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A Place in the Sun: Options for Space Heating in the Mountains

Cold climates and harsh living conditions associated with rapid deforestation and indoor air pollution make the prospects of using solar energy exciting. The text examines availability of solar energy in the HKH region and the options for its application. Issues arising and a legislative framework are also discussed along with recommendations for its promotion.

Context

In mountain regions, winters are usually harsh and heating is needed to keep the indoor temperature at a comfortable level. In traditional houses, wood and dung are used, whereas in urban houses kerosene heaters, electric heaters, and/or air conditioners are used. In remote and inaccessible mountain areas, long-term use of biomass fuels is not sustainable because of the increasing rate of deforestation and decreasing livestock numbers. Also, continuous exposure to in-house biomass fire has given rise to numerous health problems such as acute and chronic respiratory diseases.

The growing concern for deforestation associated with increasing drudgery and deteriorating health conditions, particularly in the case of women and children, make it necessary to look for appropriate energy options for mountain areas. Availability of solar energy in the Hindu Kush-Himalayan (HKH) region and the possibility of using this 'free gift of nature' provide a suitable option. Passive solar building technology (PSBT) is one way of providing space heating, thereby reducing the consumption of biomass fuels and associated environmental hazards.

Passive Solar Building Technology: What Is It?

For cold climates, a passive solar building can be defined as "*a building in which the various components are arranged in a manner that maximizes the collection of solar heat, it is then stored and finally distributed into the space without any expenditure of conventional forms of energy*" (Flavin 1980). This implies that the use of passive solar energy will have an impact on the art and science of building construction, and on maintaining the architecture. There are four basic steps to capturing the sun's energy to increase thermal comfort inside the building during winter months in mountain areas.

Location, layout, orientation, shape, external colour, and opening of the building should be such that the maximum amount of solar energy is trapped inside the building (Knowles 1996). The trapped solar energy should be retained within the building envelope by **reducing heat losses**. Proper insulating materials and/or air gaps should be used to reduce heat loss through walls, roofs, and floors. Double-glazed windows and weather stripping would be an appropriate way to reduce heat loss from large openings on the south wall. The choice of appropriate material for walls, roofs, and floors, and their thickness plays an important role in **increasing heat retention capacity** which will act as a thermal flywheel. Generally, heavy building materials, such as brick, concrete, sand, gravel, and adobe (mud), possess the best heat retention capacity.The **control of the heat flow** in a passive solar building must include control over the sunlight passing through the glass. The simplest and most effective method of controlling the amount of sunlight that enters the glass is to use overhangs. A roof can be extended beyond the end of a wall in such a way as to block most of the higher summer sun from striking the glass (Bansal & Minke 1995).

... although the basic principles are simple, there are many ways to harness the sun's energy effectively.

The beauty of passive solar design is that, although the basic principles are simple, there are many ways to harness the sun's energy effectively.

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Availability of Solar Energy in the HKH Region

The amount of global radiation received in a particular location varies with the latitude of the place, the time of the year, and the time of the day, besides other local conditions such as cloud cover and snow cover. In general, regions with dry climates within the latitude of 35° from the equator are much more suitable for the use of solar energy, since the percentage of diffuse radiation is substantially less at latitudes higher than 35°.

Generally speaking, within the HKH Region, the Tibetan Plateau is most favourable in terms of the availability of solar radiation. The Trans-Himalayan Zone, Hindu Kush, western part of the Himalayas, and valleys in the Hindu Kush and Himalayas can be considered favourable. The eastern part and central part of the Himalayas are less favourable (Figure 1). Figure 2 provides a comparison of solar radiation between selected places in the HKH region. It shows that the global radiation varies almost twice during the months of December and January at two extreme locations; viz, Lhasa (Tibet) and Chitral (Pakistan). The variation is due to the prolonged fog in the mornings that prevail due to the micro-climatic conditions in a particular place. Variation in the summer months is due to the extent of cloud cover. The lowest variation is observed in the month of April, as the sky remains relatively clearer during this month all over the region.

... factors such as relief, altitude, slope, and aspect influence the availability of solar energy in mountain areas to a significant degree and thus need careful understanding.

