HUYS ADVIES

Plastic Waste Insulation
Re-Use of PET for
High Altitude Houses

Thermal Insulation for House Construction with used PET bottles

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ABSTRACT

Plastic waste is increasingly becoming an eyesore and is polluting the environment, especially in high mountain villages where no garbage collection system exists. A large amount of plastic is being brought into the tourist trekking regions (PET and HDPE bottles, food wrappers, PVC and plastic bags used for transport and packing materials) and discarded or burned. This plastic waste can be perfectly reused as source material for thermal insulation. Empty PET and HDPE bottles are separated into "clean" and "less-clean", and packed in PP fibre bags can be utilized as thermal insulation material inside housing. Designs are provided for floors, over ceilings and inside cavity walls. Used PVC shopping bags can be used to insulate water piping of solar water heaters and warm water piping inside houses. Common non-biodegradable waste products are re-used as high value thermal insulators, being extremely needed in the high altitudes to conserve warmth and reduce firewood consumption. A basic explanation on how thermal insulation works and a comparative table of insulation values is included.

FORWORD

The first report about the re-use of wasted PET bottles (Polyethylene Terephthalate) was realised in May 2003 after a working visit to the foot mountains of the Himalayas in Nepal, a popular trekking area for tourists. Not only the tourists brought PET, HDPE (High Density Polyethylene) and PVC bags to the area, also the local population imported the materials for sale to tourists and own use. The result was an accumulation of non degradable waste, remaining for years polluting the environment. The plastic is not only an eye-soar for the people who otherwise would come to the mountains to enjoy the scenery, but cattle and other animals would eat the material and with that kill themselves. PET bottles are often finding a second use as container, but eventually end up as waste or being burned in the winter. With very large numbers of PET and HDPE bottles, recycling may become an option, but the transport from the high mountain regions back to recycling plant will be too costly, even if the PET bottles are shredded first. Direct re-use therefore is preferred above re-cycling. Using the empty PET and HDPE bottles as thermal insulation in the building construction saves firewood and firewood collection time, thus being an additional benefit to the environment. One year after this report the first house was thermally insulated in Kathmandu, using the empty bottles in the cavity wall and in the ceiling under the roof.

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Photo front page: Plastic waste of a few weeks of one household.

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List of Abbreviations

ACAP	Annapurna Conservation Area Project.
AEPC	Alternative Energy Promotion Centre, Department of MoST, dealing with RE.
Dokha	Bamboo woven basked, carried on the back, holds about 30kg biomass.
EPS	Expanded Polystyrene. Light, white insulation material used in package industry. High density, medium density (packing material) and low density does exist.
EPE	Expanded cellular polyethylene foam. Closed cells expanded with LD PE resins.
HABR	High Altitude Biogas Reactor (over 1800m altitude).
HDPE	High Density Polyethylene. Plastic used in water and sewerage piping.
LDPE	Low Density Polyethylene, terminology used in plastic industry.
NRs	Nepalese Rupee. One Euro = NRs. 85 (at date of report date).
PE	Polyethylene plastic with density 0.91–096. May be burned, non-poisonous.
PET	Polyethylene Terephthalate, used for fully transparent water and soft drinks bottles.
PE foam	Polyethylene foam, commonly sold as under-carpet in Nepal, 5mm and thicker.
PP bags	Polypropylene fibre used in agricultural and food bags.
PVC	Poly Vinyl Chloride plastic with density 1.2 -1.55. Poisonous burning gasses.
RE	Renewable Energy.
SPCC	Sagarmatha Pollution Control Centre.
SWH	Solar Water Heater.

1. INTRODUCTION

This report provides information about the use of plastic waste materials in mountain areas for thermal insulation in houses. In houses the insulation can be placed under the floor, inside cavity walls and under the roof. External and internal water piping of Solar Water Heaters (SWH) can also be insulated with used plastic bags, and mattresses can be stuffed with shredded EPS packaging, providing high quality and light weight insulation. Thermal insulation is very important in high altitude areas where the cold climate increases heating requirements. Improved insulation of houses therefore results in better comfort and a reduced consumption of firewood.

The Himalayan ranges and other high altitude areas in Nepal have suffered severe deforestation in the last 20 years due to the increasing population and their demand for:

- Firewood, to support the rise in population growth and tourist activities, and
- Timber, needed for the construction of housing and hotel accommodation.

As a measurement to reduce firewood collection for use in the tourist industry, travel organisations are now obliged to import kerosene into the region for heating fuel and to carry this kerosene to the mountain base camps. Cutting firewood has been recently prohibited in nature conservation areas. The local population is allowed to use, to a very limited extent, deadwood (branches) for local firewood needs and to collect forest waste products. In addition they use cow-dung, this however will decrease the soil fertility and with that plant growth.

Availability of Raw Biomass Material
High altitude areas have a rather slow regeneration of biomass. Tourist trekking areas often lie between 2000m and 4000m (6,000 ft. and 12,000 ft.) where a considerably slower wood and biomass regeneration exists than at lower altitudes; between five to ten times slower.

- In the Terai at 500m (1500 ft.) young hardwood trees can produce about **100 kg** wood/ year.
- At 2000m (6,000 ft.) this is, compared to the Terai, about **20 kg** wood per year, or one-fifth.
- At 3000m (9,000 ft.) this is only about **10 kg** wood per year, or one-tenth of the lowland.
- Above 4000m (12,000 ft.) no more trees will grow.

Despite the prohibitive measurements to use firewood in the conservation and tourist trekking areas, the regeneration of biomass remains far below the demand for firewood. This is because tourists, who are unaccustomed to cold areas, have high demands for space heating, warm showers and cosy fires while on holidays. Sufficient alternatives must be provided to reduce the demand for firewood.

Prohibition and Provision
Control of energy resources can be accomplished in two ways: prohibiting and providing. For example, it is prohibited to use firewood, so kerosene is provided as a substitute. Kerosene, however, is expensive and a non-renewable energy resource. The imbalance between consumption of firewood and supply of energy can only be adjusted by providing sufficient alternatives in renewable energy resources. There is little point of prohibiting without provision.

Heating Equipment Versus Thermal Insulation
Although many people are seeking solutions by making better heating equipment, more than half of the energy resources (and cost) for space heating can be reduced by adequate thermal insulation. The application of thermal insulation techniques is a permanent measurement in directly displacing energy resources. Moreover, thermal insulation once installed functions for the lifetime of the building.

Low-Income Population

The thermal insulation of the houses with waste plastic as explained in the present paper was realised by some hotel owners realising the benefit of saving firewood, cleaning the village and having warmer houses, all at the same time.

Collecting firewood consumes a substantial part of the annual workload for both men and women.
The women normally have the task of chopping the logs into small pieces that fit into the stoves.
The amount of firewood shown here is required for one winter season only.
This amount can be reduced by half with improved thermal insulation of the living quarters.
More firewood can be saved with solar water heating and some adaptation of cooking methods.

About 2 million Nepalese, or more than 300,000 families, live in high mountain areas (over 2000m) and are annually influenced by the winter cold, being severe at the very high altitudes (over 3000m). This population is highly dependent on firewood for its energy needs (cooking, warm water and space heating). About 3-4 tons of firewood is consumed per family per year, an amount that annually is becoming more difficult and costly to collect due to the continuous deforestation. Per family more than a full month of hard labour is required to collect the firewood from the hills. Due to this large firewood consumption, forests at high altitudes are not exploited in a sustainable way.

In tourist and trekking areas where large amounts of food items and plastic drink bottles are imported, these waste materials can be seen littered about. It is becoming an eyesore and having an negative environmental impact on the area if not collected and properly disposed of by the local organisations. In the two most popular trekking regions, Annapurna Conservation Area and the Sagarmatha Conservation Area, local organisations such as ACAP and SPCC (Sagarmatha Pollution Control Centre) are very much involved in organising the local population in waste collection.

This paper explains the main principles of thermal insulation and how plastic waste can serve perfectly as thermal insulation in houses and for external applications. Especially for external applications that are not exposed to the direct sunlight, the waste material can be reutilised as a very durable insulator solving five issues at the same time.

(1) Getting rid of plastic waste;
(2) Thermally insulating houses and installations;
(3) Avoiding the importation of insulation materials;
(4) Reducing firewood consumption because of increased thermal comfort; and
(5) No waste burning.

- The more tourists, the more income for the local population, but also more waste [1].
- More tourists require more food (often imports with plastics) and more energy (often firewood).
- Reducing firewood need is primarily done through thermal insulation of buildings and installing Solar Water Heaters.
- Thermal insulation of buildings can be done by using plastic waste of bottles in cavity walls and in ceilings.

Housing

- Thermal insulation of a house or hotel is a good method to increase the comfort level during the winter and at the same time considerably reduce firewood consumption for space heating. It saves energy by maintaining the warmth inside the rooms so that constantly maintaining the (wood burning) fire is not necessary. Insulating the ceilings and under the roof of houses are the most effective energy savers.

Outside Installations

- Solar Water Heaters (SWH) are very effective in high altitudes for warming shower water and pre-warming kitchen water. The piping system between the SWH and the tap point needs to be well insulated to avoid cooling down, causing a reduction in the efficiency of the system. Plastic waste can be used for this insulation, covered with (thin) HDPE pipes having a large diameter.

No More Burning

- Burying and burning are two practices being used to get rid of waste material. However, these practices destroy the possible use of a technically valuable insulation material. In very large cities facilities often exist to recycle most of the different types of plastic. In Nepal this is rather limited and the cost of bringing the plastic back to Kathmandu is prohibitive to any reprocessing. However, in remote areas the plastics can easily be recycled (reused) as thermal insulation.

The plastic waste material can consist of empty PET water and soft drink bottles, empty wrappers of instant noodles, flimsy plastic shopping bags and used transport bags, among others. This report provides some details of various applications of plastic waste as thermal insulation.

