House Improvements – General, Part 1. Introduction

Presenter Guidelines

30 slides. Time maximum one hour.

A PowerPoint or slides presentation should not be a reading exercise.
The presenter should adapt the explanations depending on the experience level of the audience.
The total presentation time should not exceed one hour or about two minutes per slide.

As with other audio-visual presentations, the equipment set-up should be tested and ready for running before the arrival of the audience in the presentation room.

Participants can be provided with note paper to write down issues they would like to have discussed in detail.

In the following pages, suggestions for presentation are added to the respective text sections.

The original text on the slides is printed in blue cursive.
The small printed text is additional information.

House Improvements - General
Applicable for high altitude areas such as the Himalayas of Pakistan, Nepal, India, Bhutan, Afghanistan and Tajikistan

These countries have many similarities – climate, physical and socio economic conditions, as well as ethnic aspects.

The project is based on the possibility to exchange the best experiences in house improvements and with that improve the life of other people living in similar and often remote mountain regions.

This does not mean, however, that all technologies and findings can always be copied entirely or without change to other countries.

In some cases, social customs need to be taken into consideration while technical adaptations might be necessary due to different availability of materials in the local market.

Often people's habits need to changed in order to save energy, for example with cooking.

Technology development is not a one time activity.
Technology is constantly developing with new findings or materials. In addition, as the economic position of people changes, they desire other types of designs and equipment.

Development therefore is a constant process that is fed by local enterprises responding to people's desires.

The consultant from "Huys Advies" has worked many years in several Himalayan countries and other continents.
He works on a combination of energy-saving technologies and sustainable housing.

1.1. House designs in high altitude countries

From 1500 - 4000 meter above sea level, the climate is considerably different from lower altitudes.
This has many effects on the environmental temperature, humidity, house-heating needs, transport costs and the availability of building materials.

- *High altitudes cause long, cold winters.*

The higher the altitude, the longer and colder the winters will be, and more house heating is required.

- *Stone or adobe constructions are poorly insulated*

Local building materials have advantages and disadvantages. One should understand the disadvantages to overcome them.

- *Extra high heat loss from poor window designs*

More light and large windows are desired nowadays, but these cause additional heat loss from the house.

- *Low-efficiency heating/cooking stoves*

Most of the heat generated in a stove disappears through the chimney, warming the birds and the mountain tops.

- *Biomass grows slowly at high altitude*

At higher altitudes, more fuel is needed for stoves, but the growth rate of biomass is much slower at those higher altitudes.

Biomass consumption is larger than new growth at high altitudes.

On the right-hand side of the scale we see stacks of firewood; on the left side seedlings.

On the one hand, we need to increase the number of plantations and stimulate growth with soil conservation, green houses, irrigation and fertilizer.
On the other hand, we need to minimize the amount of firewood needed for house heating and cooking.

The imbalance has developed with population growth, increasing the demand for firewood and heating.

While at the same time, accelerated soil degradation is being caused by grazing of livestock (cows, goats, sheep, donkeys, yaks) and the collection of dung for cooking and heating.

Two interactive mechanisms are accelerating the depletion – soil erosion and further reduced biomass growth.

Because no sustainable community pension plans exist, poor people seek old-age security in large families.

With an increasing population and that population using biomass for cooking and space heating, this imbalance will increase.

In reality, not only the technology has to be adapted, but also the social fabric of society needs to be adjusted.

Two-stone material has 1/3 insulation value (Rm = 0.7 m.K/W)
as compared with adobe block material (Rm = 2.1 m.K/W)

We speak here of the type of building material.
Every material has a given insulation value. Adobe insulates about three times better than stone material.

At very high altitudes, such as here in Murghab (3800 m above sea level), most houses are built in adobe blocks.

0.4m thick adobe wall has 0.4m x 2.1 + 0.17 = Rc = 1.01 m2.K/W
Recommended at 3500 m altitude is minimal Rc = 4.0 m2.K/W

If we really want to reduce the amount of biomass used for house heating, we need to improve the insulation value of the roofs and walls of the houses.

Heat generated inside the house will constantly leak out through the roofs, walls, windows, doors and floors.

The heat leaks out continuously until the inside temperature is similar to the outside temperature.

The heat leakage is directly related to the total temperature difference between inside and outside.

This means that all outside construction components of the buildings need to be much better insulated than is actually the case, especially at high altitudes.

Material characteristics

This short table shows the differences in insulation values of a few types of materials.

A. The best traditional insulation material is air: $R_{material}$ = **40** meter x Kelvin/Watt

Kelvin is absolute temperature. The larger the temperature difference, the larger the heat loss. Watt = energy.