Factors Influencing Solar Insolation

The availability of solar energy is primarily influenced by local climatic factors such as precipitation, sunshine hours, temperature, and seasons. A fundamental characteristic of solar energy is its intermittence. However, factors such as relief, altitude, slope, and aspect influence the availability of solar energy in mountain areas to a significant degree and thus need careful understanding.

There are several areas in the region that have been identified as having the greatest differentiations in local relief, which will have significant effects on the climate and thus solar insolation. For example, Hunza Valley in Northern Pakistan rises from about 1,850 m to the summit of Rakaposhi at 7,788m (a vertical difference of 5,939m in 11km) and the Kali Gandaki Valley of Central Nepal rises from approximately 2,470 m to 8,167m at the summit of Dhaulagiri I, with a difference in elevation of 5,697m over a distance of 11km. These great increases in altitude over relatively short horizontal distances increase the role played by slopes along with the nearby snow peaks which act like large reflectors, thereby raising the albedo factor and essentially increasing the availability of solar energy in a particular place.

The difference in temperatures at stations in the east and west of the HKH at the same altitude is striking. The summers are warmer and winters colder in the west (e.g., Leh, Skardu, Srinagar) and on the Tibetan Plateau (e.g., Chamdo, Lhasa, Leh), while the annual range of temperature is comparatively lower in the east (e.g., Gangtok, Darjeeling, Shillong) (Mani 1981); therefore there is a substantial variation in solar insolation and heating energy requirements. For example, the maximum temperature in Leh during summer is 22°C and the minimum temperature during winter is –10°C, while, in Gangtok, maximum temperature in summer is 13°C and the minimum temperature during winter is –6°C. (average daily temperatures).

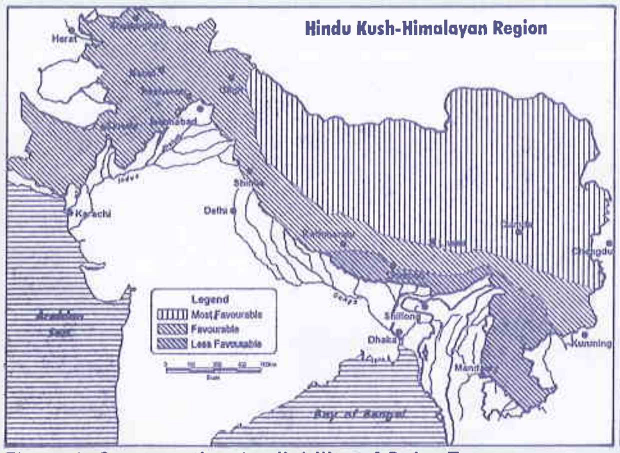

Figure 1: **Comparative Availability of Solar Energy**

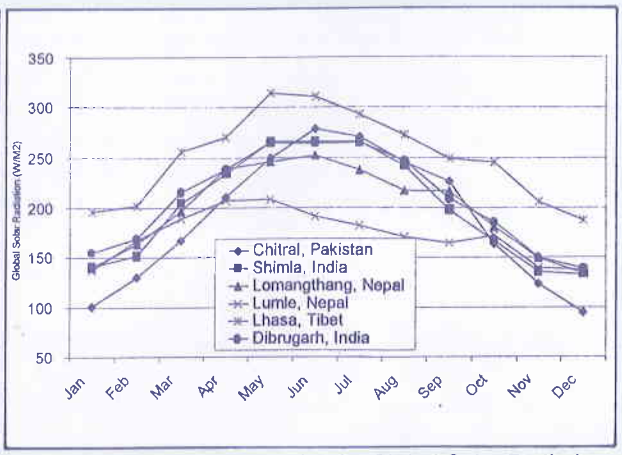

Figure 2: **Monthly Average of Daily Global Solar Radiation in Selected HKH Areas**

