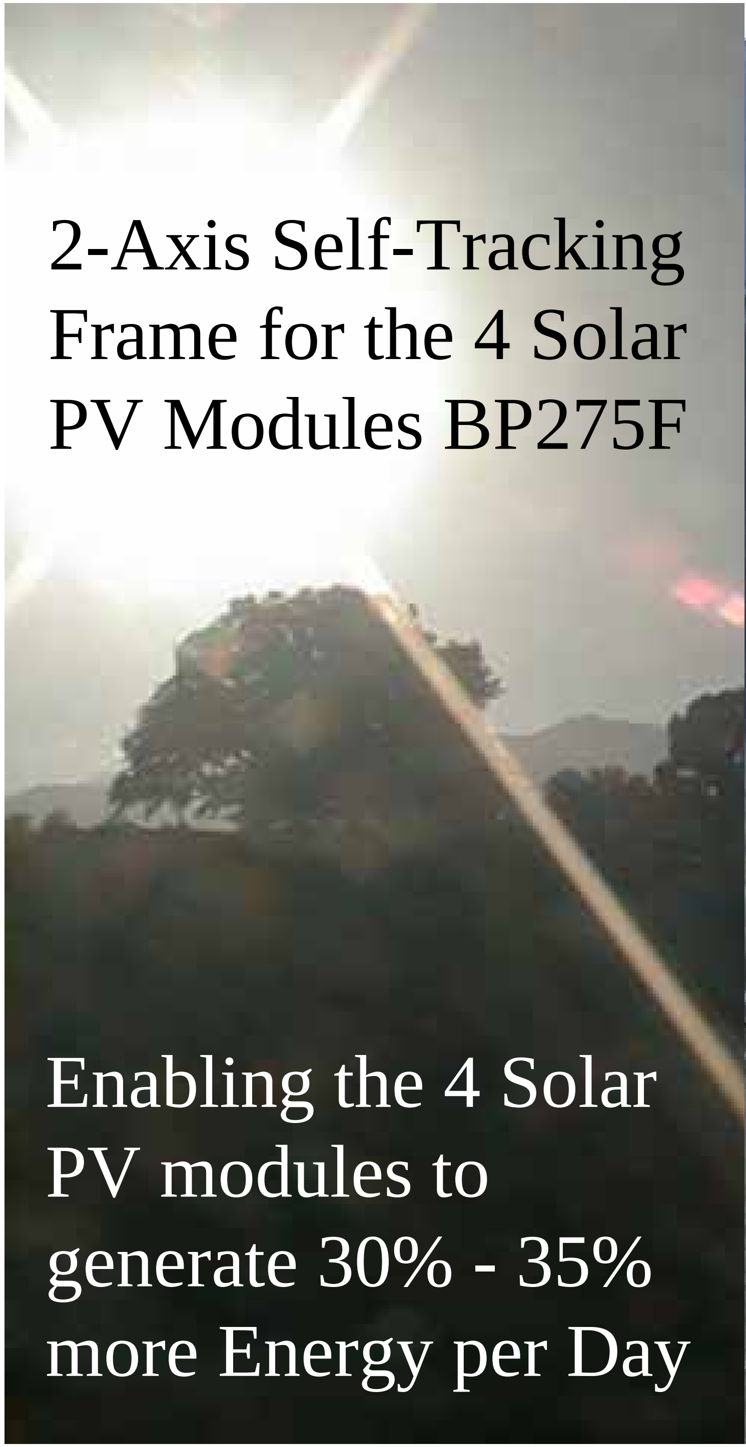
Fill Factor FF:

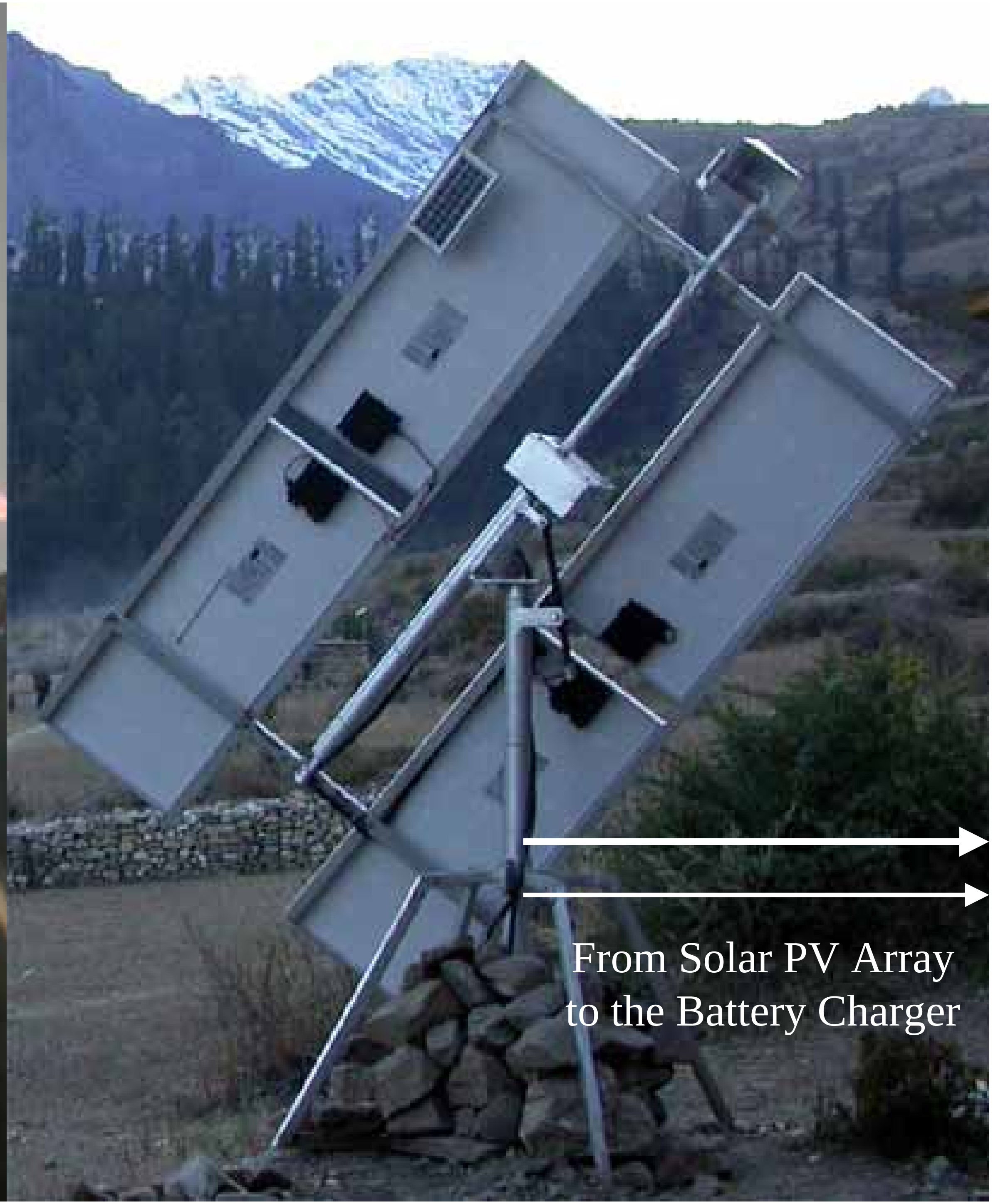
$$\frac{V_{mp}\times I_{mp}}{V_{oc}\times I_{sc}} = \frac{17.00\times 4.45}{21.40\times 4.75} = 0.744 = 74.4\%$$