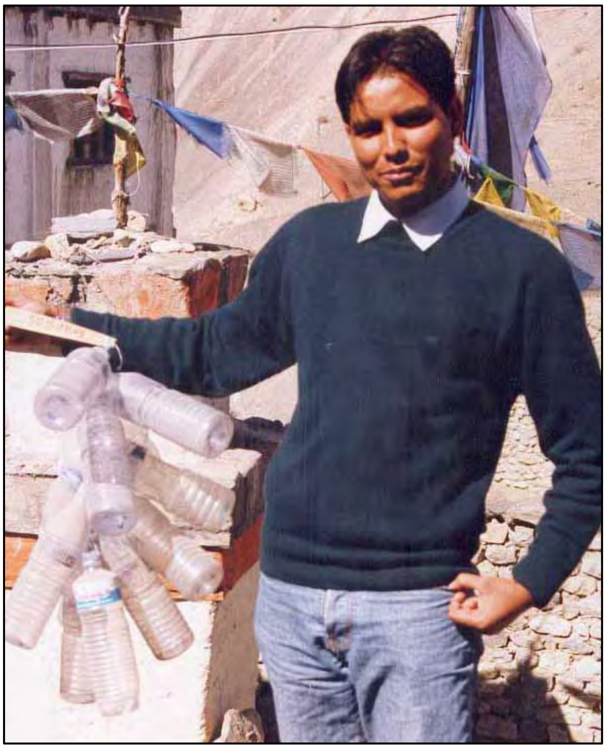
Some figures are quoted from the Sagarmatha Pollution Control Centre (SPCC), but similar quantities may also be the case in the Annapurna Conservation Area Project (ACAP) supported region. Because of the large quantities of waste material already collected by SPCC, immediate application of thermal insulation from plastic waste can be easily realized. In other areas, however, it may take some time for community organisations to organise the collection of the material and will therefore need to begin with a limited application of the thermal waste insulation, for example, use in greenhouses only.

[1] During the 2001/2002 season about 30 tons of non-degradable waste was collected in the Sagarmatha-Khumbu region by SPCC. About 10% of the solid waste consists of plastics which can be used as insulation material.

2. PLASTIC WASTE USUABLE FOR INSULATION

2.1 TYPES OF PLASTIC

Two main forms of plastic wastage are present in the mountain areas, plastic bottles and foil-type plastics, such as grocery bags and large fibre bags. Bottles without residues can be used directly as insulation because they contain air. It is the air that provides the insulation.



PET Bottles

The transparent Polyethylene Terephthalate (PET) bottles have become increasingly common and are used for mineral water, soda waters and soft drinks. In some areas (Khumbu) empty bottles are imported and bottled with clean spring water. Most containers are glossy, clear transparent, while some are green in colour. In some high mountain areas bringing in these bottles is now being prohibited because of their pollutant aspects. With a collection system prohibition is not necessary.

LDPE Bags and Wraps

Plastic grocery bags are often made from low-density polyethylene (LPDE). LPDE is also found in cookie wrappers, noodle packages, etc. Polyethylene plastic has a density of 0.91-0.96 kg/dm^3 and will float in water. Although the plastic does not emit poisonous gasses when burned, it is better to use the plastic as an insulator. When used for thermal insulation it must first be washed, sun-dried and crumpled up for packing between the plastic bottles.

PVC Foil and Bottles

Polyvinyl chloride is semi-rigid and glossy. It is used in bottles (shampoo and soap) and in transparent foils used for a wide variety of purposes. PVC transparent foils come in a variety of thickness (0.08mm = 200 gauge) but are not resistant to extended exposure to UV light, having a high intensity at high altitudes. Incinerating PVC causes poisonous gasses to be released into the atmosphere. The PVC plastic has a density of 1.2-1.55 kg/dm^3 and therefore sinks in water. This aspect can be used in both cleaning and separating the PVC from other plastics. When not extremely soiled, PVC is excellent for use in thermal insulation, but it should be kept out of the sunlight.

HDPE Bottles and Containers

Many non-transparent liquid containers (juices, bleach, soap) are made from high-density polyethylene (HDPE), being the most common plastic in consumer products. These bottles and containers are white or dyed in various colours. HDPE plastic water, gas and sewerage pipes are black, often already made from recycled HDPE plastic bottles.

In supermarkets and grocery stores large amounts of HDPE containers are used for cleaning liquids. Often small amounts remain in the bottle when discarded. All HDPE bottles should therefore be considered as unclean; they need to be cut and washed before use. The half bottles placed in bags can be used for insulation under floors.

PP Bottle Tops and Containers

Polypropylene (PP) is mainly a semi-rigid plastic material with a low gloss, used for screw-on plastic bottle lids. Therefore it is only found in smaller quantities. PP is also used in automotive battery cases and PV deep cycle battery cases. The battery cases, if available in quantity and cleaned out (no acids or lead should remain), can be perfectly used under load bearing floors. The PP bottle tops can be kept on the PET, clean HDPE and PVC bottles to make them airtight and better insulators.

PP Fibre Bags and Rope

Thin, polypropylene (PP) foil bags can be stretched to about two times it original length, until a resistant point is reached. Transport and 'agricultural bags' made from woven stretched PP fibre are used for cement, rice, grains and a variety of other agricultural products. The bags (called *bora*) are often reutilised in transporting goods on donkeys or yak and for transporting sand and gravel. After exposure to the sun for several months, the bags fall apart and become wastage. From the same fibre with added colouring pigments rope is made, having a better resistance against UV light. The bags, when in one piece, can be used for stuffing other plastic waste inside. However, the stuffed bags should not be placed in the sunlight, but used only under the floor, inside ceilings or inside cavity walls.

EPS or Styrofoam

Expanded polystyrene (EPS) is a very lightweight insulation material made up of large white granular beads. It is commonly used in cardboard packaging to protect electrical/ electronic equipment, for food packaging and insulating cooled products. Sheets of EPS are used in the building industry. EPS comes in several densities. The thermal conductivity is very low (0.02 W/m.K) and water absorption is low, therefore the thermal insulation value is high. It can be shredded by hand and stuffed into agricultural bags (see photo above). Styrofoam is a brand name. The shredded material can be very well used as high quality insulation material inside cavity walls of houses and around warm water tanks. When the material is shredded into ½ inch pieces, it can be used inside mattresses, providing high quality insulation.

A variety of empty HDPE and PET bottles in PP bags.

2.2 USEABLE AND NON-USEABLE WASTE MATERIAL

In principle, all non-conductive waste materials that contain lots of air are useful for thermal insulation. However, for use in house they should be non-degradable and non-water absorbing.

For use indoors in ceilings, they should be reasonably clean. Plastic waste can be easily washed and sun-dried to this effect. Bottles should be well drained after washing and re-capped if the tops are available. Wash water should be discarded in a soak pit well away from open water or water sources.

The following chart lists some materials that can be used or should not be used.

Can be used under floors in PP or PVC bags	Can be used in ceilings, cavity walls and under dry roofs	Cannot be used for thermal insulation
Plastic bottles (empty/closed).	Plastic bottles (empty).	Metal cans and containers.
Plastic foil, bags (crumpled).	Plastic foil, bags (crumpled).	Aluminium cans, containers.
Plastic foam, PP, EPS (waterproof and shredded).	Plastic foam, PP, EPS (waterproof and shredded).	Hard and brittle PVC (as this may cut the container bags).
Rubber goods (shredded).	Rubber foam mattress (shredded).	Glass bottles (any size).
Cleaned battery containers.	Fleece and nylon (shredded).	Earthenware.
Chip bags, candy wrappers	Wood shavings, curls, saw dust.	Dirty or soiled materials.
Wax paper, shopping bags.	Glass wool, rock wool [2], air bubble plastic.	Paper or cardboard waste. Leather, animal skin.
Clay mixed with straw (1:1) volume and 5% lime/cement	Straw in PP bags with 2%-3% lime dust against mice.	

A wide variety of agricultural waste products can be used for thermal insulation, but the present paper only looks at re-use of plastic waste as insulation material.

[2] Glass wool is made of spun glass and is an excellent insulator. It is commonly used in SWH and boiler storage tanks. However, the material compacts under pressure and can fill up with water, both negative aspects for outside use. Rock wool is rather similar to glass wool and is made of spun refractory material (stone).

3. HOW DOES INSULATION WORK?

Each material has its own characteristics in thermal insulation depending on its own weight, the internal contact of that material and the conductivity.

The following general rules about insulation and humidity apply:

1. The best insulator is lack of contact between one material and another through vacuum.
2. Thermal insulation is created by dry air, well contained in its location, avoiding circulation.
3. Wet air does not insulate very well, because the humidity is the heat transporter. Humidity and water and ice are good heat conductors and thus poor insulators.
4. When an insulation material gets wet inside, its insulation value will strongly reduce.
5. Humidity in the air can condensate on the coldest surface, depending on the temperature and humidity level. The higher the humidity or the colder the surface, the faster it condenses.
6. Condensation inside materials will freeze when temperatures are low in high altitudes. The freezing process will damage the material.
7. Humans constantly produce humidity by exhaling. Cooking also produces humidity. This humidity must escape through the building construction or by means of ventilation.
8. Circulation or movement of air will reduce its insulation factor, and the comfort factor.
9. The thicker the insulation layer, the better it insulates.
10. Damp proof foil on the warm side of the construction will reduce damp going inside the construction and condensate.
11. Most warmth or heat will escape through surface with the highest temperature difference and the least insulated area or surface.
12. Warmth moves upwards and will escape through the ceiling and roof.
13. Warmth (or cold) is stored in all materials. When the weight of the material is large, the heat storage capacity of that material will also be large.