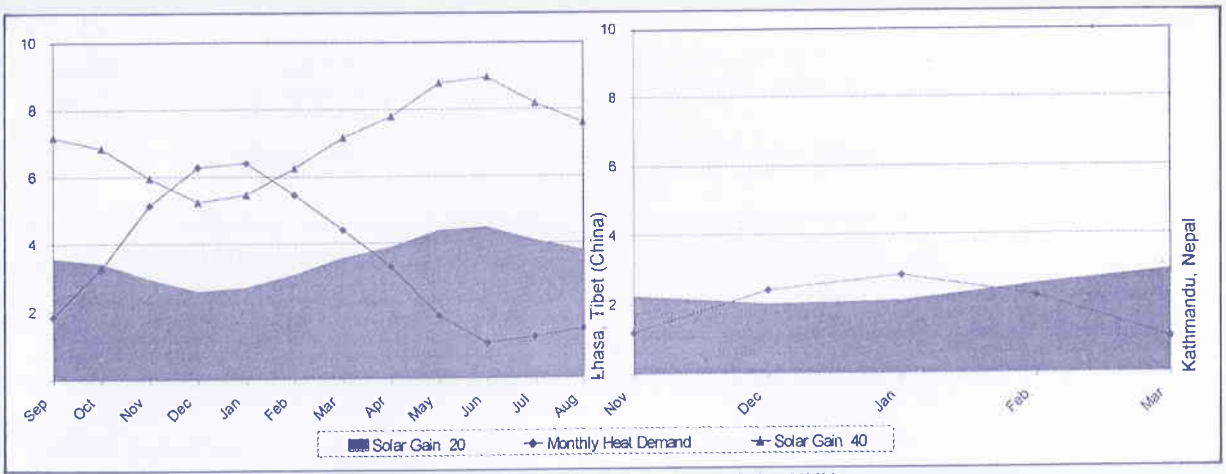

Figure 3: **Heating Energy Demand and Solar Gain in Selected Places of the HKH**

Application Potentials for Meeting Heating Energy Demands

The heating energy demand for various months in places such as Leh in India, Lhasa in Tibet, and Lomangthang in Nepal compared to Shimla in India and Kathmandu in Nepal depend on the outside temperatures of these places. The horizontal and south facing walls receive the highest radiation during winter months compared to the north, east, and west facing walls. In places like Kathmandu, tapping the incoming solar radiation can provide almost all the heating needs of the building during winter months by providing an opening measuring 20 per cent of the total floor area on the south-facing wall (Figure 3). In places like Lhasa, for the same reason, an opening measuring more than 40 per cent of the floor area is required on the south-facing wall.

Passive Solar Heating System

The two basic solar heating systems - active and passive - are distinguished by the way they retain heat once it has been converted from sunlight. Active systems use an additional source of energy to pump a liquid or blow air over the absorber. Passive systems have absorbers that also store heat, but require no additional energy source (Schepp & Hastie 1985). The passive solar systems are not bought as a product but are designed, built, and made; careful planning of measurements and sizing calculations is required.

Direct Solar Gain Systems

The easiest way to heat a building with solar energy is to place glass on a south-facing wall to attract solar radiation. This method is called direct solar gain. Heat is gained by the living space directly (Figure 4), although a dark-coloured thermal mass needs to be exposed directly to the incoming solar radiation to convert sunlight into heat and to control the heat flow (Gut & Ackerknecht 1996). This system is quite popular in mountain areas, but lack of knowledge of suitable methods of heat retention make it difficult to maintain the desired level. The extra cost required for a direct solar gain system is small compared to the cost of conventional homes.

