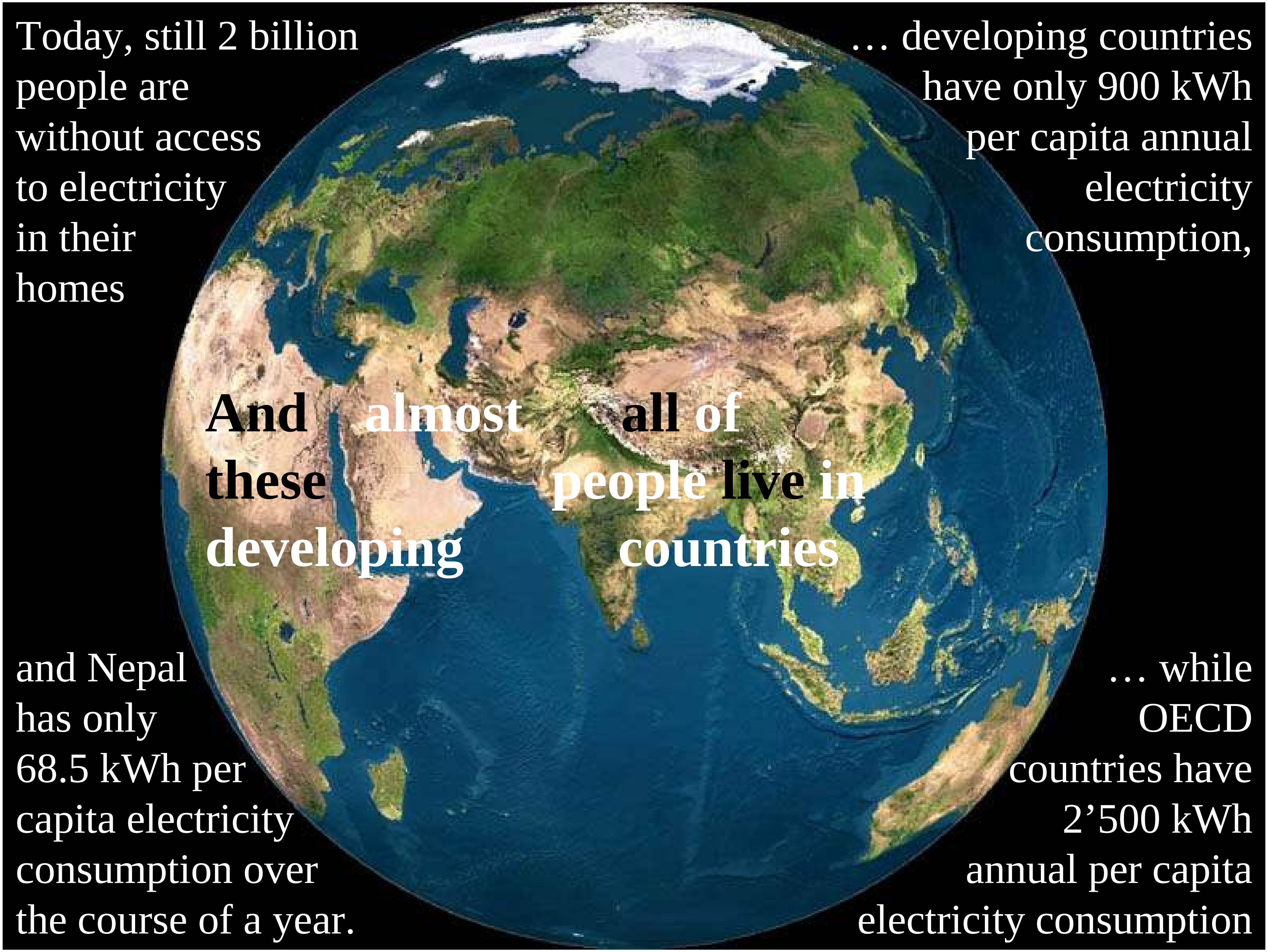
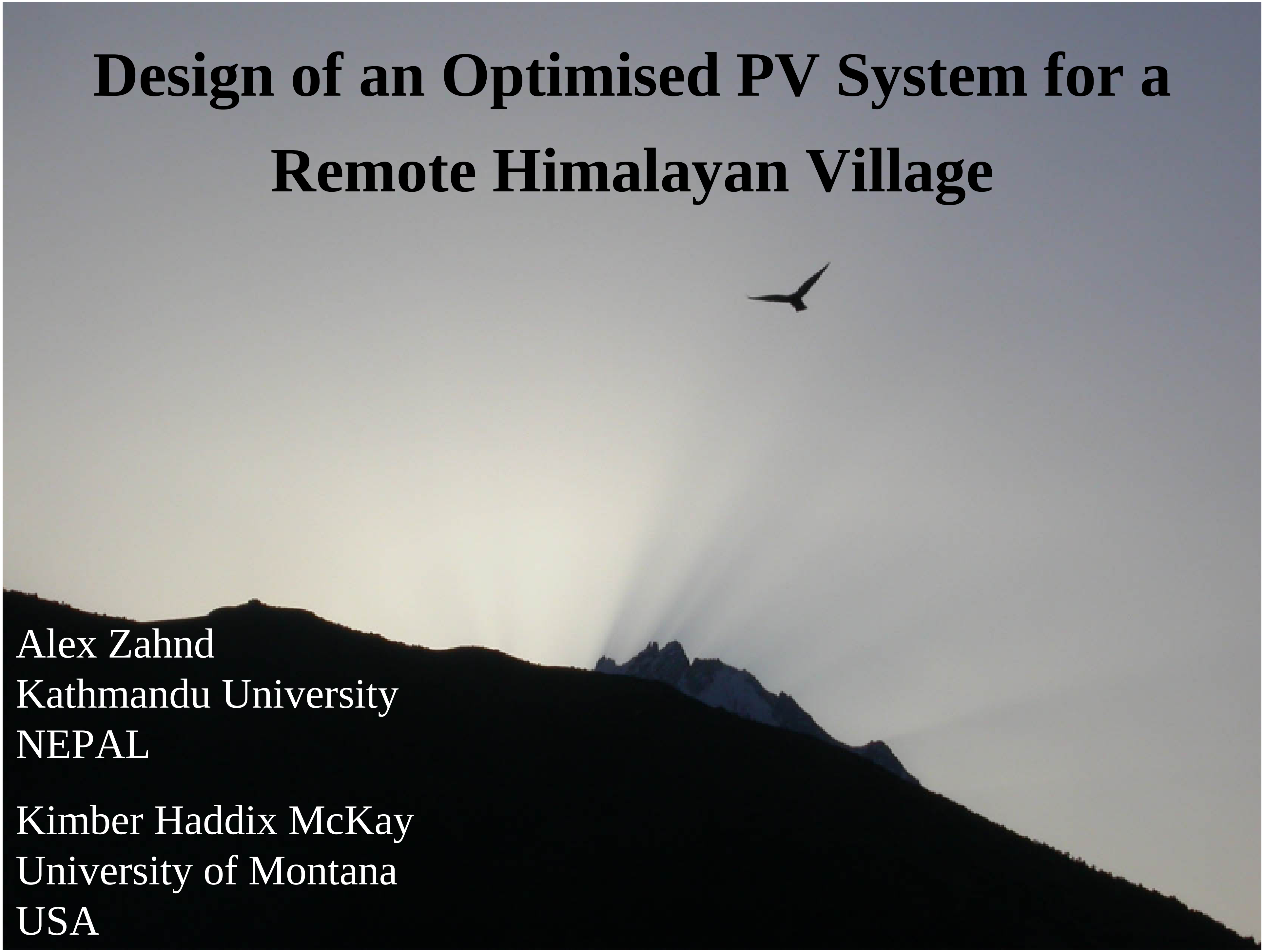
[redacted]


Today, still 2 billion people are without access to electricity in their homes
… developing countries have only 900 kWh per capita annual electricity consumption,
And almost all of these people live in developing countries
and Nepal has only 68.5 kWh per capita electricity consumption over the course of a year.
… while OECD countries have 2’500 kWh annual per capita electricity consumption


NEPAL


88% of Nepal’s 27.5 million people live in rural areas, with estimated half of them in such remote and difficult to access areas that neither a road nor the national electricity grid will reach them for decades to come.