Explanation of the above rules:

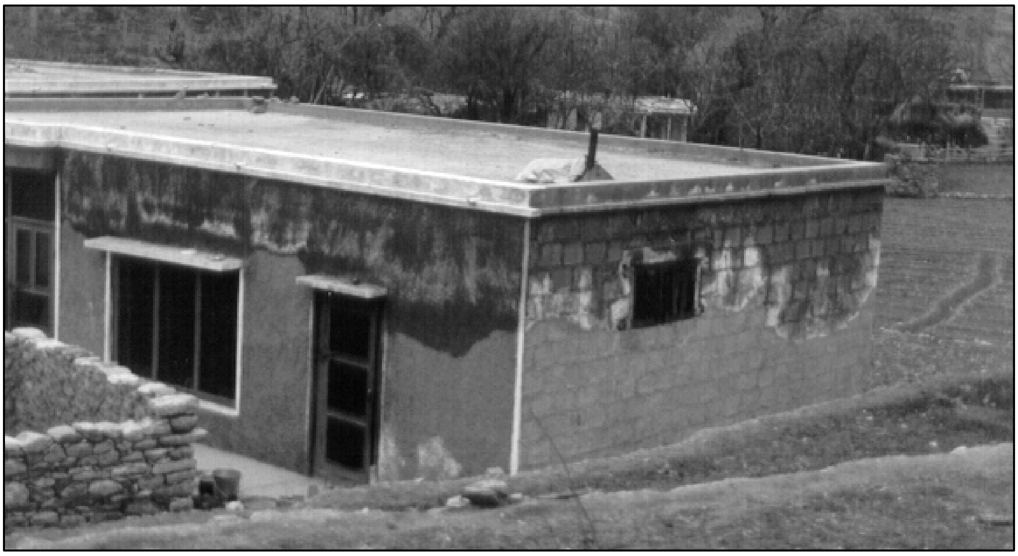
1. Heat needs to be conducted from one place to another, when there is no air or other material , there will be no conduction. Therefore vacuum bottles are good insulators. Vacuum or special dry gasses (Argon) insulate better than dry air because the absence of any material (air is a material) will eliminated transfer of heat. For example, thermos bottles having a double wall vacuum glass bottle inside are the best. Some SWHs have vacuum tubes; these keep the water inside warm, also with frost outside.

2. Thermal insulation of houses works like a warm coat; whilst the outside air is cold, you stay warm inside the coat. The fibres of the wool keep the air in place and that trapped air avoids that the warmth of your body is lost. Dry air also has a very high insulation value R = 50 m^2.K/W (thermal conductivity λ = 0.023 W/m.K).

3. The more humidity in the air, the worse is its insulation value. Wet air can have a thermal conductivity factor of λ = 0.23 W/m.K, being ten times higher than dry air. Ice has a thermal conductivity factor of λ = 2.3 W/m.K, being one hundred times higher than dry air.

4. Based on the above facts, it must be avoided that inside an insulation material humid air accumulates and condensates or freezes. Thermal insulation material that has closed cells and cannot absorb water is therefore preferred. Natural fibres that can absorb humidity vary in their insulation value with the change of humidity. When a coat gets wet, the moisture creates a heat flow bridge between your body and the colder outside air. You will lose heat fast, also because the body hat is used to evaporate the humidity, drawing heat from the wet material. In order to

keep warm you must remain dry and pack a thick layer of dry air around your body. When the foundation, wall or roof of a house is wet, warmth will pass faster through the wet construction.



Wet walls greatly increase heat transmission and reduce the insulation capacity of the construction.
Walls can become wet from outside influences.
Here the porous cement blocks absorb water from the roof surface.

5. Humidity exists in all air and will form little drops of water when becoming cold. Clouds in the sky consist of little drops that will fall down when the cloud rises higher and gets colder. When the glass window is the least insulated surface in the room and outside it is colder than inside, condensation can be seen on the glass, forming drops that eventually slide down (see photo right). This same condensation will also occur inside cold walls, but is not visible. Walls which are wet inside can be easily identified because they lose far more heat than dry walls and therefore feel extra cold.

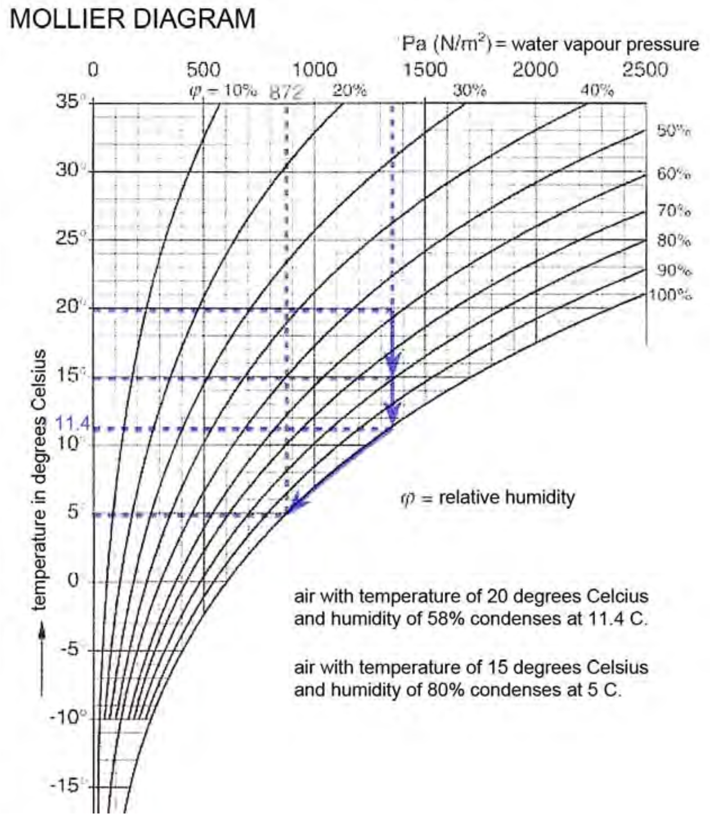
Condensation in building constructions is often the cause of fungus, corrosion of iron fittings and concrete reinforcement (in the case of poor quality concrete) and the breaking of plaster. Especially in cold climate zones and in rooms that have high humidity levels due to people living/sleeping or cooking, damage due to condensation often occurs.

The picture above is of a plywood ceiling panel of a normal room, above which insufficient thermal insulation is applied; constant humidity allowed fungus to develop.

6. Humid air has a condensation point depending on the saturation level of the humidity in that air. The higher the humidity, the faster that air will condensate on a colder surface. A comfortable house has 50%-55% air humidity with a temperature of 20°C -18°C .

At low and freezing temperatures, most humidity in the air will respectively condensate and freeze.

The Mollier diagram on the right gives two examples of humid air at 20°C and 58% humidity condensing at 11.4°C and air of 15°C with humidity of 80% condensing at 5°C. These are the surface temperatures of the material.

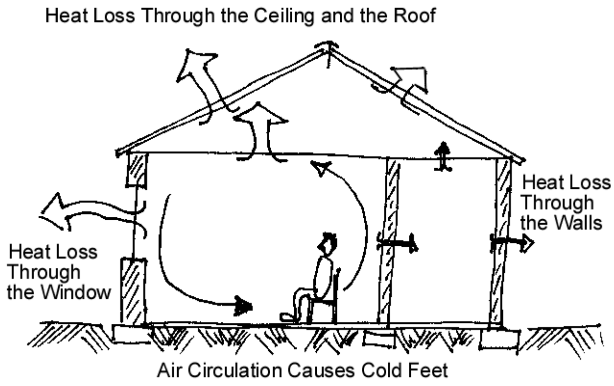


Freezing water expands and therefore breaks the material in which it is locked up. When water freezes inside porous masonry, cement mortar and plaster work, it will break the material to dust. These effects may not be easily visible from the outside, but will reduce the strength of the construction. For this reason and the reduced thermal insulation of wet material it must be avoided that constructions are getting wet inside due to condensation.

7. Human exhalation evacuates humidity from our lungs. In poorly ventilated bedrooms, large amounts of condensation on windows and in walls can occur during the winter because all night the occupants increase the air humidity while outside the temperature drops. With condensation inside the walls, the wall temperature will rapidly drop and condensation may appear on the inside surface. With a freezing air temperatures the outside air can absorb only a small amount of water. When inside walls are sealed with large plastic foil sheeting, sufficient ventilation must be assured to get rid of the humidity. Plastic foil on the warm side of the walls stops the humidity getting inside the wall. Windows should have easy-to-regulate ventilation openings.

The very open structure of some stone walls masonry, with an inside and outside finishing of stabilised soil plaster allows a very high moisture transmission through the walls. Because these wall have poor insulation, condensation will occur inside, while freezing will destroy the little cement mortar bonding.

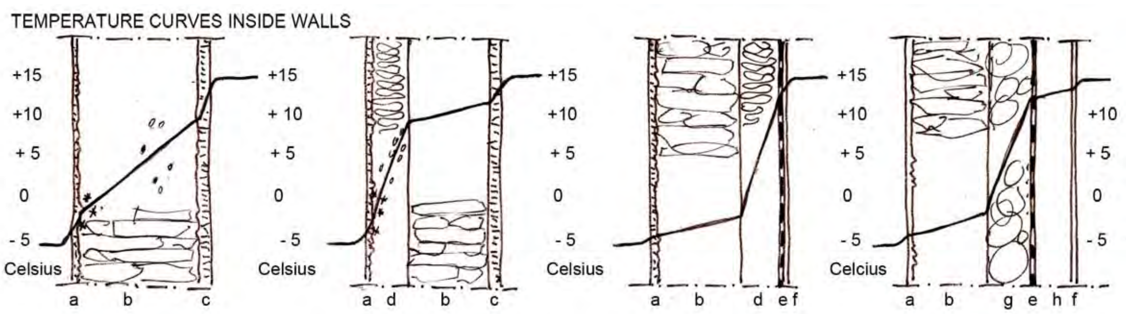
8. Because the air expands when warmed up, it becomes lighter and rises upwards. This creates air circulation in a room. When a window is cold, it will cool the air next to the window and that air will flow down towards the floor. Sleeping on the floor under a cold window can be very uncomfortable. Because the warmest air rises to the ceiling, the greatest heat loss will occur against the ceiling. That is why the ceiling or the roof of a building should be the first priority for insulation as the greatest heat loss will occur there.



9. The thicker the insulation, the warmer you stay. The thicker the sleeping bag, the warmer it is. If a sleeping bag has been flattened, then it first has to be well shaken to give the inside more volume and become airy again; that way the sleeping bag will be warm. In a house 10cm insulation works twice as good as 5cm insulation of the same material. To insulate the house or a room, a thick layer of fixed air has to be packed around it. This can be on top of the ceiling, inside the walls or under the floor. For all three areas plastic waste material can be used.