That is why wool insulates. Down feathers of birds insulate even better. It is the packed air inside the wool and feathers that create the insulation.

All materials having air packed inside, such as straw, are good insulators.

F. Steel is a bad insulator, but is a good heat conductor. Air insulates about 2000 times better than steel.

A thin layer of air provides good insulation. Many insulation methods are based on the creation of air pockets. Air pockets should have no internal air circulation. With air circulation the insulation effect is less.

Metalized reflective foils are also insulating because these reflect the infrared heat radiation.
Wall and roof insulation methods with reflective foils depends on the precise application of these foils.

The insulation of glass windows can be improved by adding curtains, which create air layers.
The condition is that these curtains close precisely all around the window to minimise air circulation.

*A window insulates far less than walls or roofs, for example,
a single glass window has only Rc = 0.18 m2.K/W*

A single glass window has about 1/10th of the thermal insulation value of the surrounding wall.

Every square meter of window loses as much heat as 10 m^2 of its surrounding wall.

When the glass is broken, or when the window does not close properly, additional cold air will come into the room.

Even when the window is closes well, a person sitting near it will feel a cold down draft coming from the window.

*Fitting a plastic foil outside the windows may improve the
Rc value from 0.15 to 0.2 m2.K/W at best*

Many villagers fix a thin plastic foil outside their windows during the winter. That helps a lot.

You can see that they have used small strips of hardboard and nailed these onto the wooden window frame.

One disadvantage is that the thin PVC foil deteriorates in the ultra violet sunlight, which is strong at high altitudes. The thin foil lasts only one winter and needs to be purchased every year.

Another disadvantage is that the vision through the window is strongly reduced.

A third disadvantage is that the plastic on the outside causes the inside window frame to become wet with condensation. This will cause the wooden window frame to rot.

Table-chart

On the top of the chart are the months of the year, with the winter in the middle.
On the left side of the chart is the outside average daily temperature.

The blue dotted line in the middle of the chart is the average in-house temperature below which heating is needed.
The height of this line depends on the income of the people, their habits and their clothing.
In the table, the temperature line is taken at 10 degrees Celsius.

In building calculation models in Europe, this line can be set as high as 18 degrees Celsius.

The curved lines give the average temperatures per altitude range. The double line is for 3000 m above sea level.

In the upper part of the table, the vertically striped zone represents the heating needs for that climate zone.

The temperature difference below the dotted line and the average temperature are called grade-days.
If at 1000 m and on 1 October the temperature difference is 6 degrees Celsius, that makes 6 grade-days.
For 1000 m there are about 2300 grade-days.
For 1500 m there are about 4000 grade-days.
For 3000 m there are about 6500 grade days. (double blue line)

In the lower part of the table, the vertically striped zone represents the amount of firewood needed to raise the in-house temperature to 10 degrees Celsius.

The second double line on the 3000 m altitude line represents the amount of firewood needed for cooking.

With traditional housing and stoves, the cooking heat contributes considerably to the house heating.

This last aspect will change with the use of Improved Cooking Stoves (ICS).

*Biomass consumption for heating increases with altitude,
but the annual growth of biomass decreases*

The top of the table gives the tonnes of firewood (equivalent) needed for a family of five persons.

The right side of the table gives the altitudes above sea level.

The pictures of the trees represent a 30-year fully grown tree and its annual new wood production.

What can be noticed is that (rich) tourists, coming from lower climate zones, have high heating demands.

Part of these demands are in the use of warm water for bathing.

Other part of the demands is to have open fires for cosy atmosphere or extra warm space heaters.

In general terms, richer people use more heating than poorer people.

With improving economy, the existing imbalance between growth and consumption increases.

Above 3500 m only Treshkin grows, being also food for Yaks.
A plant pulled out takes 20 years to grow back.

Different development projects have different entry points for their intervention.

The current HIHK project focuses on people's health and economic means. Space heating, cooking and sanitation are key factors in this respect. For all three issues, biomass for heating is important.

Other projects focus on the general environmental degradation caused by cutting the trees for firewood and the scavenging of biomass and dung, resulting in soil erosion and permanent ecological damage. That indirectly has a strong, negative effect on the sustainability of the society.

Both types of development projects are looking for the same effective measurements in reducing biomass and firewood needs in order to establish a sustainable balance between biomass consumption and growth.

Treshkin is about the only plant that still grows above the 3500 m altitude.

The elimination of *Treshkin* will cause starvation of the Yaks and grazing herds, leading to the further impoverishment of the poorest population groups that depend on these animals.

