Practical Guide for Passive Solar Heated Buildings (PSHBs) – Design and Practice

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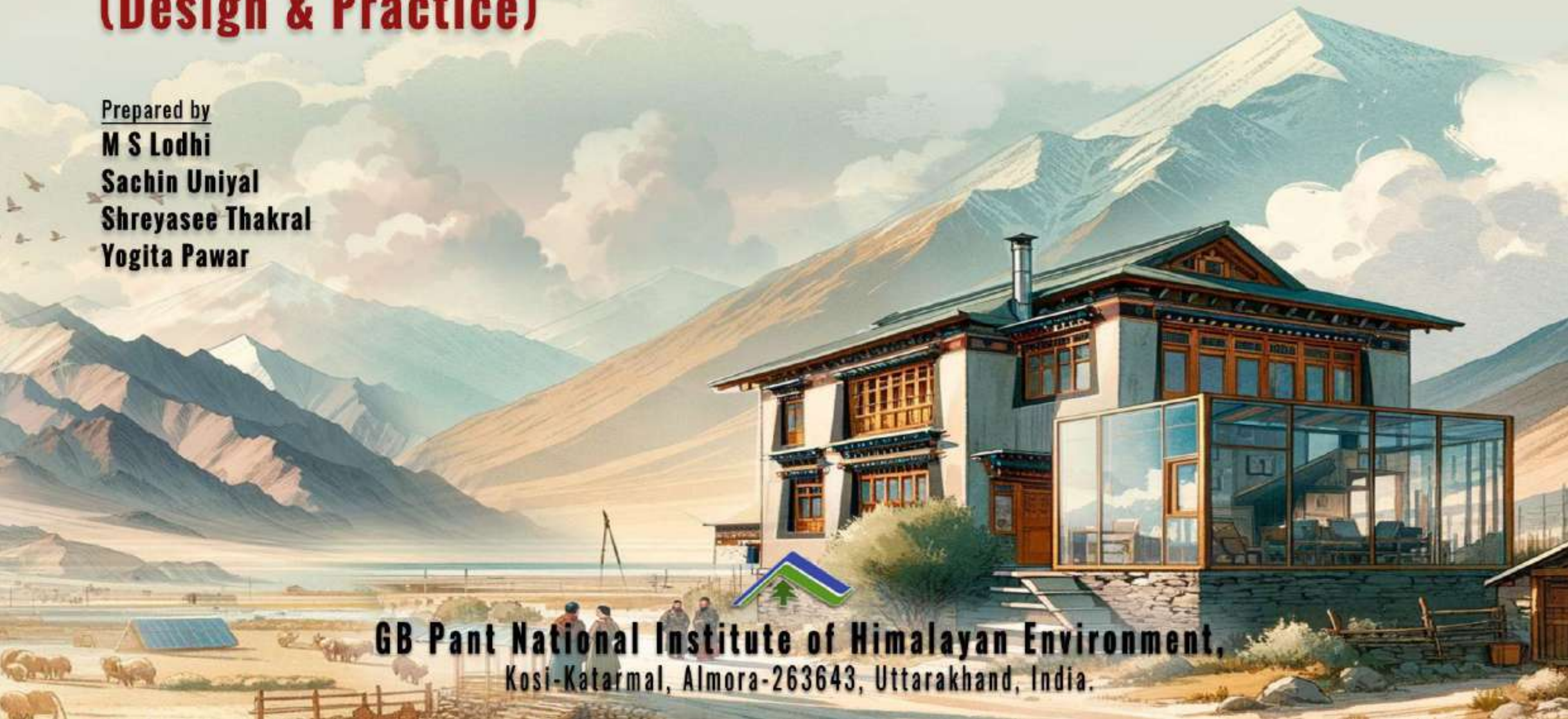
PRACTICAL GUIDE

For
Passive Solar-Heated Buildings (PSHBs)
(Design & Practice)



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Acknowledgement and Credits

The strategies proposed in this handbook are the result of research, field and literature studies undertaken by the authors in Indian Himalayan Region for the project titled "Mainstreaming Passive Solar Heated Buildings in the Indian Himalayan Region: Integrating modern science with traditional practices to enhance climate resilience," funded by the National Mission on Himalayan Studies (Ministry of Environment, Forest and Climate Change, Government of India), Implemented by the G.B. Pant National Institute of Himalayan Environment (GBP-NIHE). The authors are extremely grateful to NMHS for the financial support and resources. Also we would like to thanks Prof. Sunil Nautiyal, Director, GBP-NIHE, for his invaluable insights and guidance.

Significant documents that aided in the contents:

Energy Conservation Building Code 2016
National Building Code 2016
LEC Integration Design Manual, GERES (Groupe energies renouvelables, environnement et solidarités)

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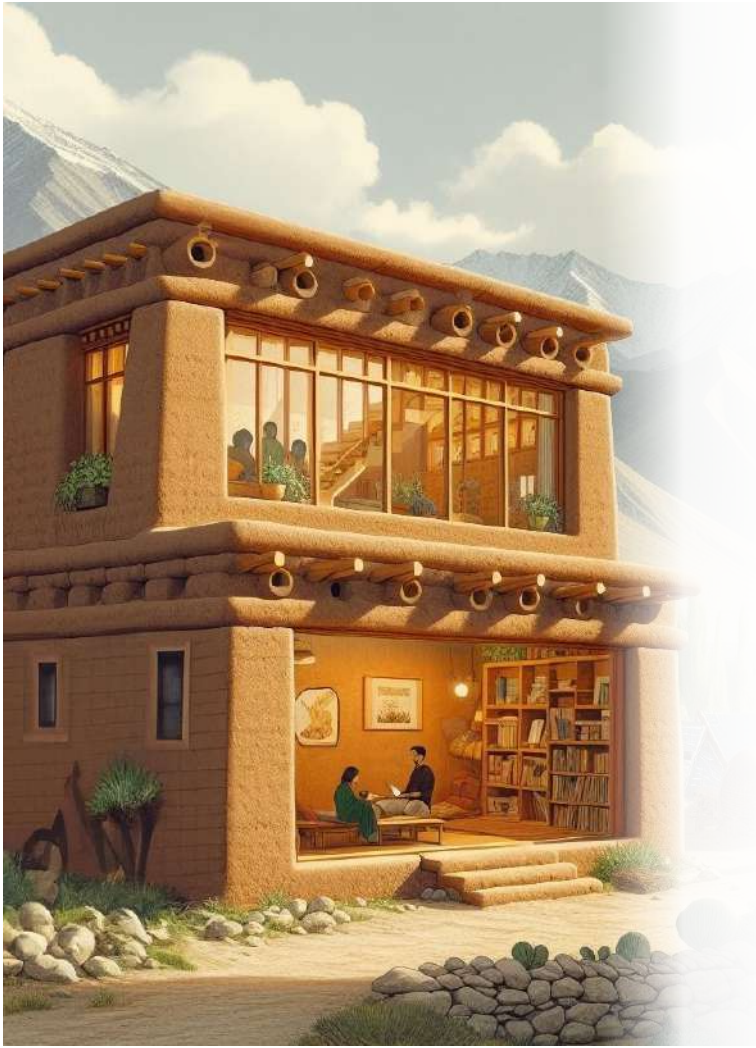
Cover Page Design

Sachin Uniyal & Shreyasee Thakral

Edition - March 2024, Cite as : Lodhi MS, Uniyal S, Thakral S, Pawar Y (2024), Practical Guide For Passive Solar-Heated Buildings (PSHB)- Design & Practice, GBP-NIHE, Kosi Katarmal, Almora, ISBN : 978-93-340-3505-6

Published By - G.B. Pant National Institute of Himalayan Environment (An Autonomous Institute of Ministry of Environment, Forest and Climate Change, Govt. of India), Kosi-Katarmal, Almora, 263643 - Uttarakhand, India.