Minimum Average Winter Temperature	**Approximate Altitude**	**Recommended Thickness of Insulation Layer with $\lambda = < 0.06$ W/m.K**	**Heat Resistance of the Insulation R_c in m^2K/W**
0 degrees C.	1200 m	5 cm	$R_c = 1.3$
-5 degrees C.	1500 m	7.5 cm	$R_c = 2.0$
-10 degrees C.	1800 m	10 cm	$R_c = 2.6$
-15 degrees C.	2100 m	12.5 cm	$R_c = 3.3$
Colder than -15 degrees C.	2400 m	15 cm	$R_c = 3.9$

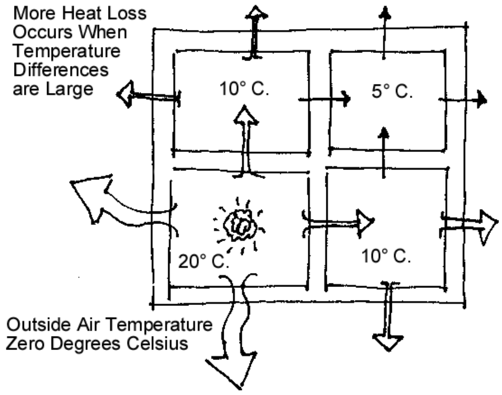
10. Many houses have very thick stone and adobe walls, often more than 60 cm thick. Inside these thick walls condensation will occur with humidity produced inside the house and low outside temperatures. To minimise the humid air going into the wall, a damp proof foil needs to be applied on the warm side of the wall. The following sketches explain the situation. In this example the outside temperature is minus 5° C and the inside room temperature is 10°C.



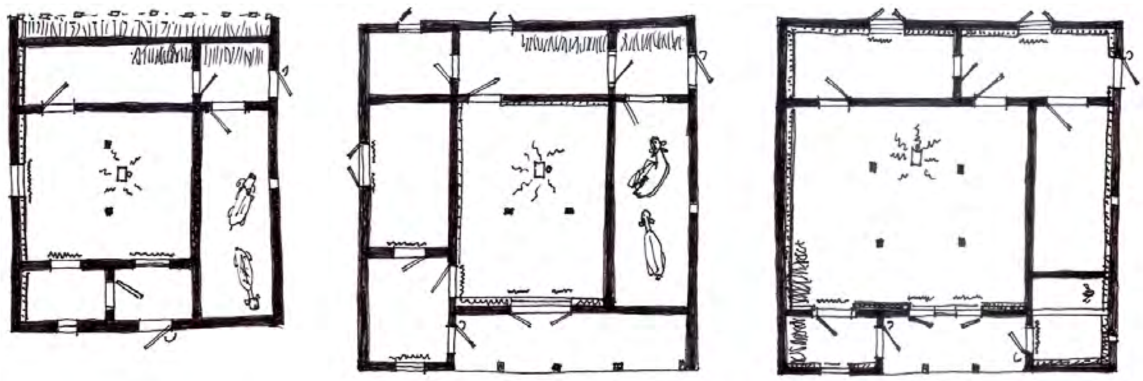
a = outside plaster, b = stone wall, c = inside plaster, d = thermal insulation material.
e = damp resistant foil, f = inside wall finishing, g = cavity wall filling, h = inside cavity wall.

The left sketch shows the current situation in many houses with stone walls. Inside the wall may occur condensation, while the outside plaster may break off due to frost damage. The second sketch shows the temperature curve when the insulation is on the outside of the wall. In this case the entire inside wall needs to be heated, and in the outside insulation condensation will occur. In the third sketch the thermal insulation is on the inside, hence the outside wall will remain cold. To avoid that humid air enters the thermal insulation layer, a damp proofing is applied on the warm side of the wall. The last sketch (right) shows a cavity wall. In this case the inside wall will have a temperature near the room temperature, whilst the outside wall will have a temperature near the outside temperature. Also here, to avoid condensation inside the cavity wall a damp proof layer is applied on the warm side of the thermal insulation.

11. When a warm room has an inside partition wall adjoining another room, and a similar type outside wall, more heat will be lost through the outside wall than through the inside wall. This is because of the higher temperature differences between the inside and the outside of the outside wall than of the partition wall. For this reason outside walls should be better insulated than inside walls. The inside room works as a temperature buffer. The size of the arrows suggest the amount of heat loss.



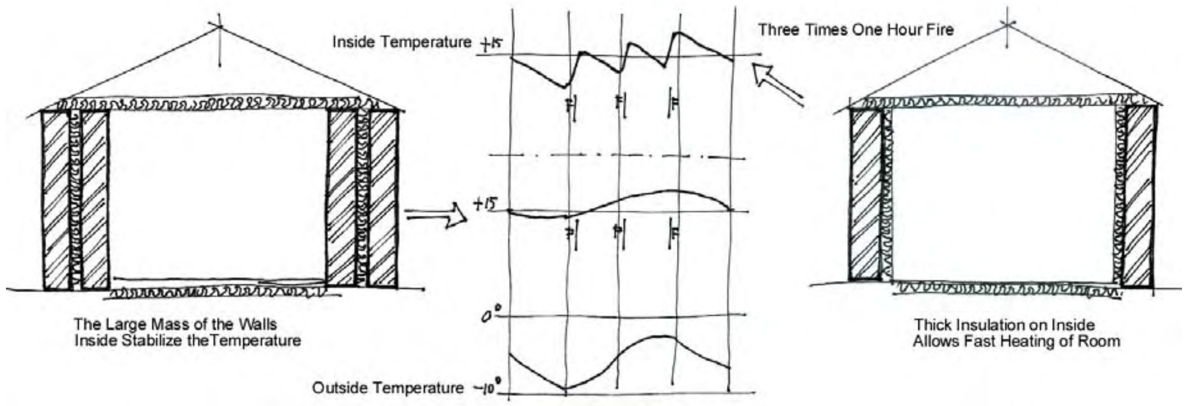
It is most economical to insulate only those rooms in the house that need to be heated (kitchen and/or living room). Rooms requiring no heating (storage rooms) should be located along the coldest outside of the building. These spaces will serve as buffer zones between the cold outside area and the warm inner rooms of the house. The smaller the temperature difference is between one room and the other, the smaller the heat loss or heat flow between those areas.



Insulation options: Small house (left) with few insulation measurements; only one outside wall insulated.
Large house (centre) with only inner room wall insulation and shutters on windows.
Large house (right) with exterior wall insulation and shutters on windows.

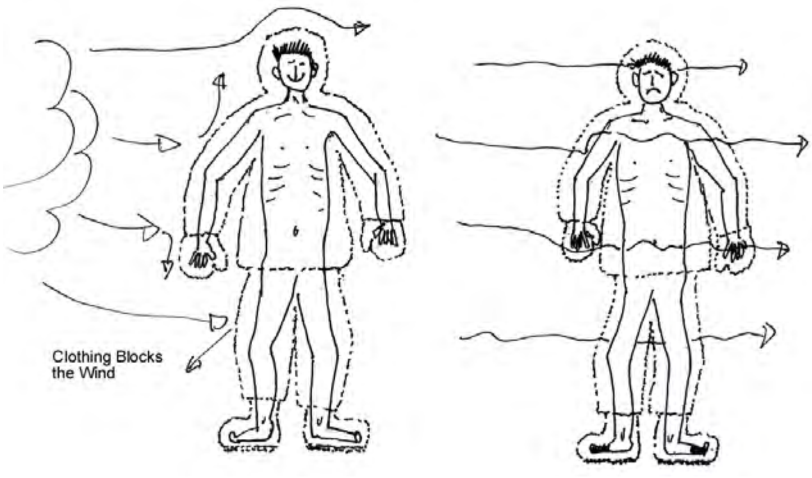
12. High rooms require more heating than low rooms, because all heat goes upward to the ceiling. The traditional Pamiri house has a central skylight (with glass) or a roof hatch window. This area, however captures the warm air because it is the highest point in the room, and above the stove with chimney. Any opening in the skylight will suck out all the warmest air from the room. With single glass in the skylight it will be the largest heat loss area, and double glass is advised.

13. A thick cold stone wall inside a house takes a lot of time and heat to become warm. This is because the mass (weight) of the cold stone is much larger than the mass (weight) of the warm air needed to heat up the stone. One m^3 air weights about 1 kg, and one m^3 stone wall over 1500 kg. This means that 1500 m3 air has the same heat storage capacity of $1m^3$ stone, also meaning that the inside air has to circulate for many hours along the heavy stone wall before that stone wall obtains the same temperature of the inside air. Once that heavy wall inside the house is warm, it will release the warmth slowly to the inside air when that air becomes colder than the wall. The effect is that the room will stay warm for a long period before cooling down. Heavy stone walls in the interior can therefore have a stabilizing effect on the inside house temperature.



General

Thermal insulation works by trapping air in one place and not allowing it to move. It is the air that insulates, not the wool fibres of the coat, but the air between the wool fibres. If it is windy, the coat should also be windproof on the outside, otherwise, the cold wind will blow through the coat and take away the warm air inside. All insulation material is based on this principle; the more air it is containing in relation to its own weight, the better it insulates. The outside surface of a house should therefore be without open joints between the stones.



Temperatures in our environment want to equalize themselves and all heat flows automatically to the coldest areas. Thermal insulation does not produce warmth, it only contains it in its place. If the wall of a room is well insulated but has a glass window, all heat will escape through the window until the inside and outside temperatures are the same.