$$\eta = \frac{P_{\max module}}{P_{\inf romthesun}} = \frac{V_{oc}\times I_{sc}\times FF}{1kWm^{-2}\times A_{modulecells}} = \frac{21.40V\times 4.75A\times FF}{1000Wm^{-2}\times 0.5616m^{2}}\times 100 = 13.47\%$$

(η for STC: 1,000 W/m^2; 1.5AM; 25°C)

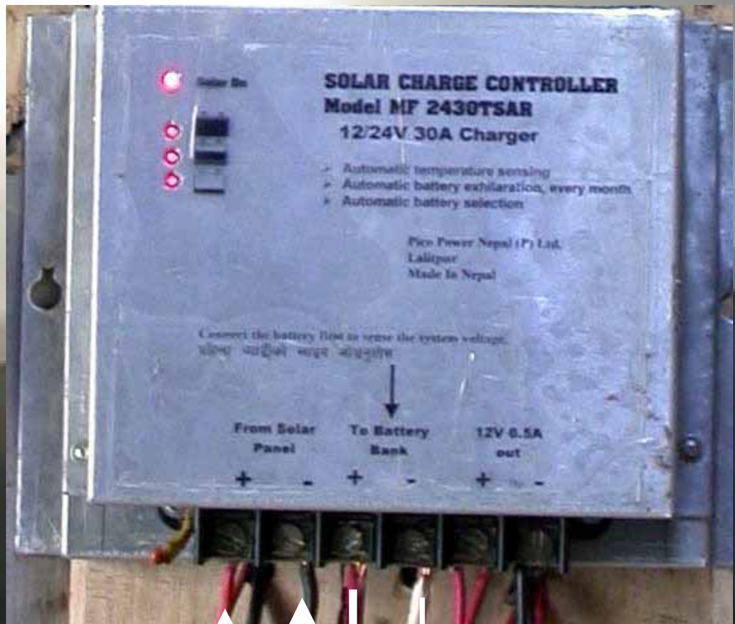



2-Axis Self-Tracking Frame for the 4 Solar PV Modules BP275F
Enabling the 4 Solar PV modules to generate 30% - 35% more Energy per Day


From Solar PV Array to the Battery Charger

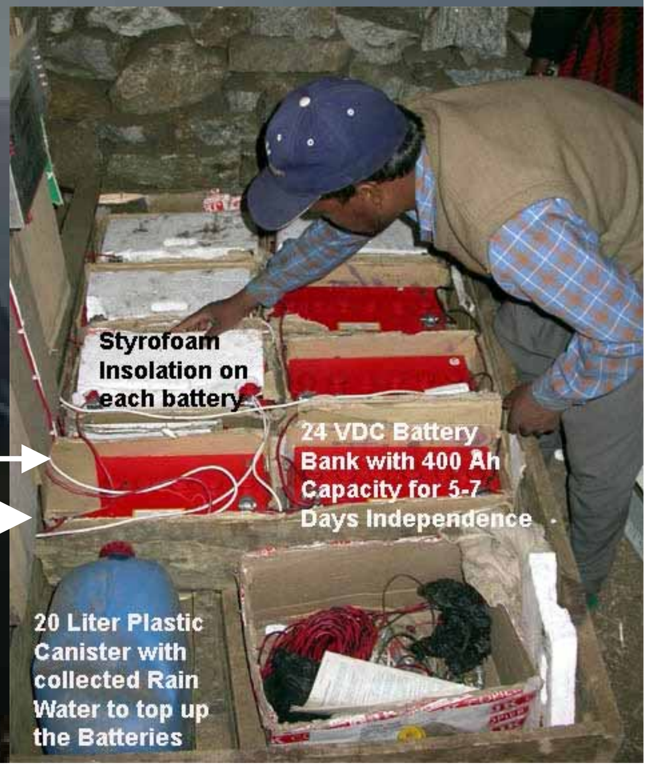
Solar Charge Controller:

- Up to 30 Amps Charging
- Max. Charge Voltage 14.4 VDC
- Temperature Compensation
- Equalizing Voltage 15.4 VDC
- Ambient Temp. 10° C - 50° C



Battery Bank:

- 24 VDC Battery Bank
- 10 kWh Capacity
- 8 x 12 VDC x 100 Ah
- 5 Days Independency



From Solar PV Array

From the Solar Charger to the Battery Bank

Battery Discharge Controller:

- Up to 2 x 140 WLED lights
- Max. load 20 A @ 12 VDC
- Visual Battery Charge condition
- Ambient Temp. 10° C - 50° C

189 x 1 Watt WLED Lights

Underground Cables to the WLED Lights

From Battery Bank to Solar Discharger

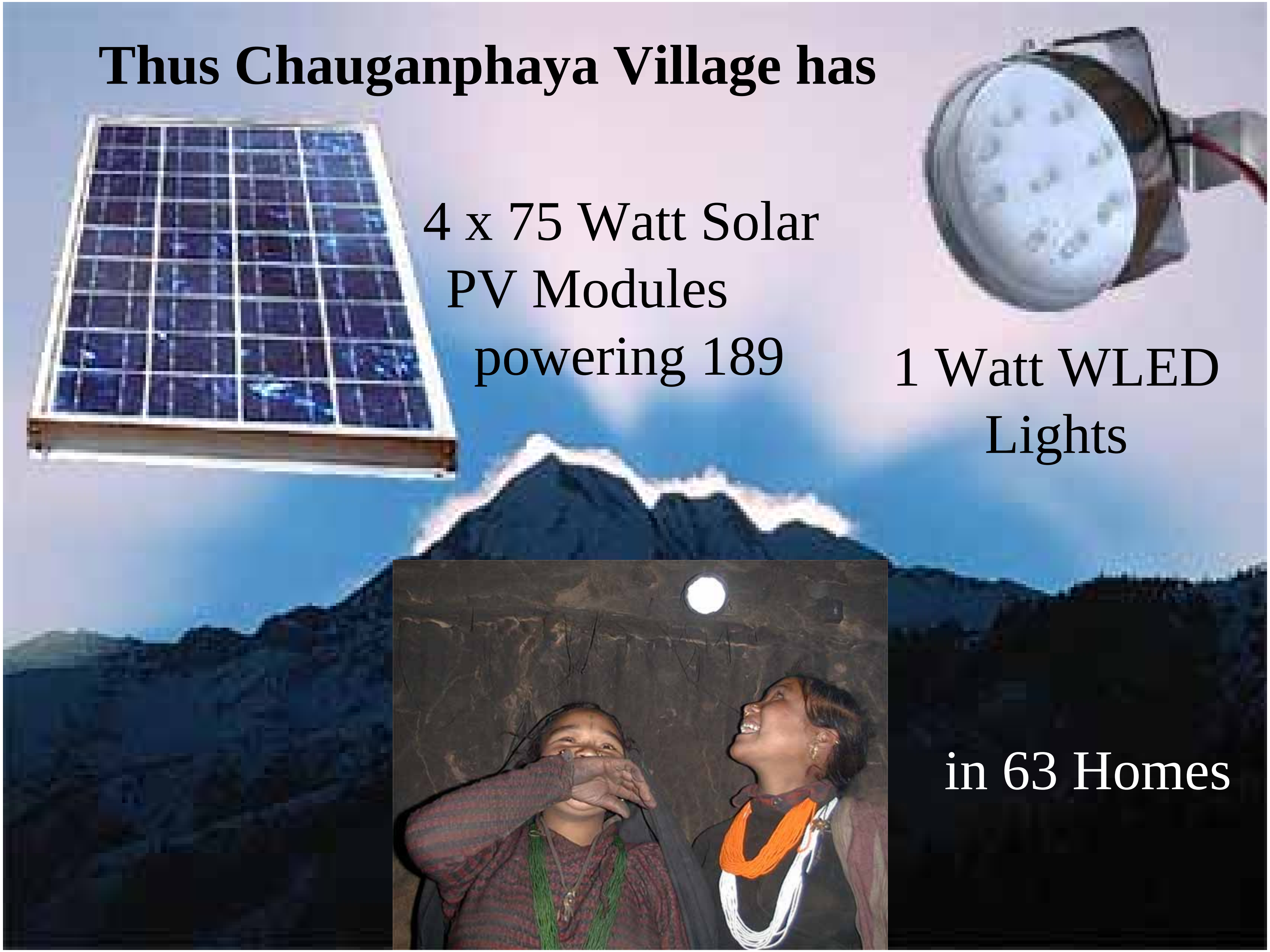
Solar Discharger to the Underground Cables