About the Practical Guide

This practical guide is tailored for architects, practitioners, civil engineers, contractors, local masons, and home builders in the Indian Himalayan region. It presents practical insights and strategies for embracing passive solar design to craft energy-efficient and comfortable spaces. Through site-specific examples and illustrations, the guide promotes the adoption of passive solar principles, tapping into ample sunlight and natural resources to enrich living conditions while reducing environmental footprint. Whether you're starting to construct your house or an experienced home builder, this guide will equip you to design climate-responsive buildings that make the most of solar energy.

How to use this Practical Guide ?

1. **Sections :** The manual is divided into several sections, each focusing on specific aspects of passive solar design and practice. Take advantage of the table of contents to quickly locate information relevant to your project needs.

2. **Illustrations and Diagrams:** Throughout the manual, you'll find detailed illustrations and diagrams that visually depict key concepts and design strategies. These visuals are designed to enhance understanding and facilitate the implementation of passive solar principles in your projects.

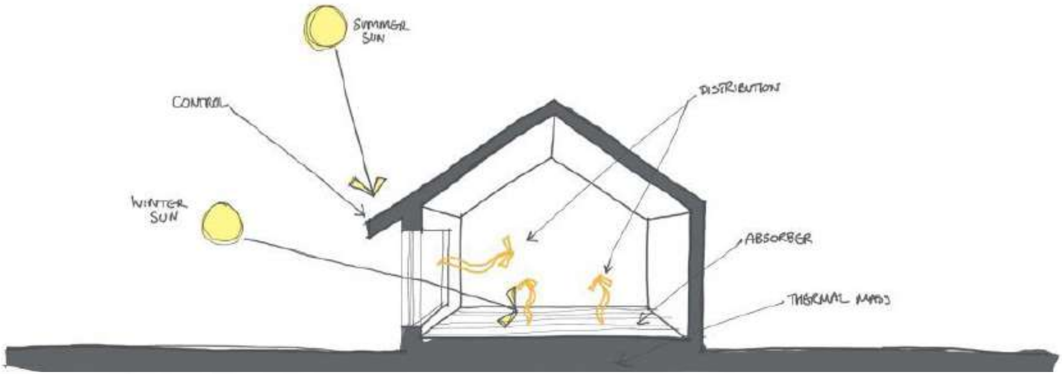
3. **Annexures:** To find out your space heating needs and climate zone, you can directly go to annexure and locate your region.

PRACTICAL GUIDE

For **Passive Solar-Heated Buildings** (PSHBs)- Design & Practice.

CONTENTS

What are **Passive Solar Heated Buildings ?**

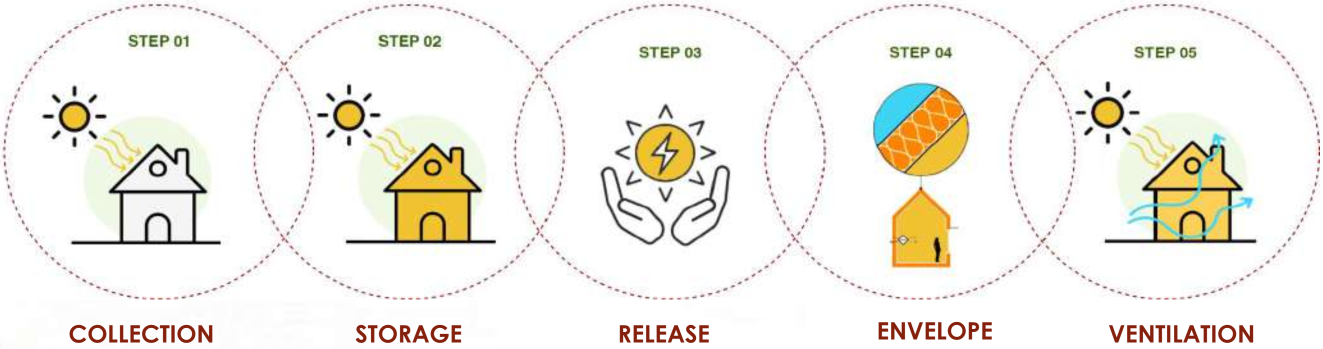


- Refers to **technologies & design features** used to **heat buildings without power consumption.**

  OR

- Refers to kind of construction **uses the maximum of sun energy for heating** **without using mechanical tools** to transform/ transport the energy.

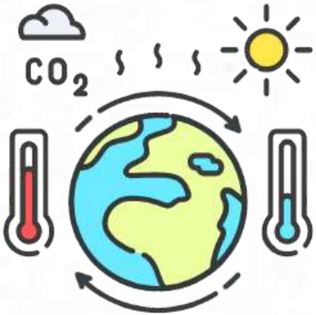
What are Passive Solar Heated Buildings ?



Passive Solar Concept involves the above mentioned processes for harnessing solar energy and creating comfortable indoor conditions.

Embrace the sunshine and dance with the wind, for in their gentle whispers lies the promise of a sustainable future powered by renewable energy.

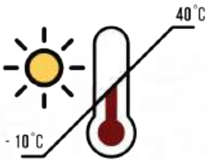
~ Yashu P ~



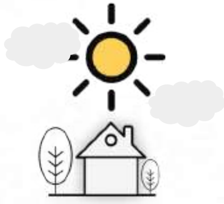
01 Know your Climate Zone

Before constructing or designing any passive solar heated building, It is essential to have a good understanding of the local climate. (Including factors like: exterior temperature, sunshine, wind direction)

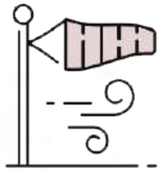
Factors affecting Local Climate



Exterior Temperature



Sunshine & Sky Condition



Wind Speed

Humidity

Topography

Precipitation

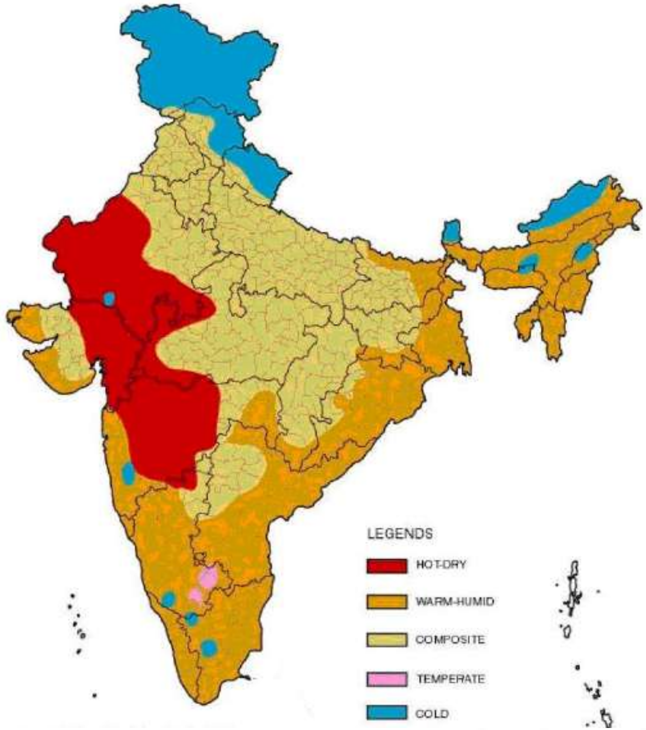
The local climate of a region is affected by various climatic factors as mentioned above. These factors affect the **lifestyle** of people as well as **thermal comfort** and **space heating demands.**

Climatic Zones

The Energy Conservation Building Code (ECBC) defines climate zones based on specific energy consumption requirements for building design and operation.