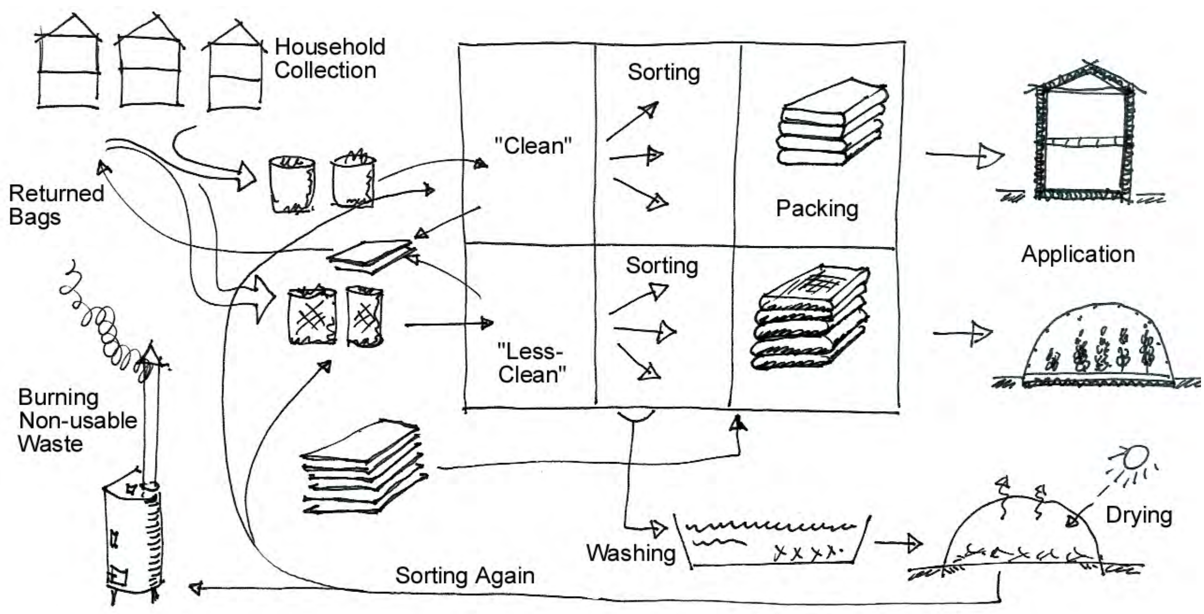
4. MAKING PLASTIC INSULATION

<u>Types of Plastic Insulation</u>

I. For use inside a cavity wall or under the floor the insulation material does not have to be super clean, but it should not have food or soap residues either. Collecting the material and stuffing the plastic PET and HDPE bottles and waste from plastic grocery bags (crumpled) into larger PP bags will be adequate, especially when the plastic containers have their tops fitted.

II. For use inside the ceiling of a house, the insulation material needs to be reasonably clean from fats, proteins, liquids and sugars because these ingredients may attract either insects or cause smells when becoming very hot (under the roof). The best method is to make first a visual selection and then wash those materials that are not very clean but are still useful as insulation material. After washing these can be sun dried and stuffed into the bags.

For both types a waste material collection system is required. In order to accumulate adequate quantities, all villagers must be active in the collection and stuffing of the waste material into larger PVC plastic or PP fibre bags. When possible the caps of the PET and HDPE bottles should remain tightly screwed on.



<u>Organisation of Collection</u>

The collection and reprocessing of the plastic waste needs to be centrally organised. By asking a small price for the sorted, repacked insulation material, a substantial part of the collection and processing costs can be recovered.

A. The village collection committee can supply the large PP bags. Clean (new or white, non-printed) bags can be used for really “clean” material, such as PET water bottles with caps, washed HDPE bottles and clean grocery bags; while yellow or printed PP bags can be used for “less-clean” plastic waste material. The bags are available in large quantities in the bigger towns at low cost.

B. Each household can have one or two (free) bags (one for “clean” and one for “less-clean”), depending on the expected amount of waste, the planned use of the insulation material and the level of participation of the villagers.

C. Each participating household should attend a briefing and demonstration on what materials can be collected in the bags and what should not. The demonstration needs to show how the bags are filled so that the PET bottles are not crushed and the bags are well utilised. The demonstration can be supported with a small leaflet explaining the most important points.

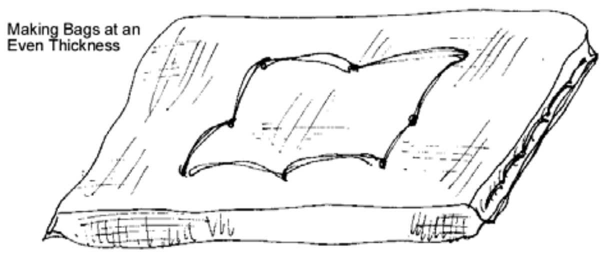
D. Villagers who bring in a full bag should have their bag emptied immediately in a depot (one depot for “clean”, one depot for “less-clean”). This allows an on-the-spot inspection of the quality of the material and the collector can provide immediate feedback to the villager.

E. It should be possible for villagers to buy the PP packing bags if they want to collect the insulation materials for their own use, for example when they plan to insulate their house.

F. The villager should be paid a certain amount for the supply, depending on the volume. It is the total volume that provides the insulation, not the weight. This payment should provide the villager with sufficient incentive to continue the collection and at the same time keep the environment clean from plastic waste.

G. A filled PP bag of 45cm (1½ ft.) wide x 75cm (2½ ft.) long = 1/3m^2 with PET + HDP bottle plastic waste. This bag filled to 8cm (4") or 15cm (6") and may contain 25-50 litres and has an insulation value comparable to respectively 6-11cm glass wool. The value of 10cm glass wool in the city is NRs 250/m^2. The cost of 1/3m^2 x 10cm glass wool would be about NRs 80, not yet considering transport costs to the remote areas. With NRs 5 for the bag, another NRs 15 can be paid for the “less-clean” content and NRs 20 for the bag with “clean” plastic content. The resale value can be NRs 35 and NRs 40 respectively, still being half the cost of the glass wool for the same insulation value.

H. The collection centre should fill the bags according to demand and use. The “clean” material can be packed immediately into insulation bags. The thickness of the bags can be about 8cm, being the thickness of the 1.5 litre PET bottle. Special large bags can be sewn from larger sheets of PP cloth, or larger bags can be made from sewing different smaller bags together.



I. The bags are then sewn closed with PP rope and marked. Equally, the “less-clean” materials can be collected and marked differently and stacked for resale. Hard or sharp plastic articles need to be removed from the stock.

J. Plastic waste material not adequately clean needs to be separated and washed. Several types of plastic will float in water, while others will sink. The floating types of plastics will serve best as thermal insulators. Large pieces of EPS packing material need to be shredded.

K. After washing the plastic waste it needs to be dried and redistributed into the "clean" and "less-clean" stock. It is possible that some elements remain too dirty. Either they can be cleaned in the next washing cycle or be rejected. Washing should be realised away from all other water sources and/or streams. The dirty water should soak away into the ground, away from water sources.

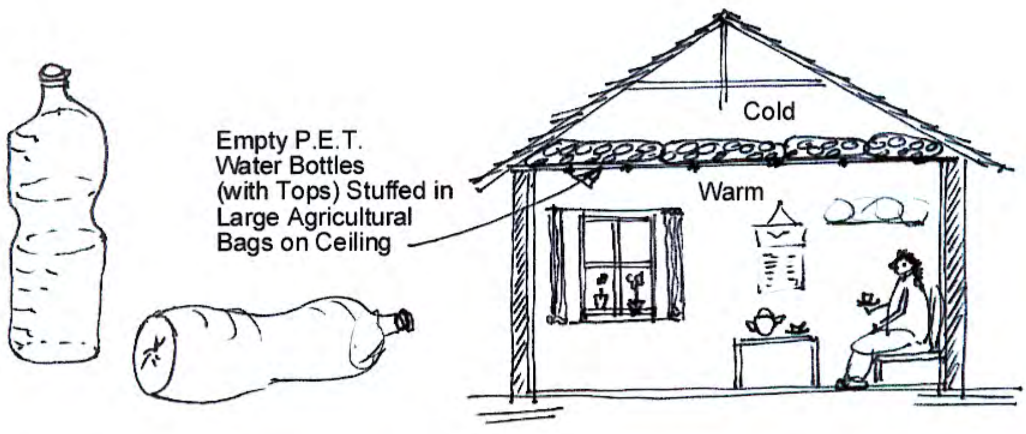
L. After washing the materials should be sun-dried. Sun drying can be difficult in the event of (strong) local winds. Most of the plastic grocery bags are so light that they float easily away in any wind. Netting or greenhouses can be used to keep the plastic in place.

M. Very dirty plastic can be burned, but care must be taken that the burning process has a sufficiently high temperature and combustion is complete. Complete burning may require supplementary firewood or fuel. Examples are clinic and hospital waste, latex gloves, soiled clothing, etc.

N. Once the collection centre has been in operation for a period of time and gained work experience, the most realistic prices can be set to keep the process going. After one winter season the demand for plastic waste insulation should pick up, once the villagers who applied the insulation realize the increased comfort and the firewood savings in time and money.

O. If a shortage of source materials occurs, contracts can possibly be made with nearby towns, but only washed waste should be contracted and the collection centre must organise a regular quality control before transport.