Design of an Optimised PV System for a Remote Himalayan Village

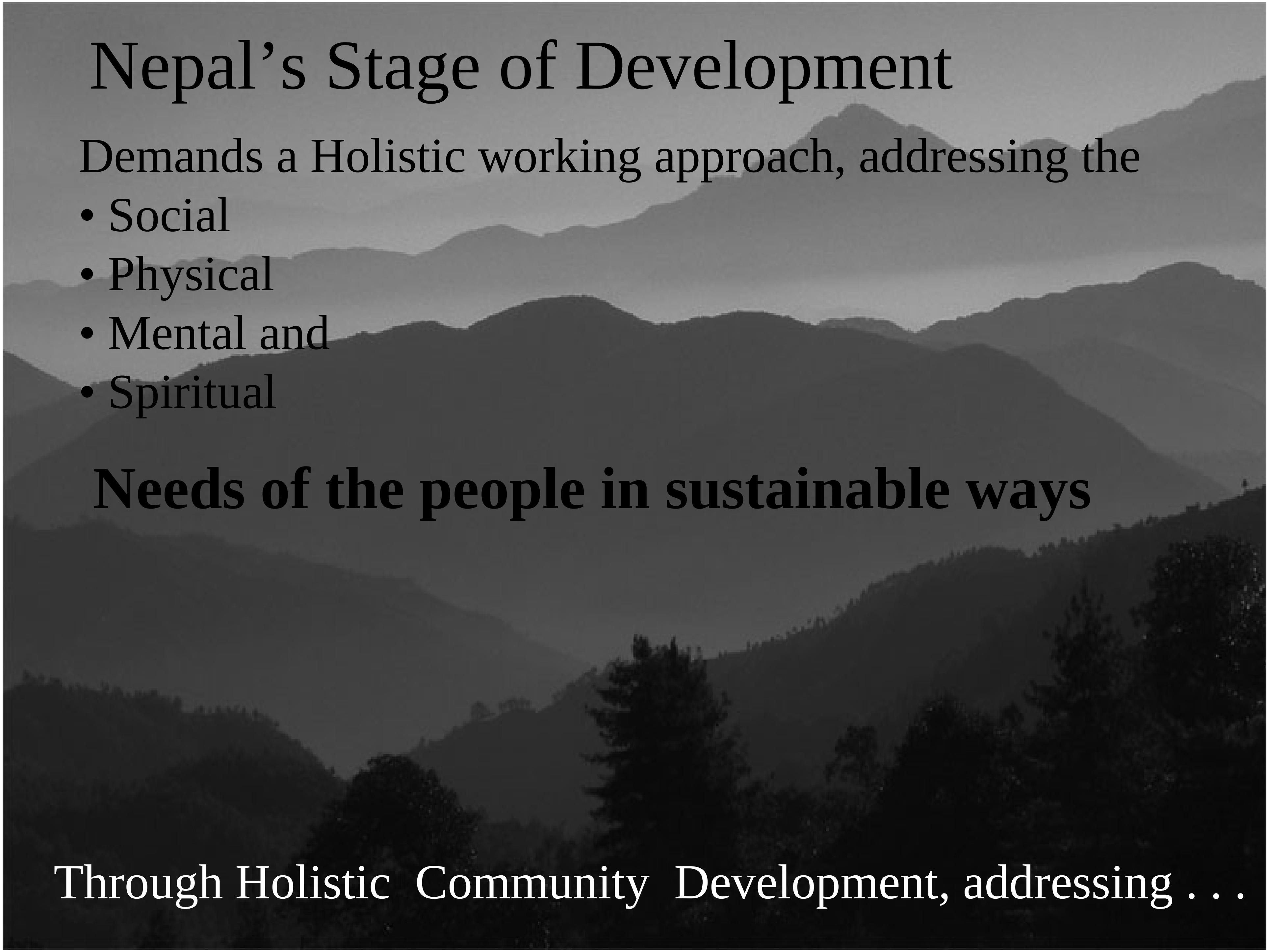


Alex Zahnd
Kathmandu University
NEPAL

Kimber Haddix McKay
University of Montana
USA

Nepal at a Glance

1. **85% of Nepal’s people have no access to electricity.**
2. **Literacy rates in the remote mountain areas is 4% - 20%.**
3. **Annual population growth 2.3%.**
4. **The average annual income per capita is 30 US$ - 260 US$.**
5. **42% of Nepali live below the poverty line, and there is a clear relationship between poverty and access to electricity.**
6. **Nepal is rich in renewable energy resources, in particular its potential hydro power and solar energy.**


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, addressing . . .

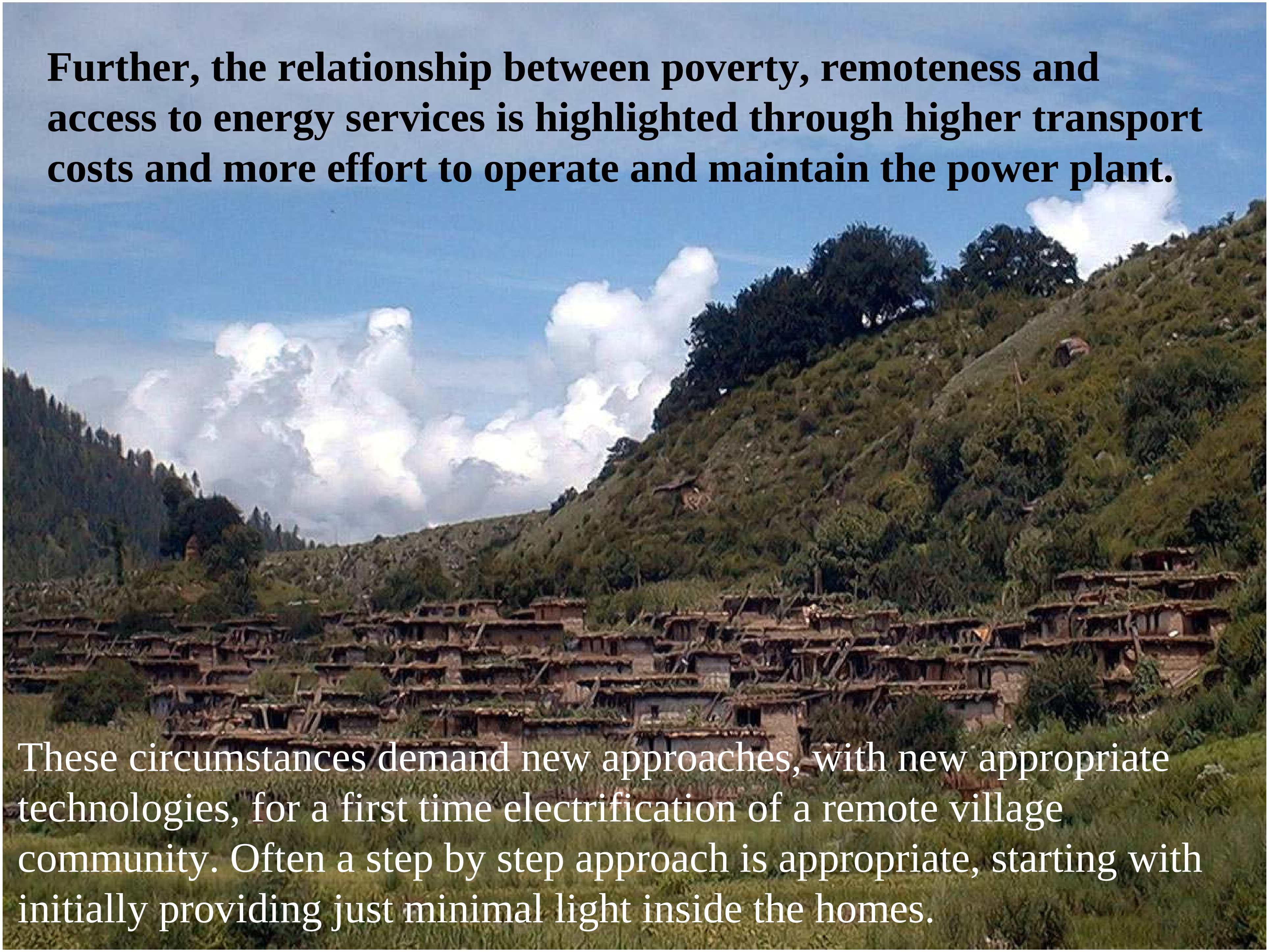
. . . health, food security, drinking water,
indoor pollution and education,
alongside each other.

Thus rural electrification, in order to be sustainable and relevant, benefiting from the synergetic effects of a holistic community development project, has to be embedded alongside with other projects simultaneously.

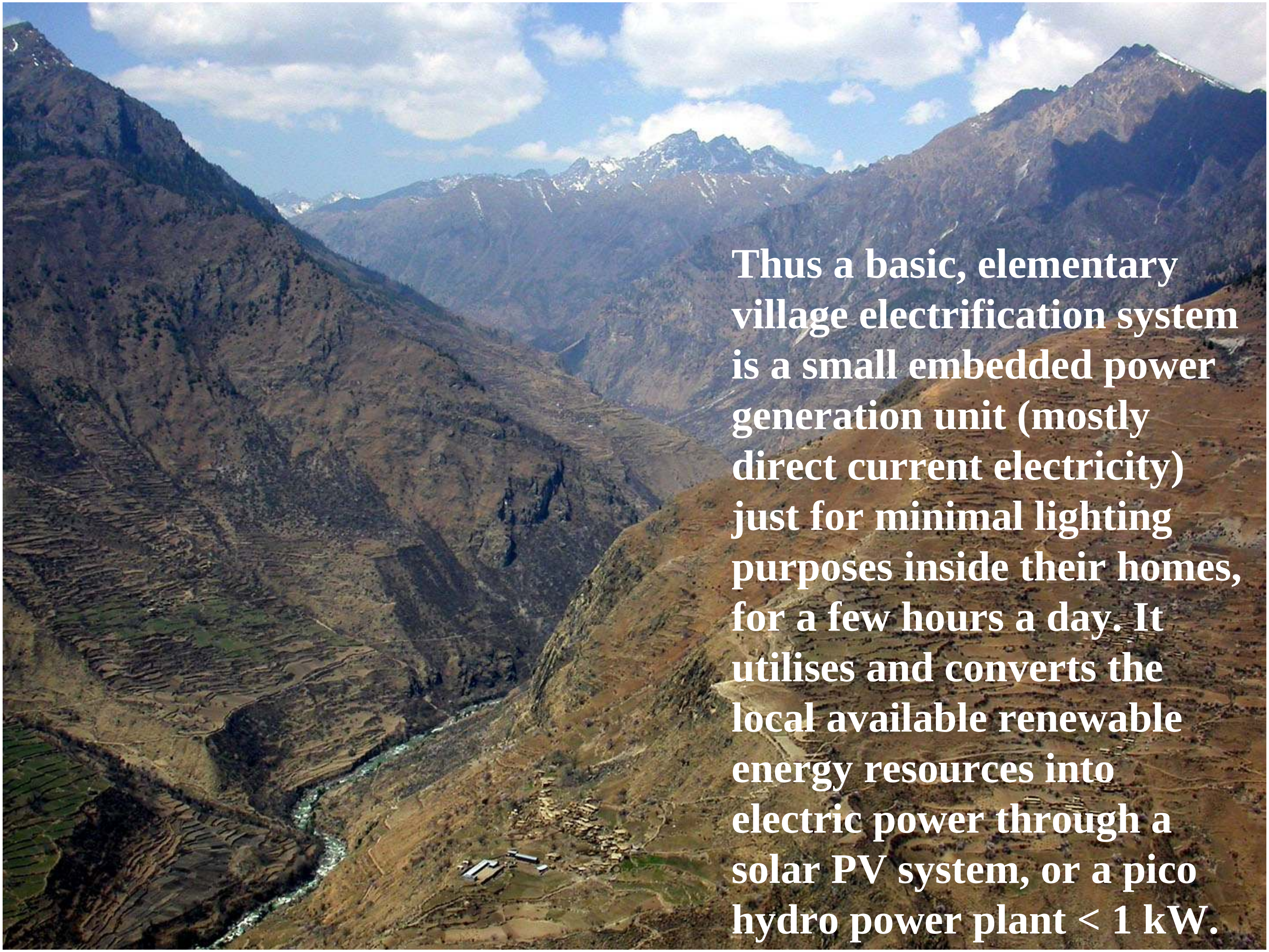
In Nepal the “normal thinking” in regard to rural village electrification is, that each household needs access to a minimum power rating of 100 watt. Thus homes, powered by 8 - 20 kW micro-hydro power plants,

. . . and sometimes even by PV systems, have 2 – 3, incandescent bulbs per household, consuming each 25 - 60 watt.