- **Hot- Dry:** Ahmedabad, Vadodara, Jaisalmer
- **Warm-Humid:** Mumbai, Panjim, Bangalore, Tezpur, Guwahati
- **Composite :** New Delhi, Saharanpur, Nagpur
- **Cold :** Kullu, Leh, Shillong, Srinagar
- **Temperate :** Bangalore

Out of all climate zones, following are part of the Indian Himalayan Region: Cold, Composite, Warm-Humid



Characteristics of Climate Zones

Climate Zone	Climate Variations	City Examples
Composite	Temperate in Winter and Hot in Summer Cold in Winters & Warm in Summer	Kalka (Himachal Pradesh)* Shimla (Himachal Pradesh)*
Cold	Cold and Sunny	Kaza (Himachal Pradesh)** Leh (Ladakh)**
Cold	Cold and Cloudy	Srinagar (Jammu & Kashmir)**
Cold	Cool and Humid	Guwahati (Assam)*** Shillong (Meghalaya)***

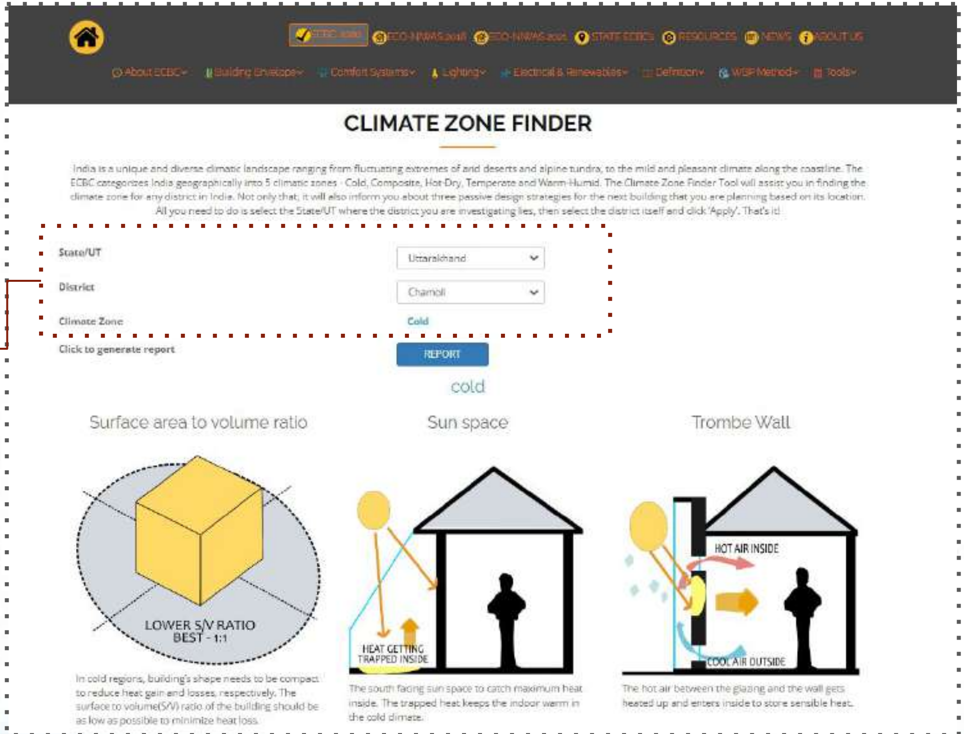
Refer **Annexure 1** for a comprehensive list of districts with their climate zones.

*GERES-LEC Integration Design Manual.
**ECBC Design Guide
*** Singh et al, 2007. "Bioclimatic Chart for Different Climatic Zones of North East India." In 3rd International Conference on Solar Radiation and Day Lighting (SOLARIS 2007). New Delhi: Anamaya Publishers

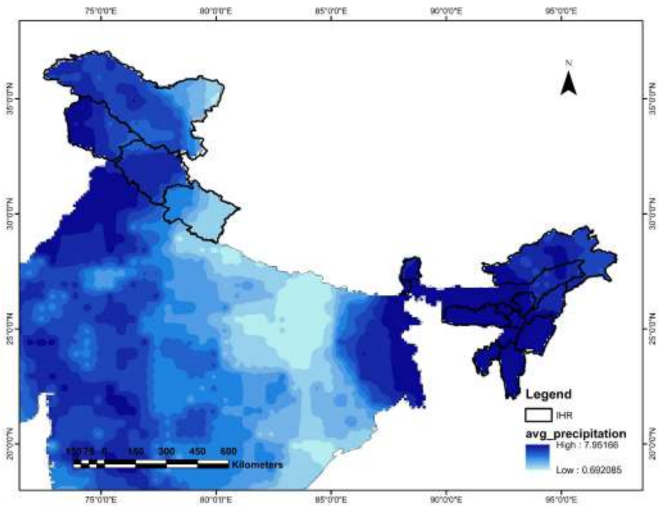
How to Find out your Climate Zone?

The **Climate Zone Finder** Tool will assist you in finding the climate zone for any district in India

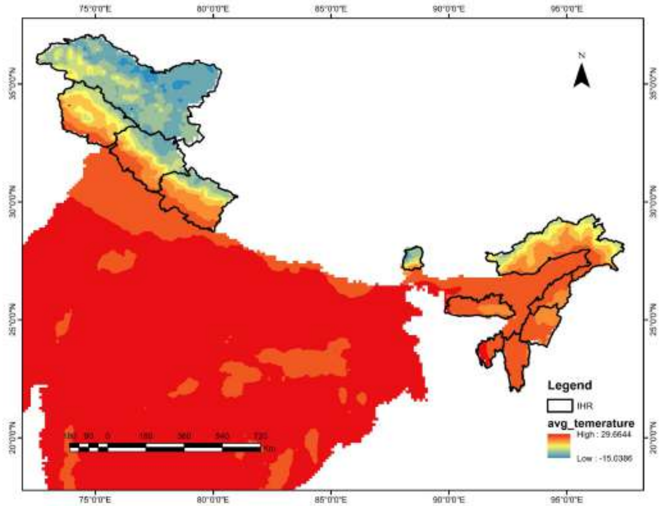
1. Go to the website: https://ecbc.in/climatezonefinder
2. Select your State and relevant Region
3. It will tell you your climate zone and also three passive design measures suitable for the zone



Climatic Data



Annual Average Precipitation*

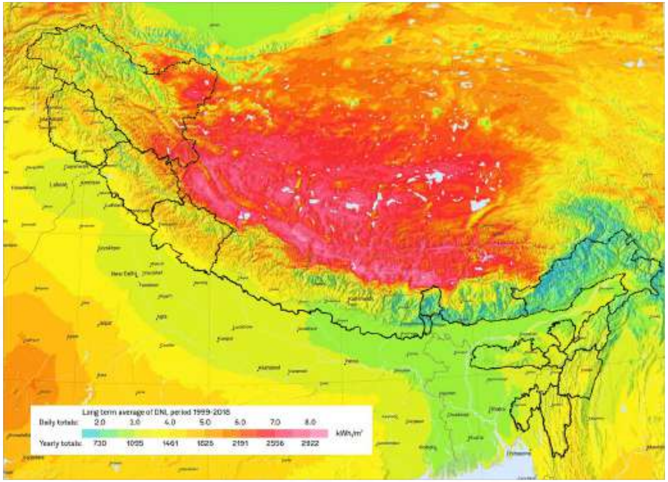


Annual Average Temperature*

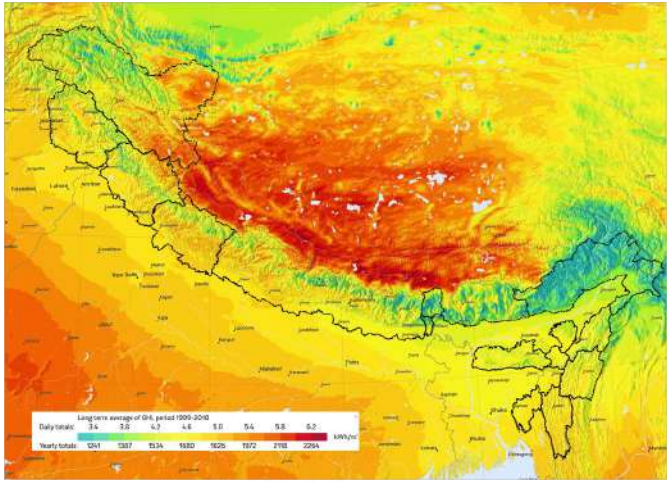
Climate data related to **Annual average precipitation & Temperature** of Indian Himalayan Region.