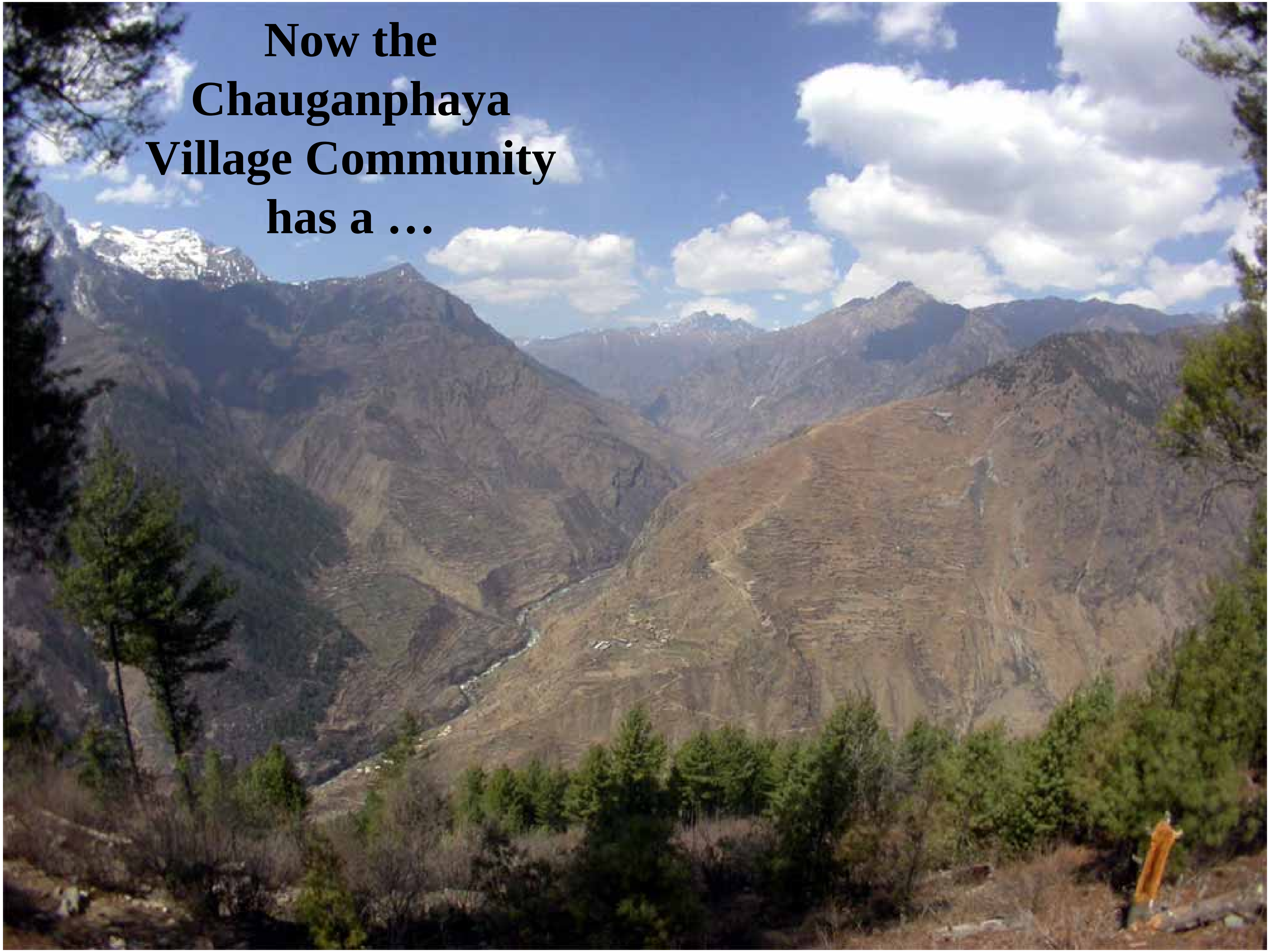
Training and Hands – On Practical Installation

Creating Ownership

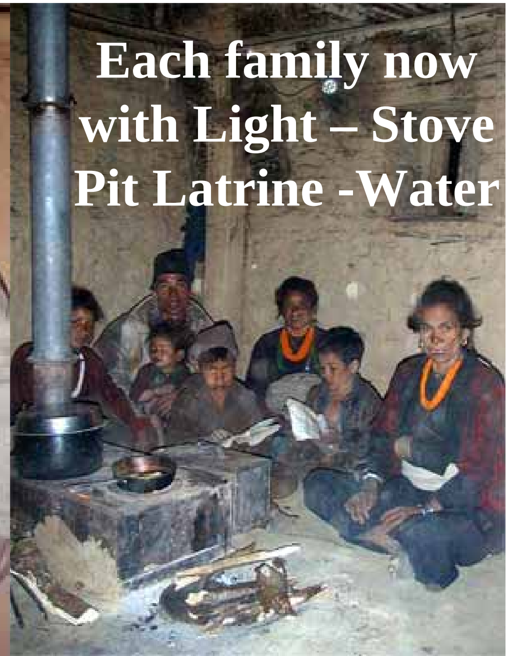
Two chosen Local Peoples have been Educated to Look After and Maintain the Solar PV System

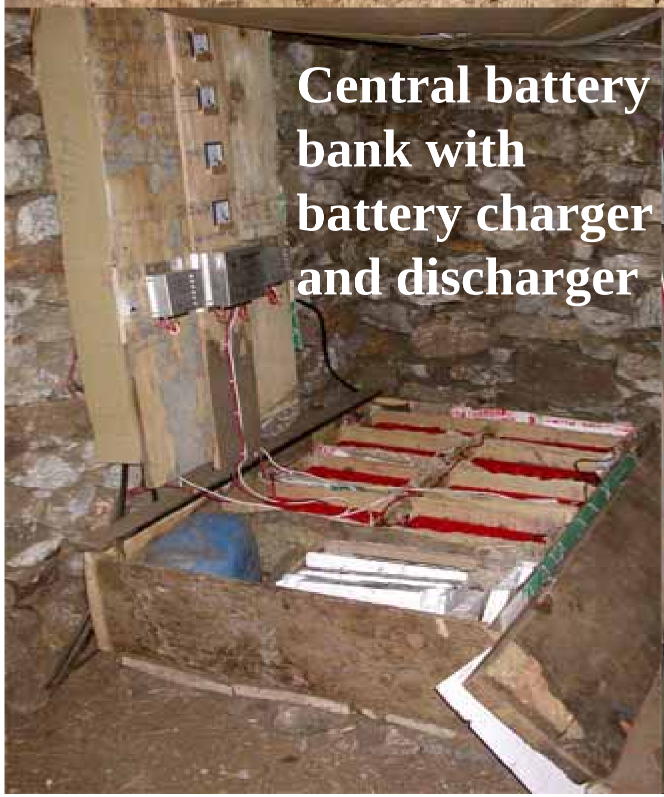
Each Household Participates in the Underground Cabling