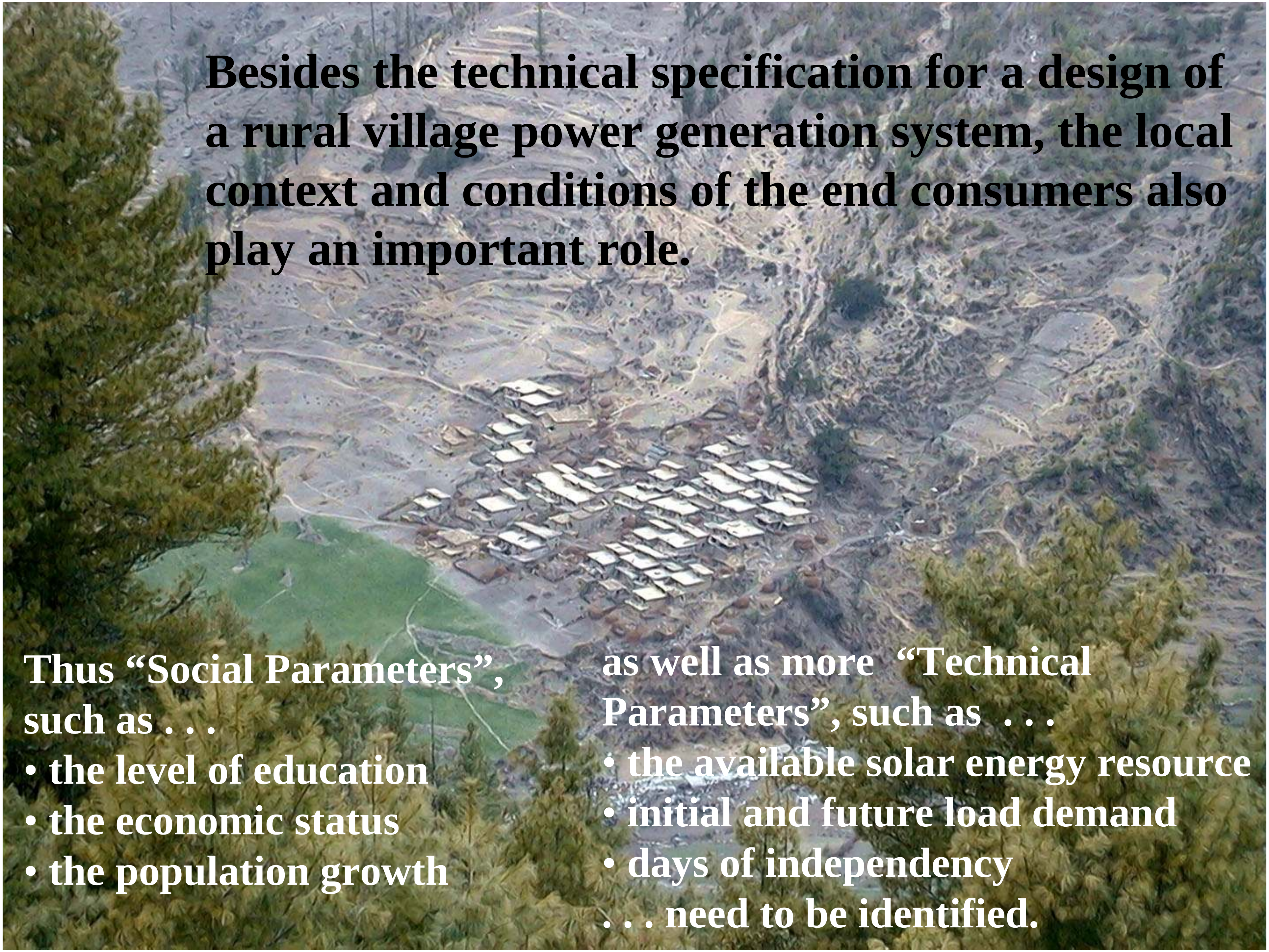
Further, the relationship between poverty, remoteness and access to energy services is highlighted through higher transport costs and more effort to operate and maintain the power plant.



These circumstances demand new approaches, with new appropriate technologies, for a first time electrification of a remote village community. Often a step by step approach is appropriate, starting with initially providing just minimal light inside the homes.



Thus a basic, elementary village electrification system is a small embedded power generation unit (mostly direct current electricity) just for minimal lighting purposes inside their homes, for a few hours a day. It utilises and converts the local available renewable energy resources into electric power through a solar PV system, or a pico hydro power plant < 1 kW.


Besides the technical specification for a design of a rural village power generation system, the local context and conditions of the end consumers also play an important role.
Thus "Social Parameters", such as . . .
• the level of education
• the economic status
• the population growth
as well as more "Technical Parameters", such as . . .
• the available solar energy resource
• initial and future load demand
• days of independency
. . . need to be identified.

Social Parameters

1. Village Population growth, affected e.g. by:

- high urbanisation
- high unemployment
- poor education facilities
- a shortage of arable and irrigated land
- political instability and civil war

Social Parameters

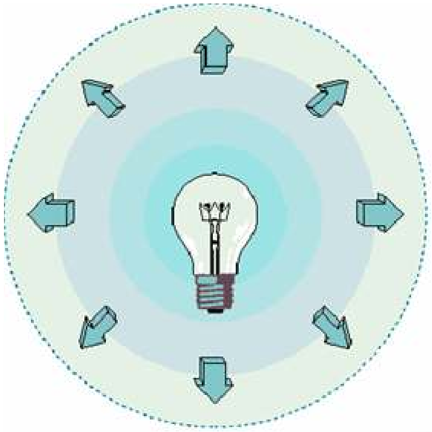
2. Economic Capacity, affected e.g. by:

- high project building and operational costs
- low capacity level
- need for high sustainability
- high migration rate of the income generation group
- policies on available subsidies, loans, grants
- external earned revenues sent back to the families

Social Parameters

3. Educational Level, affected e.g. by:

- local literacy rate, which is e.g. only 4.8% for women in Humla
- average schooling years, which is only 0.88 years per person in Humla
- missing of educational infrastructures and opportunities, thus the need for local non-formal-education classes



Social Parameters

4. Lighting Services Needed

What is the appropriate light output needed in the homes of the remote mountain villages for different tasks

Lighting need to:

- provide a safe visual environment
- make it possible to easily see the task
- provide a comfortable, pleasant visual environment
- achieve the lighting function as efficiently and cost-effectively as possible
- be easy to clean and maintain
- enable save orientation within buildings

Social Parameters

5. System Ownership, influenced e.g. by:

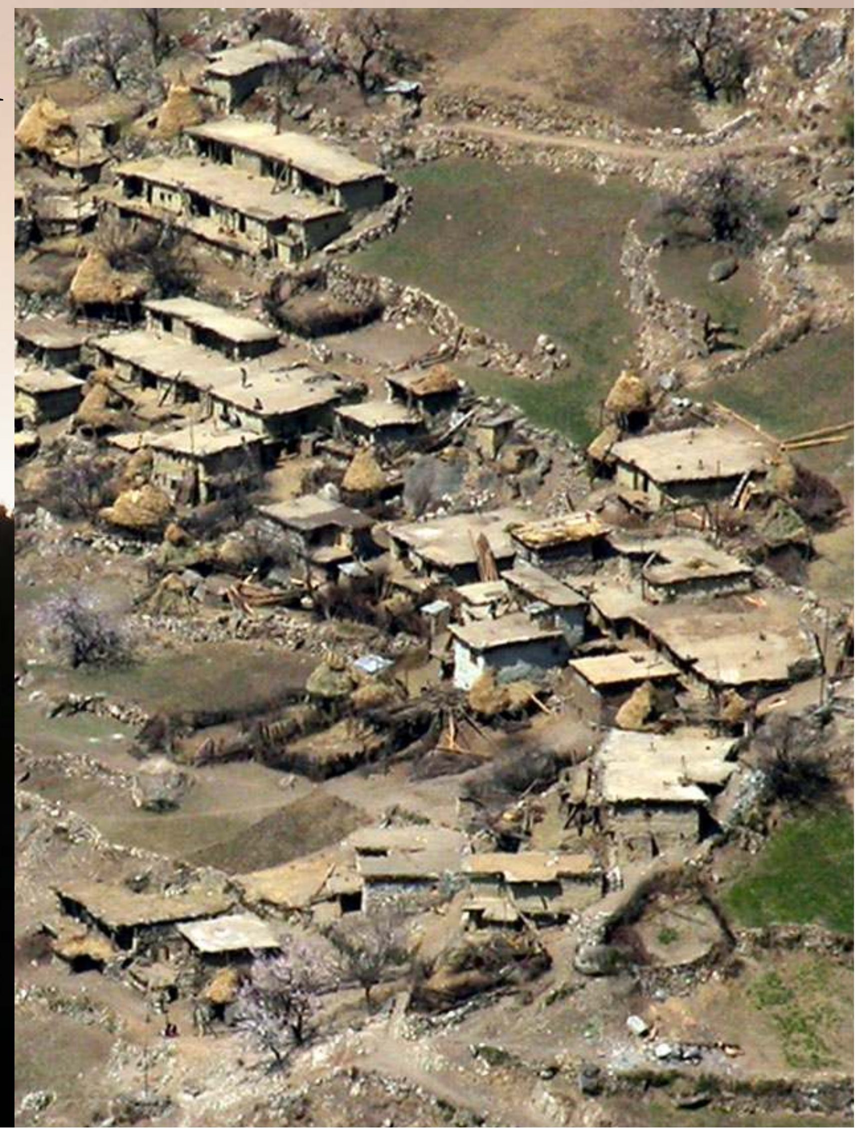
- cooperative, public ownership, demanding more organised management for the operation and maintenance
- private ownership, which can expect more self-initiative and responsibility for the operation and maintenance

Technical Parameters

1. Load Demand and Growth

The size of a basic rural village solar PV system depends directly on the load demand and the number of homes.