*Maps Created by Dataset sourced from Climate Research Unit. University of East Anglia, WorldClim

Solar **Insolation**



Direct Normal Irradiance(DNI)



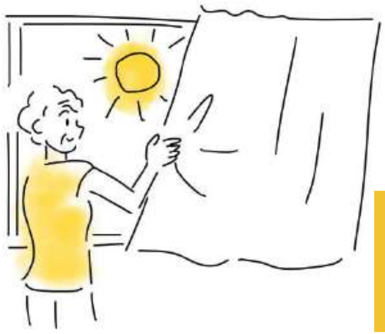
Global Horizontal Irradiance (GHI)

***DNI -it refers to the amount of solar radiation that reaches the Earth's surface directly from the sun in a unit area, typically measured in watts per square meter (W/m²). It represents the solar energy received when the sun is directly overhead and is not affected by any obstacles or atmospheric conditions.**

***GHI - it is the total amount of solar radiation received on a horizontal surface, including both direct and diffuse sunlight, measured in watts per square meter (W/m²). It accounts for all solar radiation that reaches a given area, considering the direct sunlight as well as the diffuse sunlight scattered by the atmosphere.**

Maps Created by Dataset sourced from Data Global Solar Atlas

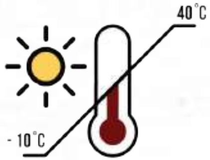
Sustainability isn't just a goal; it's a journey of joy, discovery, and innovation. Let's walk this path together, fueled by the renewable energy of passion and purpose.



02 Know your Building's Heating Demand.

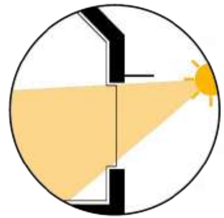
On the basis of Climate Zone, Daily Heating Demand of Particular Building can be calculated by **Heating Demand Degree (HDD).**

Heating Degree Day (HDD)



Exterior Temperature

Heating Degree Day



Daily sunshine

- A **heating degree day (HDD)** is a **measure of how much heating is needed** for a building in a given location on a **particular day or time duration.**

- It is calculated by **subtracting the daily average outdoor temperature from a reference temperature (usually 65°F or 18°C).**

- **If the average temperature is below 65°F or 18°C**, then there will be a **positive number of HDDs**, indicating that **heating is needed.**

Calculating HDD

HDD Calculation:

Heating Degree day for your home is calculated by summing the differences between a base temperature (Usually 18° C) and the average daily outside temperature over a year. This helps estimate the amount of heating needed to maintain comfort.

$$HDD_{18} = \sum_{i=1}^{365} (T_{base} - T_{avg})$$

If T_{avg} is less than or equal to 18 °C, then HDD = (18 -T_{avg})

If T_{avg} is higher than or equal to 18 °C, then HDD = 0

Where- HDD: Heating Degree Days.

i : day number (Ex: 7th January → i=8, 3rd February→ i=34)

T_{base} : base temperature (usually a comfortable indoor temperature like 18°C or 65°F).

T_{avg} : average daily outdoor temperature for each day over the specified period.

$$T_{avg} = \frac{(T_{min} + T_{max})}{2}$$

T_{min} : Outside minimum temperature for one day

T_{max}: Outside Maximum temperature for one day

Σ : sum of all the differences between T_{base} and T_{avg} for each day.

Example

Day	Average Temperature (T_{avg})
Day 1	0 °C
Day 2	2 °C
Day 3	5 °C

Calculation of HDD of given three days for base temperature at 18 °C

$HDD_{Day\ 1}$ = (18- 0) = 18
$HDD_{Day\ 2}$ = (18- 2) = 16
$HDD_{Day\ 3}$ = (18- 5) = 13

Calculation of total HDD for the three days:

$HDD_{(total\ 3\ days)} = HDD_{Day\ 1} + HDD_{Day\ 2} + HDD_{Day\ 3}$

= 0 + 13 + 10

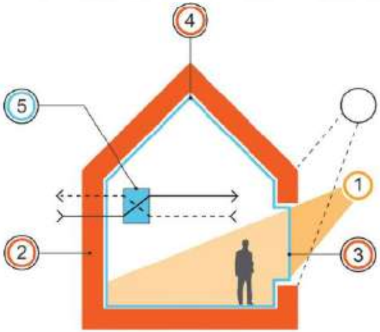
= 23 $HDD_{(base18\ °C)}$

It is also possible to calculate HDD for other base temperatures and according to the schedule of the building (Day use: 10 AM to 5 PM & Night Use: 24 hr)

Calculating HDD

HDD @ 18°C - [base- 360/24hrs(day)]	Space Heating Demand	Example Cities
Below 500	Low/Negligible	Agartala (Tripura), Itanagar (Arunachal Pradesh), Kohima (Nagaland), Imphal (Manipur), Aizawl (Mizoram)
500 - 1000	Some	Pithoragarh (Uttarakhand), Almora (Uttarakhand), Mussoorie (Uttarakhand), Shimla (Himachal Pradesh), Nubra Valley (Ladakh), Ziro (Arunachal Pradesh), Shillong (Meghalaya)
1000 - 1500	Moderate	Pauri (Uttarakhand)
1500 - 2000	Significant	Pratapnagar (Uttarakhand)
2000 - 3000	High	Pithoragarh (Uttarakhand), Gulmarg (Jammu and Kashmir), Srinagar (Jammu and Kashmir)
3500 - 5000	Very High	Munsyari(Uttarakhand), Joshimath (Uttarakhand), Gangtok (Sikkim)
Above 5000	Extremely High, Intensive	Gangotri/Bagori (Uttarakhand), Kaza (Himachal Pradesh), Leh (Ladakh), Kargil (Ladakh)

- In **Low HDD** region, **heating** is **not a priority**
- For **moderate to high HDD**, **space heating is required** and **passive solar measures** are recommended.
- Refer to **Annexure 2** for List of **Major Cities** with their **HDD Values**

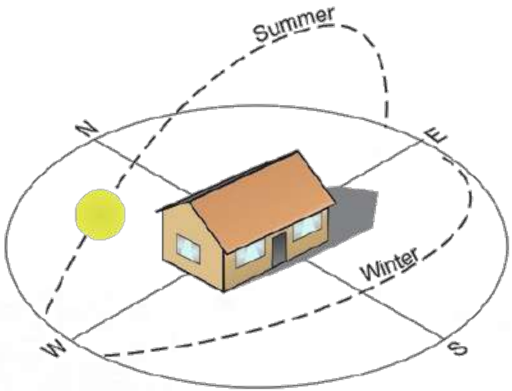


03 Know the Basic Design Principles of Passive Solar Heated Building

**Prior to construct or design any passive solar heated building,
It is essential to know well the General basics design principle for Passive solar Building.**

