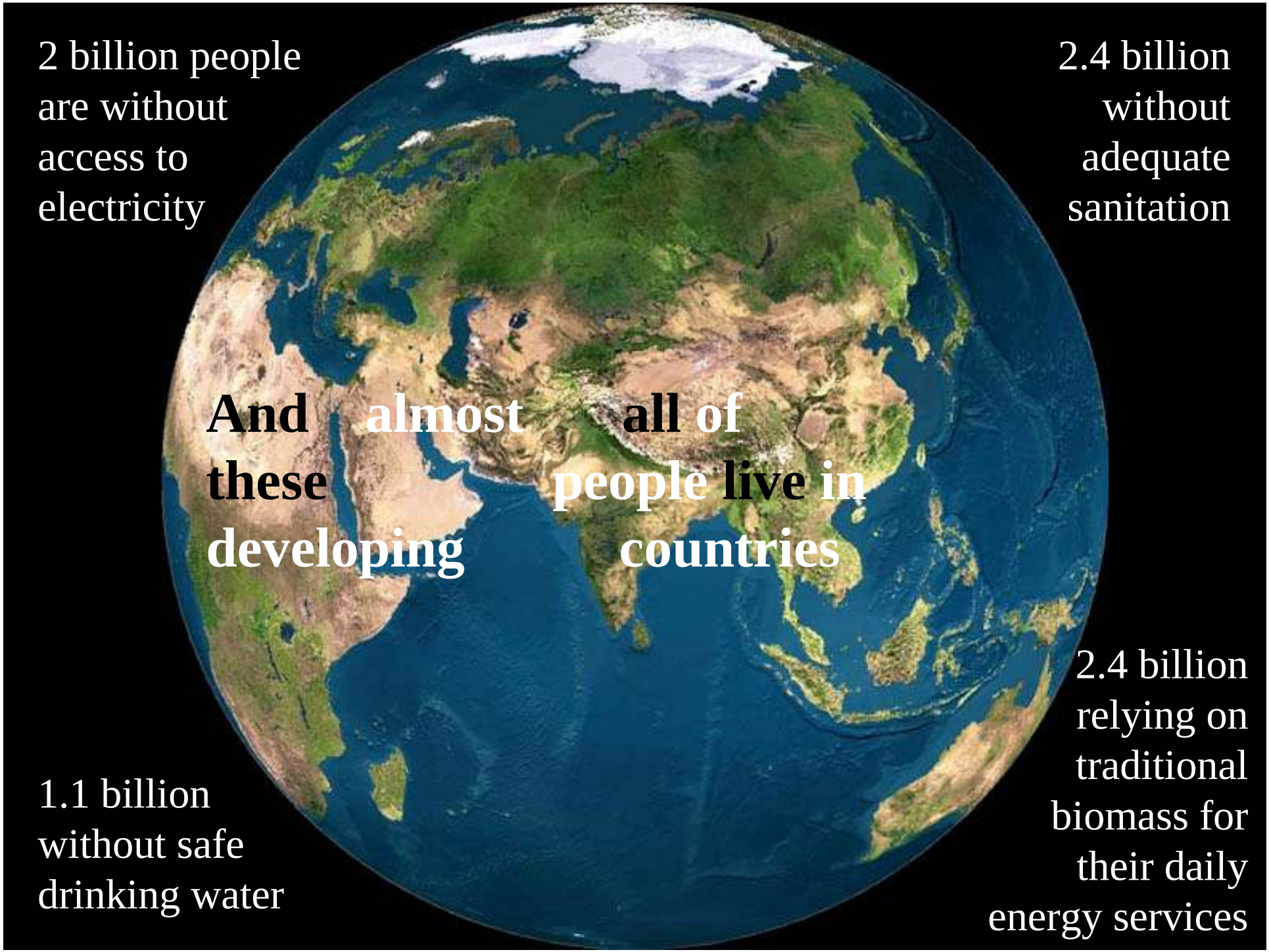
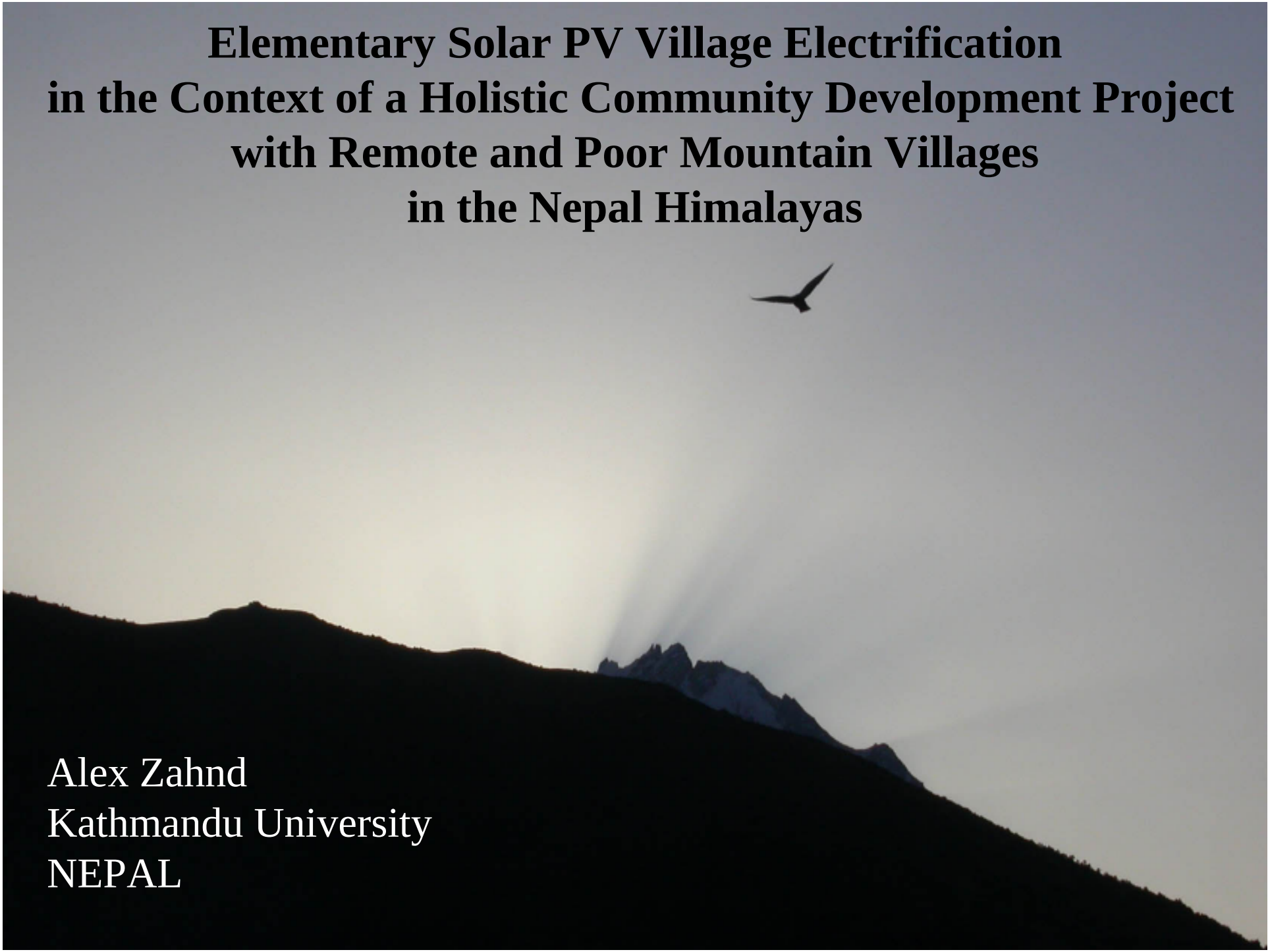

2 billion people are without access to electricity
2.4 billion without adequate sanitation
And almost all of these people live in developing countries
2.4 billion relying on traditional biomass for their daily energy services
1.1 billion without safe drinking water

NEPAL

Bringing Light into . . . . . the Dark Homes
of the Poorest of the Poor

# Elementary Solar PV Village Electrification in the Context of a Holistic Community Development Project with Remote and Poor Mountain Villages in the Nepal Himalayas



Alex Zahnd
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: 27 Mio. 86 % in rural, remote mountain areas.**
4. **Average annual population growth 2.3 %.**
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 (2004) 68.5 kWh.**
9. **42% of Nepali live below the poverty line, and there is a clear relationship between poverty and access to electricity**

# Nepal’s Renewable Energy Resources

10. **Nepal's potential hydroelectric power capacity amounts to an estimated 83,000 MW, with 42,000 MW to be technical and economical feasible.**
11. **Nepal's installed total electric generating capacity (September 2005) is 609 megawatts (MW), of which 90%, or 548 MW is hydroelectric, representing just 1.3 %**
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

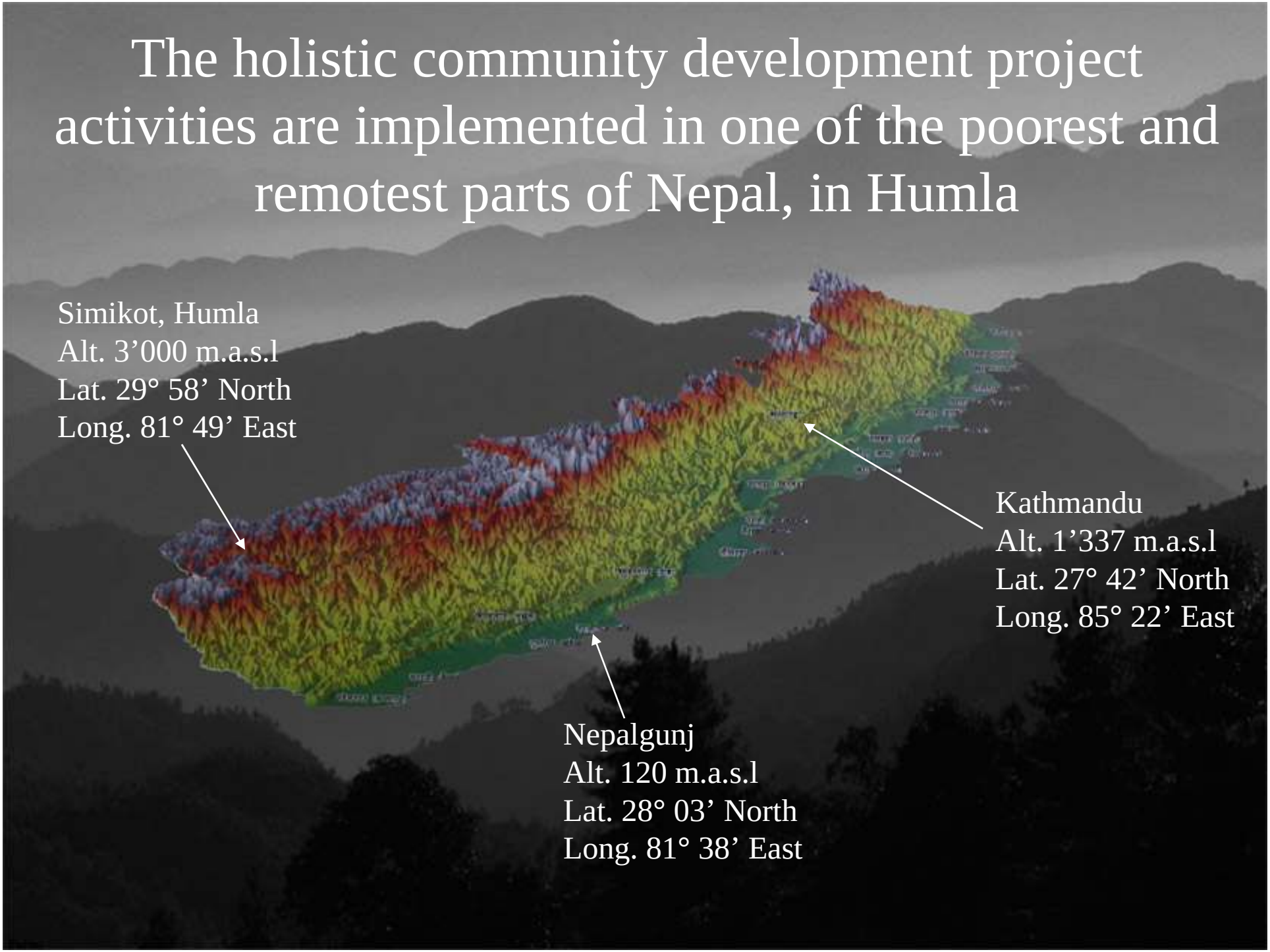
Demands a Holistic working approach, addressing the

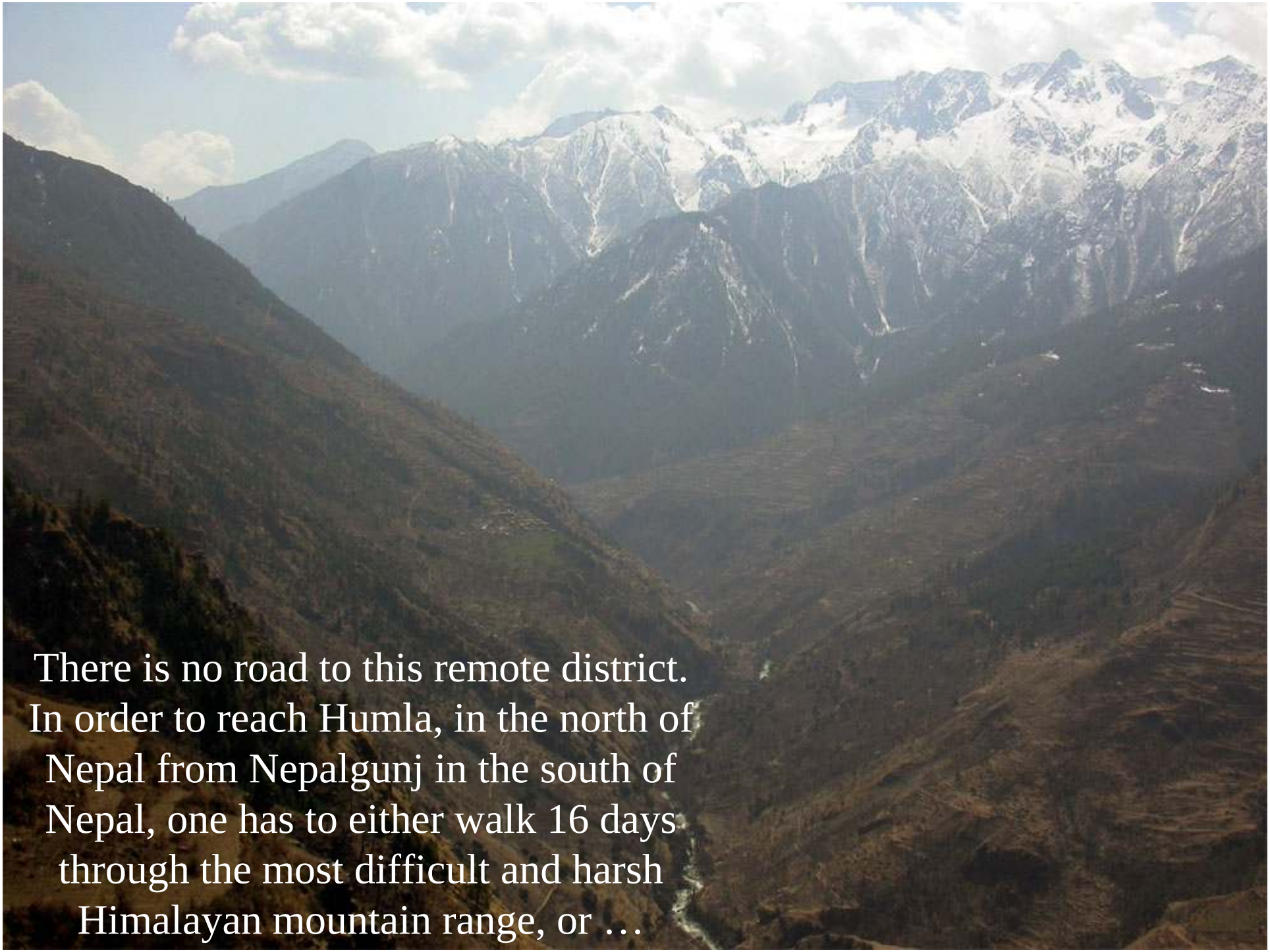
- Social
- Physical
- Mental and
- Spiritual

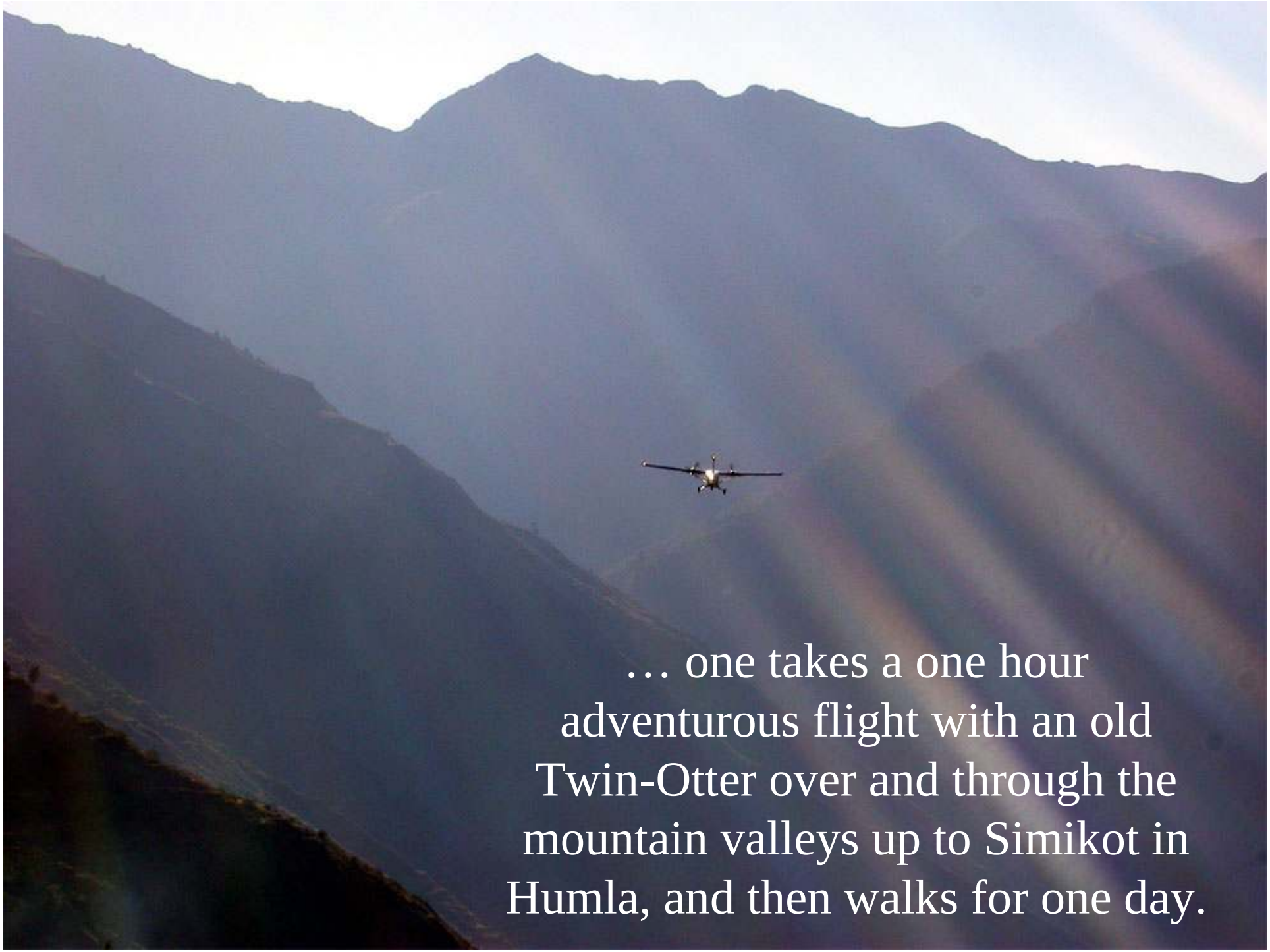
**Needs of the people in sustainable ways**