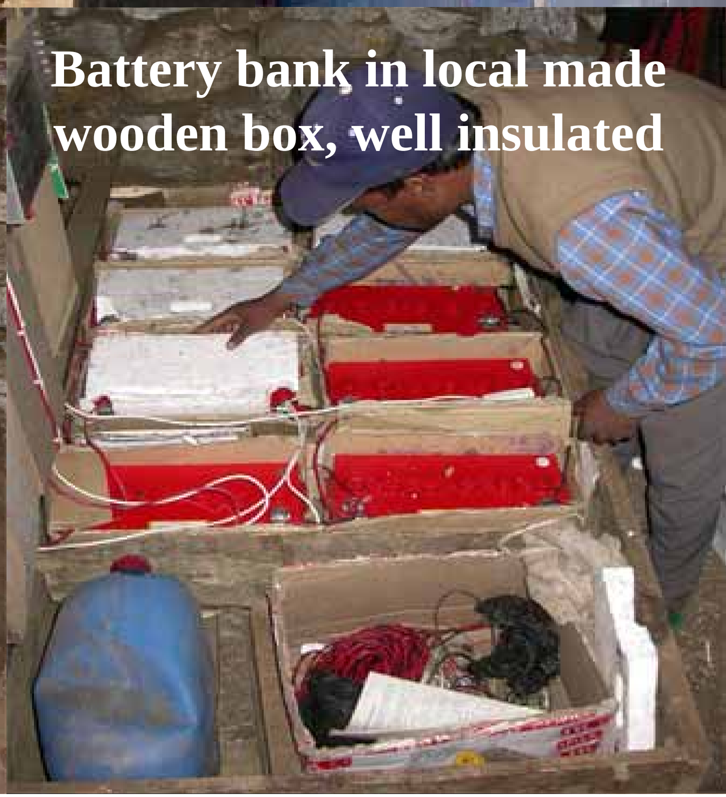

Thus Chauganphaya Village has
4 x 75 Watt Solar PV Modules powering 189
1 Watt WLED Lights
in 63 Homes

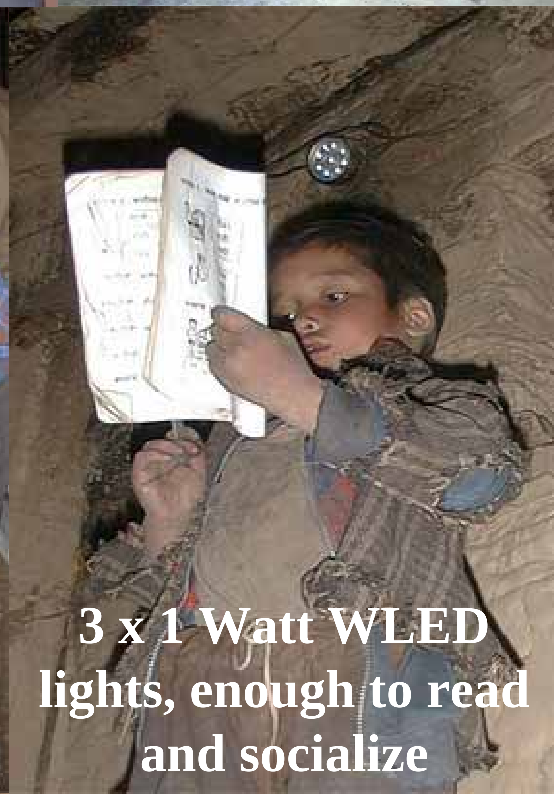

Now the
Chauganphaya
Village Community
has a …


Central village located
300 W_R Solar PV system
with a self-tracking frame.


Each family now
with Light – Stove
Pit Latrine -Water


Central battery
bank with
battery charger
and discharger


Battery bank in local made
wooden box, well insulated


3 x 1 Watt WLED
lights, enough to read
and socialize

WLED Lights

Smokeless Metal Stoves

..to Meet the Needs in a more Holistic Way, not only Lights, BUT also . .
… have been installed in the Chauganphaya Village Community

Pit Latrines

Clean and save Drinking Water


No Smoke - Less Firewood
Smokeless
Metal Stove
in the Home

No Smoke - Less Firewood

Open Fire Place, the Homes Full of Smoke. The Daily Firewood Consumption is as high as 30 kg – 50 kg, and the Health of Women and Children is in great danger.

No Smoke - Less Firewood

No Smoke insides Homes through a Smokeless Metal Stove. Daily 40% - 50% less Firewood Consumption. Great Improved Health Conditions.

Open Fire Place, the Homes Full of Smoke. The Daily Firewood Consumption is as high as 30 kg – 50 kg, and the Health of Women and Children is in great danger.


1. Improved Health
2. Improved Hygiene
3. Cleaner Walking Paths
4. Cleaner Fields
5. Cleaner Rivers
Pit Latrine

For healthy Families

Pure and Clean Drinking Water

In close partnership with the local community the drinking water system is defined, and planned.

Pure and Clean Drinking Water

Where the pipes have to go through, where the water taps have to be, are issues decided by the community. The whole system is built together and enjoyed together . . .

Pure and Fresh Drinking Water

To have participated in the building of the own village drinking water system increases also the interest to keep it maintained and running.