Building Orientation

Orientation



South Facing

- **Position of the Sun** is a major factor in heat gain in buildings, which makes **accurate orientation of the building a fundamental consideration** in passive solar construction.
- **North-facing building is less** ideal **than south facing buildings** as they receive **less direct sunlight.**
- Best choice for a **Passive solar building** is to orient its maximum facade **towards South.**

Wind Pattern

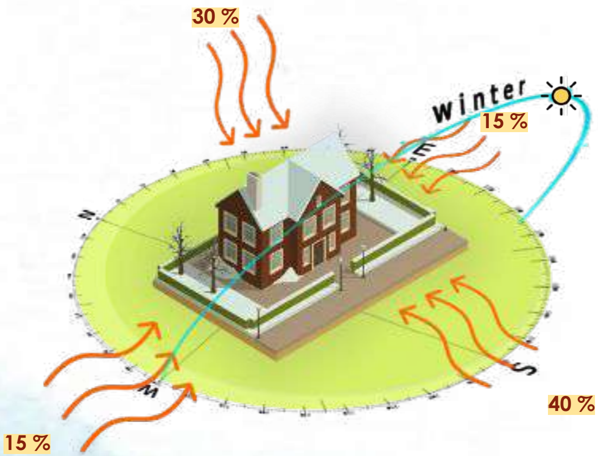
Orientation

COLD CLIMATE
Window size should be minimized in the direction of wind.

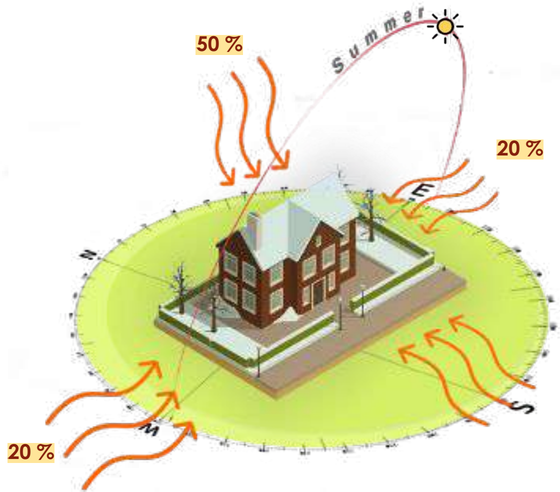
COMPOSITE OR TEMPERATE CLIMATE
Window size should be maximized in the direction of wind to induce natural ventilation

- **Wind needs to be restricted** in cold regions (a major factor in heat gain in buildings), which makes **accurate orientation of the building a fundamental consideration** in passive solar construction.
- However in moderate or composite regions, building orientation should consider wind patterns for inducing ventilation in summer months. Windows should be openable towards the windward side.

Sun Path & Radiation



Sun radiation
in Winters

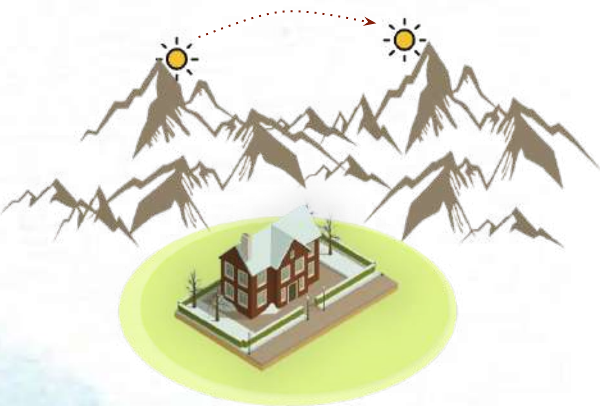


Sun radiation
in Summers

Sun Radiation received by each face of Building in LADAKH

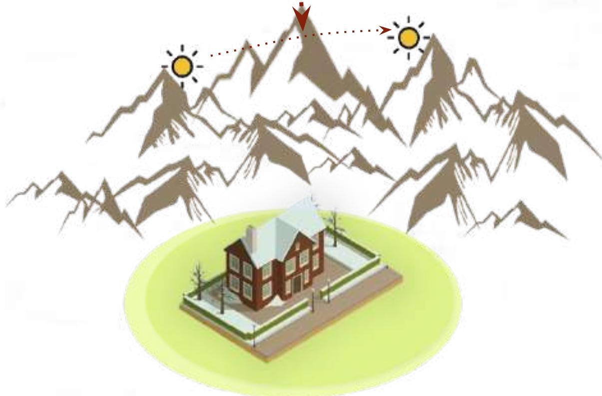
Site Selection

No Obstacle Interference



More Sun

Obstacle Interference



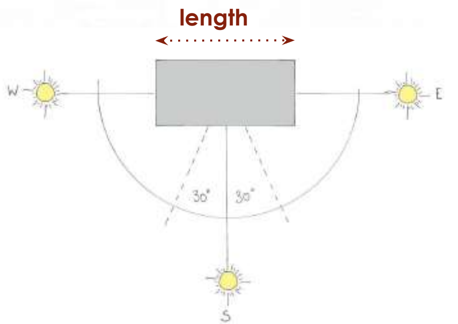
Less Sun

Distant Obstructions mainly created by Mountains.

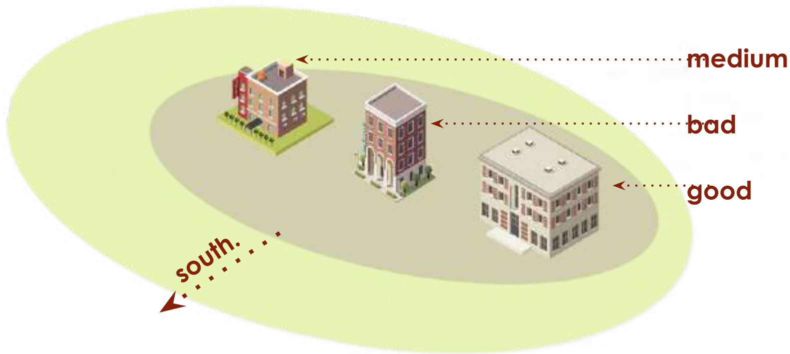
Site Selection

Distant Obstructions mainly created by neighbourhood buildings.

Building Arrangement



Max. Building facade towards south.



Building shape / surface to Volume ratio

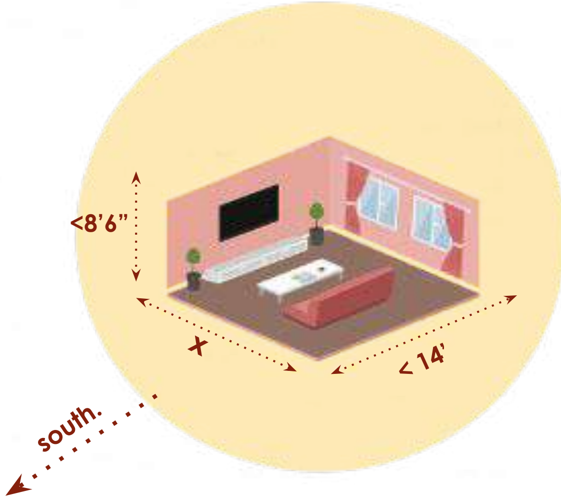
- Surface to volume ratio = $\frac{\text{Total Envelope surface of the building (sq. ft.)*}}{\text{Total volume of the building (cu. ft.)**}}$
- In ideal case for Cold Regions: Surface Volume ratio is 1:1

*Total Envelope Surface Area: This includes all external surfaces of the building that are exposed to the environment, such as walls, windows, and the roof. It's the sum of the surface areas of all these components.
** Total Volume of the Building: This represents the total amount of space enclosed by the building, encompassing all the floors and rooms.