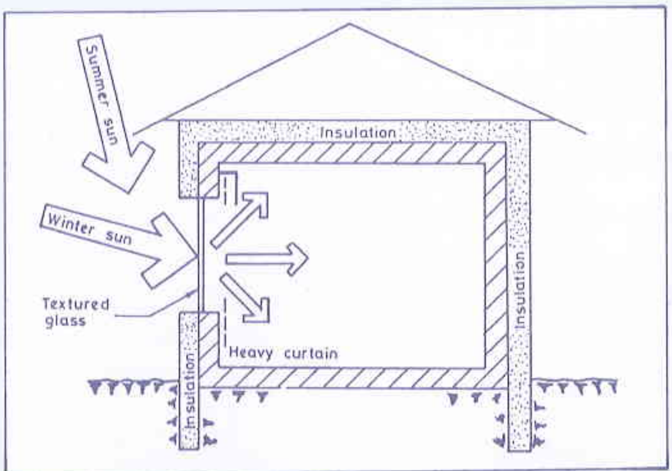

Figure 4: **Direct Solar Gain**

Thermal Storage Walls

This option avoids many of the limitations of the direct gain passive solar systems. The thermal storage wall is placed about 4 inches behind a glass area that is about the same size as the wall (Schepp and Hastie1985). The sunlight passes through the glass and strikes on to the dark-coloured mass; the wall acts as an intermediary between the sunlight and the living space. The inner surface of the wall then releases heat to the room in much the same way as a radiator does. For this reason such a system is also called an **indirect solar gain system**. These are of two types. One uses heavy masonry painted in a dark colour called a **Trombe wall** (Figure 5), and the other uses water in a dark-coloured container made of metal or plastic and called a **Water Wall**. The 'Water Wall' is a little more efficient at transferring the sun's heat to the inside compared to the Trombe Wall.

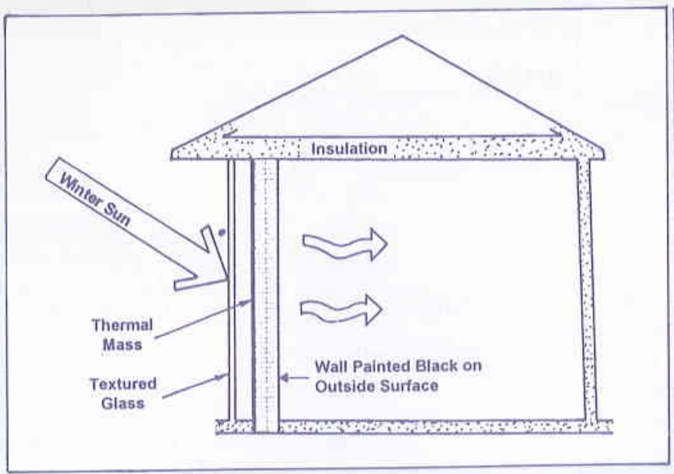

Figure 5: **Trombe Wall**

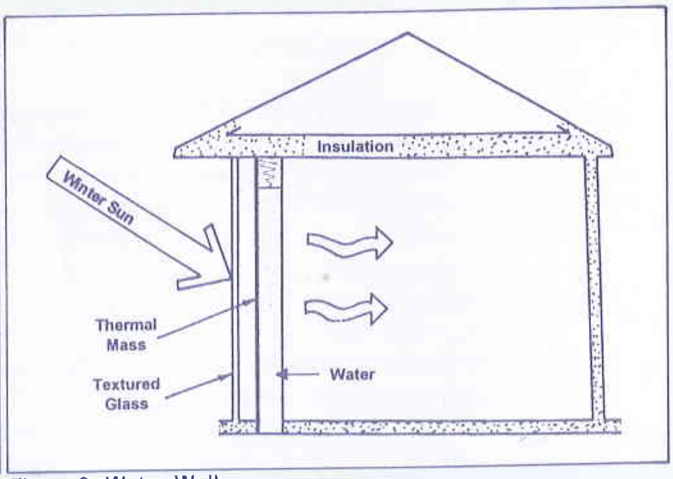

Figure 6: **Water Wall**

Phase Change Walls

A slightly different concept of absorbing sunlight is the application of phase change material. These substances change phase - usually from solid to liquid - when they are heated. Most importantly, they store more heat than stone, brick, and water and are available in tubes or as floor tiles and are also lighter than the other materials. Phase Change Materials (PCMs) usually change phase between 25 and 40°C. Tubes of phase change materials sometimes are placed together to form a sort of thermal wall (Figure 7). The advantage the phase change wall has over a Trombe or Water Wall is the constant lower temperature, so less heat is lost through the glass. One of the disadvantages of PCMs is that, over time, their phase-changing properties decrease.

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Sun Spaces

Sun space, solar greenhouse, solarium, sun room - all are names for a room with a lot of south facing glass that is in some way separated from the rest of the house (Figure 8) and which is called an isolated solar gain system. The reason sun spaces are popular is because of their versatility in terms of design and use of the winter sunlight which passes through the windows and warms the darkened surface of the floor, wall, and water-filled drums or other storage elements to absorb heat.

Roof Ponds

The basic concept of a roof pond is one of a horizontal water storage (pond) facility on the flat roof of a building. The water is kept either in small bags or in one large container (Figure 9). During winter, the water on the roof is exposed to the sun and is heated by it. When the sun goes down, an insulated roof covering covers the water and the heat radiates down into the living space. In the summer, the system works in reverse.