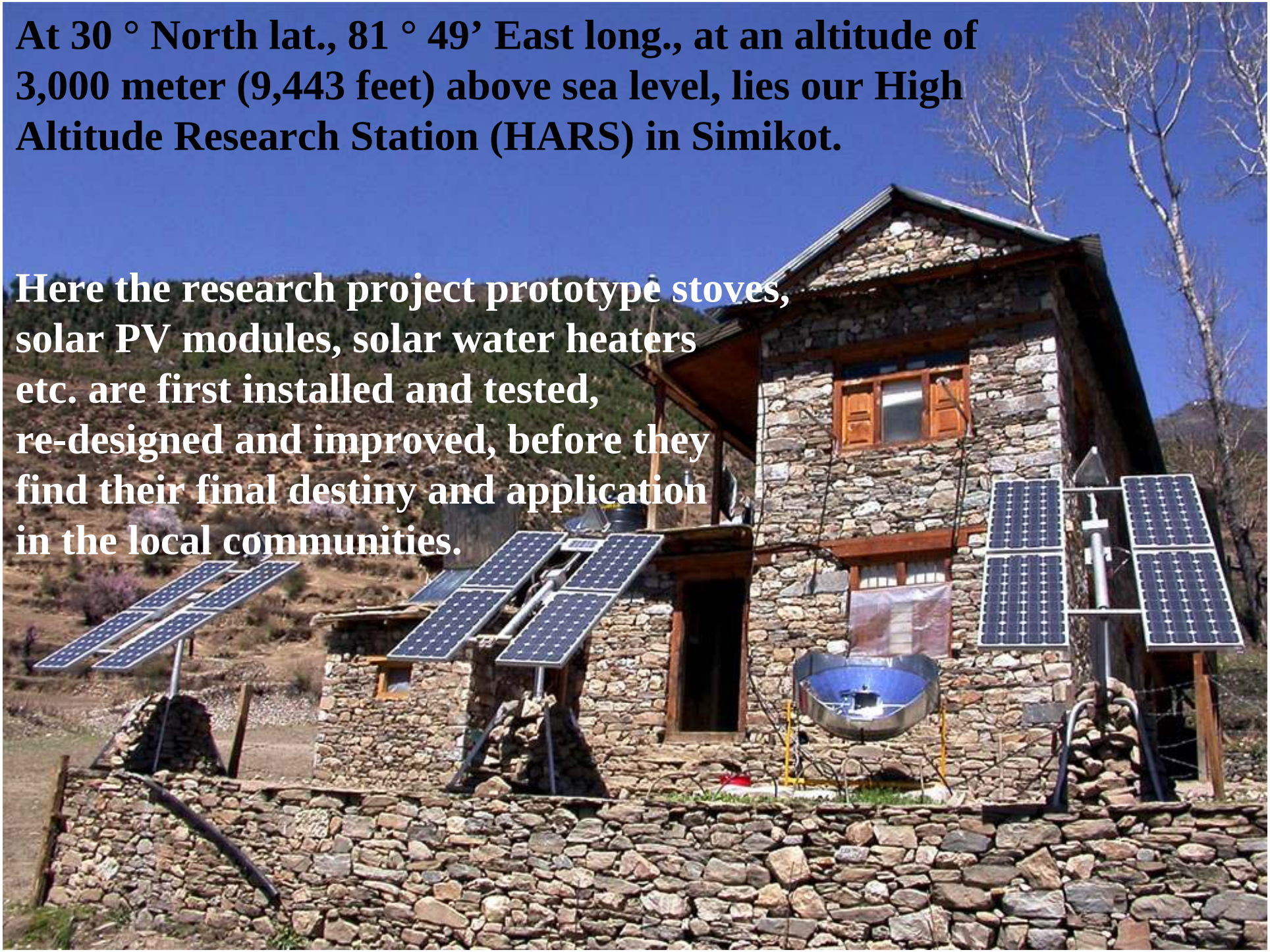
Through Holistic Community Development

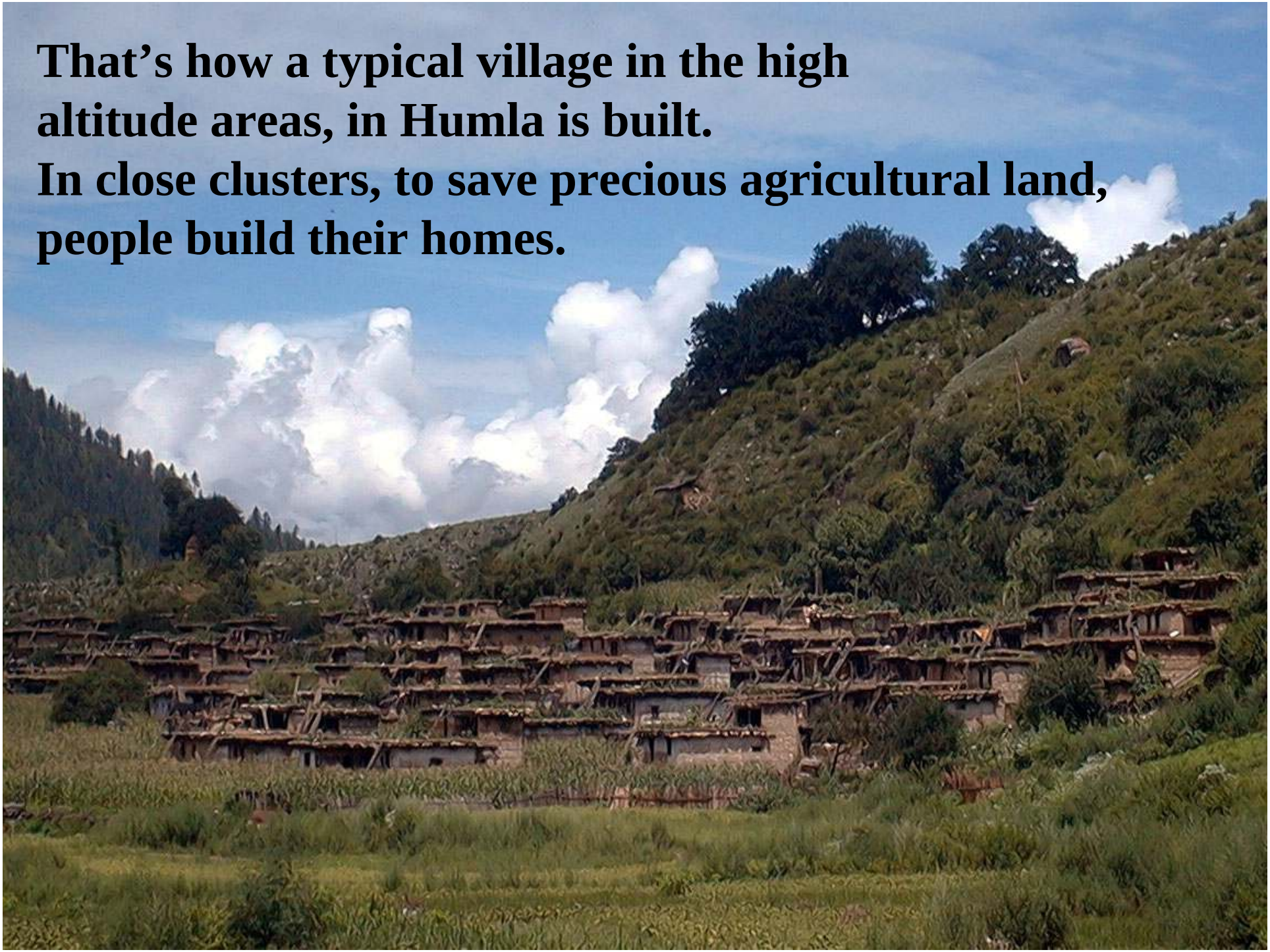
# The holistic community development project activities are implemented in one of the poorest and remotest parts of Nepal, in Humla



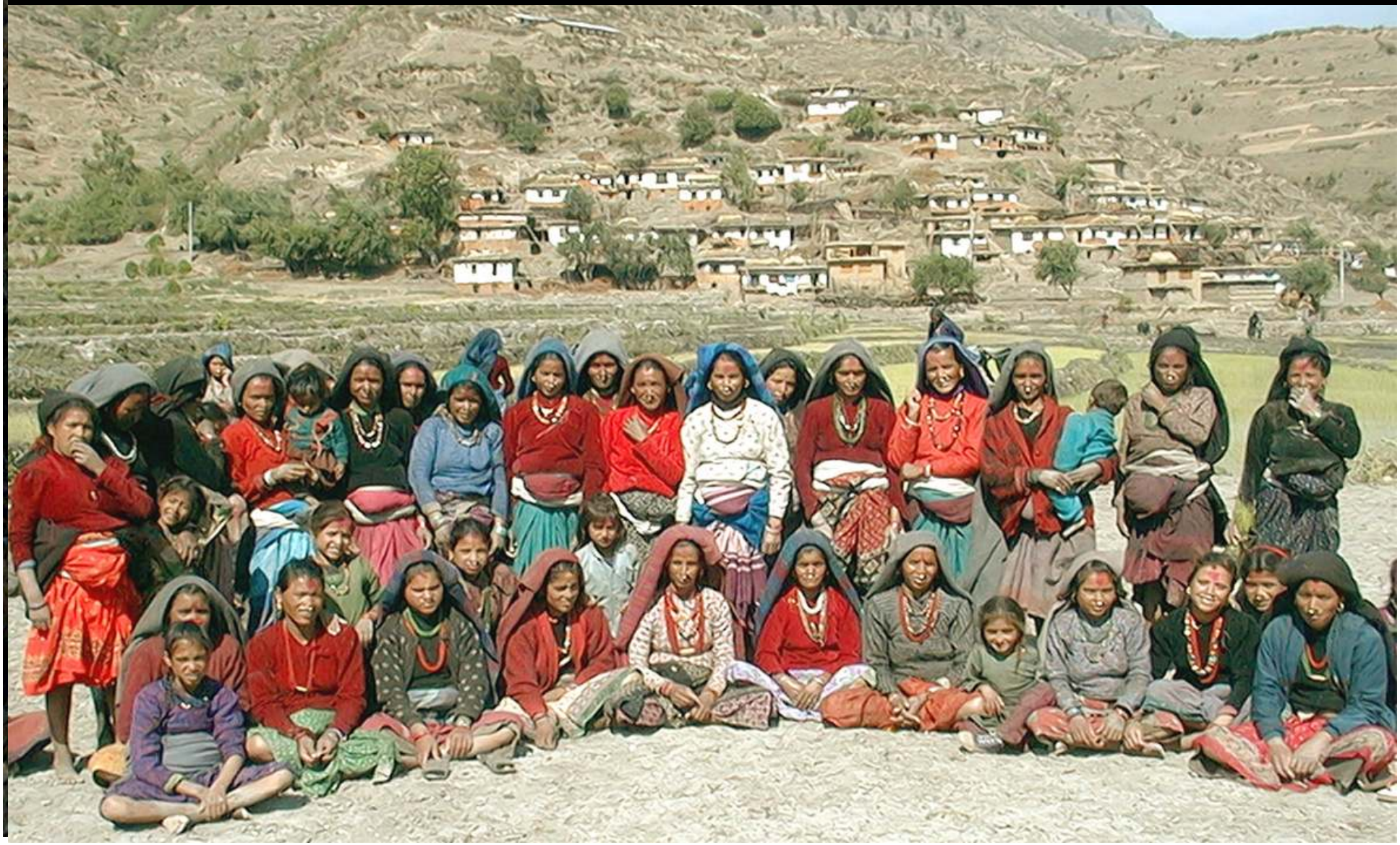

There is no road to this remote district.
In order to reach Humla, in the north of
Nepal from Nepalgunj in the south of
Nepal, one has to either walk 16 days
through the most difficult and harsh
Himalayan mountain range, or …


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


At 30 ° North lat., 81 ° 49’ East long., at an altitude of 3,000 meter (9,443 feet) above sea level, lies our High Altitude Research Station (HARS) in Simikot.
Here the research project prototype stoves, solar PV modules, solar water heaters etc. are first installed and tested, re-designed and improved, before they find their final destiny and application in the local communities.

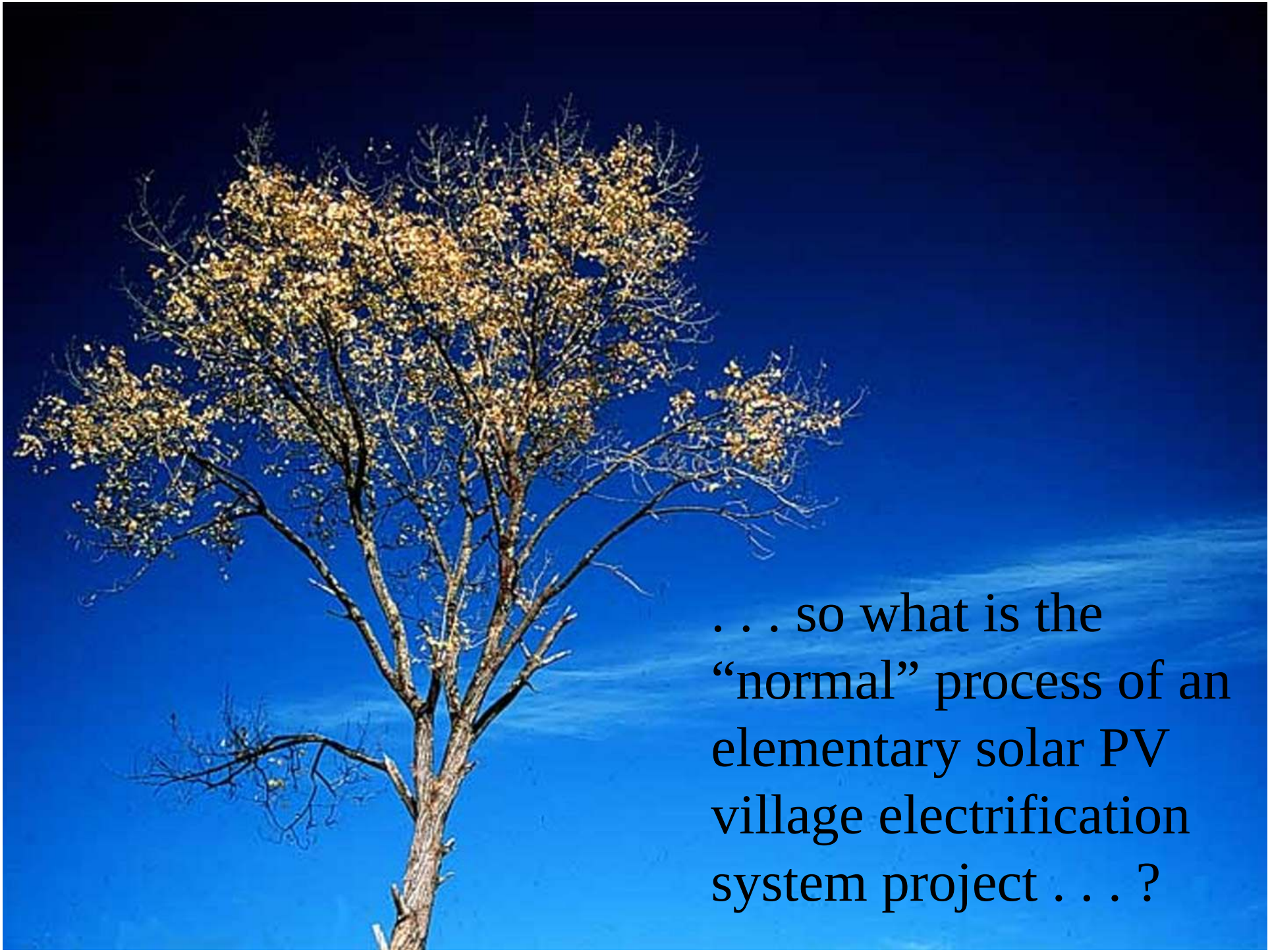

That’s how a typical village in the high altitude areas, in Humla is built.
In close clusters, to save precious agricultural land, people build their homes.