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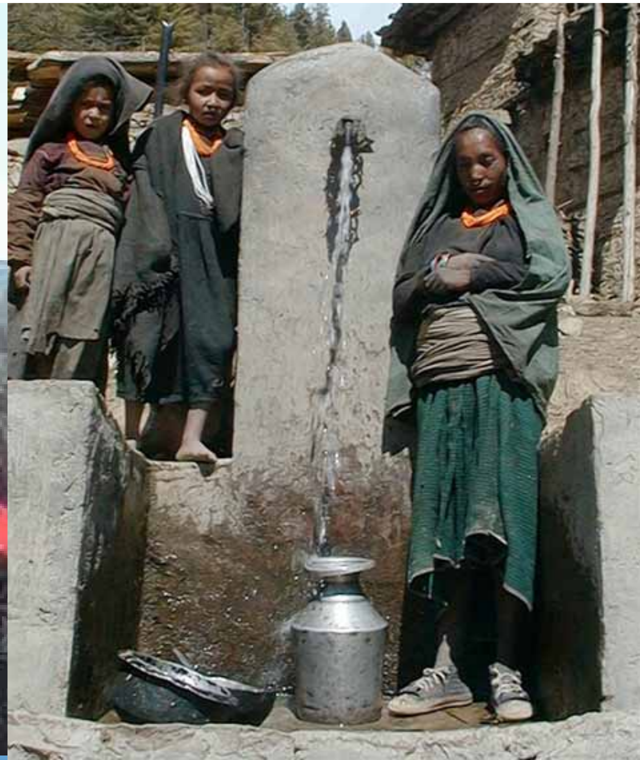
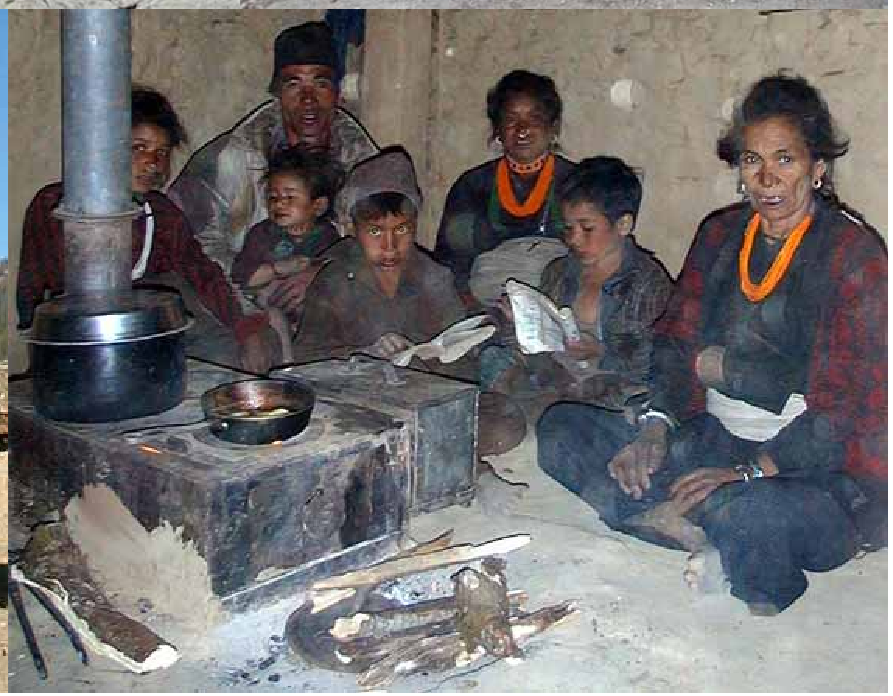
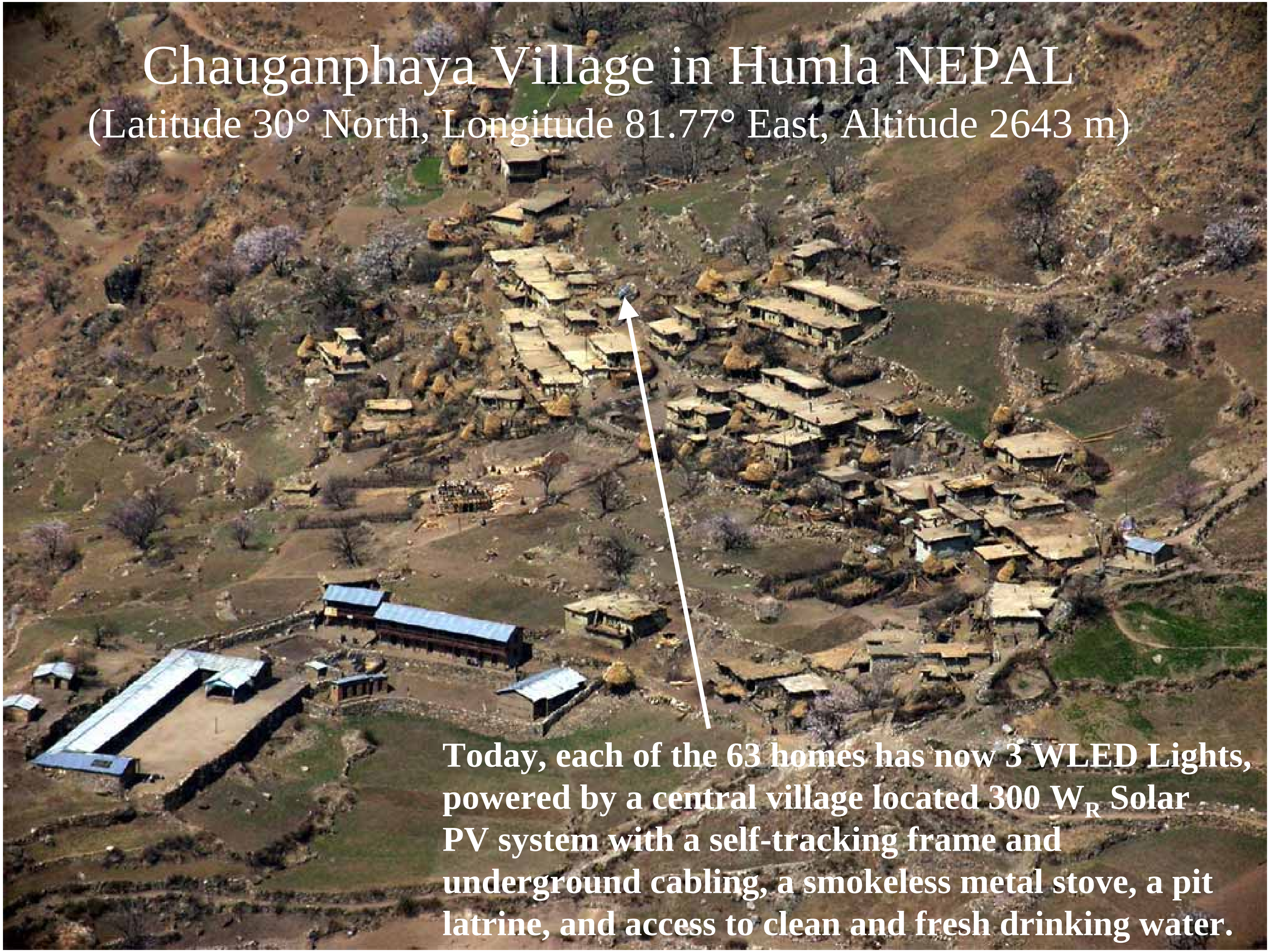