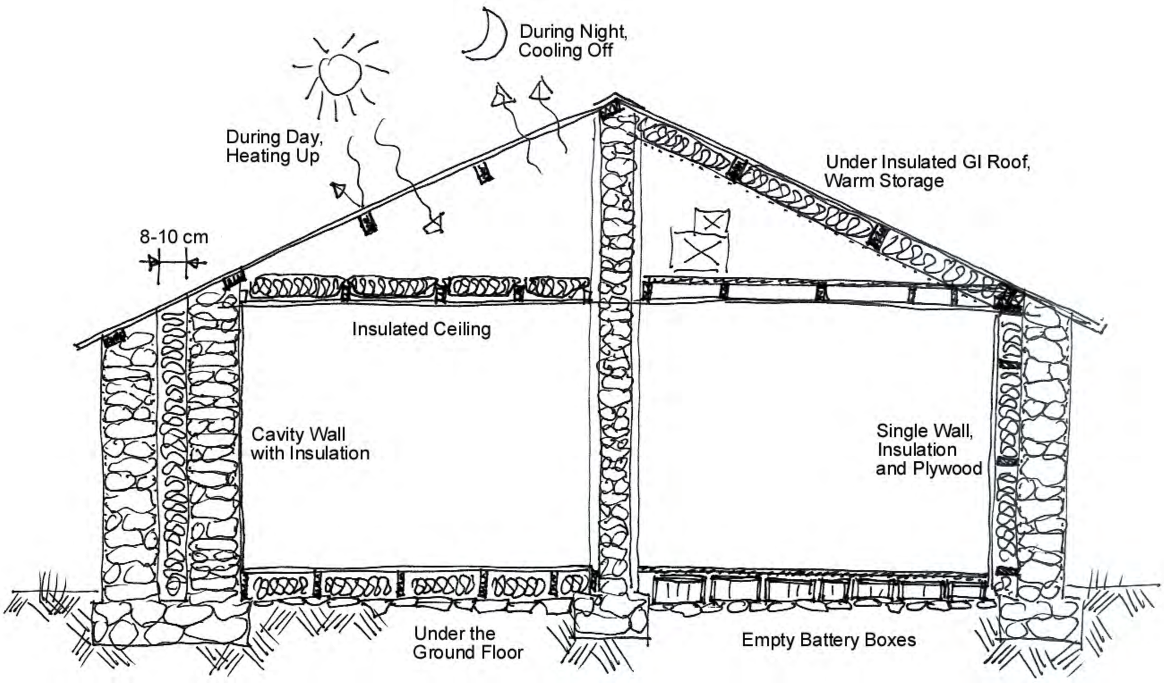
P. The collection organisation can specialize in the application of the thermal insulation; by doing so it will ensure correct application, high customer satisfaction and good firewood savings. The company which applies the insulation material should also provide the plastic or reflective PE foil as moisture barriers. With the use of reflective (aluminium coated) foils, the total insulation value will be substantially enhanced.



5. DOMESTIC APPLICATION

For inside the house "clean" plastic waste is strongly recommended.

Most effective is the insulation to be applied above the ceiling of the heated room. Secondarily, insulation under the roof should be applied. Insulation under a sheet metal roof will also keep the rooms cooler during hot summers. The reflective foil should be facing the warm area. This means that under the GI roof one reflective foil should be directly under the GI sheets facing upwards to reflect the heat of the summer sun. Another reflective foil should be on the room side with the reflective side facing the warm room during the winter period.



Depending on the design of the house, bags with insulation material can be placed under the ground floor or fixed with galvanised wires in between the floor beams, under the living room. In this case the reflective foil should be facing upside to the warm room.

Reflective Foil

Thin sheets of grey Polyethylene (PE) are often used as under carpet. The same material with on one side a reflective aluminium coated PVC foil is used for pipe insulation and as reflector foil to be placed on the wall behind radiators (picture right). The reflective side reflects the infrared radiation coming from the room or warm area. This way it enhances substantially the insulation value of the material and makes the surface damp proof.

Also glass wool blankets are available in the market with a paper side and covered with a reflective aluminium coated PVC.

In the picture on the right, the top roll is 5mm PE with reflective PVC foil, used for pipe insulation.

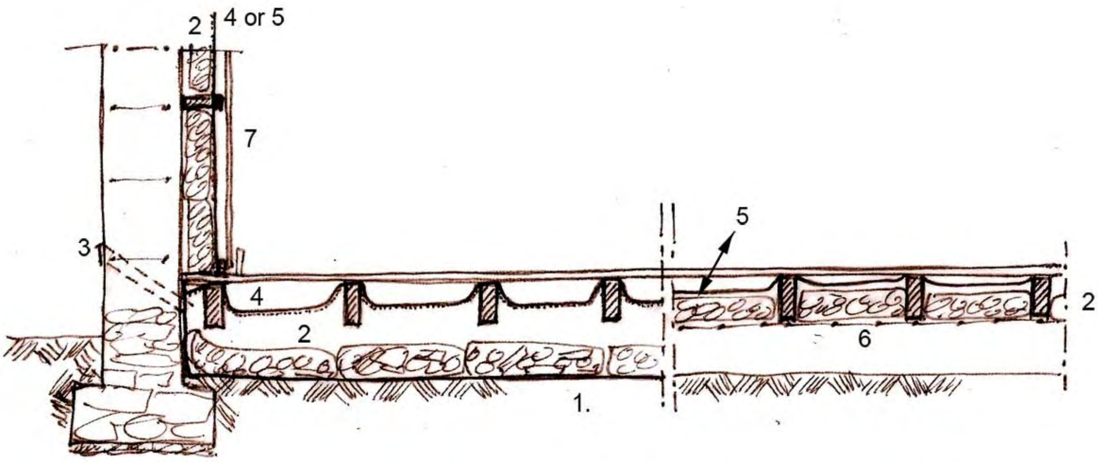
A lower cost reflective foil can be obtained from the food packaging industry because this is without the PE backing. This plastic foil has a reflective aluminium coating and is commonly used for chip bags and food wrappers for chocolates and candies. In some cases rolls of misprinted foil can be bought for a price of about USD 10/ kg. The material comes in several thickness (0.01-0.05mm). The thickest type used for chip bags is recommended. The rolls come in widths of 100cm to 150 cm wide.

<u>Floor Insulation</u>

Timber floor beams are supported on stones and fixed with cement mortar; the wooden floor will be nailed over the beams. In this case it is essential to ventilate under this floor to remove moisture from the soil and avoid rotting of the beams. Ventilation below the timber deck, however, would substantially reduce the insulation value of the floor.

The following measurements are necessary:

(a) Over the soil durable plastic should be laid to reduce moisture coming up. As an alternative a layer of asphalt bitumen can be placed over a thin layer of stabilised soil (sketch # 1).
(b) Ventilation openings need to be made in the wall and above the outside soil level, allowing a little cross ventilation under the floor (sketch # 3). This is necessary under a wooden floor, especially when in the rainy season the groundwater table can become high at soil surface level.
(c) The timber beams need to be treated with a wood preservative before setting them on the cemented supports (mix 50% diesel + 50% used engine oil).
(d) Under the beams a galvanised wire mesh is fixed to carry the bags with plastic insulation (sketch # 6).
(e) One layer of reflective foil need to be hung in between the floor beams before the deck is nailed (sketch # 5).



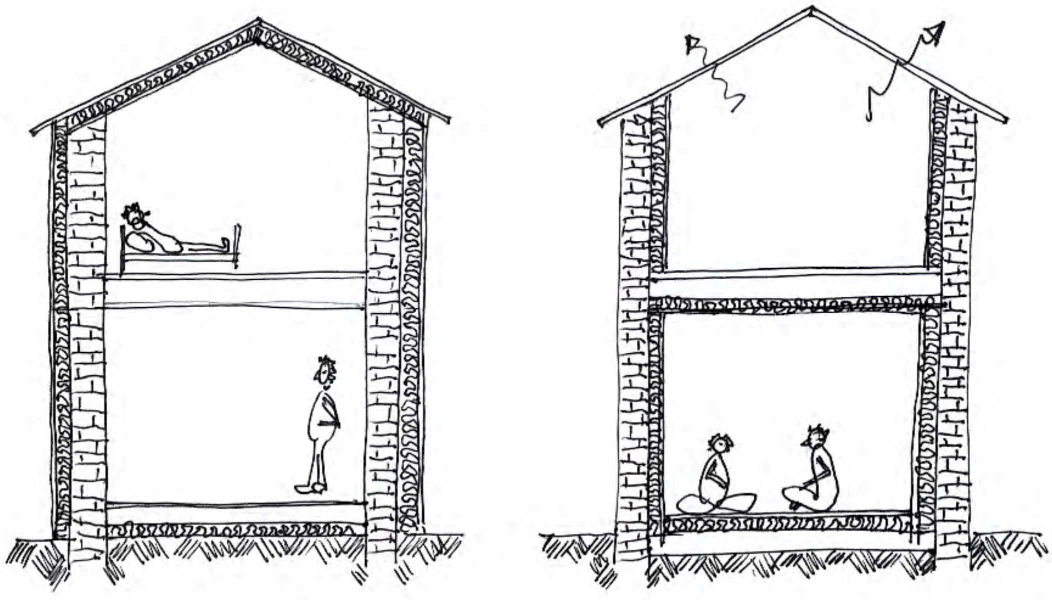
Description of numbers in the sketch.
1. Compacted soil covered with moisture barrier and PP filled bags or PVC bags with empty bottles. PP bags are probably cheaper than thick PVC bags, but also environmentally preferred. However PP bags should not be left on moist soil.
2. PP bags with empty PET and HDPE bottles and other plastic waste (suspended and dry).
3. Small ventilation opening assuring some cross ventilation to the benefit of the timber beams. The right hand side of the sketch is a more energy efficient solution because the ventilation is under the insulation. The choice will be based on costs and fitting possibilities.
4. PE foam 5 mm with reflective PVC aluminium foil on the warm side. This is a slightly warmer solution than the use of foil only (#5). A double reflective foil with air space in between will strongly enhance the insulation value. In such a design the lowest foil should be stapled against the wooden floor beams to assure that a space is kept between the two foils.
5. Reflective PVC foil, coated with aluminium, reflective side on the warm side.
6. Galvanised wire mesh to hold up the thermal insulation bags or glass wool, etc. In the case of using glass wool the topside should have the reflective foil (and 5 is not necessary, but adds insulation).
7. Panelling of hardboard (low-cost), plywood or gypsum board (medium cost), wood panelling or cement plaster on wire mesh (high cost).

The insulation of the ground floor is important when people sit or sleep on the floor. The thermal insulation with bags of PET bottles is low cost and not affected by a little humidity under the floor. A cold floor will cause heat loss downwards and can be a cause for rheumatism. Additional comfort insulation may be required with PE reflective foil directly under carpets and the use of mattresses.

Wall Insulation

All types of wall can be post-insulated with thermal insulation, either inside or outside.

When deciding on a particular insulation measurement, the house or hotel owner must consider the effectiveness, cost and inconvenience during the renovation. Each thermal insulation technique has a different effect on the living quality in the room and may cause a change in other parts of the house. In addition each insulation method requires space and has different cost implications.