The historical population growth over the last 20 years is identified, averaged and calculated for the next 10 years.



Technical Parameters

1. Load Demand and Growth

The size of a basic rural village solar PV system depends directly on the load demand and the number of homes.

The historical population growth over the last 20 years is identified, averaged and calculated for the next 10 years.

The initial battery bank's designed capacity has to reflect the realistic initial daily load demand after 5 year. Further, it needs to be able to provide the energy to get through the defined numbers of sunshine independent days

Technical Parameters

2. Life Expectancy

PV modules are often the most expensive equipment in a project. Today PV module manufacturers guarantee a 25 years life expectancy. Accordingly all the periphery equipments have to be designed to either match that, or some multiple of it during the project's life cycle.

Approximate Lifetime Expectancies for some of the Equipment are:

1. Solar PV modules and PV array frame: 25 years
2. Battery charger and discharger: 8 - 10 years
3. Battery bank with conservative design: 5 – 10 years
4. Lights, dependent on the technology and use: 4 – 25 years
5. Transmission cables: Underground 25 years, untreated wooden poles: 3 – 5 years
6. Switches: 3 - 5 years

Technical Parameters

3. Solar Energy Resource Assessment

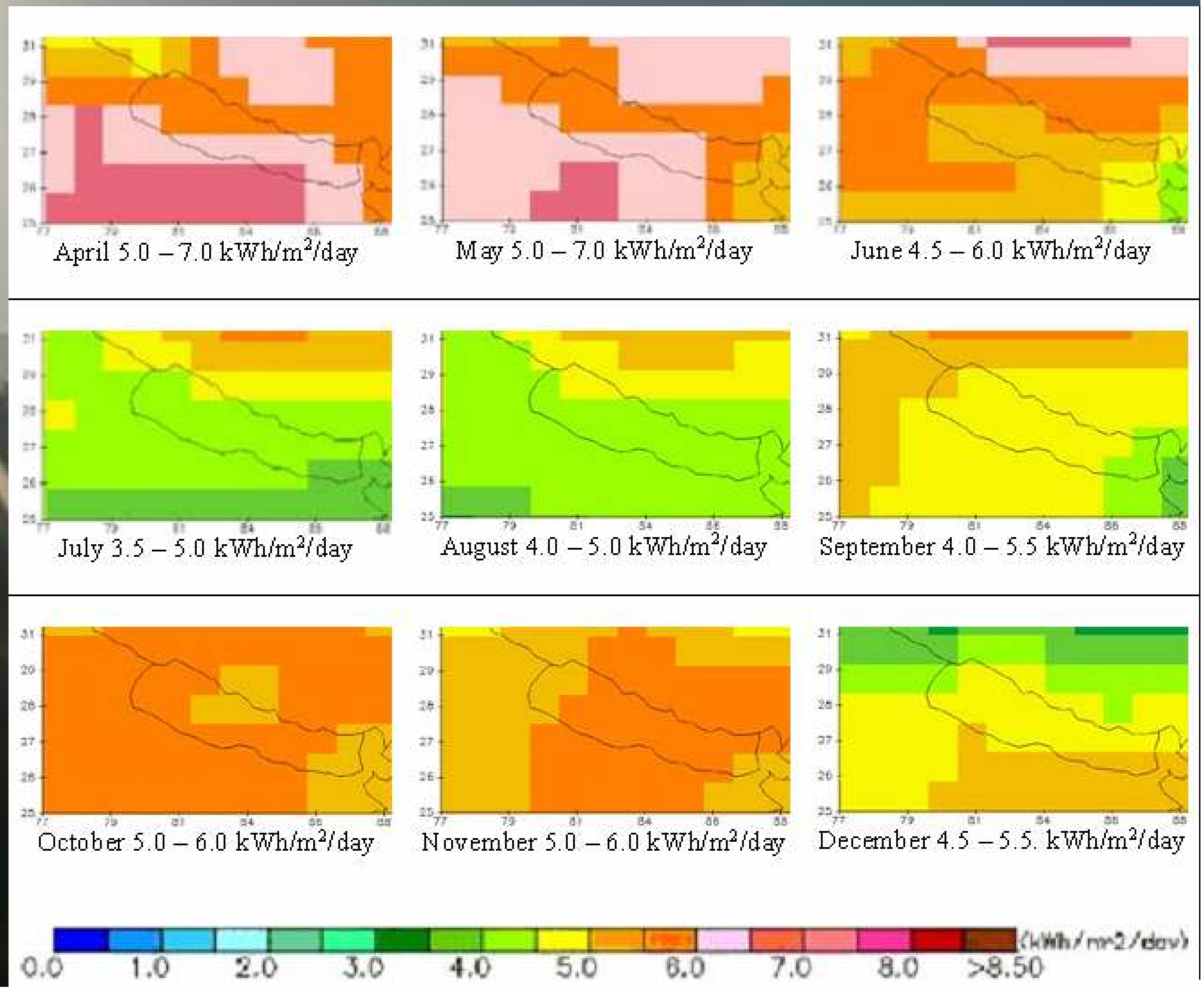
In order to define and calculate a Solar PV Village System properly, the local available solar energy resource has to be known.

The Local Available Solar Resource can be defined through 3 Processes:

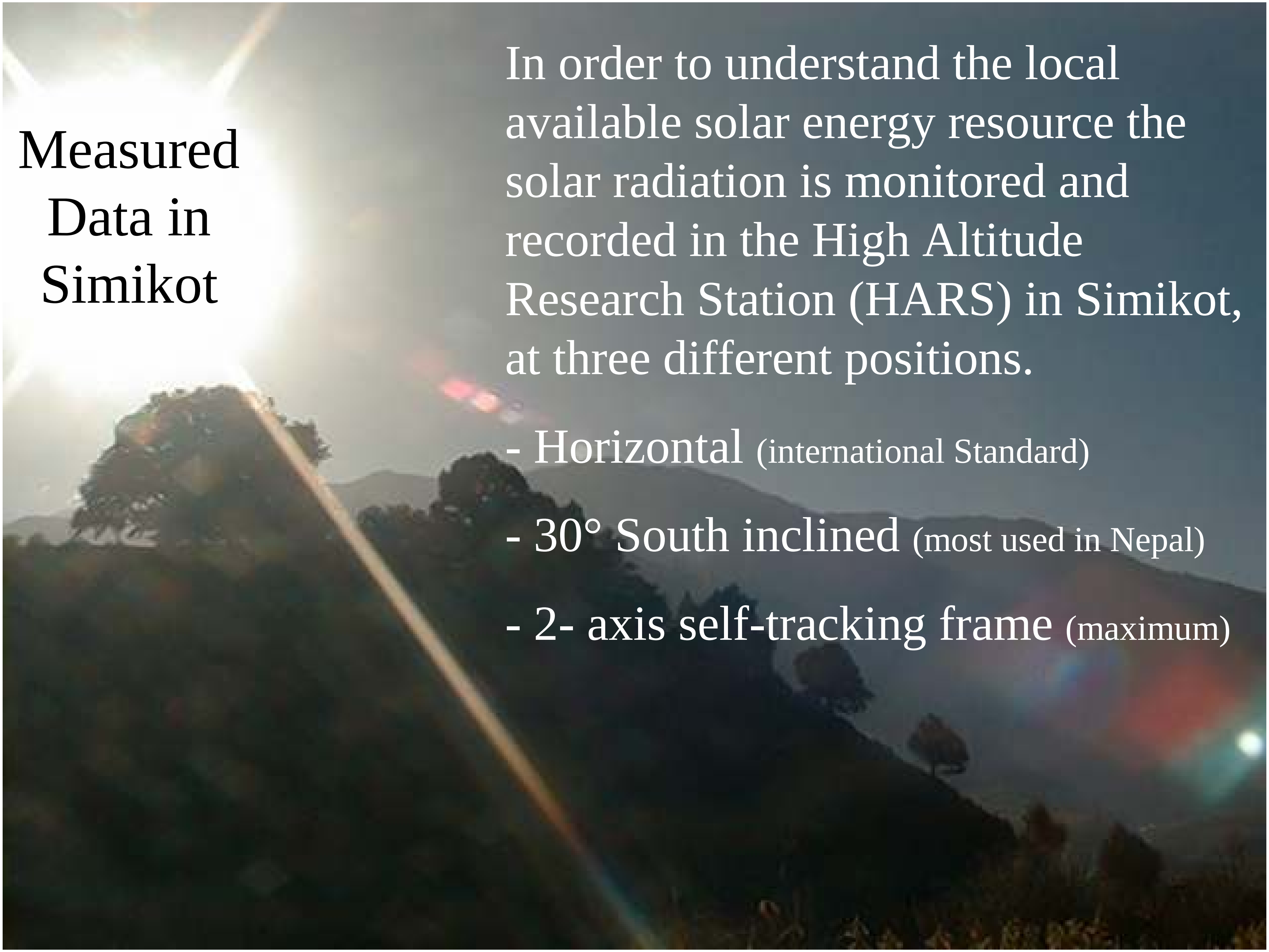
- ❑ through the NASA satellite data
- ❑ through the Meteonorm software simulation
- ❑ through measuring the local available solar insolation.