Water
Pit Latrine
A Family of 4
Light, Stove,
Pit Latrine,
Water
Light
Stove


Chauganphaya Village in Humla NEPAL
(Latitude 30° North, Longitude 81.77° East, Altitude 2643 m)
Today, each of the 63 homes has now 3 WLED Lights, powered by a central village located 300 W_R Solar PV system with a self-tracking frame and underground cabling, a smokeless metal stove, a pit latrine, and access to clean and fresh drinking water.

Chauganphaya Village Solar PV System Experience after 8 Months

- The 189 WLED lights are used 5 hours a day, from 06:00–08:00 AM, and from 18:00–20:00 PM.
- The children study in the evening up to 2 hours.
- The fire wood can be cut in the evening. No “jharro” is used anymore.
- 2 WLED lights had to be replaced due to mal functioning.
- Some families wished that the WLED lights are brighter.
- One cluster with 19 homes, which has been connected to the powerhouse with a distance of 400 m instead of 200 m, has too high voltage drop, thus the WLED lights can not provide their full power out put. Remedy: Installing a shorter new line, or a second parallel line.

- Generally more social activities take place in the evenings inside the homes.
- A monthly maintenance fee of NRp 10 (US$ 0.14) is paid by each family. Till end of August NRp 3,500 (US$ 50) has been collected.
- The battery bank’s voltage over the first 8 months (including the monsoon time) was always between 13.5 VDC maximum and 12.3 VDC minimum.
- The 2 axis-self-tracking solar PV module frame runs well so far.