***House Insulation**, pressure cookers, solar water heaters, electric power and other methods reduce biomass needs*

From the various options existing at the individual household level, house insulation is the most important contributor to energy saving at high altitudes.

People often think that modifying stoves is the best option; that is not true.

When only the stove is improved, people will first raise the temperature in the house, causing more heat loss.

When the house is insulated, people will use less firewood and have it warmer at the same time.

Changing cooking habits can save tremendous amounts of firewood; changing habits, however, is a long process.

Instead of burning the cow dung, it can be used for the production of biogas.

This produces a very efficient and comfortable energy source for cooking.

Changing first cooking habits makes better use of the little amount of gas from a biogas installation.

Biogas installations require more technology than house insulation and is increasingly more difficult at higher altitudes.

With solar energy, water can be pre-heated, making sanitation easier and comfortable.
Food preparation consumes less energy if pre-heated water is used.

Realising heating with electricity requires financial capacity of the users and in-depth investments for power companies.

Reflective insulation materials will greatly improve the thermal insulation values of roofs and walls.

Analysing traditional houses, we see that most heat is lost through the roof, especially with a roof-top window.

The traditional Pamiri design of the roof accelerates heat loss through the top opening by the warm air stacking effect.

These roof-top windows need to be made with double glass and have additional insulation for the winter period.

Ventilation through the roof-top window should be minimised because stacking warm air in the upper part of the room will rapidly escape through the top window, without people feeling a draft coming from the top window.

Roofs and walls can be effectively insulated on the inside with light (infrared) and heat-reflective foils.
These are lightweight and can be applied in many different solutions.

Each foil + 1 cm air has the same insulation value as 3 cm glass wool/EPS or 8 cm straw.

The application needs to consider the existing roof and wall construction, transport, skilled labour, space use and affordable finishing materials.

The final insulation value of each construction should be compared with the total cost.

When reviewing all these aspects and costs, the reflective foils often are the most economical.

1.2. Building in high altitude and earthquake prone areas

The choice of a technical solution does not depend solely on the financial cost of the solution.

For people living in remote mountain areas, traditional values are often important considerations.

If change of habit is involved, the benefits should be very obvious.

Demonstration of the benefits is important to convince people to change habits.

- *High transport costs of building materials in mountain areas*
- *Economic means of people is often very limited*

Villagers often copy what rich people do or have, or what town people do.

What rich or town people do is seldom economical, and often not affordable or sustainable for mountain people.

Examples can be found in building construction, energy use and sanitation.

*Locally available, **heavy**, stone building materials alone, do NOT make a house adequately earthquake resistant.*

The force of an earthquake on a building is directly related to the weight or the mass of that construction.

When the weight of the building materials is high, the force on that construction is also high.

Stone and cement constructions do not resist stress or tension forces, unless reinforced with steel.

That steel reinforcement should be applied horizontally and vertically along all openings and wall endings.

Cement provides good bonding between stones, but its high cost often results in minimal use of cement mortar.

An earthquake causes both vertical earth movement and horizontal movements.
These horizontal movements (accelerations) of the larger earthquakes cause forces in the building that are equivalent to about 20% of the mass of the upper construction.

Plaster conceals the lack of any tie-beam or wall reinforcement.
Any major earthquake will be another human disaster.

The current type of stone and cement block buildings going up in many areas will not withstand a major earthquake.

Mainly due to lack of vertical and horizontal reinforcement in the supporting wall structures.

When the height of the building increases, the horizontal forces or the horizontal load on the lower parts of the building will also increase.

Higher buildings are therefore more vulnerable to earthquakes than low (one floor) buildings.

To resist these horizontal forces, internal and external cross walls should be well connected to all the other supporting cross walls in both horizontal directions of the building.

For a cross wall to resist a load, that wall should be framed all around with stress resistant reinforcement.

*In the 2005 Kashmir earthquake, 75.000 people died because of **heavy** and non-bonding construction practices*

The picture of the broken wall section shows part of the problem.

The natural stone has been cut to make a nice looking and flat façade, but in masoning the wall, no bonding exists between the inside and outside face of this wall.

In using this technique with soil as filling material, the walls fall apart with an earthquake.

In the case of the house on the right, the earthquake movement from left to right and back was the strongest.

Thanks to a lightweight roof, being nailed together, this part did not fall down.

Galvanised wire reinforcement, applied correctly in stone and adobe walls, brings safety to house occupants

Hot-Dip Galvanised Iron (HDGI) wire mesh does not corrode when used in walls with little cement.