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 any place in Nepal, on a 30 ° south tilted surface

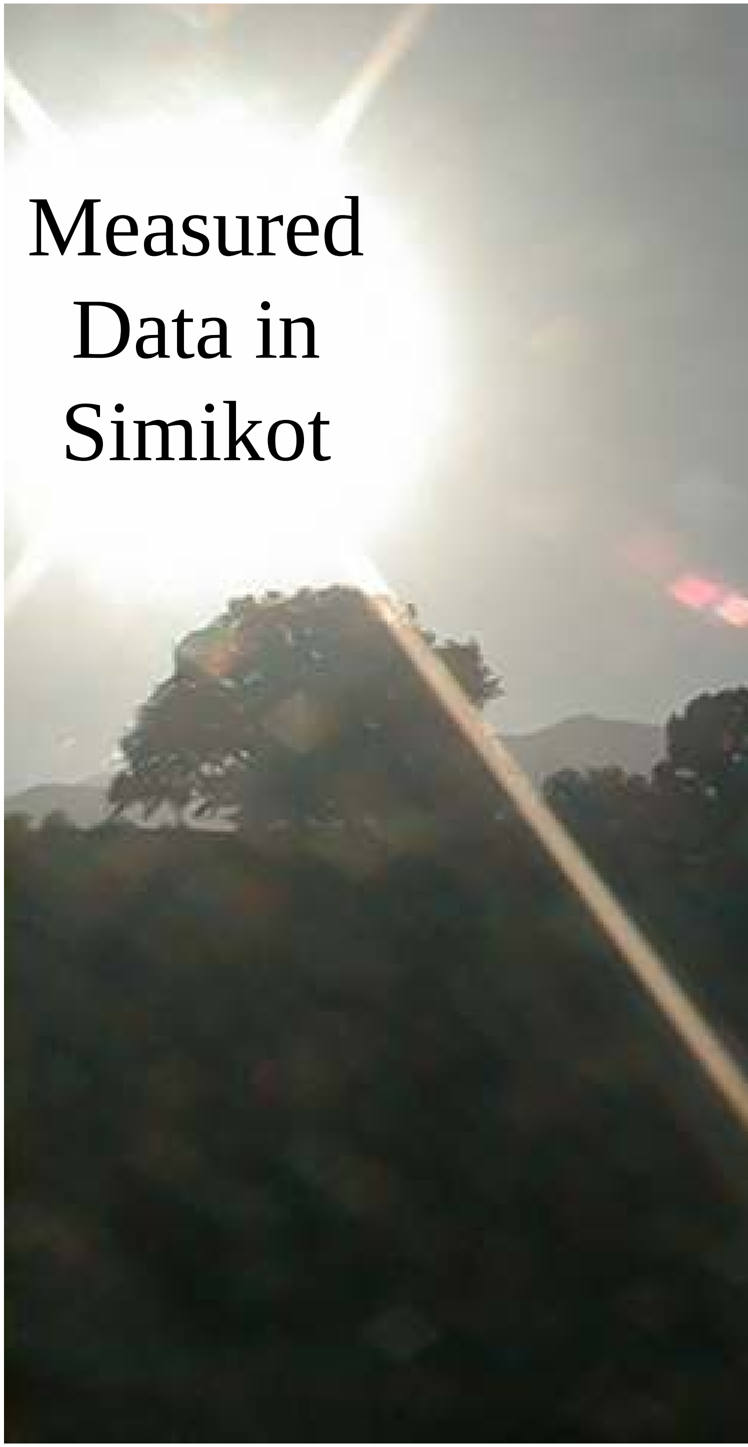


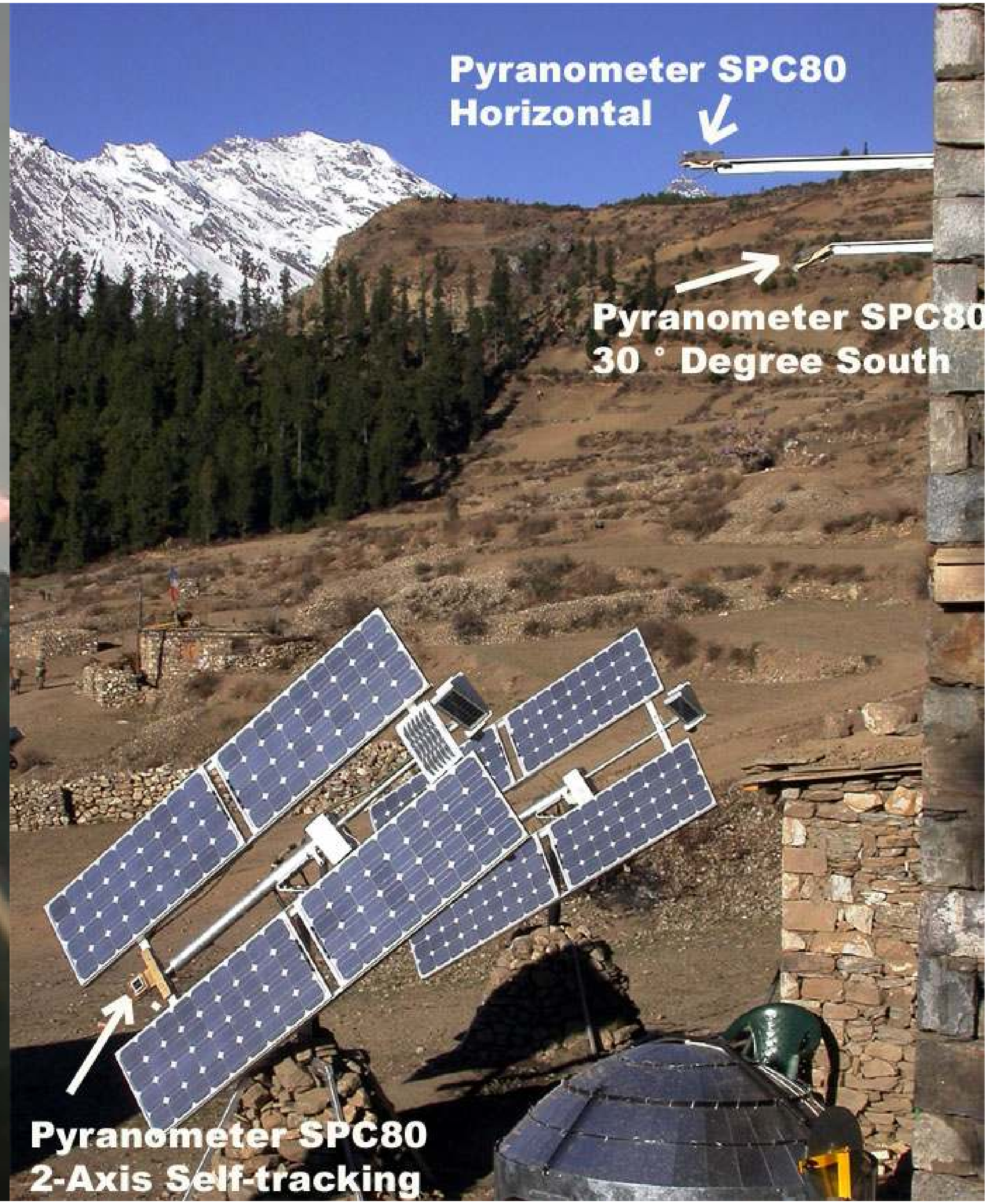
Measured Data in Simikot

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.

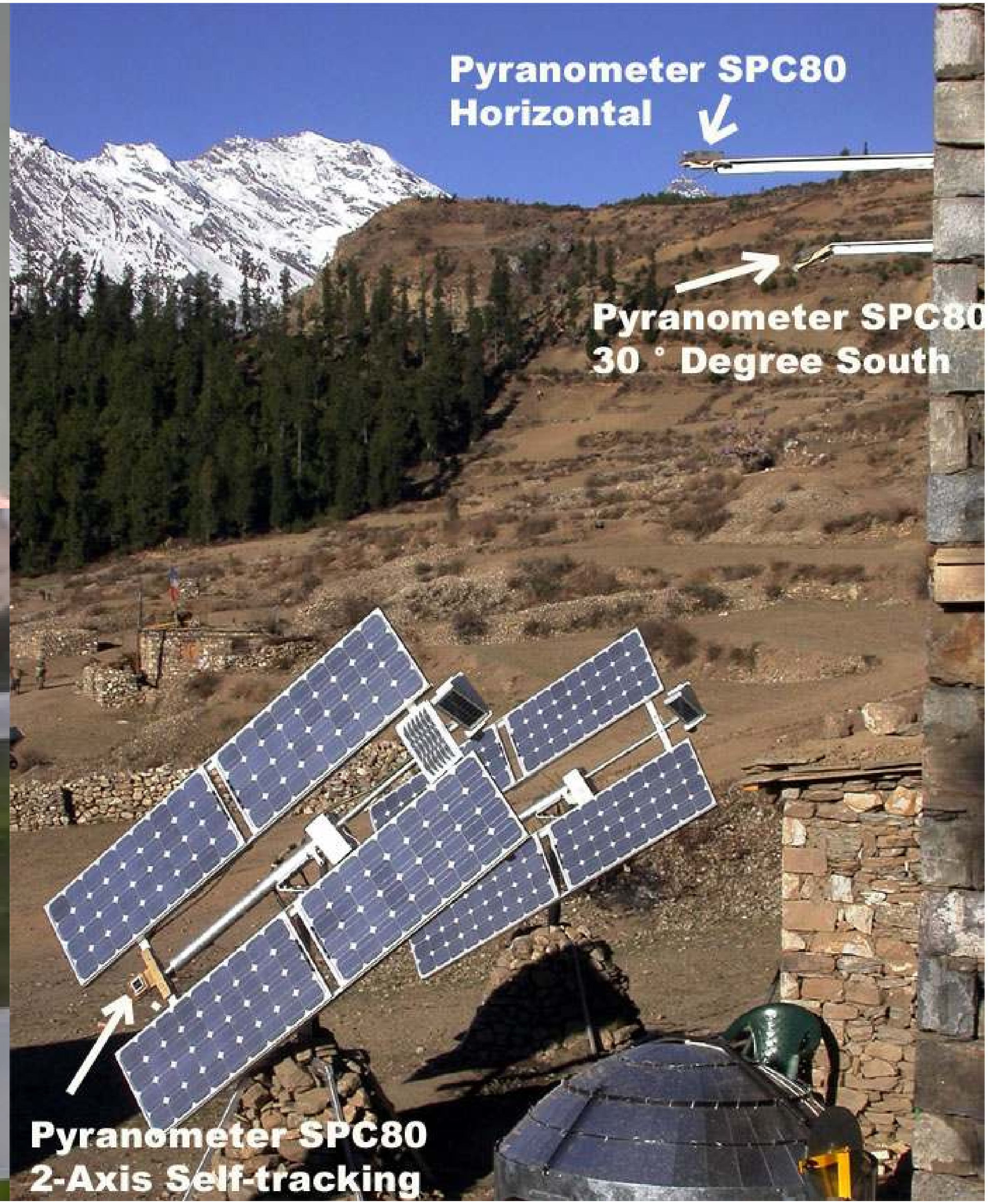
- Horizontal (international Standard)
- 30° South inclined (most used in Nepal)
- 2- axis self-tracking frame (maximum)