Room Size

Room Size Limitations:

Dimensions	Limitations
Width	≤ 14 feet
Height	≤ 8.5 feet
Length	No limitation



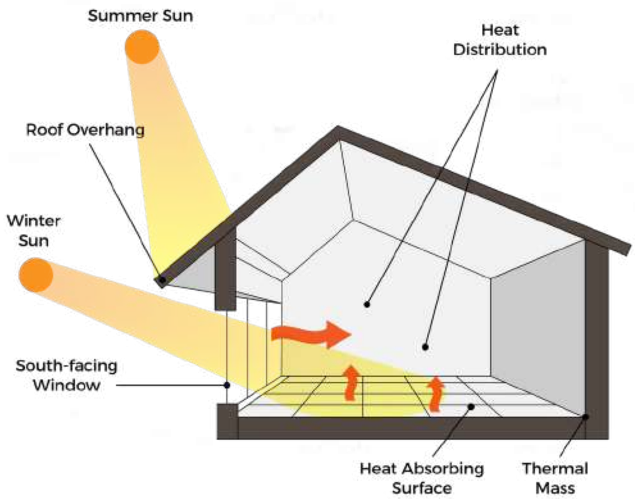
Max. Building facade towards south.

- **Height of room should be limited to decrease the volume of room to Heat.**
- **The width should also be limited in order to not decrease too much the ratio between south face & floor surface.**

Fenestration & Shading

Rules for Windows opening:

Orientation of Building Face	Size of Glazing
South	Large
North	Nil / As small as possible
East	Small
West	Small

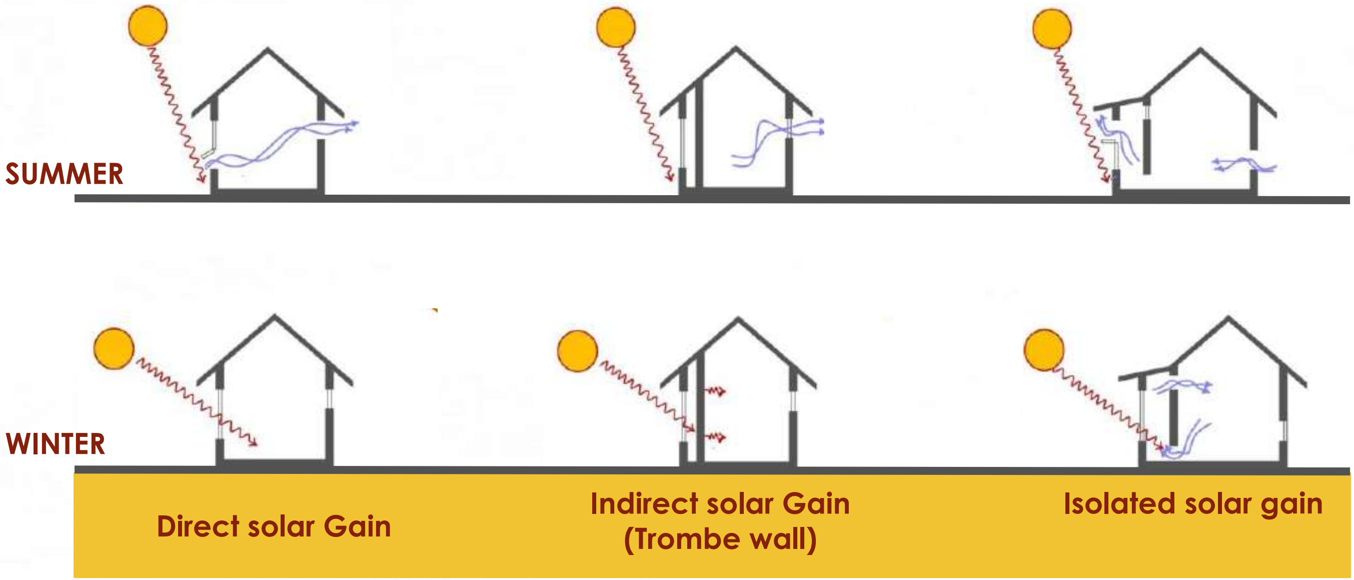


South horizontal overhang design rule.

- Windows installed on North face will create **heat loss during winters.**
- Limiting **Windows' size** on West and East orientation.

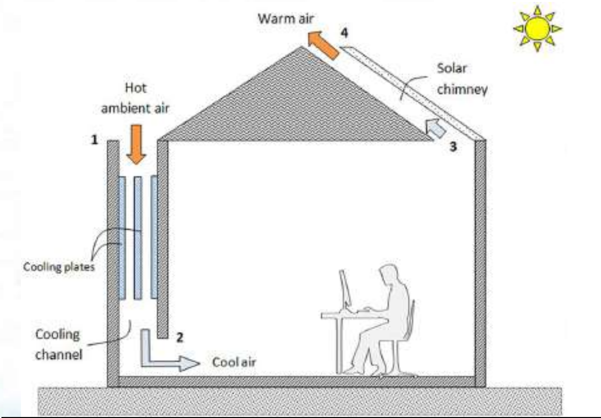
Image Source: https://enviindia.com/sustainability

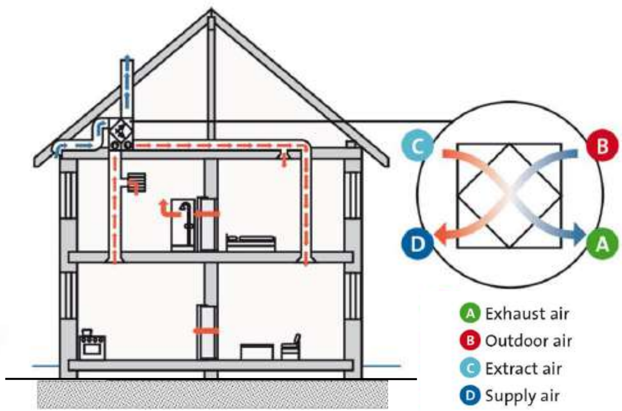
Solar Heat Gain



Different strategies for maximum solar gain in summers and winters.

Natural Ventilation





2.

Scope for ventilation in PSHB

Image Source : 1- Jafari, A., & Poshtiri, A. H. (2017). Passive solar cooling of single-storey buildings by an adsorption chiller system combined with a solar chimney. Journal of cleaner production, 141, 662-682. , 2- https://www.bdh-industrie.de/en/heating-systems/ventilation-systems

As we tread lightly upon the Earth, let's leave behind footprints of hope, powered by the renewable energy of determination and kindness.

04 Know the Material Selection Process & Vernacular Natural Resources.

Become aware about your **surrounding natural resources,** which can be helpful in creating your **passive solar heating building.**

Natural materials are the **best** option for **construction.** They have excellent **thermal and acoustic characteristics** and **avoid harming** the **environment.**

Mud based Adobe Construction

Mud as insulative material

Adobe brick wall

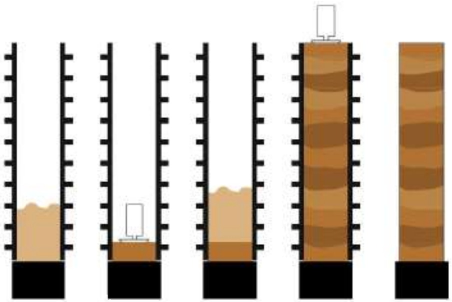
Adobe Building- Dharmalaya, Keori, Himachal Pradesh

- Adobe brick is made from a mixture of **mud and straw**, which is shaped into **bricks and dried in the sun.**
- Adobe brick is an excellent insulator, and it's very **good at storing heat.**
- When used in **passive solar heated buildings**, adobe brick walls can absorb heat during the day and release it at night, helping to keep the **building warm.**