The cross wires have the same width as the wall and connect the two faces.

The length wires provide the strength of the support walls and the connections at the corners.

The wire-mesh is applied throughout the construction.

Factory-produced rolls or handmade in the village.

With a simple technique, the wire-mesh reinforcement can be manufactured on-site from a roll of wire.

One roll 0.4m X 500m is sufficient for a large house.

The weight of steel of the HDGI wire is about 1/4th of the amount of steel bars otherwise needed for the same strength by reinforced concrete columns and beams.

1.3. Stove improvements lead to a better life

After house insulation, improvement in the efficiency of the stove is important.

- *Less energy use for space heating, cooking*

For summer cooking, the most efficient stoves are not good for house heating.

- *Time savings in firewood collection, cooking and cleaning*
- *Warm water for bathing, dishwashing and sanitation*
- *Less smoke and less in-house air pollution*
- *Less lung-eye irritation*

The diseases resulting from lung irritation by smoke are the cause of early death of millions of people yearly.

- *Warm and dry sitting areas and bedding*
- *Wood saved during one winter ------>>>>*

The villager shows the amount of firewood he saved during one winter because of a new roof-top window in combination with a chimney connected stove and warm-water attachment.

Warm water is produced while cooking on the stove with a back-boiler or buchari, saving about 30% firewood.

Improved stove designs make better use of the smoke heat.

With the smoke heaters, ice-cold water is heated.

The villager does not have to use additional firewood for heating the wash water.

The water heater of BACIP produces almost boiling water, which can be used for cooking.

Water should be regularly heated to over 60 degrees Celsius to avoid bacteria growth inside the system.

Smoke water heaters need to be annually cleaned to remove sediments.

Stainless steel smoke water heaters are recommended over zinc sheet water tanks.

Tandori type ovens use ***three*** *times the amount of firewood than the new ICS with heat-exchanger bread oven.*

Tandori ovens make nice flat bread (*chapatti's*) but are only efficient in energy use when they are used constantly by bakery businesses and restaurants.

When these ovens are used for only a few hours to make bread for one day, they are highly inefficient in energy use.

The heat exchanger bread-oven can be placed directly on the ICS or in a chimney.

When the house-heating stove is working, the chimney bread-oven does not require any additional heat or firewood.

Changing the method of bread making is an example of changing technology and behaviour at the same time.

In some villages where there is little firewood, communal bread making is practised or all people buy from the local baker.

Several families can use the same *tandori* bread-oven. When all families use the oven one after the other, some firewood saving is achieved. Using the same *tandori* oven on different days does not save firewood.

More than 10 firewood efficiency improvements have been made to the large house-heating and cooking stove

Some of the improvements are already known in the area and bought together in this stove.

- The air and firewood intakes are improved to ensure better/hotter combustion of the biomass.
- Thinner metal sheets facilitate manufacturing and improve heat radiation.
- The stove can be insulated for the summer period by inserting five baked bricks in the burning chamber.

  This way the cooking is more efficient and the house becomes less hot during the cooking process.
- The oven doors are insulated and fixed on two sides of the stove.

  When these doors are opened, the heat radiation of the stove improves.
- The chimney has a valve and an improved soot pot for easy cleaning.
- The wok opening in the top has been enlarged to improve contact with the hot flue gasses.
- A steel water pipe can be placed in the top to produce hot water.

Introducing improved house-heating stoves is not very difficult.

De difficulties lie in the manufacturing process by village metalworkers and the marketing, including credit.

Using a combination of pressure cooker and heat retention box consumes only 1/5th of the usual amount of cooking energy

In high altitudes, the benefit of pressure cookers increases with the altitude.

In combination with a heat retention box or bag, a substantial amount of cooking energy can be saved.

This energy saving applies to firewood, gas or electricity.

Using a pressure cooker requires change of behaviour and some knowledge about its use.

Marketing pressure cookers requires the availability of simple and well illustrated cookbooks with local recipes.

Financing good quality pressure cookers requires village-based low-cost credit systems.

Most stove heat disappears through the chimney.

Heat-exchangers improve heat generation by more than 25%.

Measurements have been conducted with several types of heat exchangers giving up to 35% more heat.

A very simple option is to make the metal chimney pipe longer; not straight out of the roof.

- The metal pipe needs to be sloping upwards and be smoke tight.
- The space heating stove needs to be improved, reducing the large amount of soot.

Technical improvement of the stove is by making the burning chamber smaller and improving the air intake from below.

- The chimney pipe needs to be cleaned regularly, depending on the soot build-up.