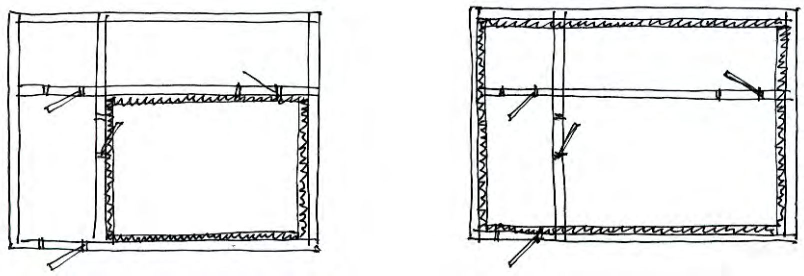


Insulating the outside of the house creates a stable inside temperature because of the large mass of the walls.
In the house on the left, both rooms will have about the same temperature. This is useful for clinics.
The house on the right will warm up very fast because the outside walls do not have to be heated.
The ground floor room will be comfortable, but the first floor room will lose all the warmth through the roof.

Inside or Outside Insulation

To insulate the whole house, only the outside walls need to be insulated. If only one room needs to be kept warm, then all the walls of that one particular room can be insulated.

Natural stones, baked bricks and cement block walls have a high thermal storage mass due to their heavy weight. Air is light and therefore has a very low thermal mass. This means that a very large amount of warm air is needed to increase the temperature of heavy wall materials. The interior walls and floors of a house provide some stabilisation of air temperature because of their mass. This will be the case with the sketch on the right (below).



The floor plan on the left has a smaller surface of wall insulation that the plan on the right.
The advantage is that the insulated room requires only a small amount of energy for heating.
The disadvantage is that the outside smaller rooms will remain cold.
The house on the right has a large surface of wall insulation, but the whole house will be warmer.
If the heating source is in the large room, the smaller rooms will be only slightly cooler.

Rooms needing to be warm for only a limited number of hours per day or needing to be warmed up fast are best designed with the thermal insulation on the inside. The walls of a school being occupied for only one-third of the day (eight hours) can best be insulated on the inside so that the classroom warms up quickly.

In this school, early morning all stoves must be lit to remove the frost, but it does not get warm.

When the building is insulated on the outside, the inside air needs to be heated and circulated for a very long time in order to warm the (heavy, cold) interior walls (left picture page 19). Although the air near the stove warms up quickly, the walls remain cold for a long period. However, once the walls are warm, it will take a long time before the inside air temperature drops because the warm walls will continuously re-heat up the circulating inside air.

The choice between insulating only the inner room or the whole house is based on cost and comfort factors. The smaller the insulated surface, the lower the installation cost. If only one central living room is heated, the heating needs will be also little (firewood collection, chopping, maintaining fire, etc.). In many situations the sleeping quarters or store rooms can have a lower temperature. Insulating a house on the outside walls is more expensive and will require more heating to make it warm and keep it warm.

Cavity walls

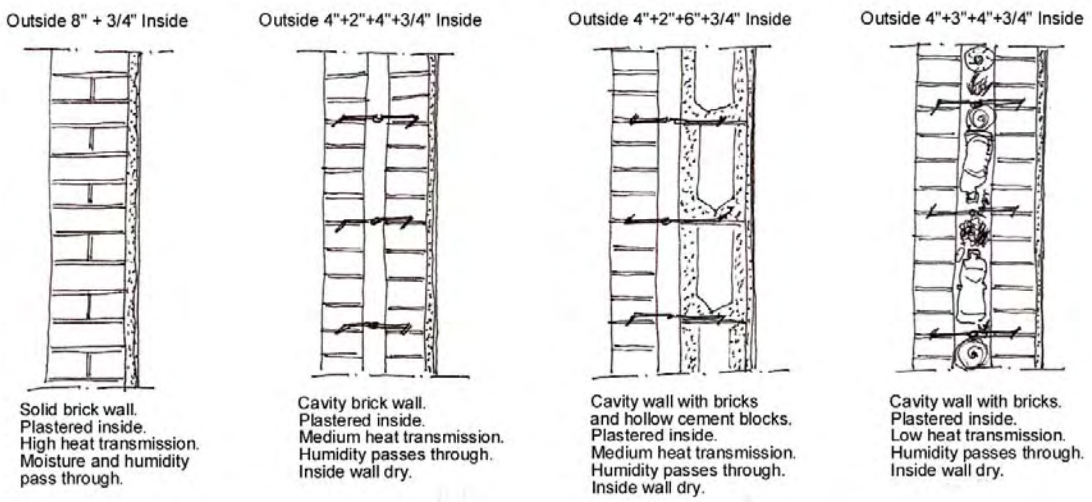
When a cavity wall is constructed the following considerations apply. See sketch page 17.

- Apart of the thickness of the thermal insulation, being between 5-10-20cm, depending on altitude and insulation material, the thickness of the cavity wall itself needs to be added. For baked bricks 10 cm, hollow cement block walls 15 cm, adobe walls often 20 cm and for stone walls minimal 30 cm.
- The total volume of the additional wall material and the cost of masonry makes the building of inside or outside cavity walls with their foundations expensive.
- Because of the mass of masoned cavity walls, there need to be well anchored and able to withstand earthquake forces. The larger the weight, the larger the earthquake forces.
- When rooms are insulated on the inside of the walls, some useable floor surface area of the room will be lost. When inside cavity walls are constructed, also the thickness of these walls are taken off the floor area. Existing wall decoration or plastered surface will be covered up.
- With the outside insulation method, the insulation material will need to be protected from the weather with the cavity wall which needs to be weather proof.
- With an outside cavity wall the roof construction needs to be extended to protect the wall. In the case of an external adobe cavity wall, this needs to be well protected against the rain.

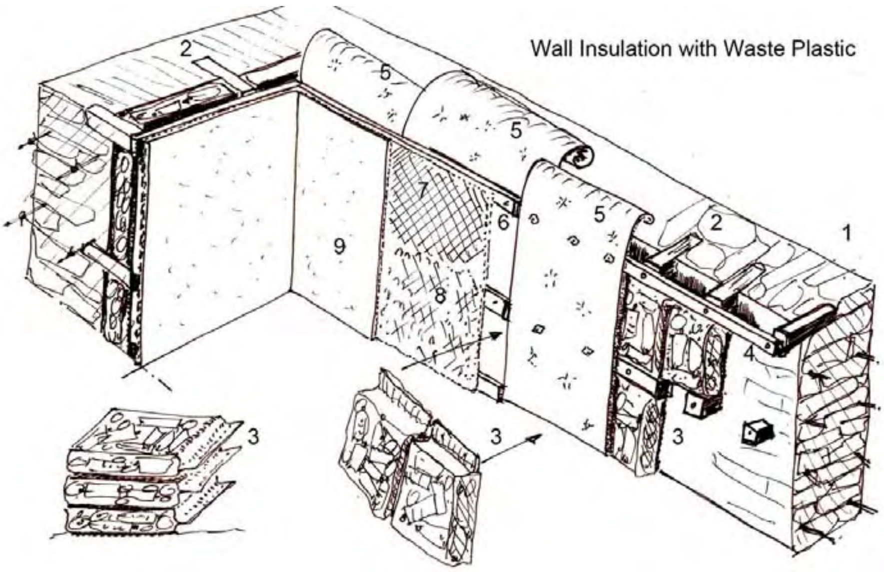
From the above points it can be concluded that an additional cavity wall is more expensive than only applying the thermal insulation with a covering, and that outside cavity walls are usually far more expensive than inside cavity walls. On the other hand inside cavity walls may reduce the floor surface to half the original useable surface.

In this school the adobe cavity wall was constructed on the outside because of space requirements.
Also the entire roof was insulated and a vestibule added to reduce the cold draft from outside.

The hollow space inside the cavity wall needs to be filled with an inorganic and non-decomposable insulation material, and the insulation material must remain dry. When no damp barriers are applied the humidity from inside the house will pass to the outside of the house.



The application of thermal insulation made from PET and HDPE bottles in PP bags can be realised according to the following design. In this sketch the main wall is of stone masonry with Galvanised Wire Reinforcement (GWR). The wall is masoned up with wooden anchors.



1. Long wooden blocks are painted with red oxide and masoned into the wall.
2. These blocks are protruding with a determined distance according to the thickness of the insulation.
3. PP bags with empty PET and HDPE bottles are hung on the pegs.
4. A plank is fixed horizontally to secure the bags, openings and pockets are filled in.
5. A 5mm PE reflective foil is fixed with overlaps on a horizontal wooden strips and nailed to the plank.
6. The strips need to allow a space between the reflective side and the cover material.
7. In this case an expanded wire mesh or plaster mesh is firmly fixed to the assembly. Alternative finishing is with gypsum board, ply wood, hardboard, MDF or hollow PVC sheeting. Plaster can be tiled.
8. The expanded metal mesh or plaster mesh is primed with a strong cement slurry to avoid rusting.
9. The cemented expanded metal is plastered. Along the floor a plinth can be made.

For new houses the insulation material can be applied directly inside cavity walls. Because most of the one litre PET bottles have a diameter of about 8cm, the cavity should not be less than 8-9 cm, providing a high value insulation for high altitude dwellings.