Measured Data in Simikot





Local Measured Data



Technical Parameters

4. Availability, Reliability, Days of Sunshine Independence

The Local Community decides:

- ❑ how many hours a day they want light
- ❑ how many lights they can afford
- ❑ how many days of independence can be afforded
- ❑ who has to be trained for installation & maintenance

For remote villages one needs to aim for:

- ❑ high sustainability, rather than highest possible efficiency
- ❑ limit the energy services to a minimum, but reliably provided
- ❑ maximum DoD of the battery bank of 35%
- ❑ designing systems able to cope with 5-10 years load growth

Technical Parameters

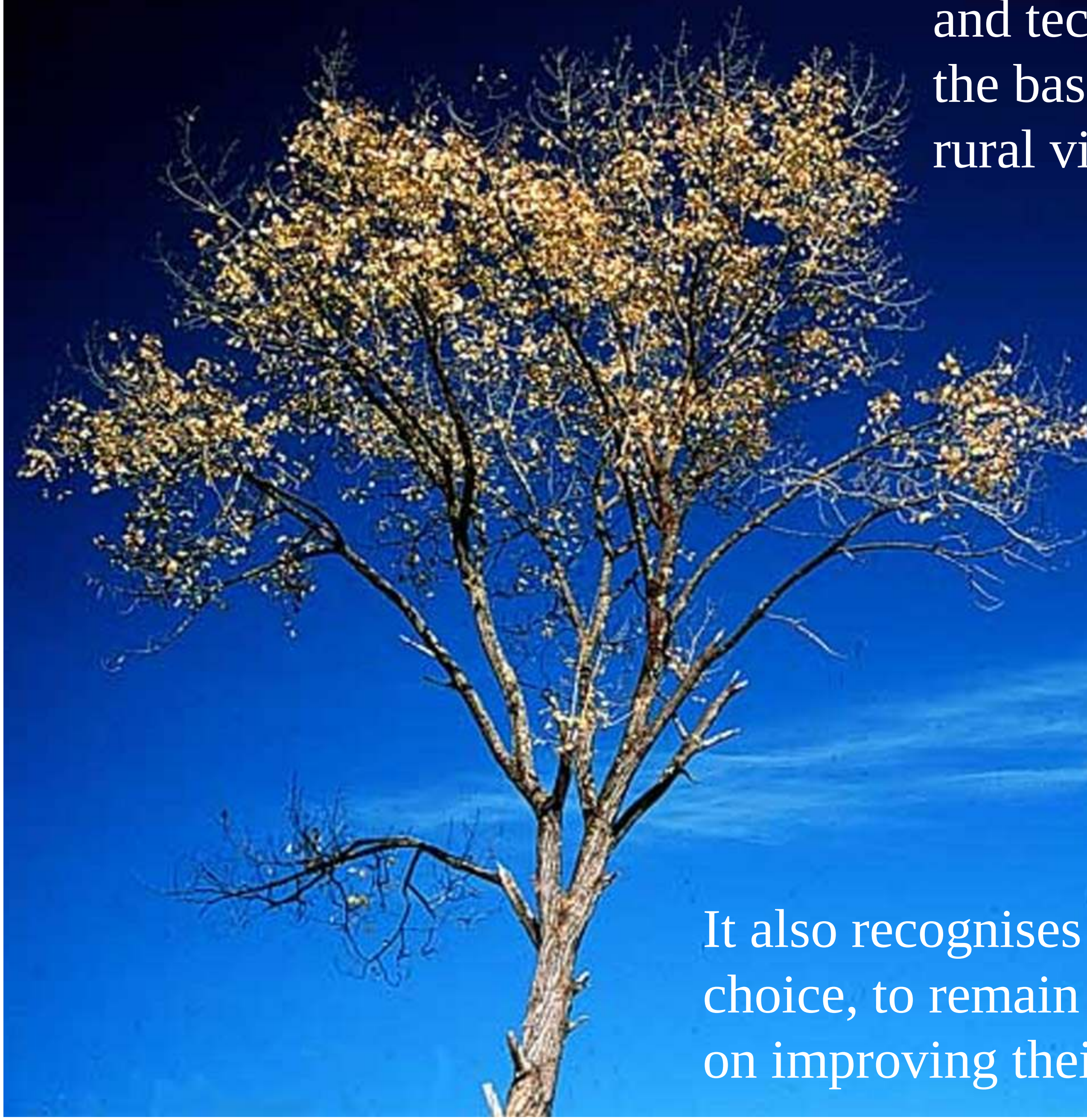
5. Maintenance and Repair

Rural village electrification systems need:

- to use appropriate, reliable, and locally manufactured material
- local people trained to operate, service and maintain it
- to be defined and built in close participation with the local community
- the leading participation of the trained local people in the initial installation (providing them with the due respect in the community)

The Operating/maintenance team is provided with:

- Operation list with the system parameters to be filled in
- Basic tools such as voltage meter, battery gravity measurement
- A defined communication procedure with the project designer
- Regular, once a month visits by the project designer



The knowledge of these social and technical parameters form the basis for the design of rural village PV systems.

Consideration of these social or “soft” issues of a project, along with the important technical issues, pays due respect to the owners’ and consumers’ living context with ample provision for the future.

It also recognises and in fact honors their choice, to remain in the village and work on improving their living conditions.

The Following Two Software Tools for the Simulation and Design of the Basic Rural Village PV System were used

- PVSyst. (3.4) (http://www.pvsyst.com/)
- RETScreen PV (3.1) (http://www.retscreen.net)

Whichever "tool" is used, what makes the "optimised" design different from the standard design method is that defined numeric values of the various social and technical parameters identified are input.

As an Example in Place, the Dhadhaphaya Village Solar PV Electrification Project

The Village situation during the 2004 survey:

- **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**

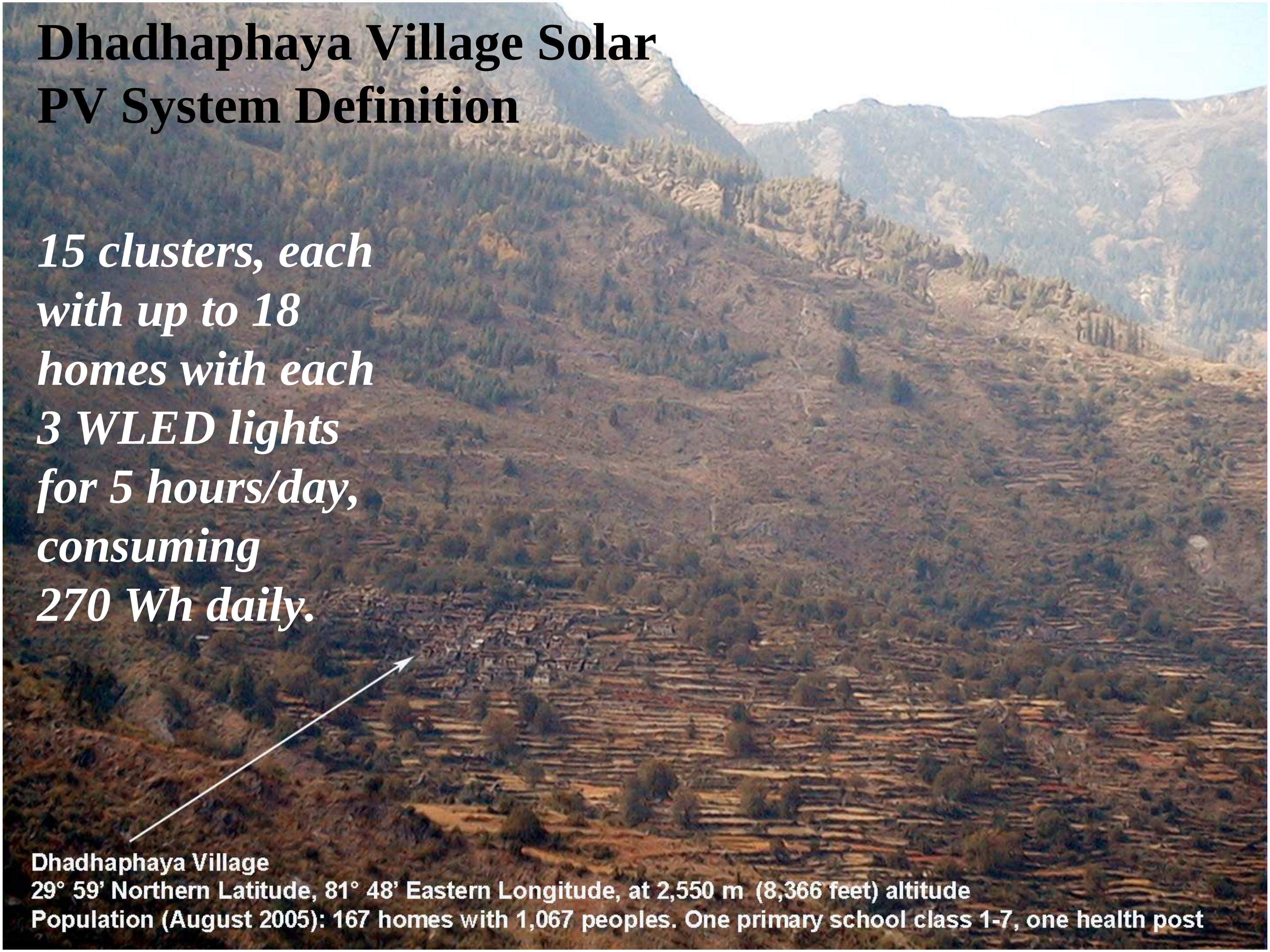
Dhadhaphaya Village
29° 59' Northern Latitude, 81° 48' Eastern Longitude, at 2,550 m (8,366 feet) altitude
Population (August 2005): 167 homes with 1,067 peoples. One primary school class 1-7, one health post

What are the Needs . . .
identified by the local Community ?

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

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.