Issues in Solar Passive Building Technologies

In the current context, mountain development involves both economic prosperity and the sound health of the environment. Given the increasing constraints in natural resources and growing environmental concerns in the mountains, improving energy efficiency and the use of environmentally-sound material and techniques for building construction are prerequisites to the creation of decent living conditions.

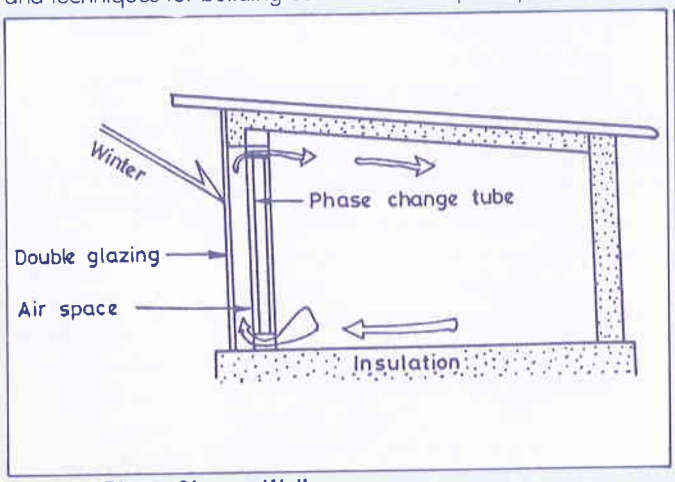

Figure 7: **Phase Change Wall**

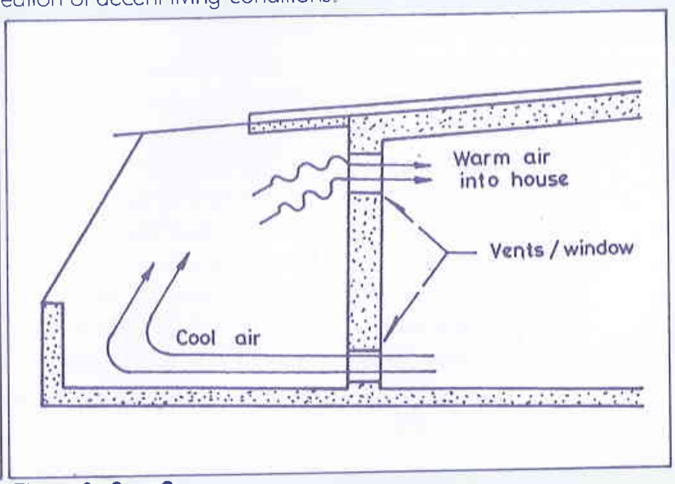

Figure 8: **Sun Spaces**

Technological Choice, Accessibility, and Cost

The types of technology employed to provide heat primarily depend on the climatic conditions and easy access to a particular form of energy. For example, in moderate climates in the rural areas of the HKH region, heat for cooking food and keeping the house warm is provided by rudimentary fuelwood-burning stoves, whereas, in the extremely cold climatic zone, supplemental heating is provided by burning biomass fuels. With increased access to materials (primarily plastic because of low transportation and handling costs) in isolated mountain areas, and by creating awareness about orientation, domestic heating can be improved and use of wood and biomass made more efficient than is currently the case by placing the fuelwood stove in the wall between the kitchen and the adjoining room.

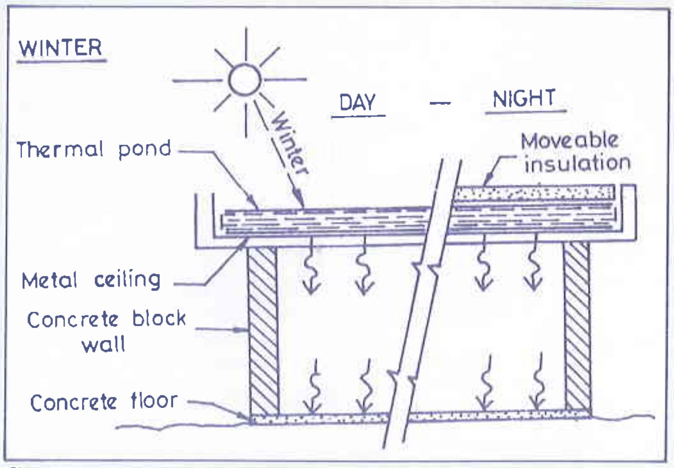

Figure 9: **Roof Ponds**

Mountain people are not unaware of the health hazards caused by smoke pollution, but they lack access to efficient options and have to make do with whatever is available. Economics limit the degree of comfort to which mountain households can aspire and also the ability or readiness to invest in building. Here it is important to look at the building from a life-cycle perspective. Pay-back periods are different for different components - the building envelope itself being the most durable.