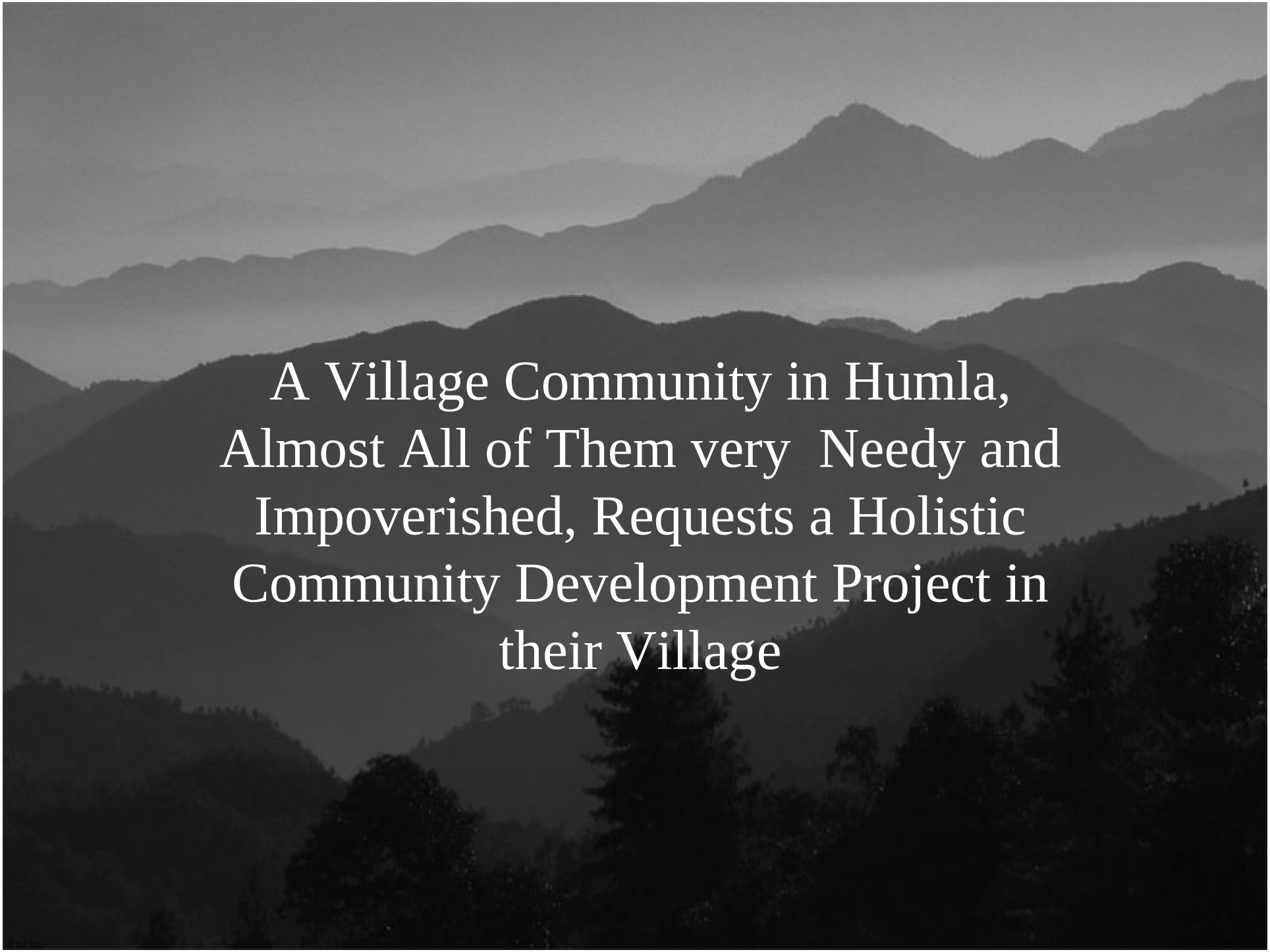
**“Renewable Energy Development ” is only appropriate and sustainable if we understand the needs of the community we live and work with in all aspects of life.**



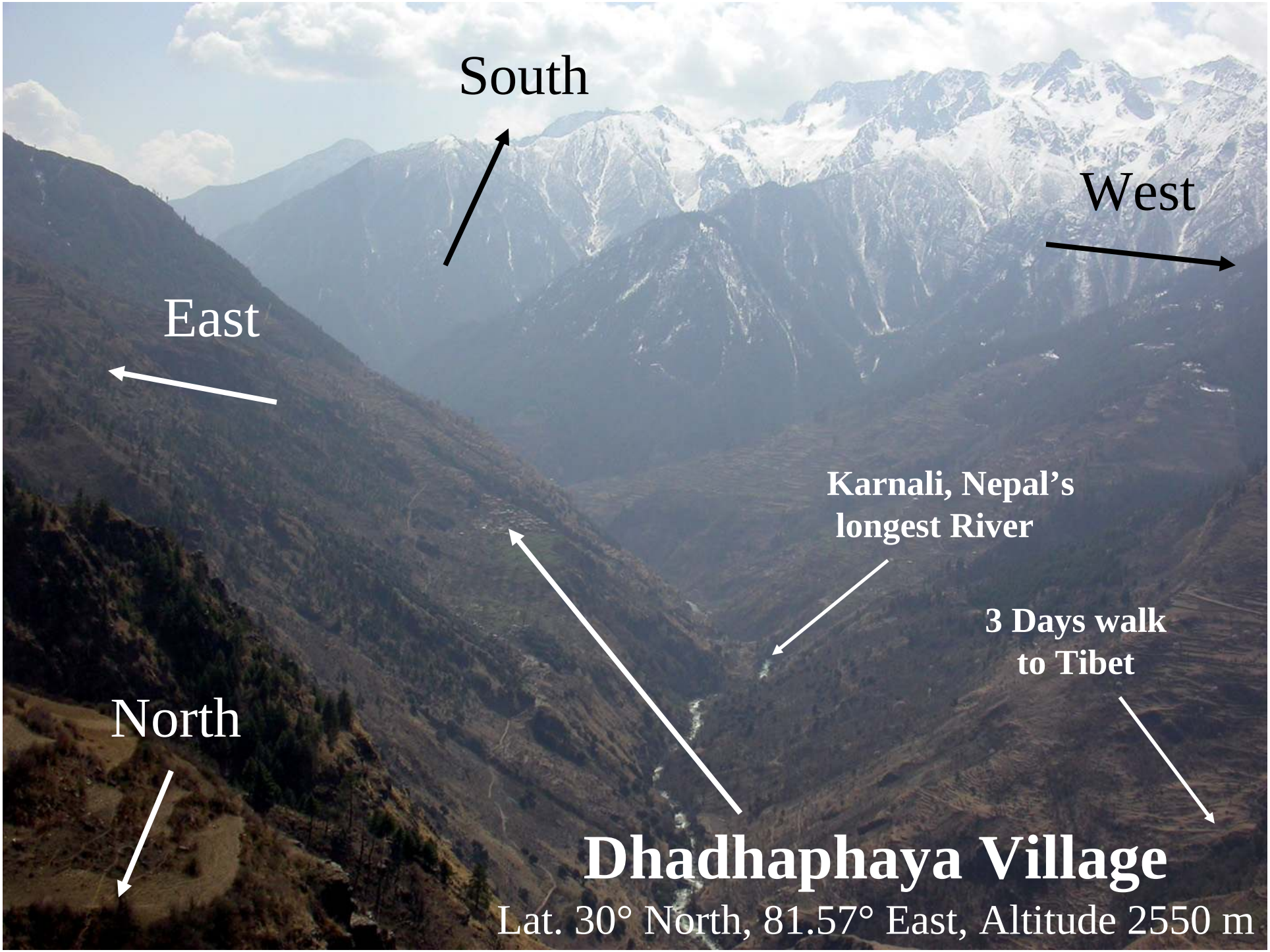
# The remote and impoverished mountain communities' needs demand particular requirements from technologies

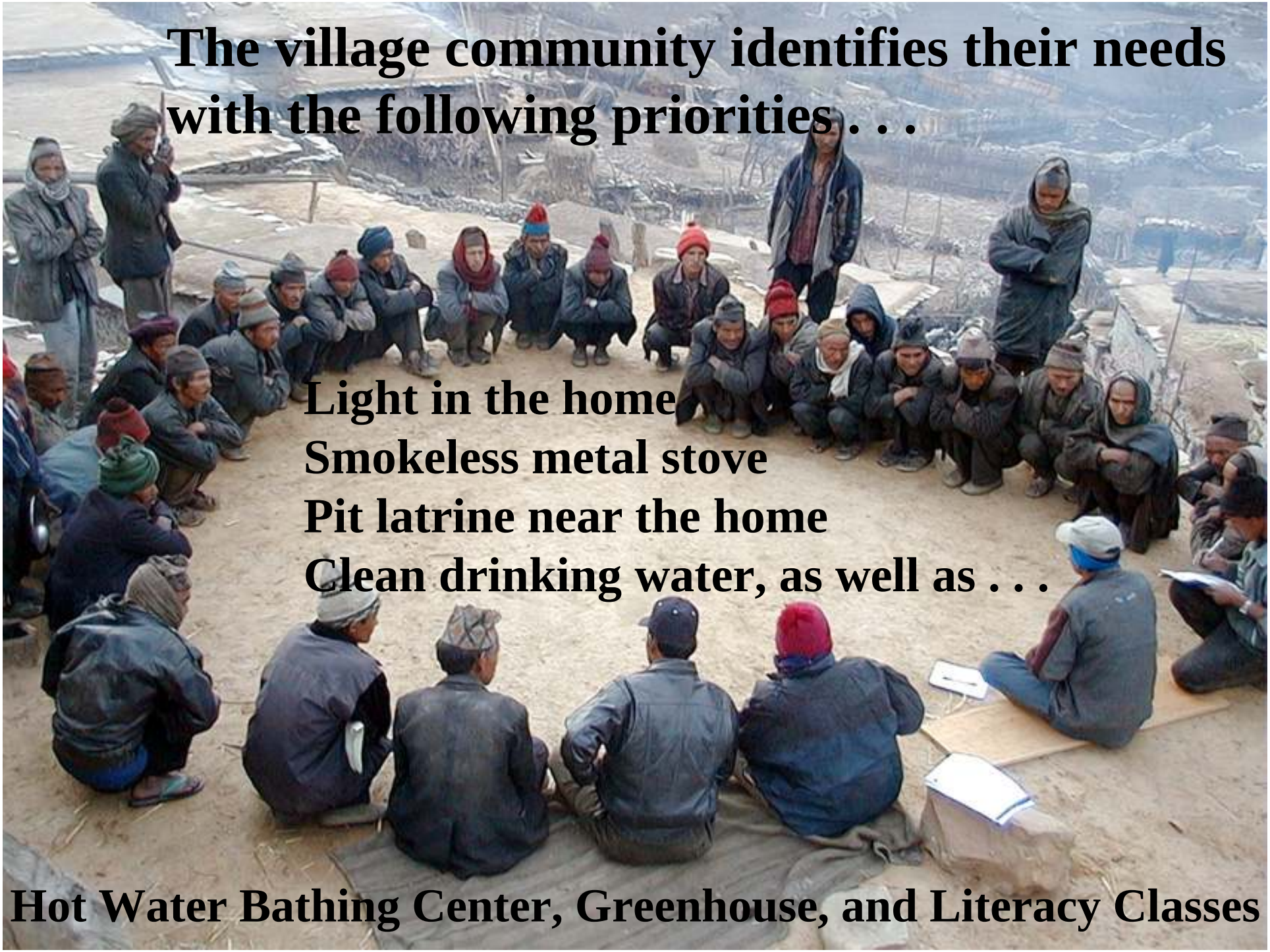
1. Technologies must be appropriate, suitable, and apt for a particular situation, and for a particular people group.
2. Sustainability comes before efficiency.
3. Technologies need to be contextualised, to be accepted by the community, to build a strong ownership.
4. They need to aim for better living conditions, to raise the living standard of the people.


. . . so what is the
“normal” process of an
elementary solar PV
village electrification
system project . . . ?



A Village Community in Humla, Almost All of Them very  Needy and Impoverished, Requests a Holistic Community Development Project in their Village


South
West
East
Karnali, Nepal's
longest River
3 Days walk
to Tibet
North
Dhadhaphaya Village
Lat. 30° North, 81.57° East, Altitude 2550 m

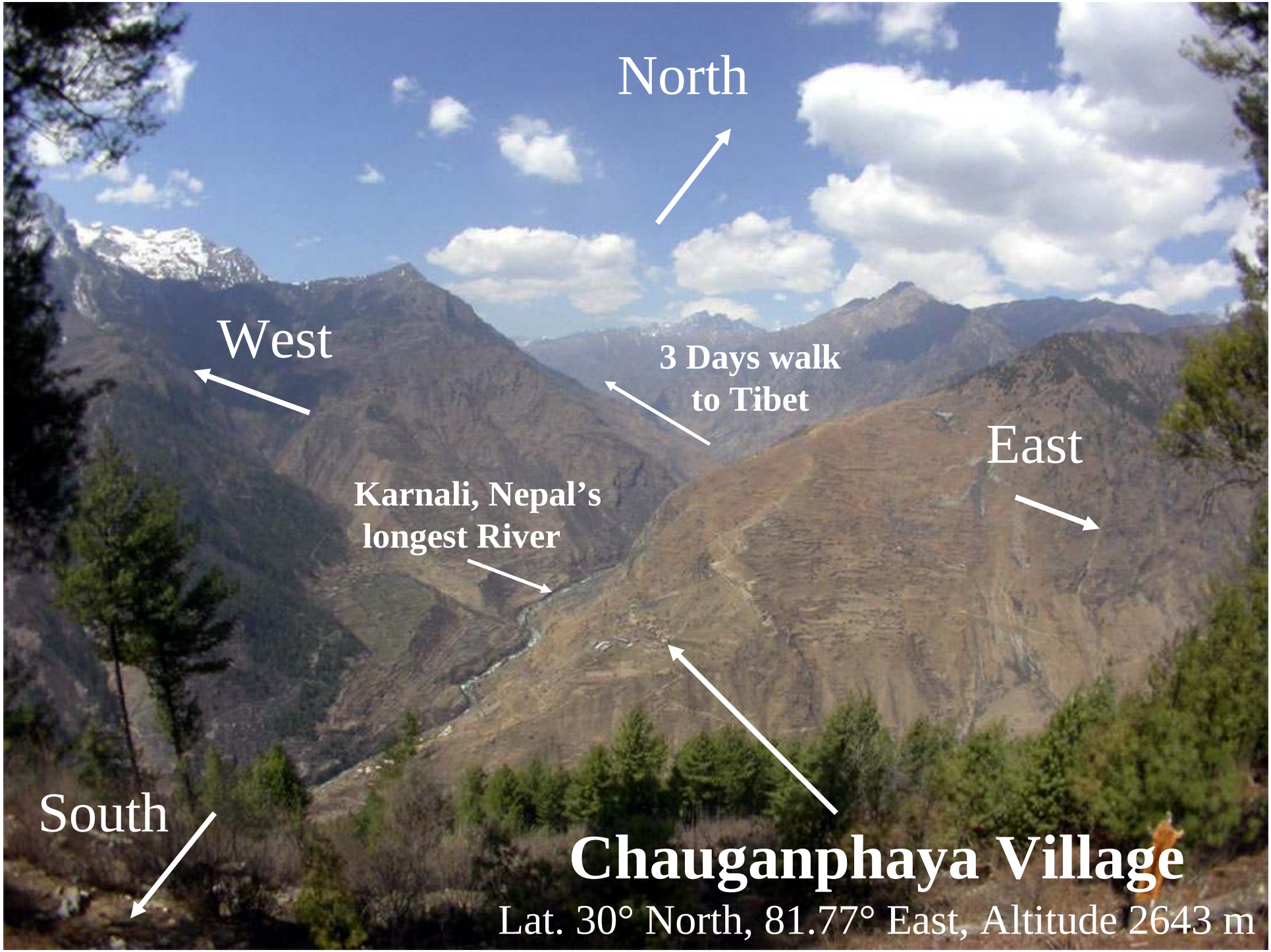

The village community identifies their needs with the following priorities . . .
Light in the home
Smokeless metal stove
Pit latrine near the home
Clean drinking water, as well as . . .
Hot Water Bathing Center, Greenhouse, and Literacy Classes

# Dhadhaphaya Village

**The Village situation in 2004:**

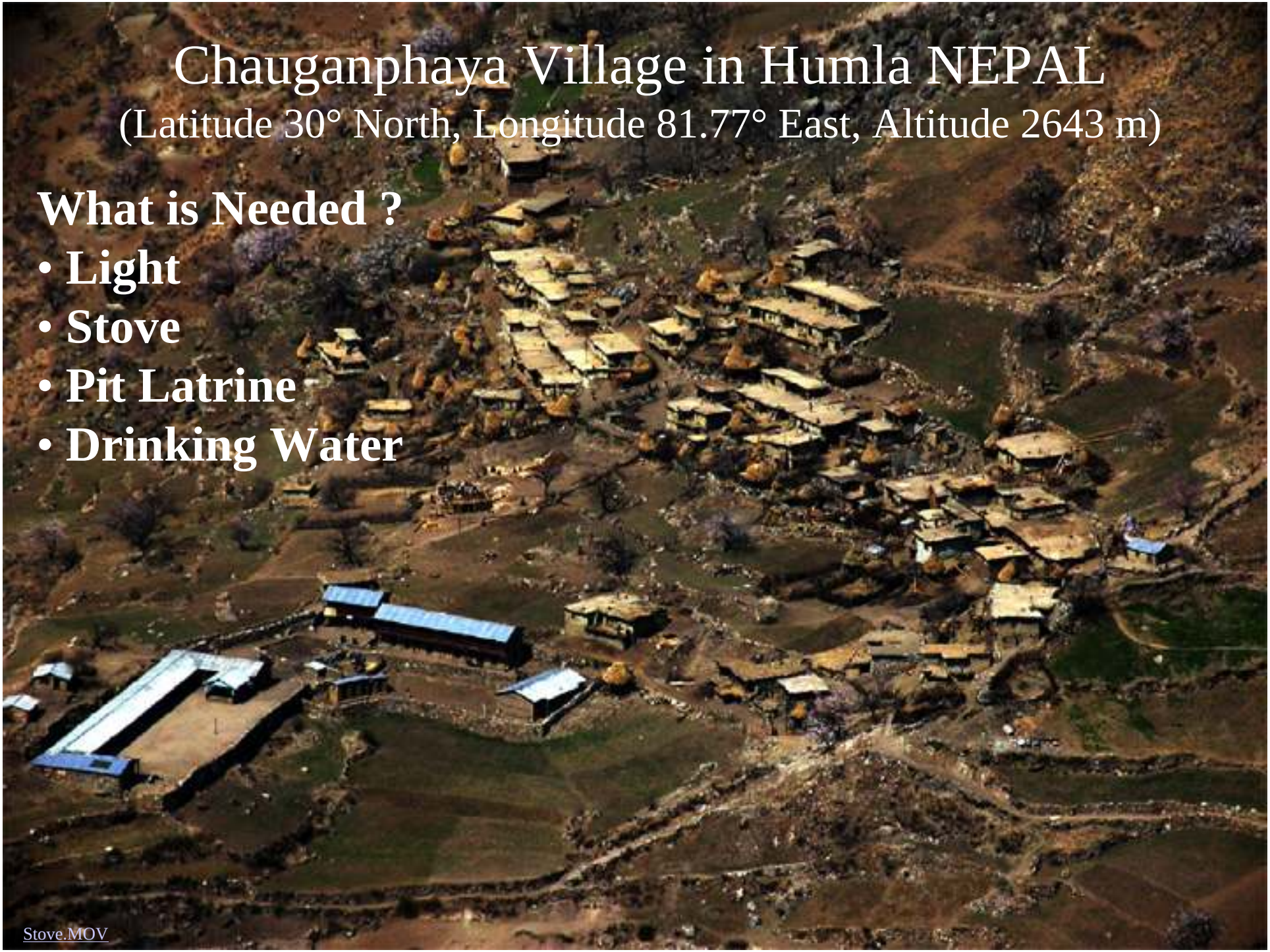
- **167 homes, and 1,067 people**
- **No house had light**
- **All homes cooked on open fires**
- **No home had a toilet**
- **All drank dirty river water**