Image Source 1: https://lovehomedesigns.com/how-much-does-a-brick-weigh/; 2: https://dharmalaya.in/

Mud based Rammed earth construction

Mud as insulative material



1. Rammed earth construction

Rammed earth building- SECMOL, Leh, Ladakh

- **Rammed earth** is a **method** that involves **compacting a mixture of mud, clay, and gravel into walls.**
- Like adobe, rammed earth is a **good insulator and heat storage material.**
- It is also **very durable**, and can **last for many years.**

Image Source
1:https://www.archdaily.com/89798/a-house-in-luanda-competition-winner-pedro-sousa-tiago-ferreira-tiago-coelho-barbara-silva-madalena-madureira/0001dc ; 2: https://architecture.live/secmol-school-in-leh/

Mud based Cob Construction

Mud as insulative material

Mud Cob construction process

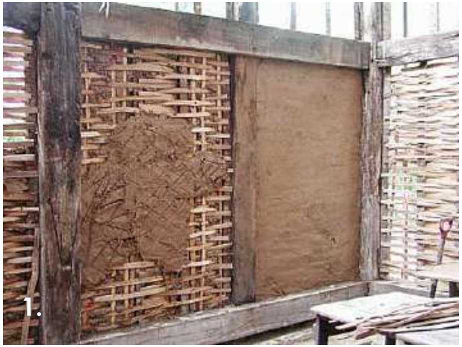
Mud Cob Cottage in SECMOL, Leh, Ladakh

- In Mud Cob, the walls are made from a **mixture of mud, straw, and water.**
- Due to **insulation and thermal mass,** cob construction has a good thermal performance .

Image Source 1: Investigating Raw Earth Construction in Morocco: Actual and Future Prospects - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Cob-construction-by-stacking-mud-balls-Vyncke-2018_fig2_371583618 [accessed 14 Mar, 2024]
2: https://earthbuilding.in/portfolio/cob-car-cottage-secmol-leh-ladakh/

WATTLE & DAUB

Mud & Wood reed/Bamboo



Wattle & Daub construction process

Wattle & Daub walls in Ganga Maki Studio, Dehradun,Uttarakhand

- This technique goes by many names—basically it consists of a **structure of vertical wooden posts, connected horizontally or diagonally** with pieces of **wood, reeds, bamboo, or other fibers.** Together they form a cage that can then be filled with an **earth mixture.**
- Wattle and daub has been **proven earthquake resistant,** and it **maintains a pleasant microclimate** in its interior.

Image Source: 1. https://www.lowimpact.org/categories/wattle-daub 2
https://themeritlist.com/2019/07/15/ganga-maki-textile-studio-citation/

Timber

Timber as insulative material

Different use of Timber in Interior & Exterior, Traditional Homes in Kwalgaon and Banas villages in Uttarkashi District, Uttarakhand

- **Wood** is not only a **good natural insulator,** and even a **bit better than standard insulated frame walls.**
- **A six-inch-thick log wall** actually provides **better energy performance** than any other **conventional kind of wall.**

Image Source: 1. Authors, 2. Authors

Existing Vernacular Practices

Kath-Kuni - Himachal Pradesh; Characterized by interlocking alternate layers of wood and stone masonry

Dhajji-Dewari - Kashmir; Utilizes a timber frame filled with stone or brick masonry infill.

Koti-Banal - Uttarakhand; Alternating layers of stone and wood with high plinth and 3-5 storeyed structure

Adobe/Rammed Earth - Ladakh; Thick mud/adobe or rammed earth walls, flat roof and small windows with carved projected frames.

Rinchenpong Heritage House - Sikkim; Stone and wood structure with sloping roof.

Bamboo & Cane House - Arunachal Pradesh; The example shows a Galo house, typically made of wood, bamboo, and cane, with roof made of toko leaves.

Image Source: 1. https://www.architecturaldigest.in/content/shivadya-eco-friendly-resort-in-manali/, 2. https://www.thehimalayanarchitect.com/architecture/dhajji-dewari-traditional-earthquake-resistant-construction-of-kashmir/ 3. Author, 4. Author, 5.https://www.researchgate.net/figure/Old-Leh-town-overlooking-Leh-Palace-of-the-left-and-Tsemo-Gopma-on-the-right_fig2_356963726%20[accessed %2017%20Mar,%202024, 6. https://commons.wikimedia.org/wiki/File:Rinchenpong_Heritage_House.jpg, 7 https://www.researchgate.net/publication/343364158_Nature_The_Ethos_of_Arunachal_Pradesh_Architecture

The relationship between renewable energy sources and the communities we expect to host them must be appropriate and sustainable and, above all, acceptable to local people.

~ Owen Paterson ~

05 Let's prepare Design Methodology/ Process & Techniques for Your PSHB.

It is essential to use appropriate design methodology, process, and techniques before constructing a passive solar heated building.

Design Process

Site Analysis

- Conduct a thorough analysis of the site's climate, solar exposure, wind patterns, and other local climatic & physical factors.
- Analyze the site's shading patterns to optimize required passive solar heating.
- Evaluate the potential for natural ventilation and cross-ventilation in the building design.
- Study the site's solar path and potential for maximum solar gain.
- Consider the site's proximity to green spaces, trees, and landscaping.

Energy Need assessment.

- Calculate the building's heating Demand using energy modeling software or manual methods. (Refer Page 10)

- Analyze the building's lighting needs and potential for natural light and energy-efficient lighting systems.

- Evaluate the building's energy demand during peak usage times and identify opportunities for load shifting or demand management.

- Also, take into account relevant energy codes or regulations, such as Energy Conservation Building Code, Eco-Niwas Samhita, and local building by-laws.

Design Strategies.

- Optimize building orientation and window placement to maximize solar gain in the winter and minimize it in the summer.
- Incorporate shading devices such as overhangs, louvers, and shading screens to control solar exposure.
- Use thermal mass materials such as concrete, brick, or stone to store and release heat energy.
- Maximize the use of natural light through the use of skylights, solar tubes, and light wells.
- Incorporate passive cooling strategies such as natural ventilation, night cooling, and earth-cooling systems.
- Design for flexibility, to adapt the building's energy use according to the changing weather conditions and occupancy.

*U-Value - The U-Factor measures how well the window insulates. While the U-Factor can take any value, in general for windows it ranges from 0.20 to 1.20. The lower the U-Factor, the better the window insulates
image Source - https://www.energy.gov/sites/prod/files/guide_to_energy_efficient_windows.pdf

Building Envelope & Insulation

- Specify high-performance insulation in walls, roof, foundation, and windows to minimize thermal heat loss.
- Properly seal and insulate all building envelope penetrations, such as around windows, doors, and electrical outlets.
- In addition, incorporate air-tightness measures to prevent drafts and minimize infiltration.
- Utilize high-efficiency windows and doors with low U-values* to reduce heat loss.

*U-Value - The U-Factor measures how well the window insulates. While the U-Factor can take any value, in general for windows it ranges from 0.20 to 1.20. The lower the U-Factor, the better the window insulates

image Source - https://www.energy.gov/sites/prod/files/guide_to_energy_efficient_windows.pdf

Active Solar System*

- Incorporate active solar systems, such as solar thermal panels or photovoltaic panels.
- Generate electricity through active solar systems.
- Use active solar systems to heat water and reduce energy consumption.
- Use solar thermal panels to generate heat for the building.
- Utilize photovoltaic panels to produce electricity for the building.

Solar Cooker

Solar Water Heater

*Not a part of Passive Heating Strategy. Can be incorporated such measures where heating demand is very high and solar insolation is very low. Therefore, to make effective heating solution approach active measures can be incorporated.