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Housing as an Energy-saving Option and Drudgery Reduction

The present situation is such that a traditional cooking stove serves multiple functions; cooking, heating, and drying. The introduction of passive solar building technologies will not only help reduce the amount of biomass fuel needed for space heating but also for cooking: and this is because the temperature difference between heat source and heat sink decreases by minimising the heat loss from the surroundings. This reduction will help decrease the time required for fuelwood collection, thereby alleviating the workloads of women and children. In addition, this would probably lead to the use of improved cooking stoves.

Housing as a Health Improvement Option

Adopting passive solar building technologies leads to a reduction in the use of open fires, substantially preventing exposure to unburned carbon particles. The need for proper ventilation to ensure efficient functioning of the passive system also creates better living conditions and improved indoor air quality. All these factors can eliminate health hazards to a significant degree; and particularly those to which women and children are exposed. In the long term, it will also help reduce the rate of deforestation in the mountains as well as the emission of greenhouse gases into the atmosphere.

Legislative Framework, Building Norms, and Codes

The modern construction sector appears to be concerned with active climatisation of buildings without being seriously concerned about increasing energy consumption and its impact on the surrounding environment. It is only concerned with cutting construction costs (financial) without considering the social costs (economic and environmental). In such circumstances, the role of the government in formulating and legislating building codes and monitoring them is mandatory. Introduction of norms, regulations, and bye-laws normally apply only to construction within what is called the formal sector of the economy. Many of the houses in mountain areas are, however, built outside this legal framework. Therefore, other means must be sought to complement the legal instrument in influencing informal construction activities. In this respect, financial incentives, combined with educational and awareness programmes for consumers, architects, and builders might provide one means of accelerating promotional activities for Passive Solar Building Technologies.

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Further constraints to energy-saving architectural design are lack of norms, information, documentation and skills, and the fact that market values exceed the value of energy and comfort.

In this respect, manuals on low-cost housing and training would be appropriate, and in this area academic institutions and technical vocational training institutions should play a catalytic role.

Concluding Remarks

It is important to improve awareness and knowledge about the prevailing conditions concerning indoor climate, thermal performance, and energy consumption in today's buildings and to suggest improvements in the form of up-to-date building norms and design parameters suitable for different climatic zones in the HKH region. Besides these, the following measures need to be taken immediately so that energy resources and technological options that are economically sound, environmentally safe, and culturally inoffensive will be adopted.

- Develop different proto-types for building designs (government housing schemes, schools, private buildings), climates, and economic levels. These designs and design guidelines should be made available to architects, building developers, and local masons.
- Develop handbooks that will encourage the use of local, environmentally benign building designs and materials to improve indoor environments in the mountains.
- Organize intellectual discourse among policy-planners, practising engineers and builders, and researchers from the region to carry out an inventory of climatic zones, assess the suitability of building types and materials, and develop methods, tools, and regulations for saving energy within the passive solar building sector.
- Organize training programmes for local masons, building developers, and architects to make them aware of new concepts, knowledge, methods, and design practices relating to Passive Solar Building Technologies.
- Generate awareness among people, construction-sector employees, and building developers about various types of passive solar technologies as well as about the ill effects of rampant consumption of biomass and commercial fuels that threaten the sustainability of the ecosystem.
- Strengthen research activities in universities and research organizations within the building industry, enabling them to develop energy-efficient building designs. Research on low-cost and energy-efficient materials and construction techniques (within both the formal and informal sectors), giving due consideration to the traditional practices and knowledge base, should receive high priority.
- Establish a suitable knowledge bank on PSBT and make it available to the market as well as to entrepreneurs.

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