Dhadhaphaya Village
29° 59' Northern Latitude, 81° 48' Eastern Longitude, at 2,550 m (8,366 feet) altitude
Population (August 2005): 167 homes with 1,067 peoples. One primary school class 1-7, one health post


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

# Chauganphaya Village in Humla NEPAL

(Latitude 30° North, Longitude 81.77° East, Altitude 2643 m)



**What is Needed ?**

- **Light**
- **Stove**
- **Pit Latrine**
- **Drinking Water**

Stove.MOV

# Chauganphaya Village in Humla NEPAL

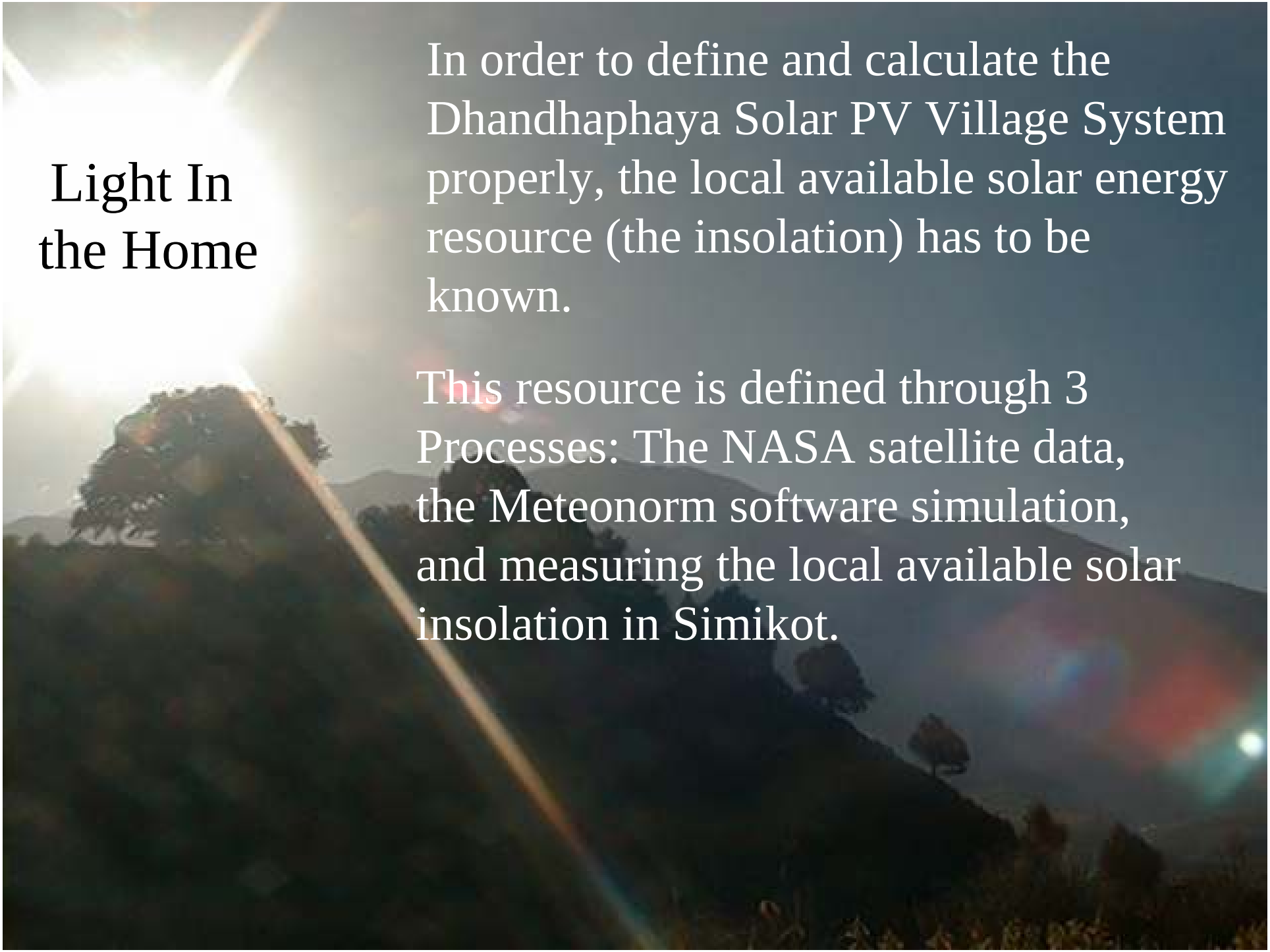
(Latitude 30° North, Longitude 81.77° East, Altitude 2643 m)

**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**



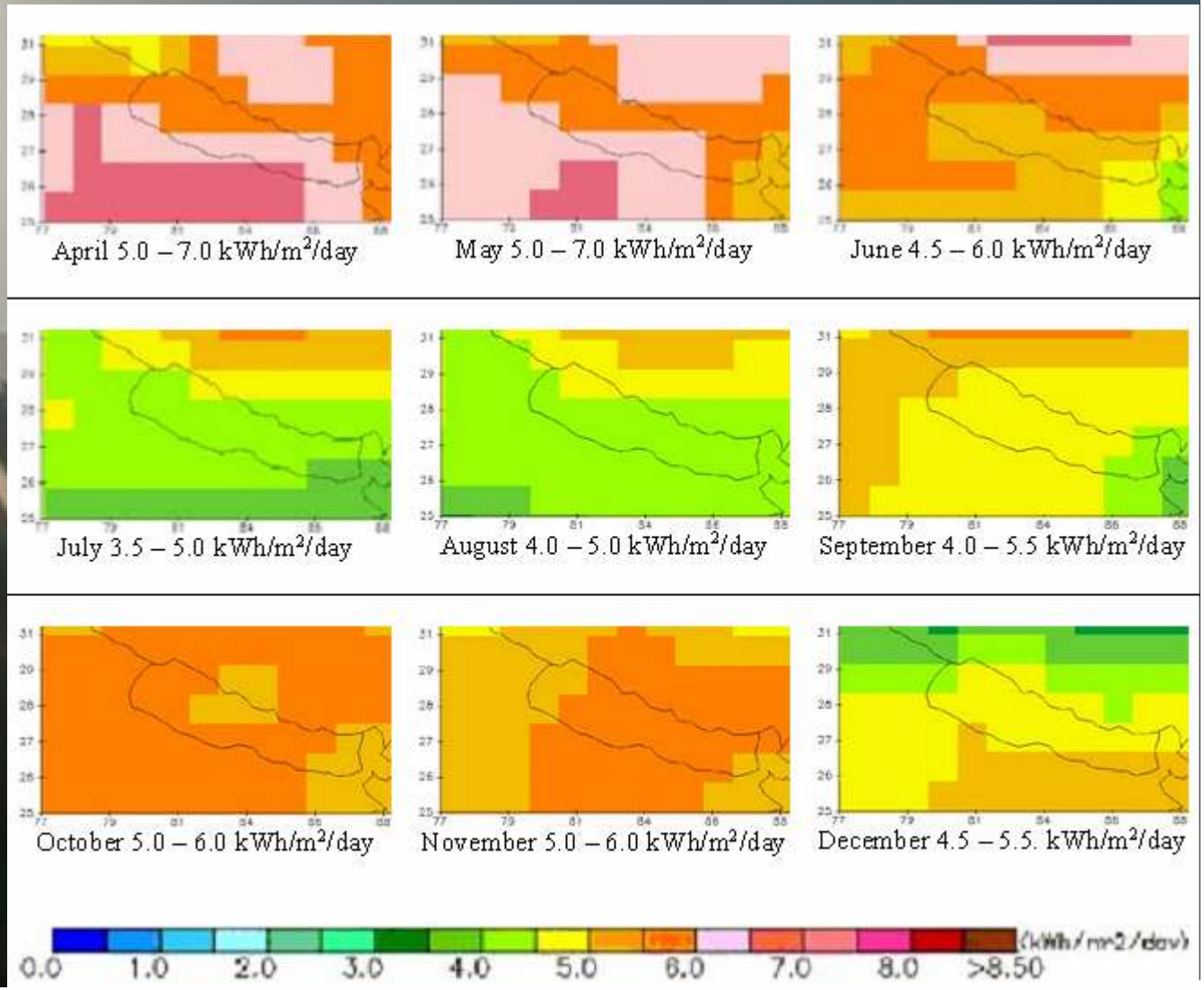
# Light In the Home

In order to define and calculate the Dhandhaphaya 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 measuring the local available solar insolation in Simikot.

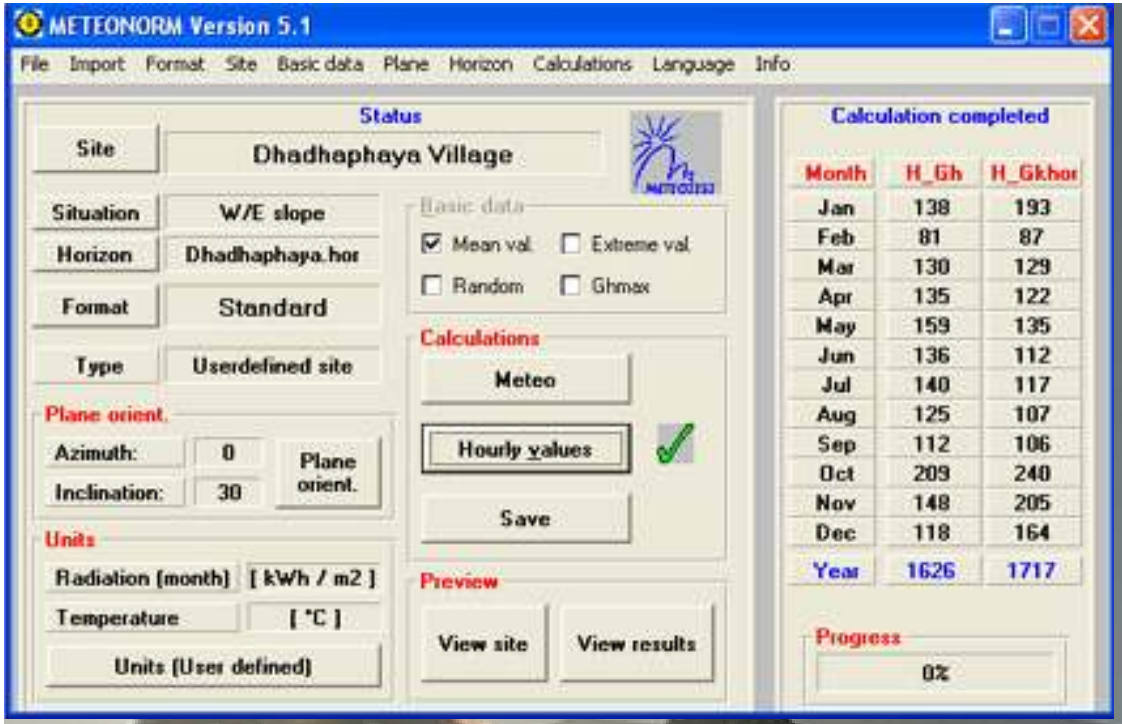
# Average 30º towards Equator Tilted Solar Irradiation from 1983 –1993 for Nepal from NASA (http://eosweb.larc.nasa.gov/ )

## NASA Data

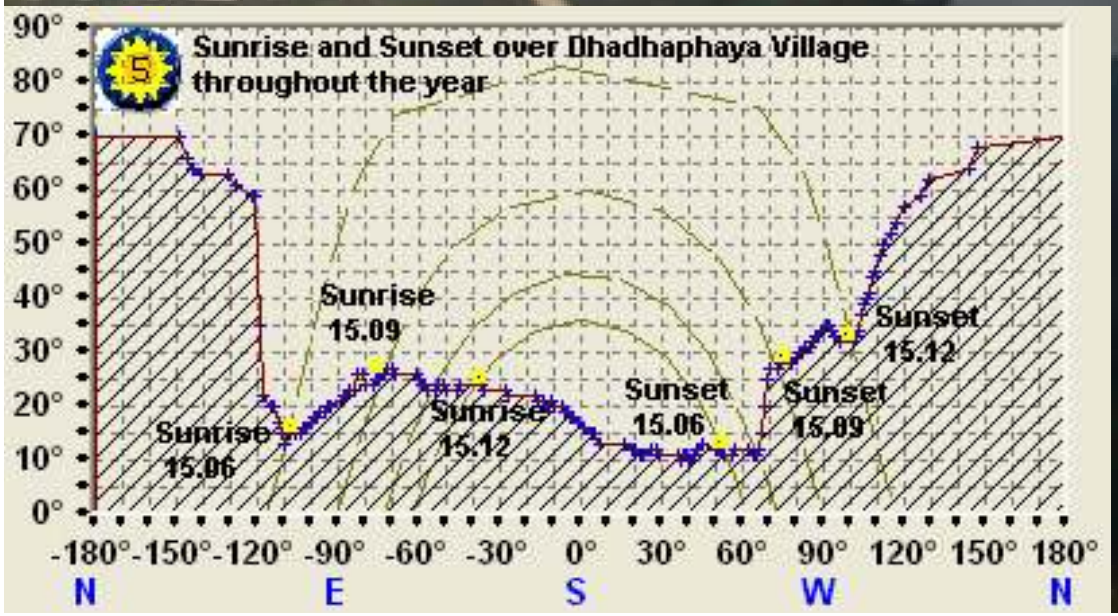



Average Annual Daily Solar Insolation for Dhadhaphaya Village, at 30° North, and 2’550 m.a.s.l. is ~ 5.2 kWh/m$^2$ on a 30 ° south tilted surface

# METEONORM Solar Insolation Simulation Software

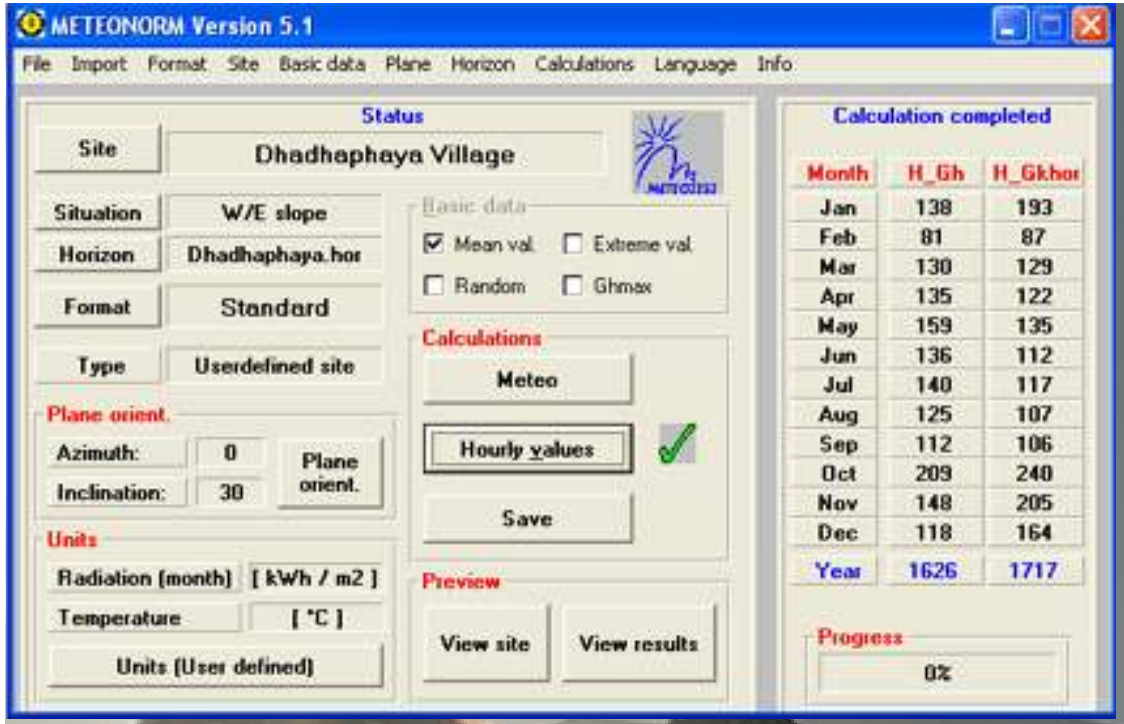



# For the Dhadhaphaya Village




Included in the Simulation is the 360 ° Horizon around Dhadhaphaya

# Simulated Dhadhaphaya Solar Insolation Data with Horizon, on a 30° South Tilted Surface




Site: Dhadhaphaya Village
Situation: W/E slope
Horizon: Dhadhaphaya.hor
Azimuth: 0
Type Userdefined site
Inclination: 30
Format Standard

All radiation datas are influenced by a high horizon!
The ending "hor" means with high horizon
Albedo = 0.25