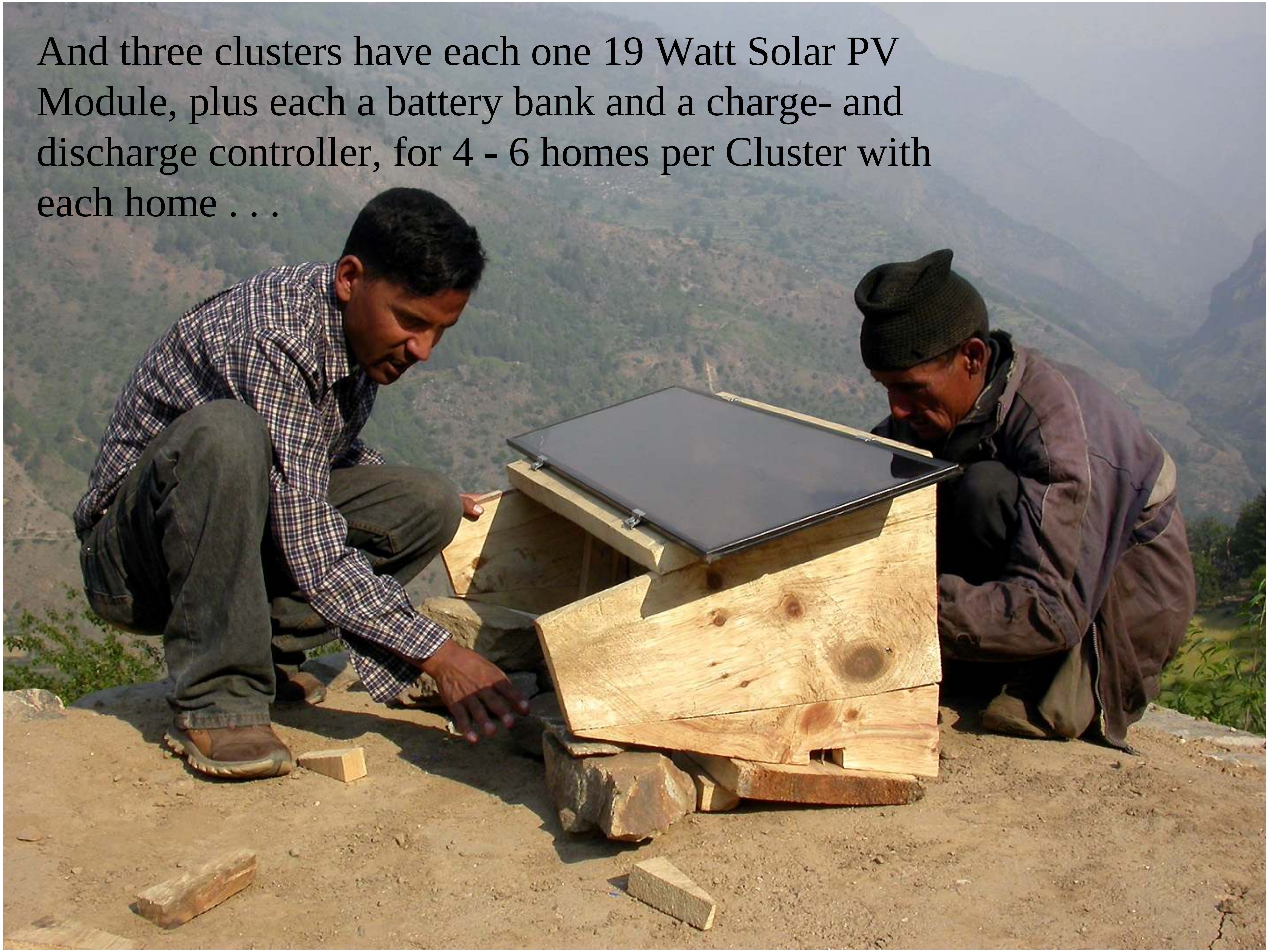
Dhadhaphaya Village Solar PV System Definition

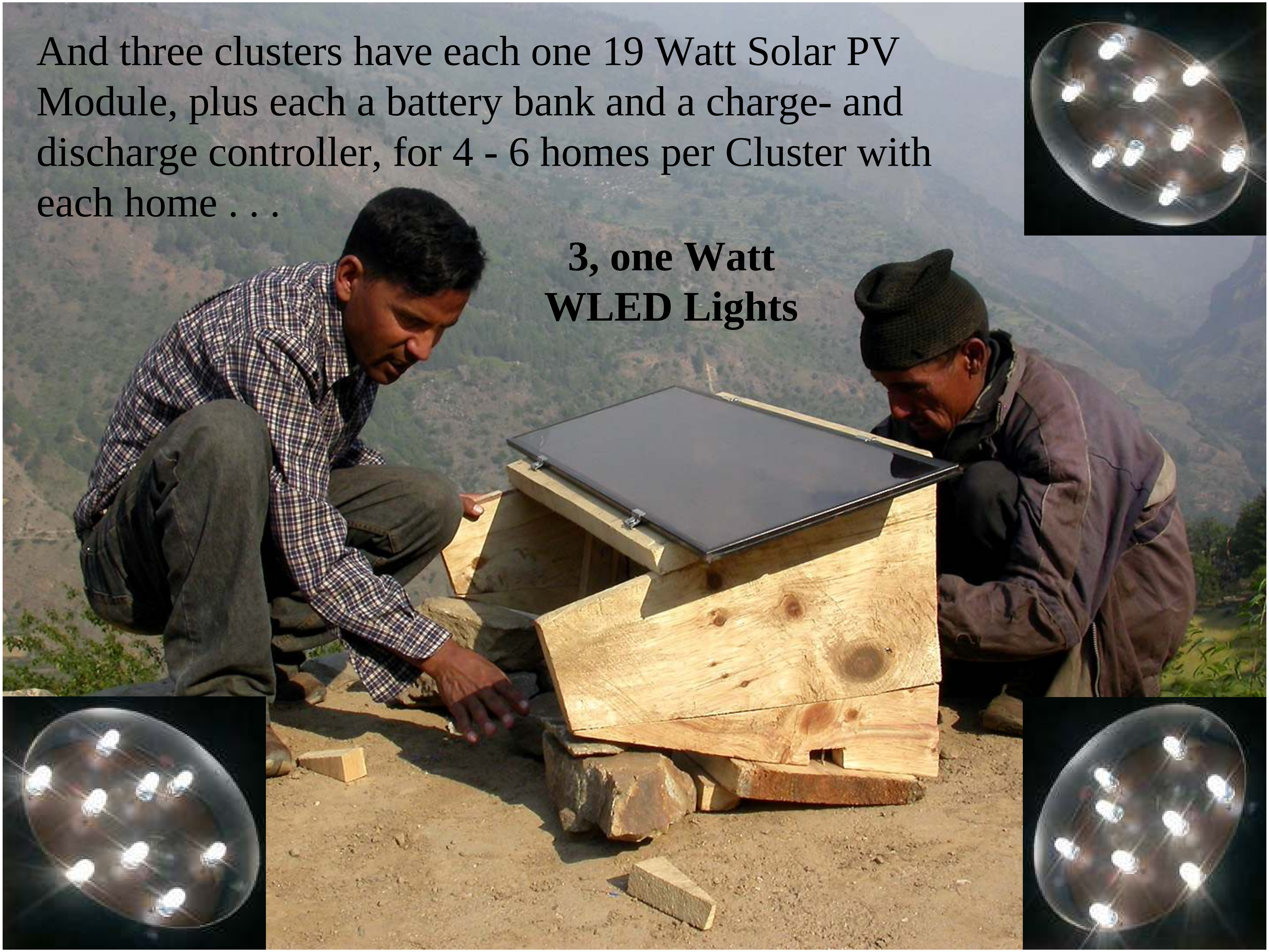
Solar Energy Resource: Daily Average Solar Radiation 4.778 kWh/m^2

(METEONORM simulation with high horizon)

15 cluster have each one 75 W solar PV module, seasonally adjustable. The Battery Bank will provide up to 5 Days the Energy for the Lights needed Independently 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


And three clusters have each one 19 Watt Solar PV Module, plus each a battery bank and a charge- and discharge controller, for 4 - 6 homes per Cluster with each home . . .