At 2000 m altitude, energy savings can be achieved by various means; up to 90% of current use.

Energy saving can be a combination of different types of measurements.

After having taken one measurement, the percentage effect of the next measurement is the same but the quantitative effect will be less.

Improving the house-heating stove before installing house insulation will not save much biomass during the winter, but it will save biomass during the summer when it is used for cooking.

Good quality ICS do not radiate heat into the room; most of the heat goes into the cooking pot.

Largest firewood savings are obtained with good ***house insulation****,*
followed by ICS and new cooking methods

1.4. Sun at high altitude has large heating power, >1.5 kWh/m^2

- *Building orientation with large,* ***clean***
  and insulating sun windows

If the sun is low during the winter, the amount of heat onto a vertical window is about 1 kWh/m^2

A large clean sun window of 4 m^2 produces from 9:00 hrs till 14:00 hrs about 20 kWh heat in the room.

That is the same amount of heat as a 2000 Watt electric heater which is on for about 10 hours.

The same technology is used for:

- *Solar water heaters*
- *Solar box cookers*

These equipments are well insulated and transfer the heat to the water or food.

Solar Water Heaters have different efficiency levels, but belong to the highest heat producers and energy savers.

In tourist areas, SWH are used for heating bath water and are commercially very interesting.

For clinics and rich people, SWH are durable and sustainable investments when frost resistant.

Vacuum tube SWH exist in low-cost, low-pressure models that need to be drained during the winter.

Medium- and high-cost systems for higher pressure and improved frost resistance are also available.

SWH with heat exchangers are less efficient but can be fully frost resistant.

The quality of the SWH depends for 50% on the installation and the location of the water storage tanks.

Different frost-resistant designs.
Training on installation is needed.

Solar box cooker saves substantial cooking energy.
PV gives bright light (11 W-24 V) as compared with 75 W grid.

Many different designs of solar box cookers exist.

Their practicality depends on the average amount of sunshine existing during the end of the morning when the lunch meal is being cooked.

The food remains clean and does not require constant attention by the cook.

A solar box cooker should be accompanied with an instruction manual and a recipe booklet for local dishes.

Only good quality, nicely finished solar box cookers will be accepted by potential buyers.

Photo-Voltaic electricity is used for charging batteries. These batteries supply power for light during the night.

With the new LED lamps, the amount of light is greatly increased as compared to CFL.

LED = Light Emitting Diodes. CFL = Compact Fluorescent Lamps Incandescent are old-fashioned glow bulbs (the red lamp).
The advantage of the incandescent bulb is that it still gives some light at very low voltage.
Incandescent lamps consume about 6 x the energy amount than a CFL for the same amount of light.

Although expensive, the benefit of PV light is very great.

1.5. Improved sanitation leads to better health and comfort

- *Water supply and clean drinking water*

Villagers easily understand the benefit of good access to clean drinking water.

- *New toilet systems are odourless (no-mix)*

The relation between good and safe sanitation systems and health is not always clear to villagers.

Educational campaigns are needed to bring awareness to the villagers and make them invest in better sanitation.

- *Urine separation allows for composting and fertilizer*
- *Less water waste, less sewerage cost and problems*

New sanitation systems should avoid that waste water is dumped into rivers.

Villagers living downstream along the river use the same river water for irrigation, washing and drinking.

Sewerage systems are very expensive. Especially cleaning up the sewerage water.

All costs related to the processing and cleaning of sewerage water is eventually paid by the community.

New and improved sanitation technology requires new construction design AND change of behaviour

One of the advantages of late development is that a community can benefit from the experiences of other communities and do not need to adopt expensive and non-sustainable systems, such as flush toilets and large piping sewerage systems.

An advantage of the new urine separation toilet is that the behavioural change is very little.
It merely requires an improved routine.

The special advantage is that the ecosan toilet generates a yearly amount of good quality fertilizer.

In combination with a greenhouse, large amounts of animal and human food can be produced in small areas.

Glass fibre reinforced resin or low-cost stainless steel units can be used

Reinforced polyester (plastic) units are readily available in the market, but can also be locally manufactured.

Low-cost stainless steel units can be developed which are easy to clean.

Thank you for helping others to improve their life

This picture is from a household where the BACIP programme in Pakistan installed a new Roof Hatch Window (top window) with a smoke evacuating stove with warm water attachment.

Together, saving over 45% of the usual amount of firewood in one winter season.

The contents of this publication are the sole responsibility of Engineer Sjoerd Nienhuys, Architect, technical advisor and consultant