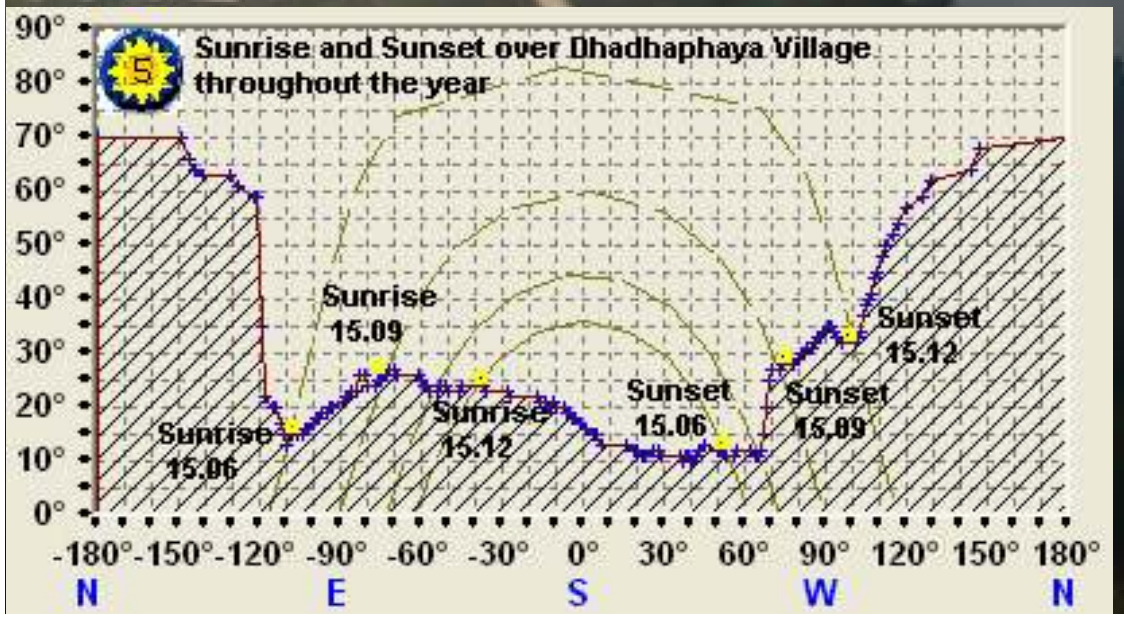
| Jan | H_Gh | H_Dh | H_Gkhor | H_Dkhor | H_Bnhor | Ta |
|---|---|---|---|---|---|---|
| Jan | 138 | 32 | 195 | 48 | 181 | 6.1 |
| Feb | 81 | 47 | 88 | 44 | 53 | 6.7 |
| Mar | 130 | 63 | 131 | 61 | 84 | 10.3 |
| Apr | 135 | 73 | 124 | 67 | 73 | 14.7 |
| May | 159 | 90 | 138 | 80 | 80 | 16.9 |
| Jun | 136 | 81 | 114 | 70 | 64 | 17.5 |
| Jul | 140 | 70 | 119 | 63 | 81 | 18.3 |
| Aug | 125 | 79 | 109 | 69 | 54 | 16.1 |
| Sep | 112 | 55 | 108 | 51 | 69 | 15.3 |
| Oct | 209 | 35 | 244 | 51 | 231 | 13.7 |
| Nov | 148 | 30 | 208 | 49 | 195 | 10.7 |
| Dec | 118 | 34 | 166 | 48 | 148 | 8.1 |
| Year | 1626 | 689 | 1744 | 702 | 1313 | 12.7 |

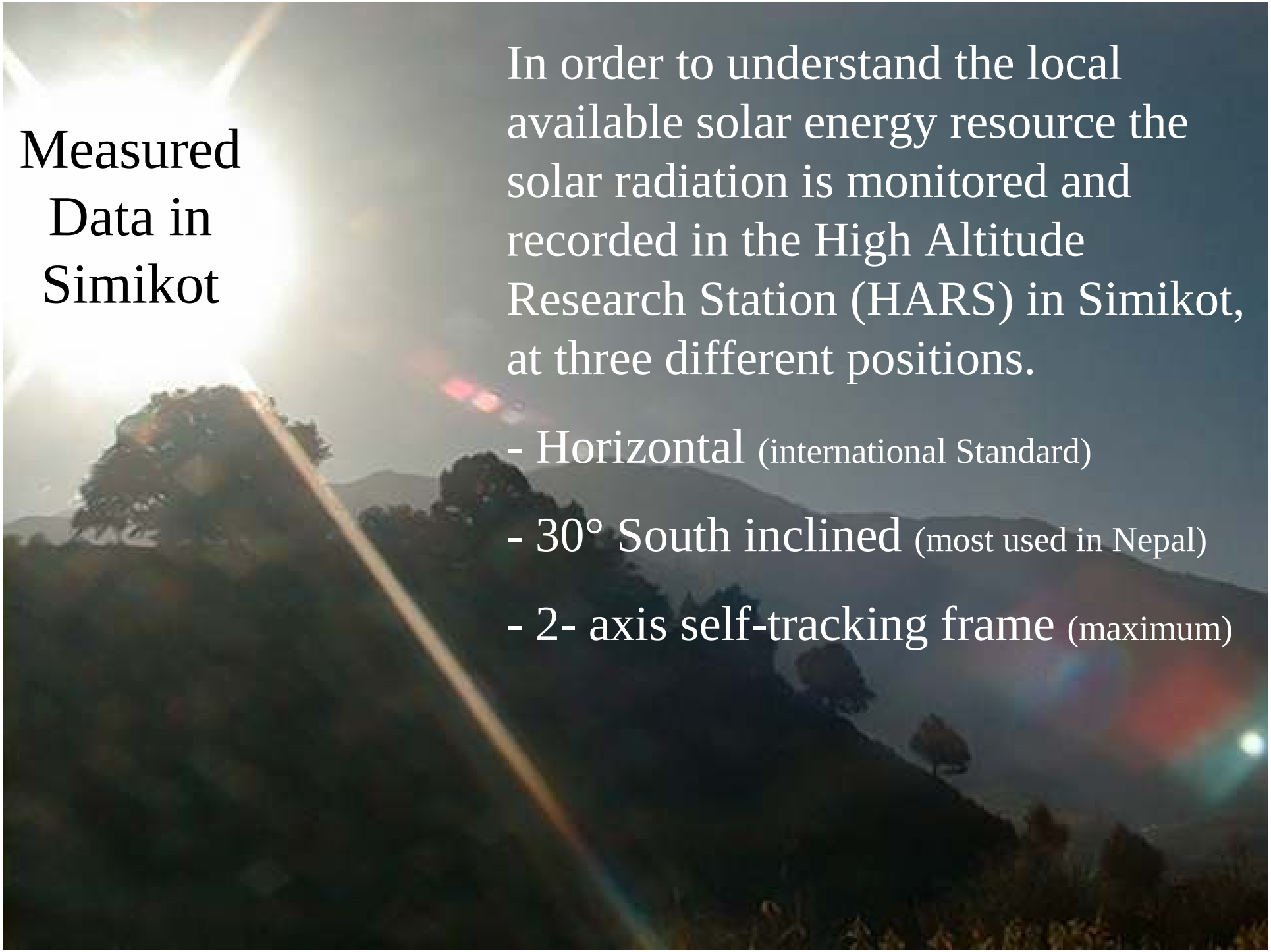
Legend:

H_Gh: Inradiation of global radiation horizontal
H_Dh: Inradiation of diffuse radiation horizontal
H_Gkhor: Inradiation of global rad., tilted plane, with high horizon
H_Dkhor: Inradiation of diffuse rad., tilted plane, with high horizon
H_Bnhor: Inradiation 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

## For the Dhadhaphaya Village





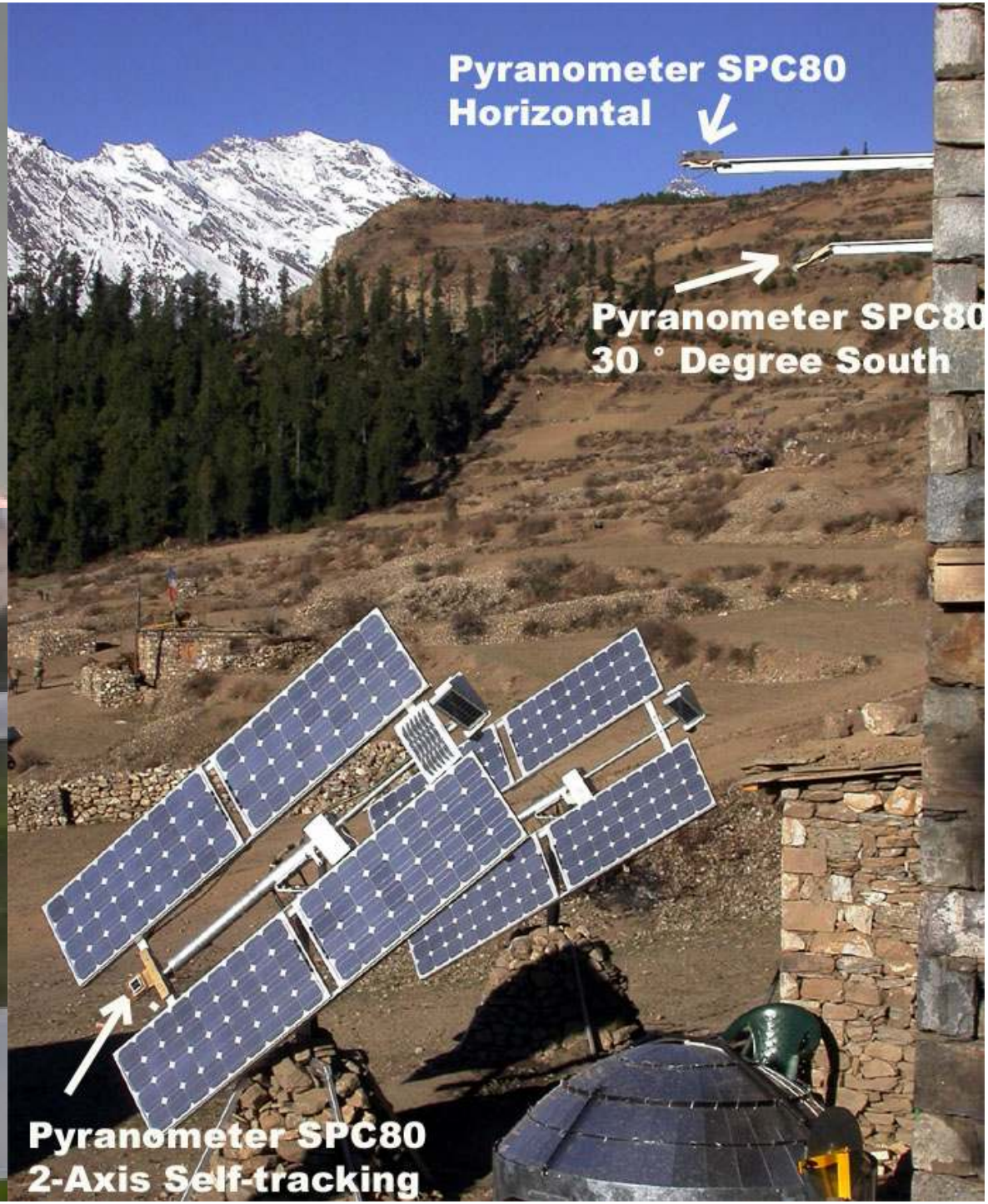
# Measured Data in Simikot

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.

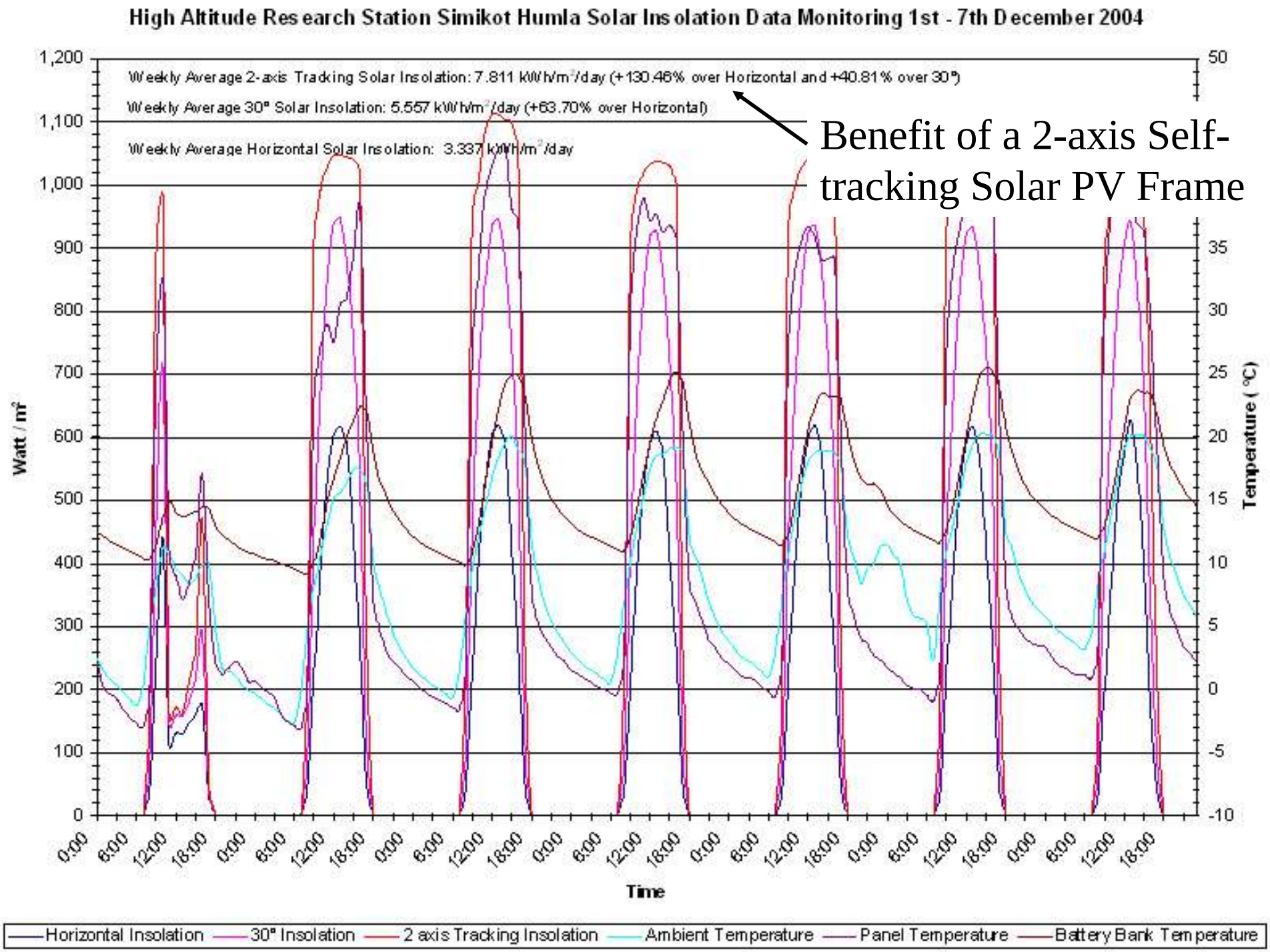
- Horizontal (international Standard)
- 30° South inclined (most used in Nepal)
- 2- axis self-tracking frame (maximum)