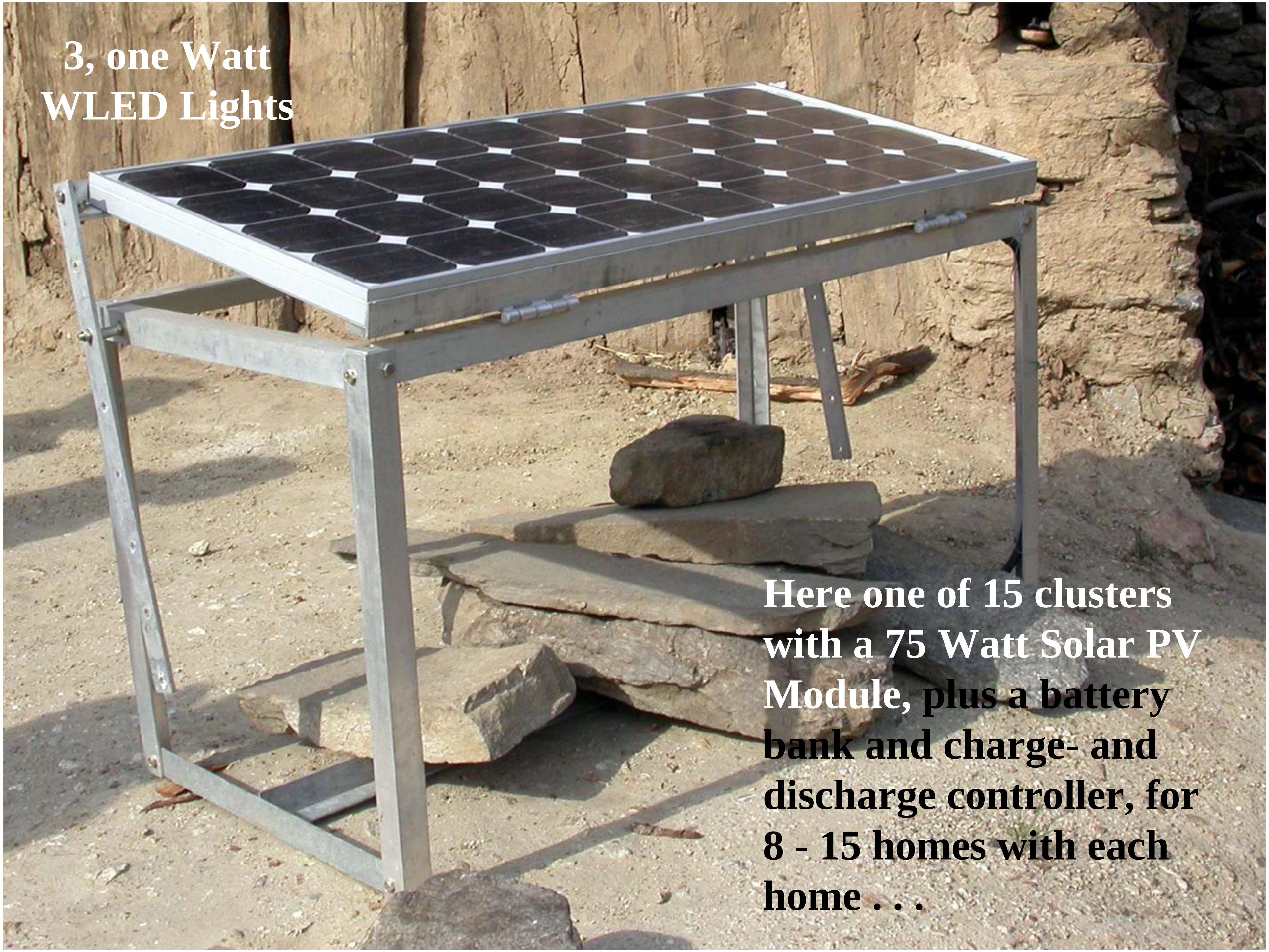

And three clusters have each one 19 Watt Solar PV Module, plus each a battery bank and a charge- and discharge controller, for 4 - 6 homes per Cluster with each home . . .
3, one Watt WLED Lights

Training and Hands – On Practical Installation

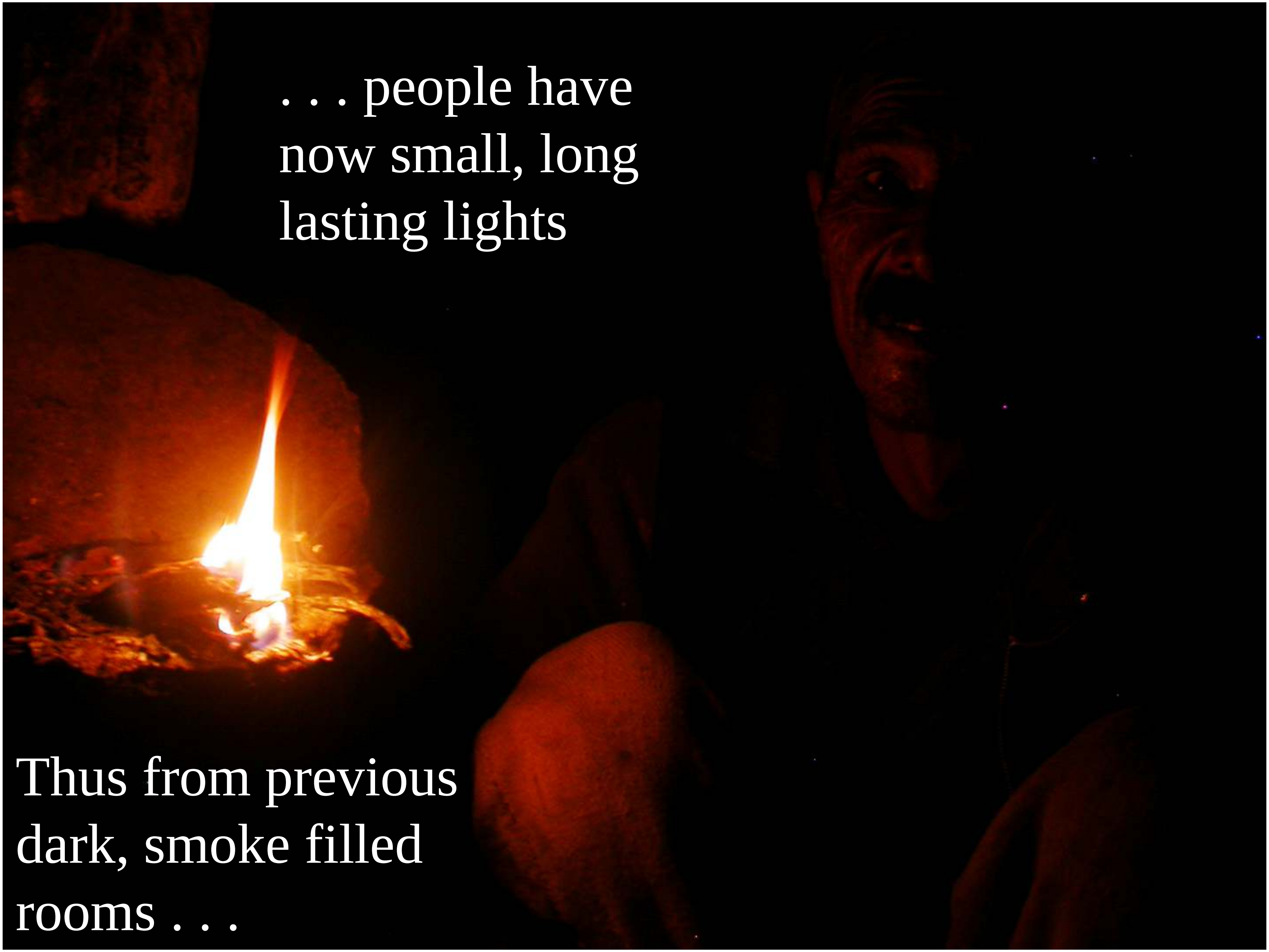
Creating Ownership

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

Each Household Participates in the Building and Underground Cabling


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


VOLTA


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


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

Some of the Lessons Learned . . .

- **Constant development of all equipment which can be manufactured locally, increases the appropriateness and sustainability of a project.**
- **That increases the ability to maintain and repair the installed equipment, providing the local economy with jobs and income.**
- **It pays of in the long term to use only genuine material.**
- **Install only well tested and approved equipment in remote areas. Strive for sustainability rather than highest efficiency.**

We know that in order to bring light in the homes of the 2 billion un-reached people, new ways and approaches are needed.

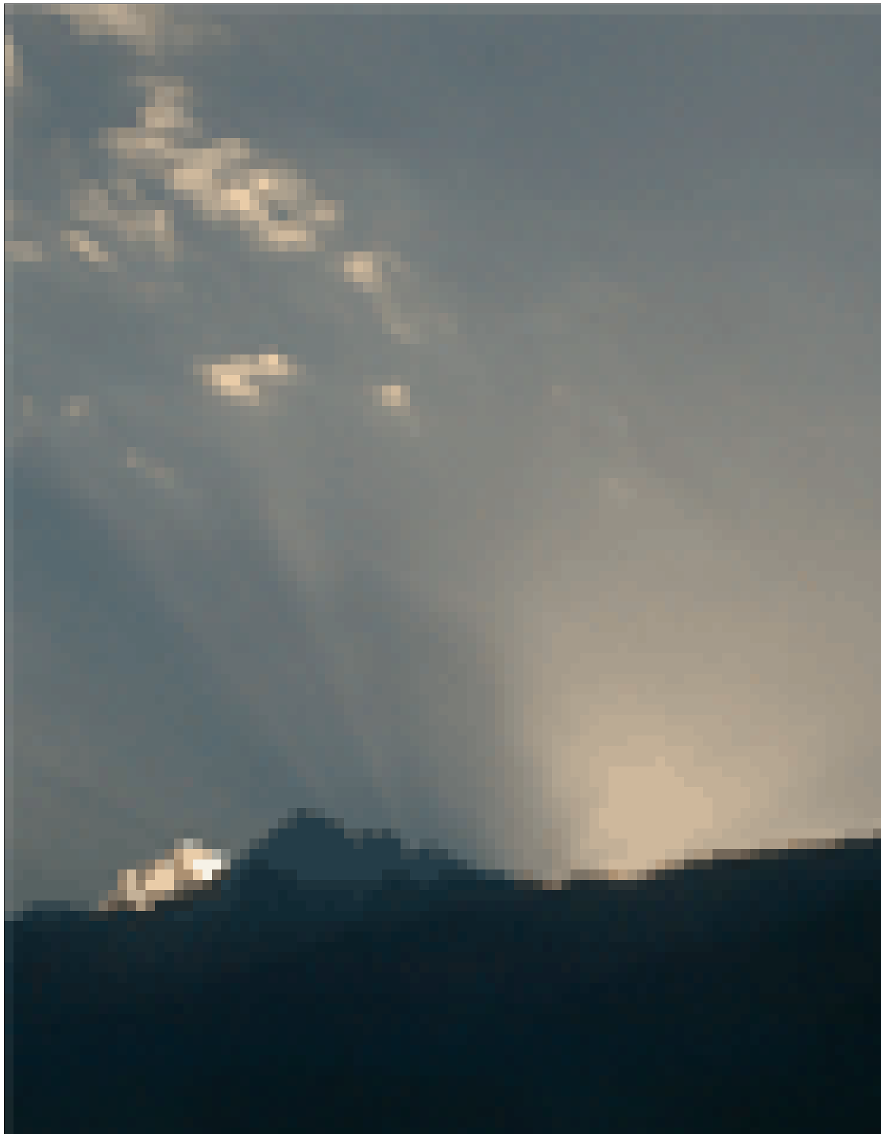
Through the identification of the social and technical parameters for the design of a rural village PV electrification system, with small amounts of power generation just for lighting, new doors and opportunities open up to fulfill this difficult task.

Further, it is also important to re-emphasise, that a lighting project should not be considered just as an individual project, but always as an integrated part of a wider holistic community development project, bringing forth synergetic benefits.

The latest implemented rural village PV project in Dhadhaphaya village in Humla, serves as a practical example of how the optimised design process has been applied.

Since May 2005 the 170 households of Dhadhaphaya village have now each 3 WLED lights for 5 hours a day.

Two non-formal education evening classes for mothers and children are now running, with their own teaching materials about the new lights, the new stove, the new pit latrine for each home, the drinking water and greenhouses.



For more Info:
Alex Zahnd
Email: azahnd@wlink.com.np