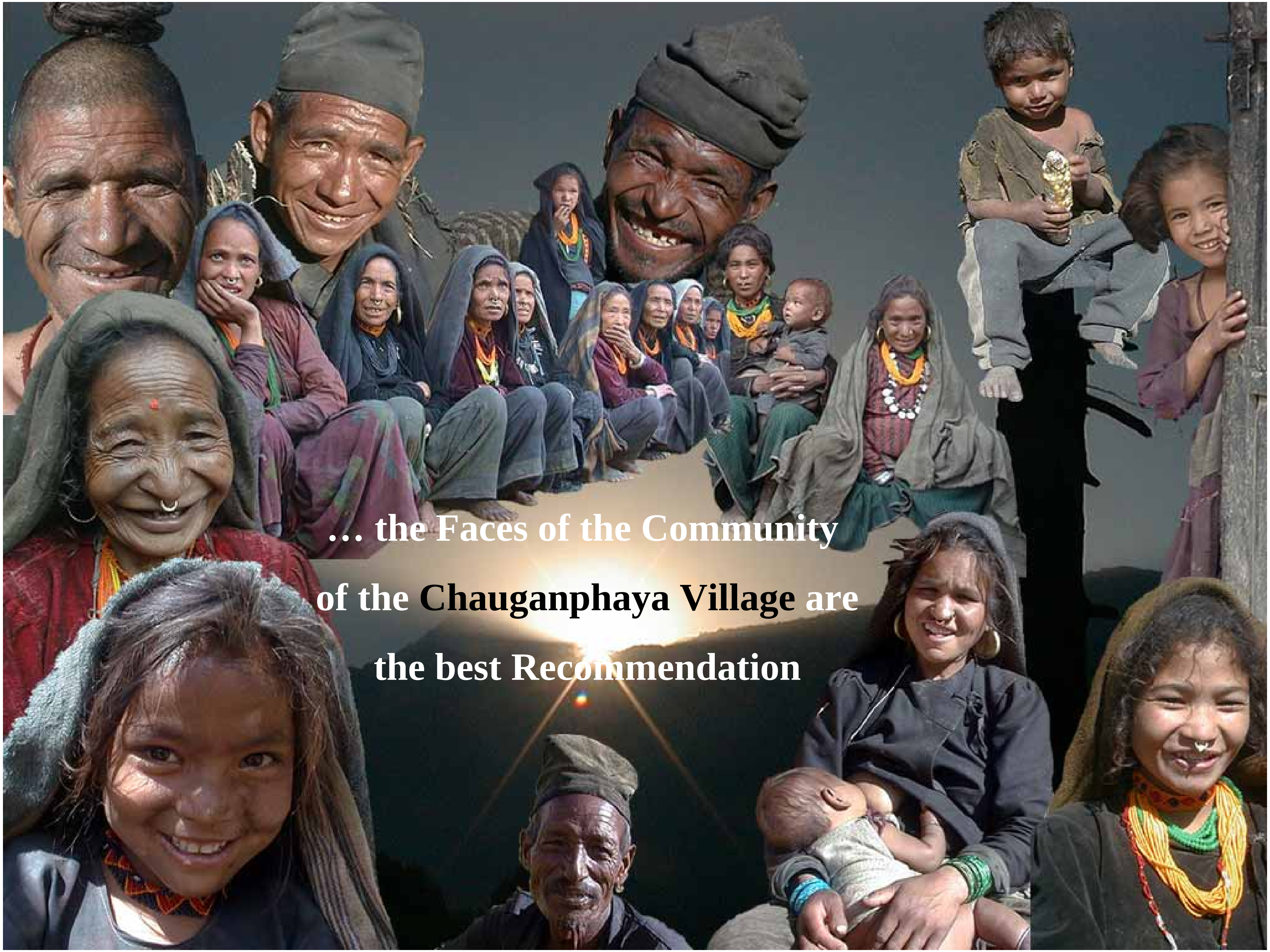

Can this Project be Sustainable . . . ?
Technically . . .
Economically . . .
Socially . . .
Environmental . . . ?

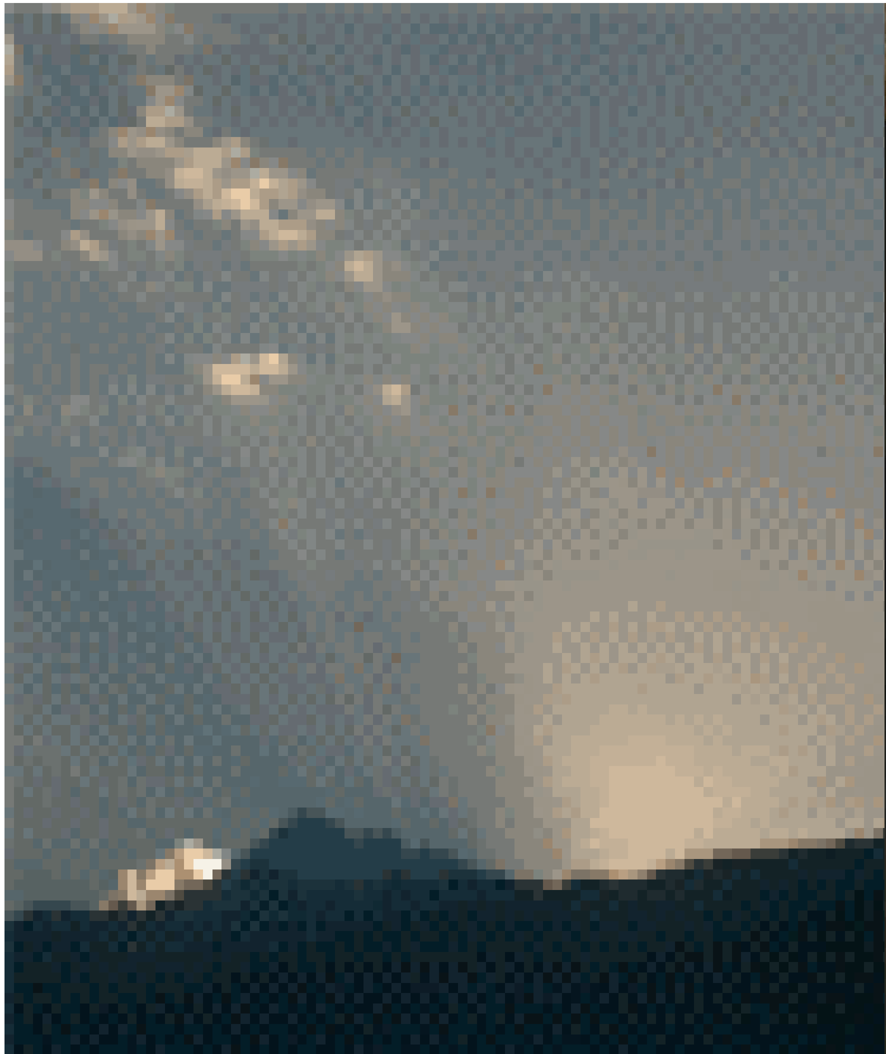
Questions which Need to be Asked and Answered Satisfactory . . . ?

1. Have the needs of all Stakeholders been met ?
2. Is it the best mix of energy and technology: Least-Cost - Preferred by the Community – Sustainable ?
3. Have the Local People Participated from the Start ?
4. Has the local Community defined the “Rules of the Game” ?
5. Have local people be appropriately trained for competently Operation and Maintenance ?
6. Has Sustainability be considered before Efficiency ?
7. Are new Activities and Opportunities created ?
8. Have the overall living conditions improved ?

Recommendation through some of the Major Lessons Learned from the Chauganphaya Solar PV Village System are :

- ❑ Understand the village's conditions before the project starts.
- ❑ Be sensitive to the culture and customs of the peoples.
- ❑ Involve the local community from the beginning in each project step.
- ❑ The choice of power generation technology has to be based on least–cost, preferred by the local community and sustainable"
- ❑ Allot enough time to plan the project.
- ❑ Manufacture as much as possible locally.
- ❑ Get the transport well ahead of time organised.
- ❑ Be aware of import policies and regulations and order accordingly.
- ❑ Incorporate time for technology transfer (teaching local manufacturers, developing and testing new products).
- ❑ Develop a training program for the local operating and maintenance peoples.
- ❑ Once implemented the project has to run according to 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.


… the Faces of the Community
of the Chauganphaya Village are
the best Recommendation



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