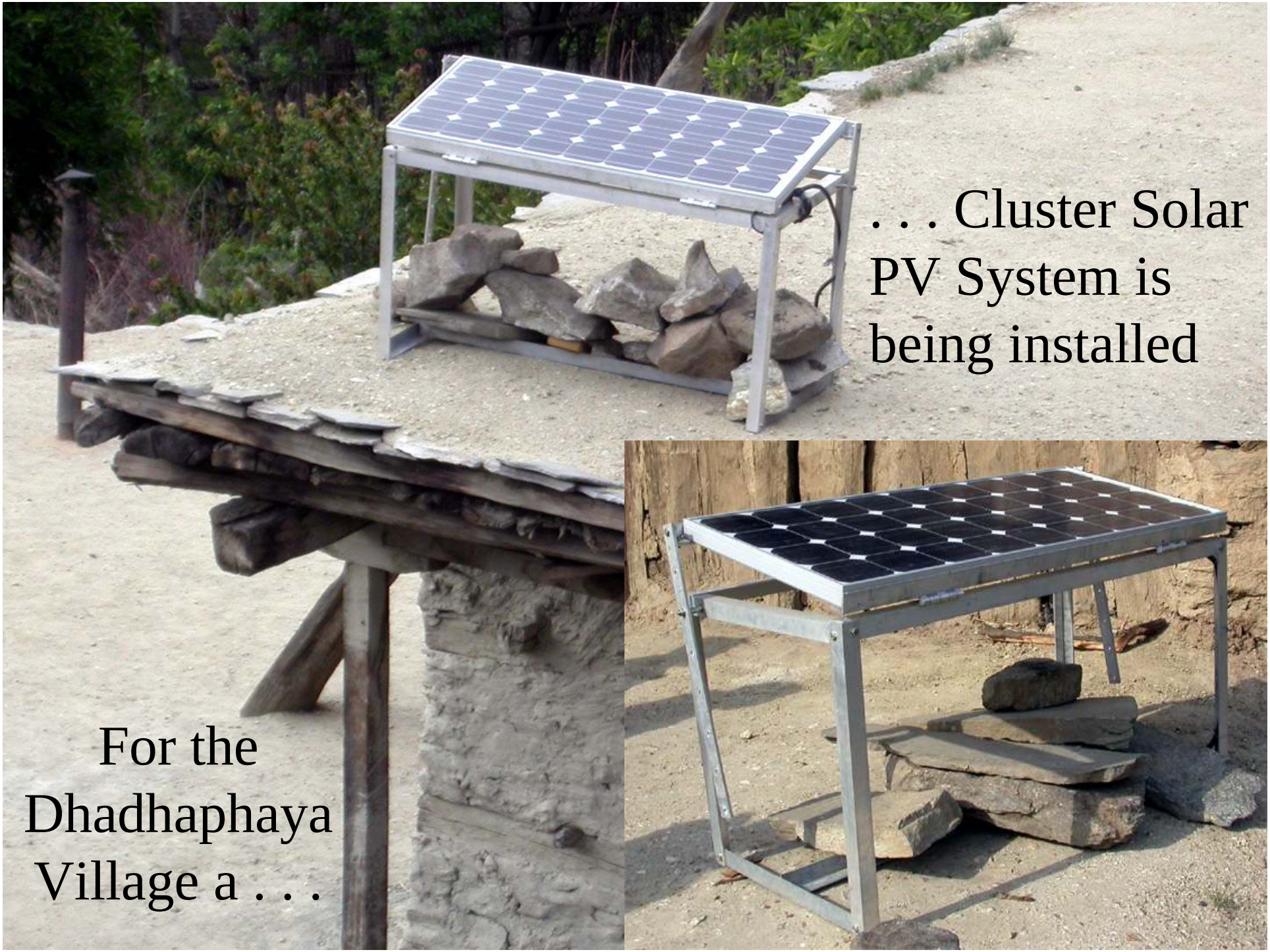
# Measured Data in Simikot

**SPC 80 Pyranometer from SolData Denmark**

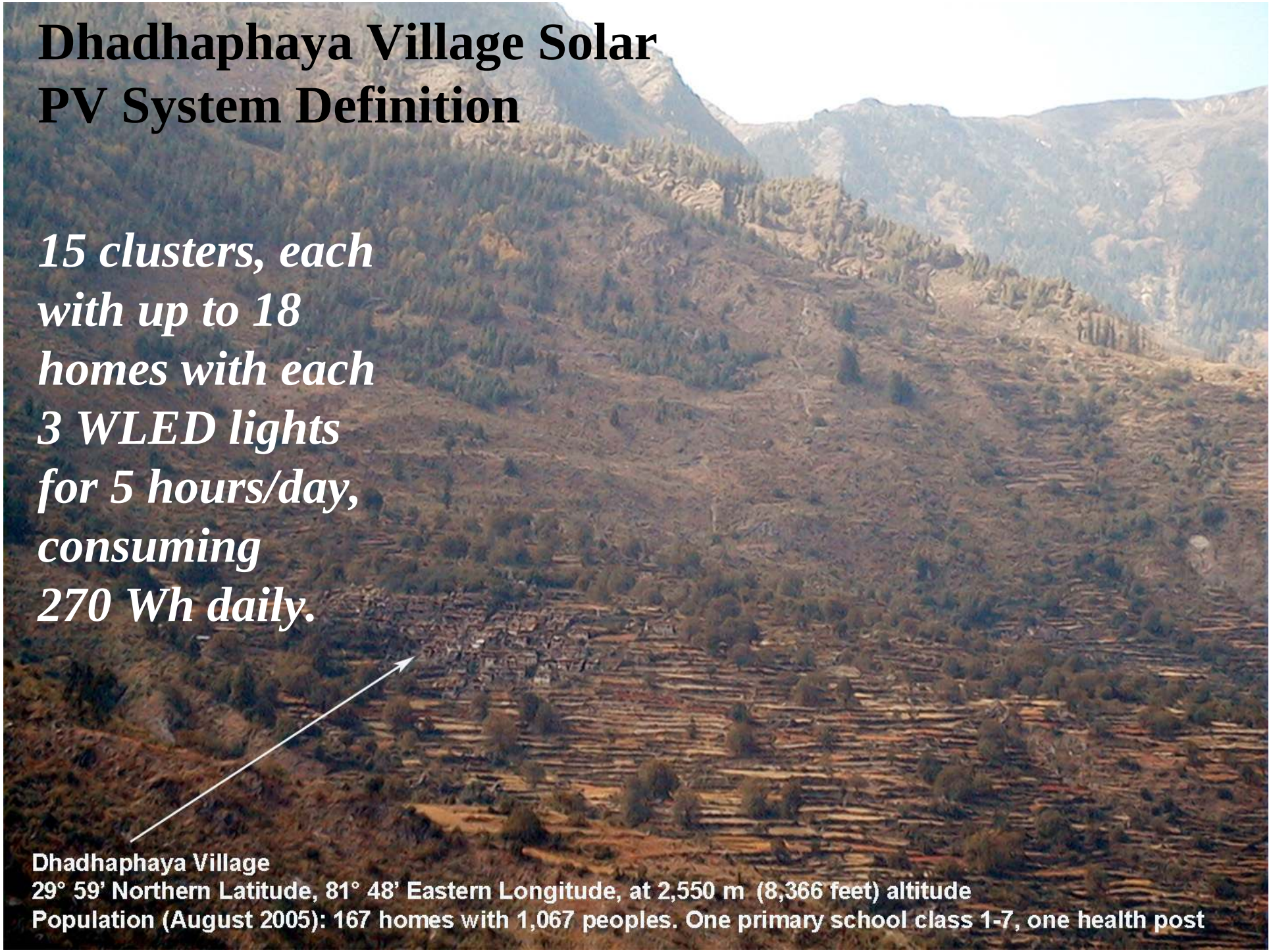


Example of one Week Recorded Solar Insolation with three Pyranometers on different surfaces, as well as Ambient, Solar PV Module and Battery Bank Temperature from the 1st – 7th December 2004, in Humla Nepal


High Altitude Research Station Simikot Humla Solar Insolation Data Monitoring 1st - 7th December 2004
Weekly Average 2-axis Tracking Solar Insolation: 7.811 kWh/m²/day (+130.46% over Horizontal and +40.81% over 30°)
Weekly Average 30° Solar Insolation: 5.557 kWh/m²/day (+63.70% over Horizontal)
Weekly Average Horizontal Solar Insolation: 3.337 kWh/m²/day
Benefit of a 2-axis Self-tracking Solar PV Frame
Watt / m²
Temperature ( °C)
Time
Horizontal Insolation
30° Insolation
2 axis Tracking Insolation
Ambient Temperature
Panel Temperature
Battery Bank Temperature


. . . Cluster Solar PV System is being installed
For the Dhadhaphaya Village a . . .

# Dhadhaphaya Village Solar PV System Definition




***15 clusters, each with up to 18 homes with each 3 WLED lights for 5 hours/day, consuming 270 Wh daily.***

# Dhadhaphaya Village Solar PV System Definition

Solar Energy Resource: Daily Average Solar Radiation 4.778 kWh/m$^2$
(Meteonorm simulation with high horizon)

***Each cluster has one 75 W solar PV module, seasonally adjustable. Up to 5 Days the Battery Bank will provide Energy Independent from the Sun***

**Dhadhaphaya Village**
**29° 59' Northern Latitude, 81° 48' Eastern Longitude, at 2,550 m (8,366 feet) altitude**
**Population (August 2005): 167 homes with 1,067 peoples. One primary school class 1-7, one health post**

# Training and Hands – On Practical Installation

Ten chosen Local People have been Trained to Look After and Maintain the Solar PV Systems

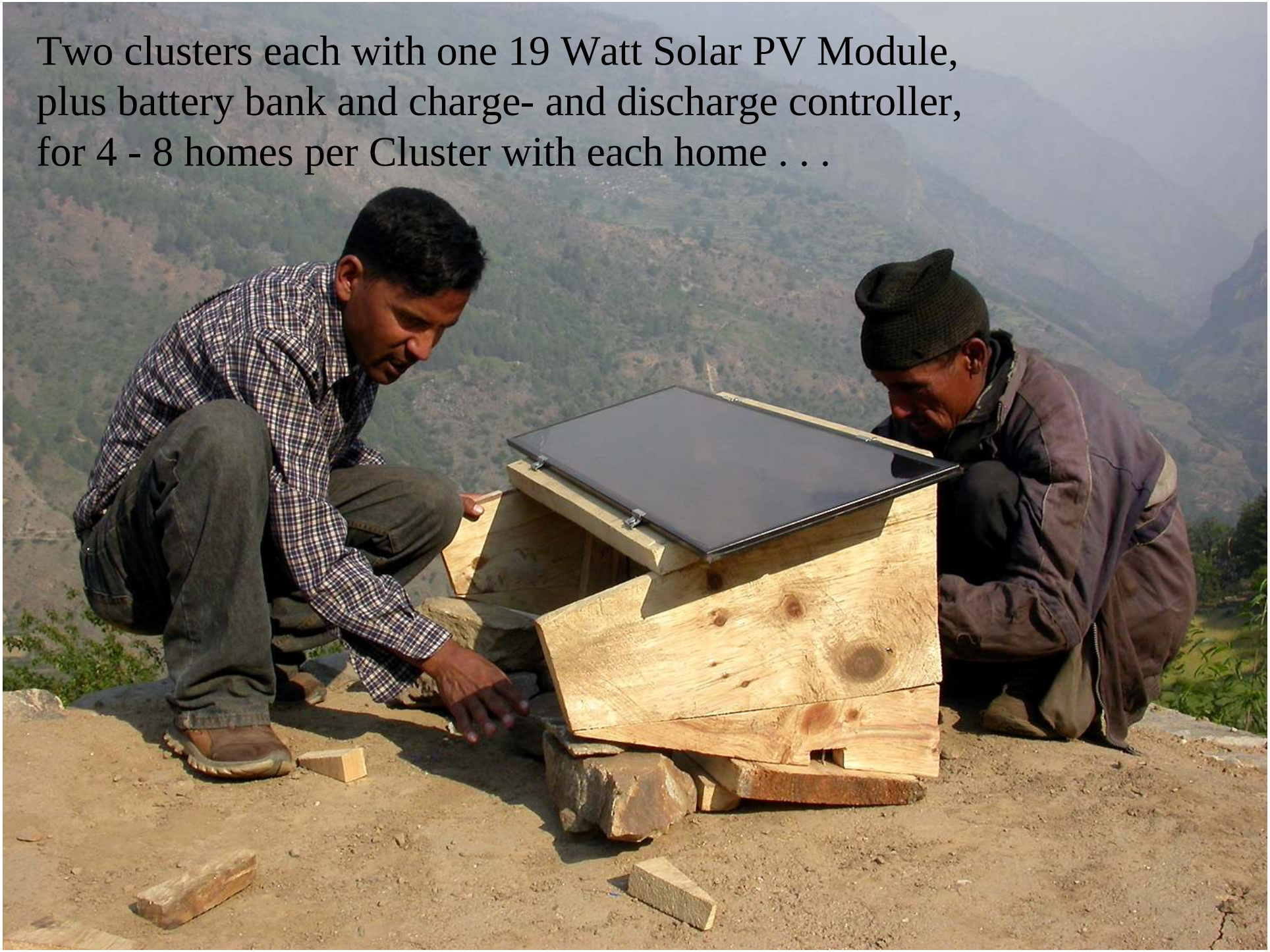
***Creating Ownership***

Each Household Participates in the Building and Underground Cabling

# Thus Dadhaphaya Village has now . . .

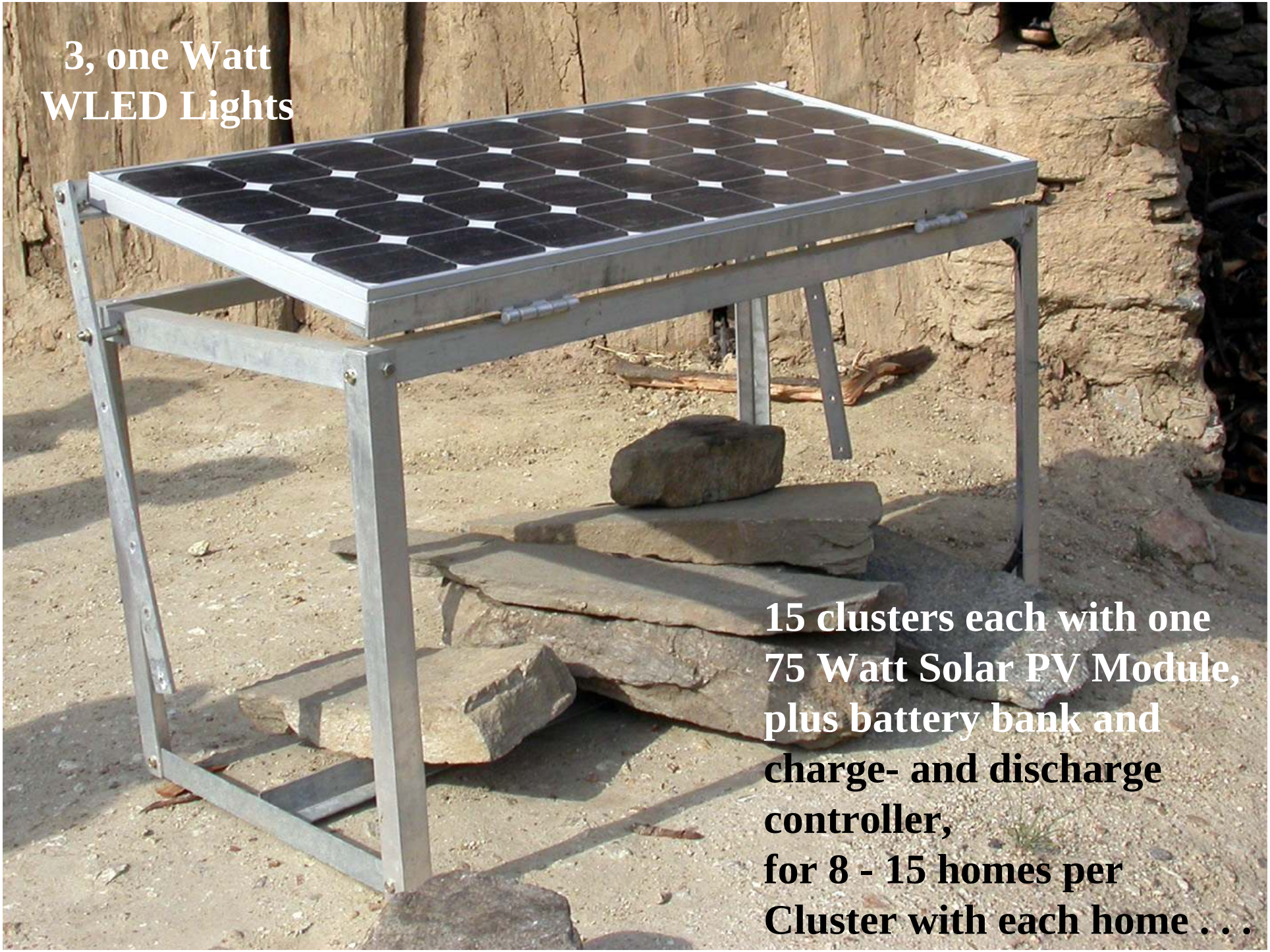
**15 Clusters with each a 75 Watt, and 2 Clusters each with a 19 Watt Solar PV Module powering total 501 x 1 Watt WLED Lights, 3 in each Home**

in 167 Homes


Two clusters each with one 19 Watt Solar PV Module,
plus battery bank and charge- and discharge controller,
for 4 - 8 homes per Cluster with each home . . .

Two clusters each with one 19 Watt Solar PV Module, plus battery bank and charge- and discharge controller, for 4 - 8 homes per Cluster with each home . . .

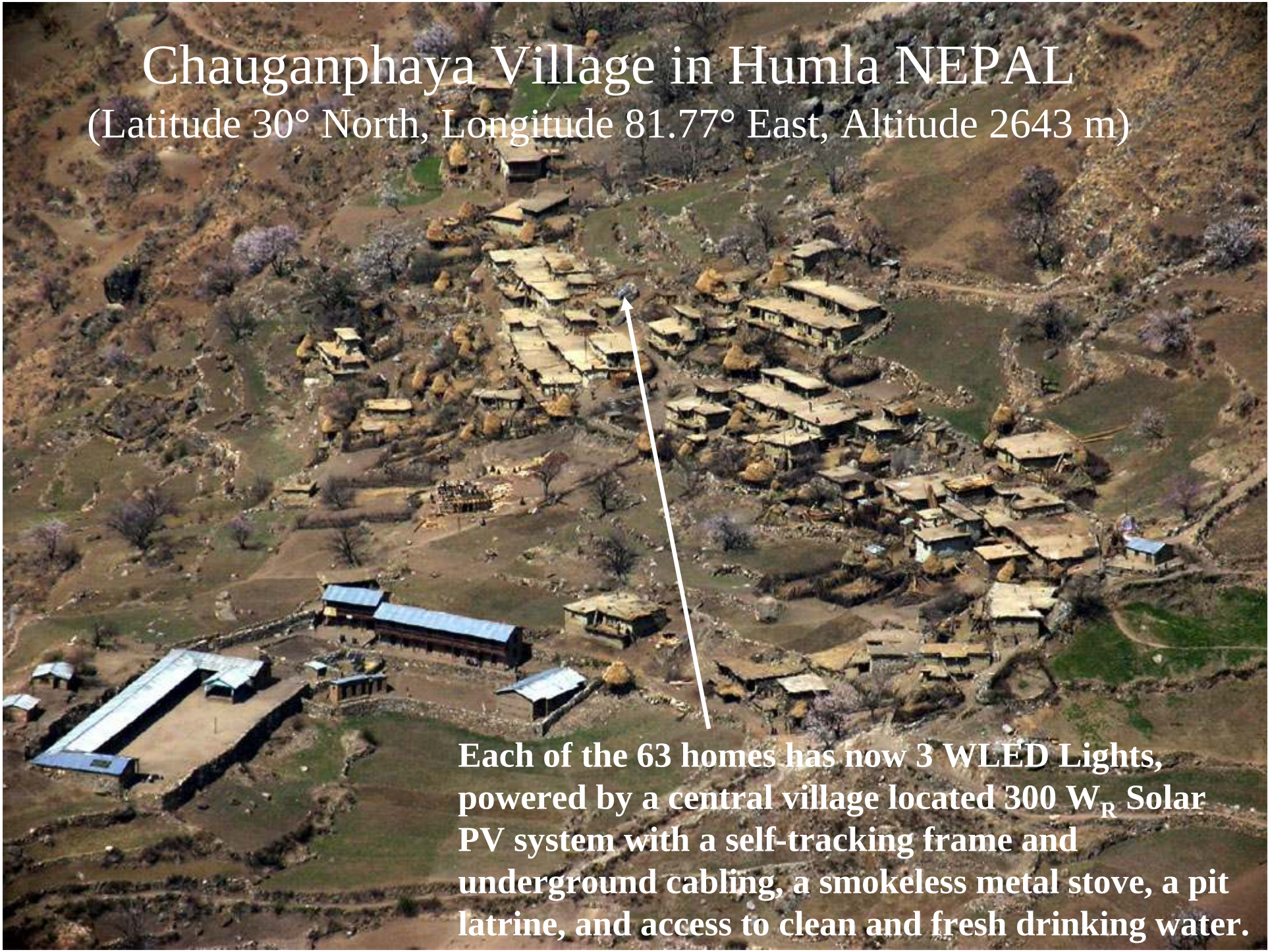
**3, one Watt**
**WLED Lights**

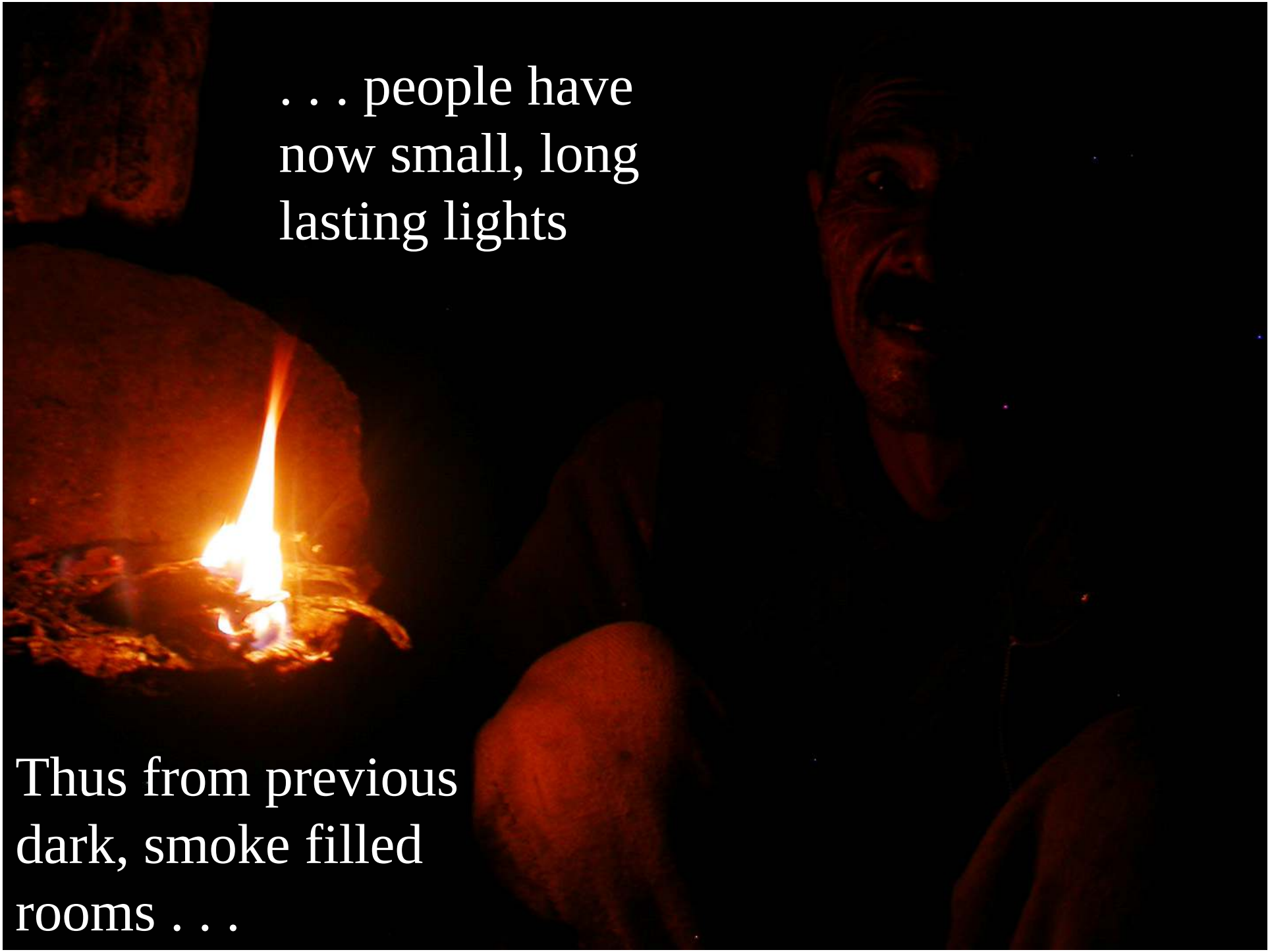

3, one Watt
WLED Lights
15 clusters each with one
75 Watt Solar PV Module,
plus battery bank and
charge- and discharge
controller,
for 8 - 15 homes per
Cluster with each home . . .