6. SWH APPLICATION

Solar Water Heaters (SWHs) are excellent energy producers and savers of firewood. The efficiency of the installation depends largely on three aspects:

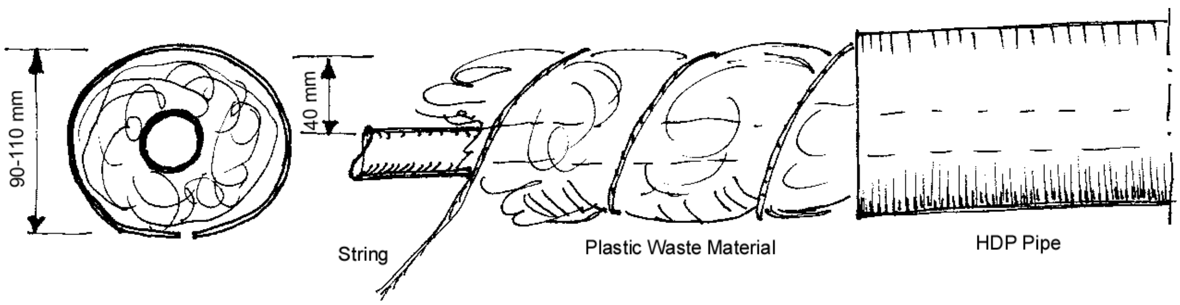
- The design of the collector panel with the warm water storage container.
- The total length of piping outside the building between the collector and storage tank and the total length of piping from the installation to the tap point inside the house.
- The insulation of the outside as well as the inside piping.

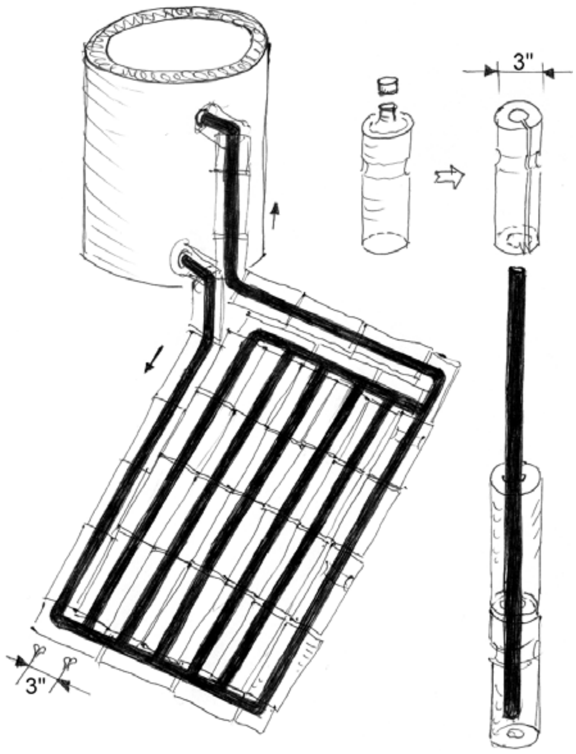
While the collector and its orientation can be of good quality and have an efficiency of about 60% (high), if the piping is too long and not well insulated, the overall efficiency of the system will rapidly reduce to 30% and even 15%.

Not only does the piping system outside need to be as short as possible, but both the piping outside and inside the building should be well insulated. For outside piping minimum 2.5cm insulation is recommended and for inside piping minimum 1cm.

The most economic method to insulate the external pipes is to wrap the pipes with at least 2.5cm (1") crumpled up plastic waste, loosely tie plastic foil around them with rope and then cover with a 10cm (4") diameter thin quality HDPE pipe. This can be done by cutting the pipe lengthwise and clipping it over the insulated pipes. Inside the house the pipes need to be packed with insulation material before these are masoned into the walls.

Although the company who installed this equipment has insulated the long external distribution pipes with yak skin, it may not prevent freezing. Poorly insulated and long external pipes will cause very poor efficiency of the SWH system.





Plastic insulation for warm water pipes masoned into the walls or used outside covered with large diameter HDPE piping can be made from knotting together empty plastic shopping bags. Strings should be not longer than 4 meters in length and then folded double to allow easy winding around the ½" metal pipes.

Contracts for the plastic bag strings can be made by weight. Two hundred grams of knotted shopping bag string equals approximately 80 meters of single length which can insulate about 4 meters of water piping. Each kg of knotted bags insulates therefore about 20 meters of warm water piping, being usually sufficient for a single house.

Transparent plastic (PET) water bottles can be used for the same purpose of warm water pipe insulation in new house constructions. The bottle neck is removed from the top, leaving a hole equal in diameter to the water pipe. The bottle is then cut open lengthwise with a strong scissor. Another hole of the same diameter is made in the bottom. The modified bottle is clipped over the warm water pipe before being covered by the masonry of the walls. The horizontal sections in the top and bottom of the plastic bottles prevents airflow around the pipes while the 1" air layer provides excellent insulation.

The same technology was used in India to make a low-cost solar water heater. Using black ½" HDPE water piping a grid was made following the above sketch. One-litre transparent PET bottles were attached over all the pipes. The black HDPE pipe captures the solar heat whilst the transparent bottles contain the heat by its insulating effect. The disadvantage of this model is that the bottles need to be regularly replaced (at least yearly) because in the full sun PET bottles deteriorate under ultraviolet light[3].

[3] This technology was field tested and implemented by Dietrich Bartel, a German engineer working in northern India.

ANNEXE I

Austrian team relieves Annapurna IV of rubbish

Himalayan News Service

Kathmandu, October 29

An eight-member Austrian expedition team cleared some 250 kg of garbage from the Annapurna IV (7,525).

Organising a press conference here today, the team demonstrated a part of the non-combustible garbage, which the Kathmandu Metropolitan City would later dispose safely.

According to the team leader Reinhold Oblak, non-toxic, combustible garbage weighing about 150 kg was burnt at the base camp after sorting. The remaining 100 kg of non-processible garbage was transported to Hongde on donkey back which would further be transported to Pokhara via plane and then to Kathmandu by bus.

Oblak blamed the government officials' inefficiency in monitoring the mountaineers. "The officials never reached even up to the base camp and how can they monitor what is going on in the mountains just sitting in Kathmandu?" he questioned.

The clean-up campaign that was organised by the Blue Sky Ltd was funded by Austria based Saubermacher Expedition.

"Being mountaineers, it is our responsibility to clean the garbage. We want all the mountaineers to follow our steps," he told this daily adding that he would come again to continue such campaigns.

He says that cleaning the famous mountains like Everest alone is not sufficient. "People should not ignore other mountains as well. They are not only the property of Nepal but of all the mountaineers." Oblak urged every mountaineers not to leave any rubbish in the mountains.

The clean-up team included team leader Reinhold Oblak, deputy expedition leader Ulrich Walser, doctor Edmund Wirbel, videographer Georges Reckinger and members Christopher Ryder, Peter Farmer, Andreas Pusswald and Alois Schimpfoessl.

Members of an Austrian team display a part of the garbage they have collected from the Annapurna IV in Kathmandu on Wednesday. *Himalayan Photo*

Mt Dhaulagiri cleaner by 3 tonnes of rubbish

Himalayan News Service

Kathmandu, October 31

An expedition led by the French to clean waste from Mt Dhaulagiri has returned after clearing 3,000 kg of garbage from the base of the mountain. The 'Dhaulagiri Clean Up Campaign' involved over 37 individuals and was initiated by the Association Dhaula Gueri of France and the Kathmandu Environment Education Project (KEEP).

"This is the second time that the team has come to Nepal to clean Dhaulagiri, which shows the immense interest the French have in the mountains of Nepal," said Claude Ambrosini, the French ambassador, while congratulating the expedition members at a press conference at Alliance Francaise. Ambrosini also mentioned that France has a long history of cooperation with Nepal and that cleaner sites would attract more visitors to the country.

The waste comprised 2,380 kg of textile, plastic wares and paper which they burnt; 500 kg of metal, 100 kg of glass, and 20 kg of batteries. The metal and glass were brought down to Pokhara on 17 mules and sold to a *kabadi* shop which would send it to India for recycling. The batteries will be taken back to France for recyling.

"This campaign was just not to clean the mountain in Nepal, but also to create an awareness amongst our countrymen back home too," said Boize, the leader of the expedition. The team also communicated and updated their website daily, and coordinated with five schools in France that were following the progress of the campaign.

The clean up was conducted along the trail from Marpha to the base camp. The campaign targeted major camping areas including Alubari, Yak Kharka, Elevation Camp, Dampus Phedi, Hidden Valley and Dhaulagiri Base Camp.

The above two articles from the Himalayan News Service report the large amounts of garbage, including a substantial component of plastic waste, recently collected from high mountain trekking areas.
Much of the 2,380 kg of waste collected from Mt. Dhaulagiri and burned could have been recycled for use as thermal insulation.
Transporting new insulation material to high mountain areas is very costly.

ANNEXE II

More information on thermal insulation, see website: www.nienhuys.info, page thermal insulation.

The subject of the following book is how to create employment by recycling plastic. Although published in 1984 it is still valid and useful. Originally published by Intermediate Technology Publications, 1984

Read more or download Pla-vogler_ebook.pdf (962 kB)

http://www.waste.nl/content/download/560/4328/file/Pla-vogler_ebook.pdf

Fact Sheet Plastic pdf (28 kB)

This four page Information Sheet discusses the definition, different types, the manufacturing and the use of plastic.

It further gives information on the sources of waste plastic, packaging appears to be the main source. The environmental impacts are briefly discussed and information on plastic waste management and resource recovery is dealt with.

http://www.waste.nl/content/download/676/5211/file/Factsheet%20plastic2002.pdf

Urban Waste Series 2 - This document describes how mixed plastic waste is reprocessed by informal small-scale enterprises and converted into end products for direct resale or use in formal industries. It provides some initial guidelines for the successful development of plastic waste recovery and reprocessing enterprises. Download UW2 PLASTIC ebook.pdf (830 kB)

http://www.waste.nl/content/download/284/2234/file/UW2%20PLASTIC%20ebook.pdf

Plastic Recycling in Bangalore - India

This report reflects the results of a case-study research in Bangalore, India. It offers the reader a picture of the role the various stakeholders play in urban waste management with an emphasis on the importance of small and micro-enterprises and community involvement. Download CS-pla ind_ebook.pdf (718 kB)

http://www.waste.nl/content/download/529/4097/file/CS_pla%20needs.pdf

APR, Association of Post Consumers Recyclers. Of the American Chemistry Council

http://www.americanchemistry.com/plastics/sec_content.asp?CID=1593&DID=6056

General Publications

This includes a broad range of information focusing on plastic benefits, plastics packaging, material comparison studies, lists of recycled products and their manufacturers, and more

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