VOLTA

While for the
Chauganphaya
Village a . . .

# . . . 2-Axis Self-tracking Solar PV System is being installed


Chauganphaya Village in Humla NEPAL
(Latitude 30° North, Longitude 81.77° East, Altitude 2643 m)
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.


. . . people have
now small, long
lasting lights
Thus from previous
dark, smoke filled
rooms . . .

No Smoke - Less Firewood
Smokeless
Metal Stove
in the Home

# 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.

No Smoke - Less Firewood
Smokeless
Metal Stove
in the Home

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

For healthy Families

# Pure and Clean Drinking Water

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

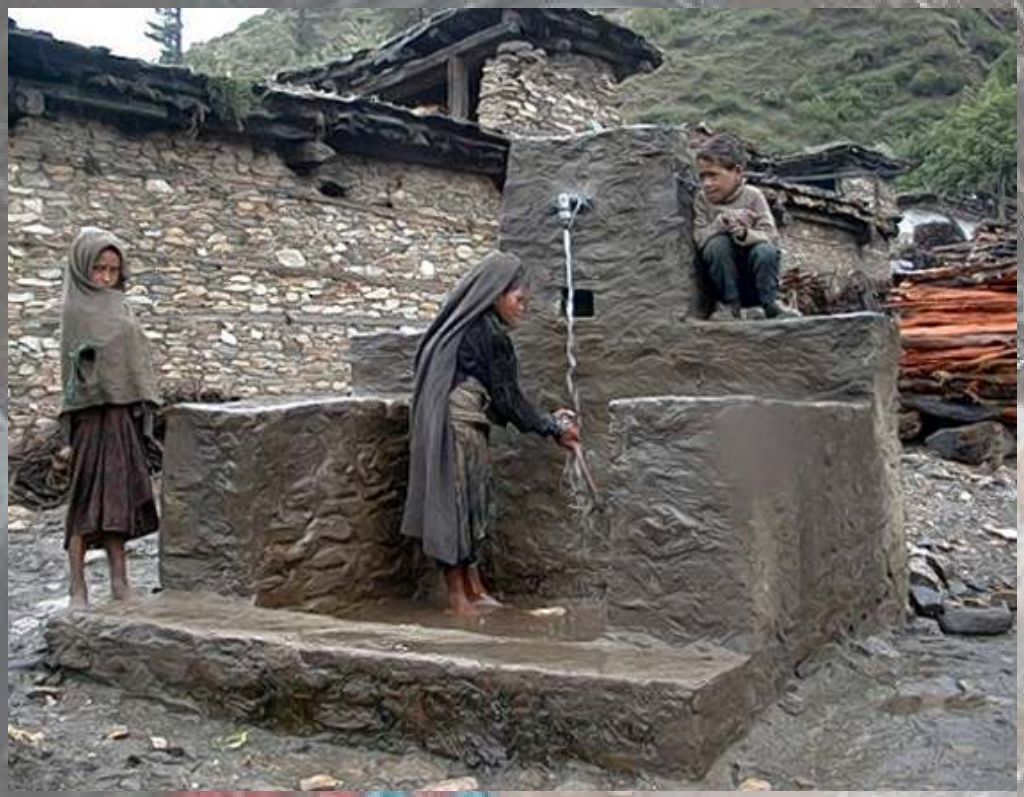
# Pure and Clean Drinking Water

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 . . .

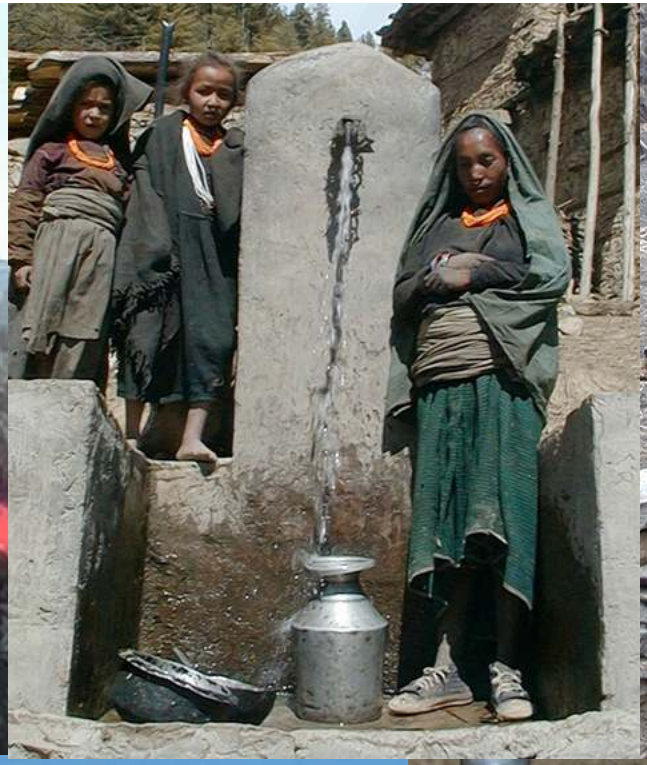
# Pure and Fresh Drinking Water

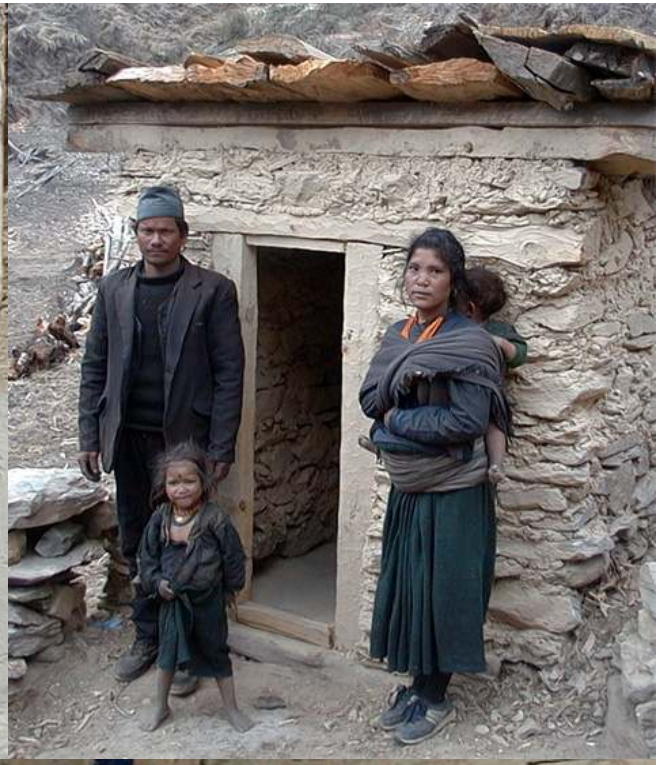
To have participated in the building of the own village drinking water system increases also the interest to keep it maintained and running.

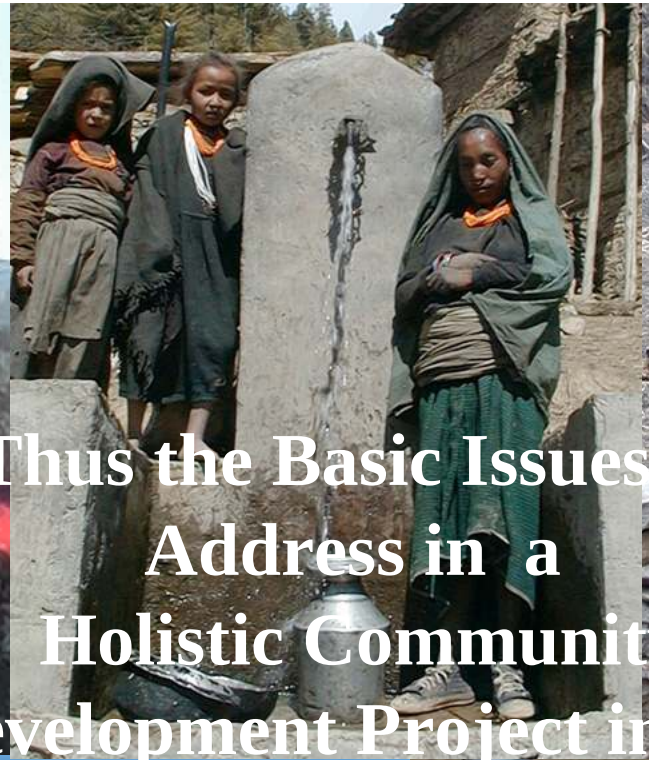
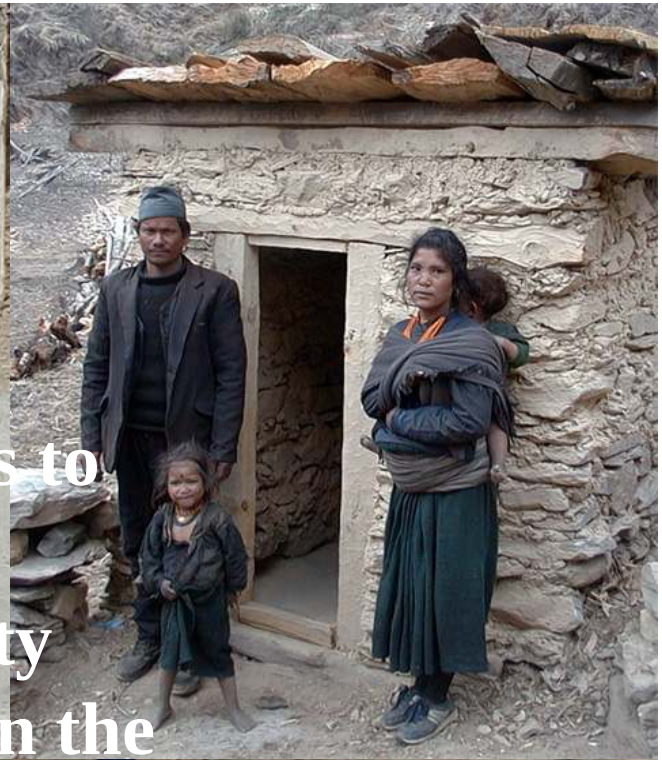
# Pure and Fresh Drinking Water



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





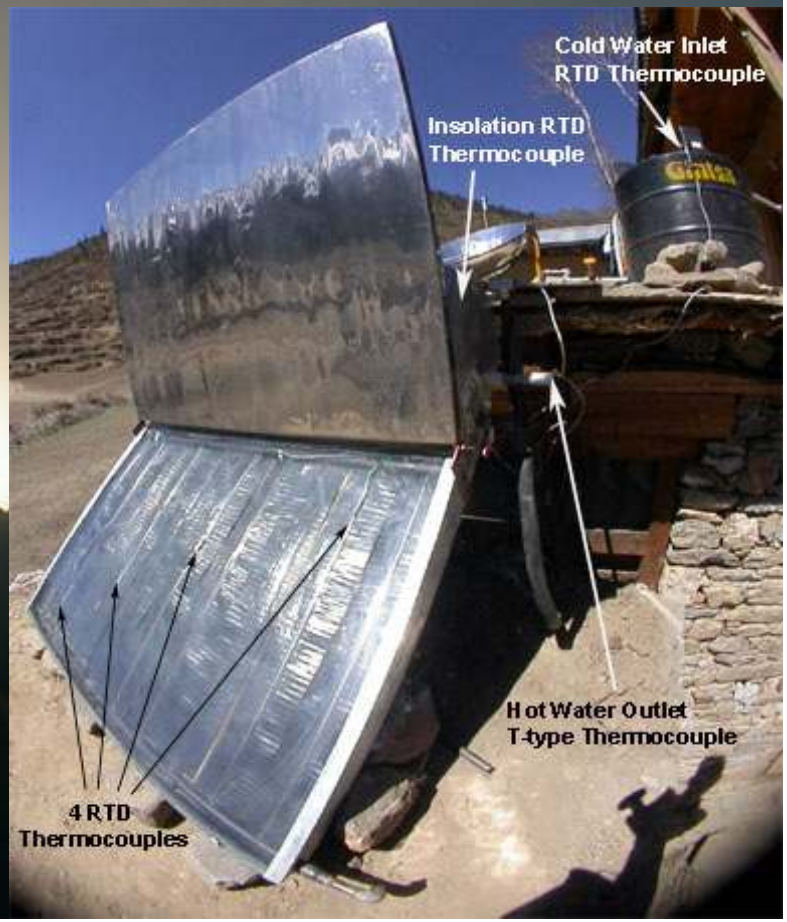
**Thus the Basic Issues to Address in a Holistic Community Development Project in the impoverished Nepal Himalayas is . . .**

Pit Latrine
Water
the Family of
4: Light, Stove,
Pit Latrine,
Water
Light
Stove
PLUS . . .

# High Altitude Solar Water Heater Bathing Center

First High altitude Solar Water Heater Prototype since 2003 under test

Hot Water



# High Altitude Solar Water Heater Bathing Center

Hot Water

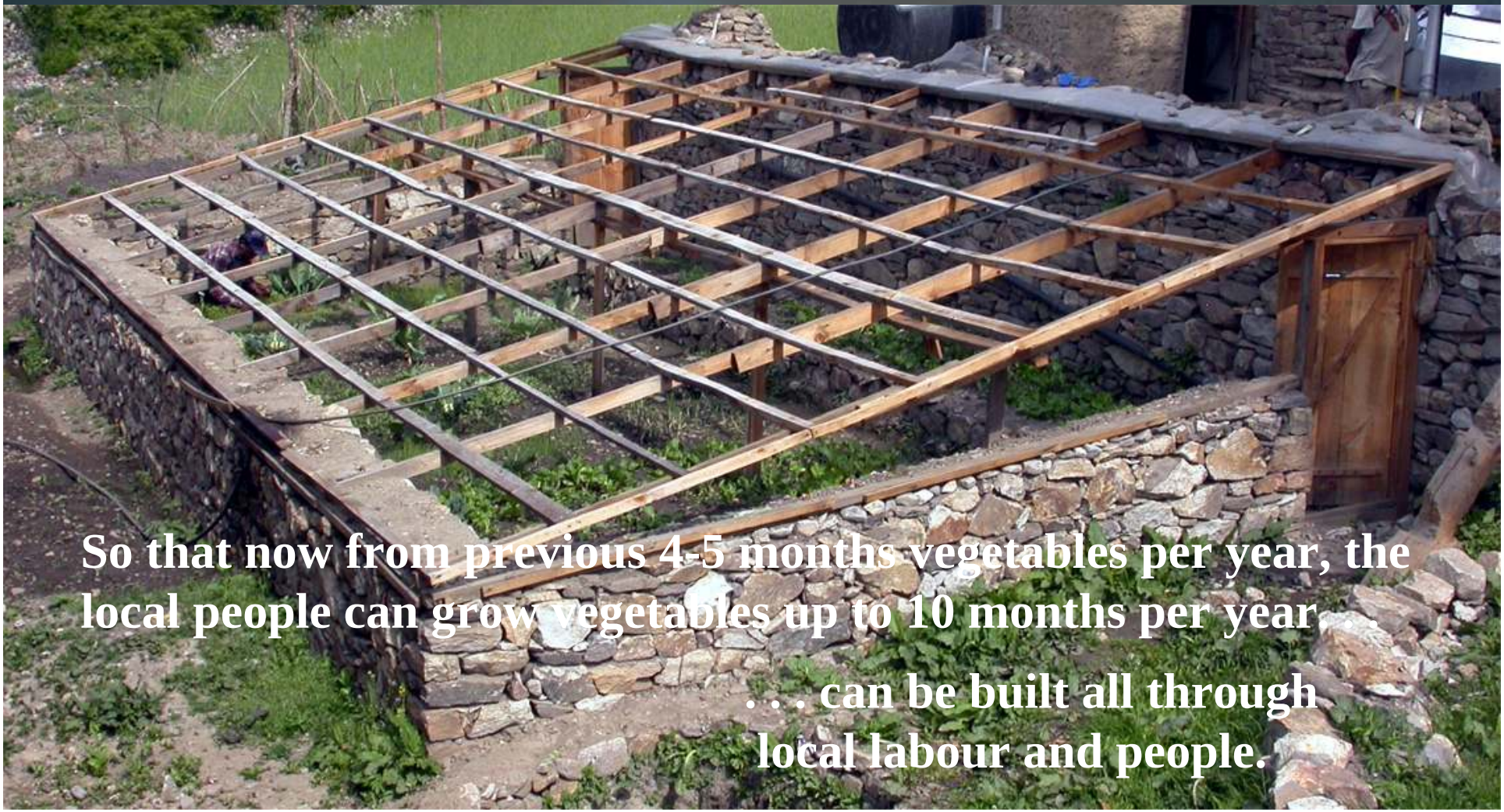
First High altitude Solar Water Heater Prototype since 2003

Followed by improved version II and tests still under test

For Increased, and More Nutritious Food
Greenhouse

# For Increased, and More Nutritious Food

**With the local materials wood and stones, and UV stabilised plastic from Kathmandu for the winter months, a suitable greenhouse . . .**



**So that now from previous 4-5 months vegetables per year, the local people can grow vegetables up to 10 months per year. . .**

**. . . can be built all through local labour and people.**

**So that now from previous 4-5 months vegetables per year, the local people can grow vegetables up to 10 months per year. . .**

**. . . improving the diet and thus the health of adults and in particular their small children enormously.**

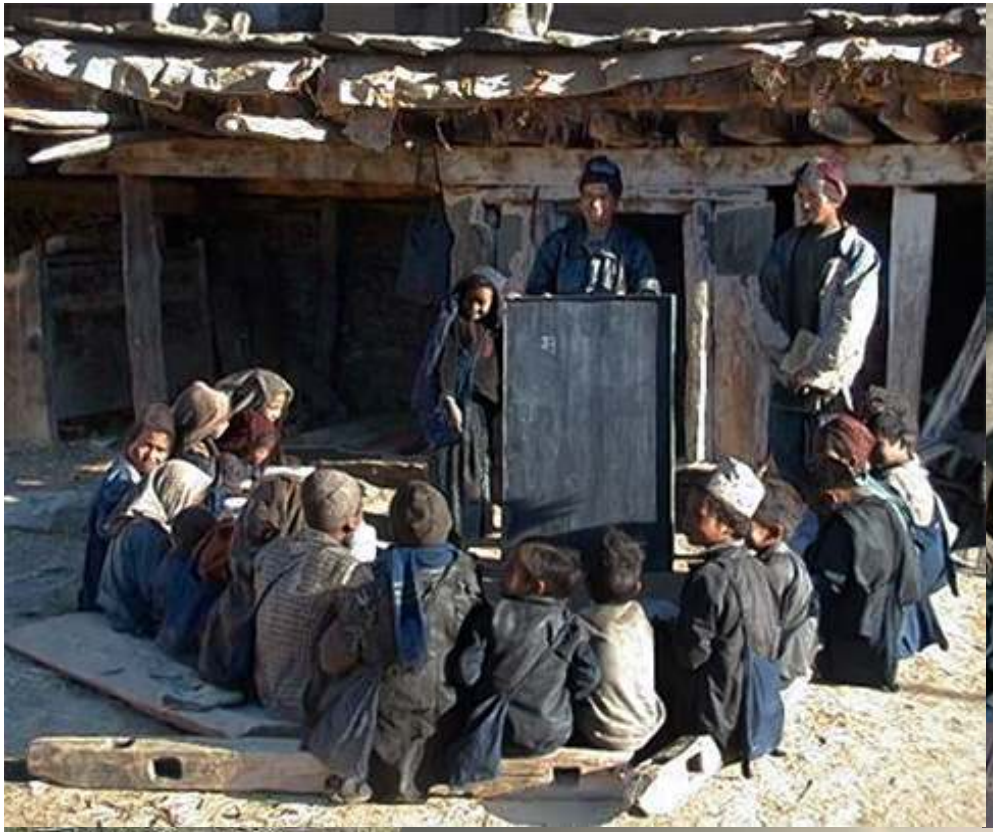
**Humla's literacy rate for women is 4.8%**

**Girls are not sent to school**

# NFE

(Non-Formal-Education)

**Now there are NFE classes for women and children**



# NFE

(Non-Formal-Education)

**Now there are NFE classes for women and children**

# Expected Impacts

If the hypothesis, that a holistic community development project will have long-term synergetic benefits is correct, the yearly conducted survey will show expected impacts such as:

- Overall Improvement in the Living Conditions
- Increased Health and Hygiene of all people
- Decrease in Firewood Consumption and work load
- Increase in the Women Literacy Rate and Awareness
- Increase in Social Gatherings after Dark resulting in
- Increased Community Development Projects
- High Utilisation and Low Breakdown of the New Technologies

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

# Strive for Sustainability

## Technical Sustainability

Reliable components
Sound design
Local O & M services

## Economic Sustainability

Least-cost preferred systems
Services that consumers can afford
Periodical fee collection

## Social Sustainability

Participation of all stakeholders
Training of consumers (system use, safety & maintenance)
Cultural acceptance by end user

## Environmental Sustainability

No ecological impact through installation and operation
Removal/recycling of batteries, lubricants

# Sustainable, Appropriate Technology Projects Can Answer Positively to . .

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 competent Operation and Maintenance ?
6. Has Sustainability be considered before Efficiency ?
7. Have new Activities and Opportunities been created ?
8. Have the overall living conditions improved ?

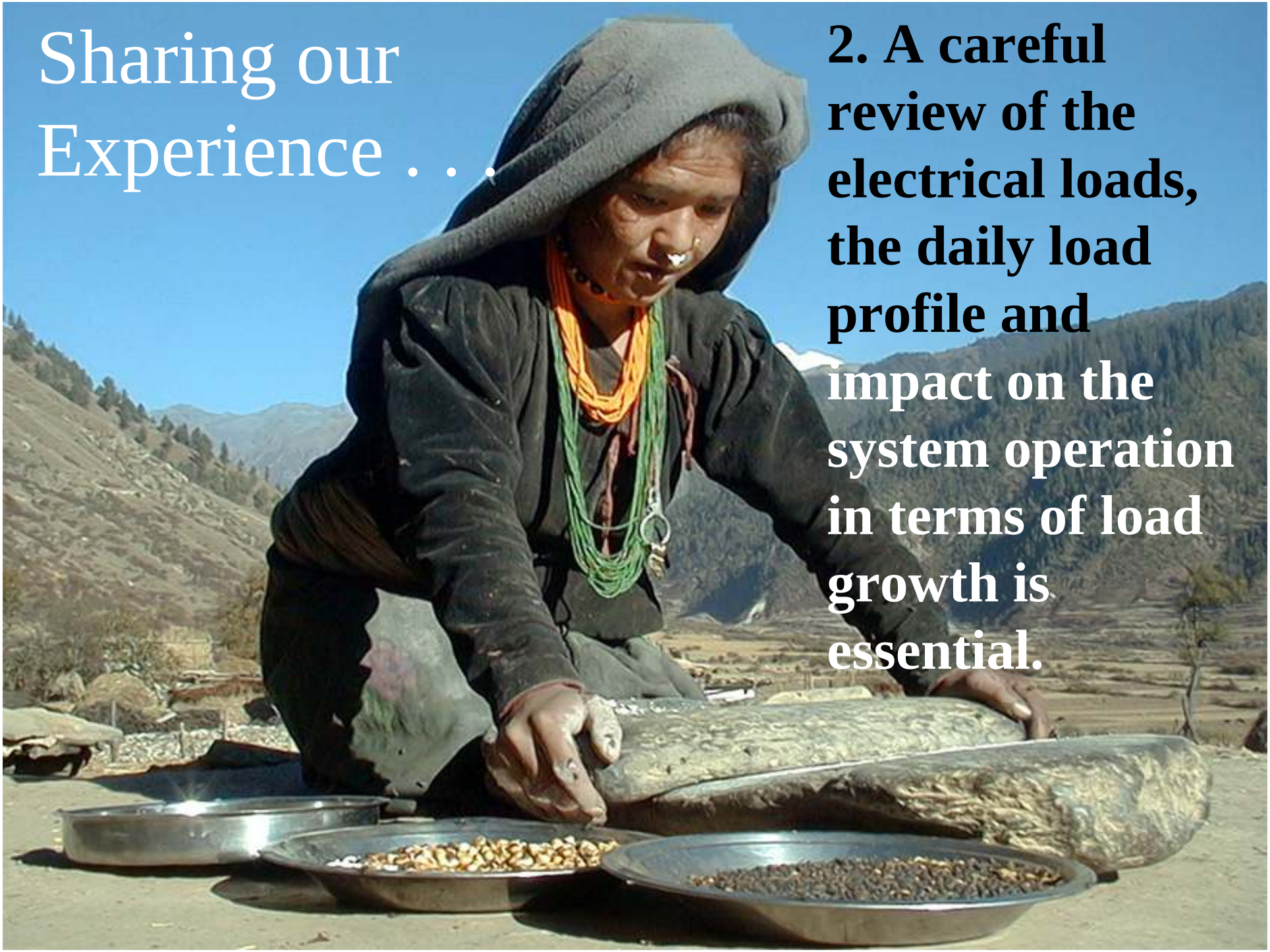
# Major Obstacles to Successful Projects serving marginalised, poor Communities

1. **History of expectation of free equipment delivery**
2. **High capital and transport cost, due to remoteness**
3. **Deep rooted poverty**
4. **No/minimal and poor education/knowledge**
5. **No community institution to install, service, collect**

# What has been Learned Over the last 9 Years involvement in Holistic Community Development in Partnership with the Poorest of the Poor Mountain Communities in the Nepal Himalayas . . .

# Sharing our Experience . . .

1. Successful renewable energy projects must focus NOT on installed capacity but on primarily meeting the minimal level of priority electricity services needed by the consumers, which are: Light, Information, Entertainment and Industry



# Sharing our Experience . . .

**2. A careful review of the electrical loads, the daily load profile and impact on the system operation in terms of load growth is essential.**

# Sharing our Experience . . .

3. Projects that can demonstrate environmental benefits will be easier to finance, implement and replicate.

Sharing our Experience . . .

**4. The choice of power generation technologies should be based on the premise of “least – cost, preferred and sustainable”,.**

# Sharing our Experience . . .

5. Successful projects always include appropriate O & M training for local people.

# Sharing our Experience . . .

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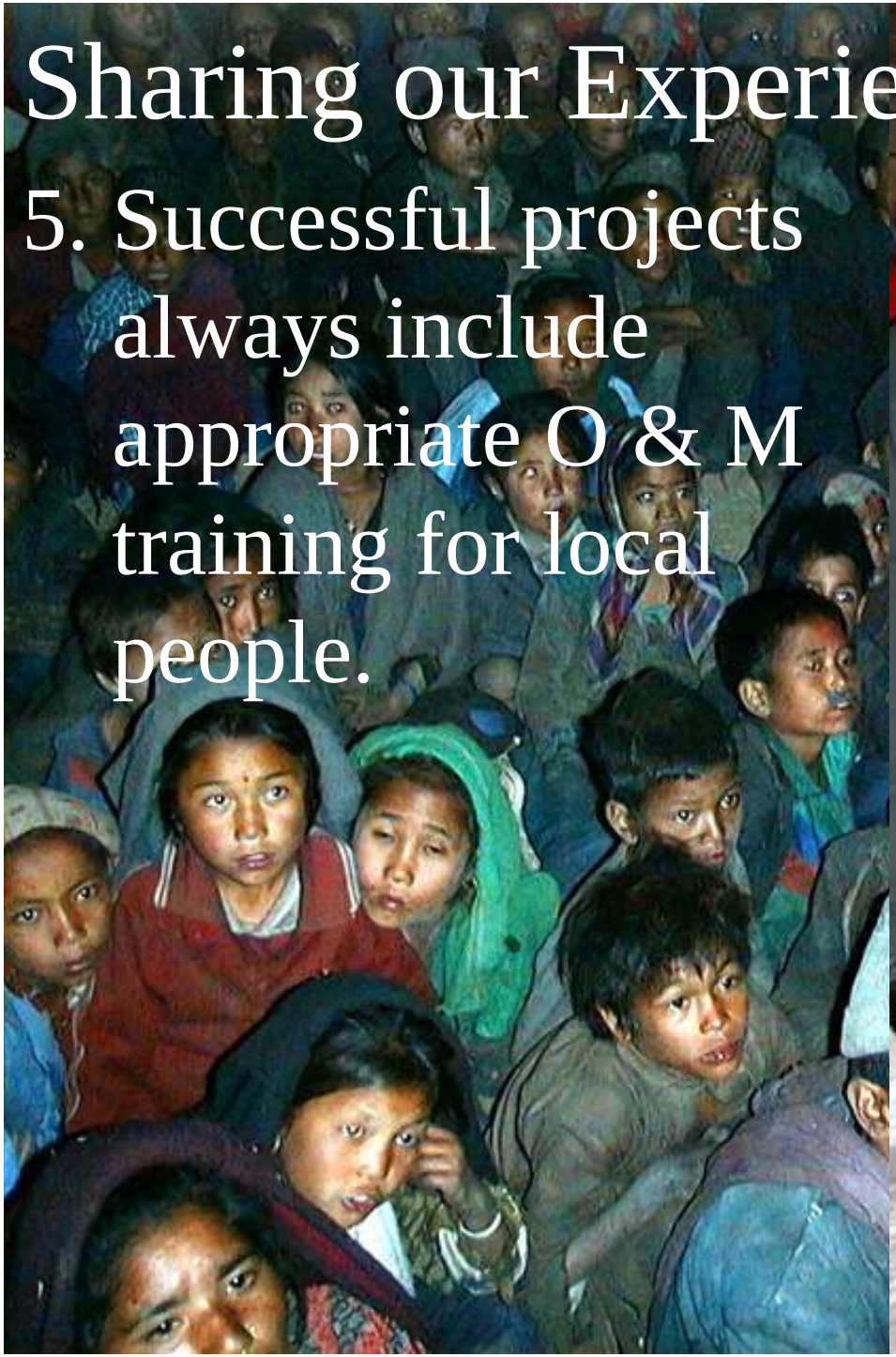


# Sharing our Experience . . .

**6. Each project has to run according to rules defined by the community.**

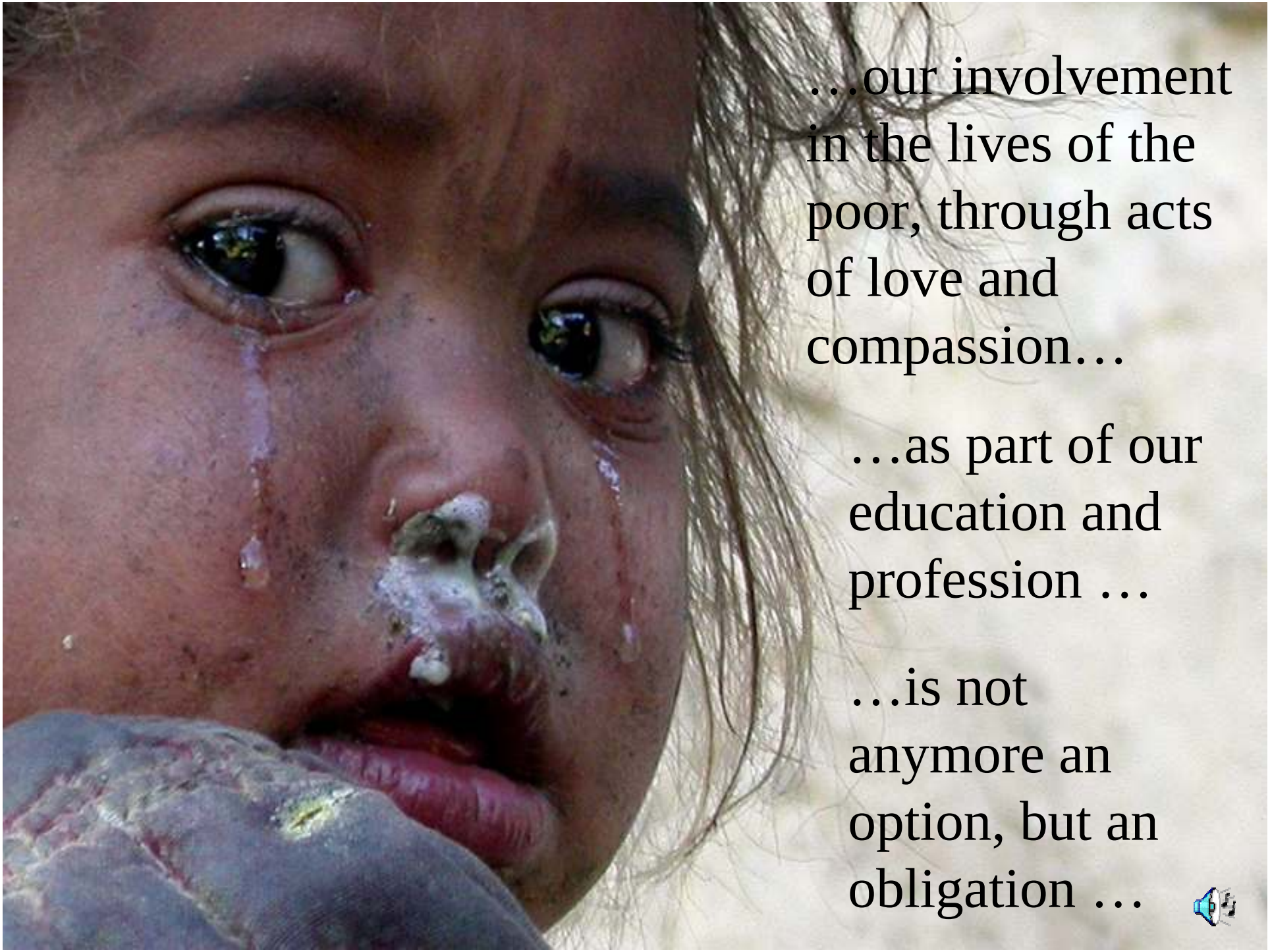
- **Appointment of responsible person(s)**
- **Appointment of operator(s)**
- **Defining the needs for maintenance**
- **Penalties for misuse**
- **Periodical fees.**

# Sharing our Experience . . .

7. Without effective cost recovery systems through periodical payments/fees, all stakeholders lose, especially the consumers.

# Sharing our Experience . . .

8. Successful projects are designed to reduce the dependence on foreign supplied equipment and fuel. Technology transfer components must be built into all projects, ranging from local manufacturing, marketing, distribution to effective training for O & M services.


…our involvement in the lives of the poor, through acts of love and compassion…
…as part of our education and profession …
…is not anymore an option, but an obligation …

dida

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