Climate Specific Design Strategies.

- Utilize cross ventilation for warm and humid climates.
- Design building envelope to suit the local climate.
- Incorporate shading devices as per local climate and your building requirement.
- Incorporate green roofs or walls to mitigate heat island effect.
- Incorporate natural lighting and ventilation in the building.

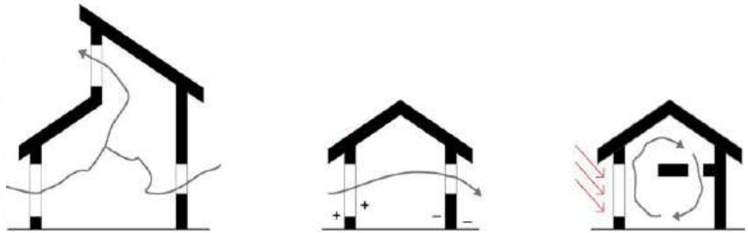


Image Source: https://www.aucklanddesignmanual.co.nz/sites-and-buildings

Simulation & Analysis.

- Use simulation software and energy analysis tools.
- Evaluate building's energy performance.
- Ensure that the building meets the design goals.
- Analyze energy consumption patterns.
- Optimize energy systems to improve performance.
- Identify opportunities for energy conservation.
- Conduct life-cycle cost analysis to evaluate the cost-effectiveness of various design options.
- Evaluate the building's compliance with energy codes and standards.

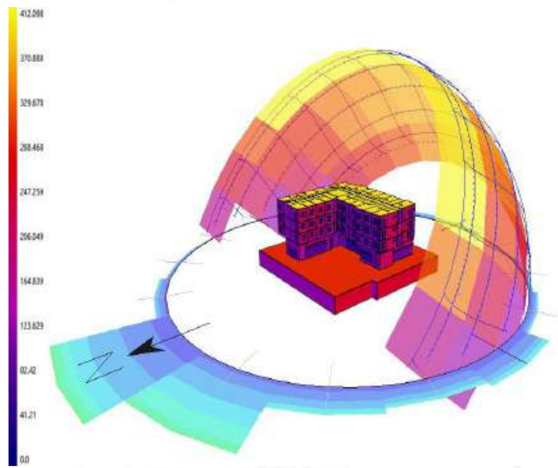
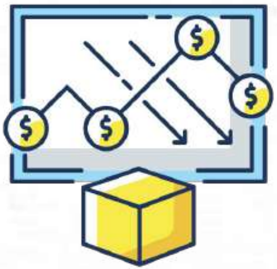


Image Source: https://egreenideas.com/

Implementation & Monitoring

- After the through analysis, Implement chosen design strategies for your PSHB construction.
- After Construction, Monitor the building's performance once it is in use.
- Ensure that the building meet its energy goals.
- Make any adjustments if required.
- Continuously monitor and update the building's energy design to improve its performance after construction.
- Involve the building occupants in energy conservation applications.
- Keep accurate records of energy consumption and cost to evaluate performance over time.



06 Let's do Cost Analysis for Your PSHB.

It is essential to evaluate the cost analysis before designing and constructing a passive solar heated building.

Define the Scope of Project.

- Clearly outline the building's size, occupancy, intended use, and location.
- Identify the key design parameters and assumptions.
- Define the building's energy performance goals and requirements.
- Identify the energy systems and technologies to be used.
- Identify any regulatory or compliance requirements that must be met.
- Define the project schedule and budget constraints.
- Identify the key stakeholders and decision-makers involved in the project.

Identify involved Costs.

Identify all costs associated with the building, Including;

- Cost of the land, materials, labor, and any other costs such as permits, inspections, and testing.
- Costs of the energy systems and technologies used.
- Costs of any specialized equipment or software needed.
- Costs of any professional services required such as design, engineering, or consulting.
- Costs of any regulatory or compliance requirements.
- Costs of any contingencies or unexpected expenses.
- Estimate the ongoing operating costs of the building, such as energy and maintenance costs.
- Identify any financing or funding sources and their associated costs.

Estimate costs for Different Design Options

- Cost Including passive solar and conventional heating systems.
- Consider the initial cost as well as the ongoing costs for operating and maintaining the systems.
- Compare the costs of different energy systems and technologies.
- Analyze the life-cycle costs of each option, including the costs of construction, operation, maintenance, and eventual replacement or decommissioning.
- Consider the economic and environmental benefits of different options.
- Consider the different costs of energy source and tariffs.
- Identify the best cost-effective option that balances the initial cost and the ongoing costs.

Assess Energy Consumption & Saving

- Estimate the energy savings that will result from implementing passive solar design strategies.
  a. Including the savings from reduced heating and cooling costs.
  b. Including any savings from reduced lighting or water heating costs.
- Estimate the payback period and the internal rate of return of the passive solar design strategies.
- Identify any potential drawbacks or limitations of the passive solar design strategies.
- Compare the energy consumption and savings of different design options.
- Evaluate the building's compliance with energy codes and standards.

Analyze subsidies & Tax incentives.

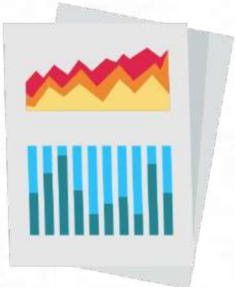
- Use financial analysis tools such as net present value, internal rate of return and payback period.
- Analyze the financial feasibility of the project.
- Compare subsidies & taxes for different design options.
- Identify the most financially viable option.
- Consider the long-term financial benefits and costs of each option.
- Consider any government subsidies or incentives available.
- Identify potential financing or funding sources.

Identify Risk & Mitigation.

- Evaluate construction delays or cost overruns and plan for how to mitigate them.
- Identify critical path and dependencies for the project.
- Assess the likelihood and potential impact of identified risks.
- Develop risk response strategies.
- Continuously monitor and assess risks throughout the project.
- Incorporate contingencies into project budget and schedule.

Renewable energy could reduce emission but also create jobs and improve public health.

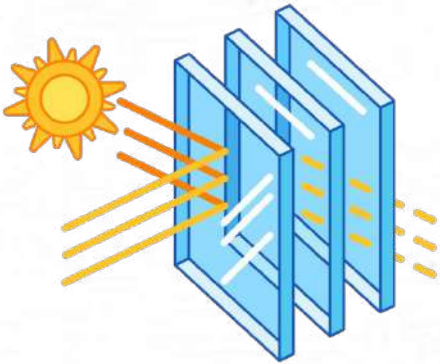
~ Paul Palman ~



07 Let's check Performance Standard/Index for your PSHB.

It is essential to evaluate the design of a passive solar heated building using performance indices and standards to ensure energy efficiency and safety.

Insulation Level



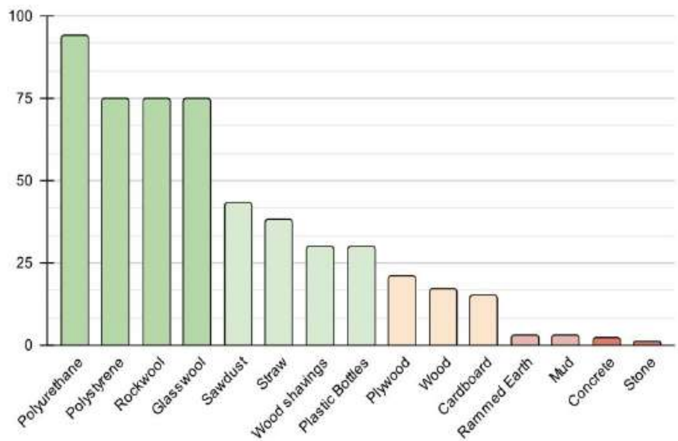
Thermal Insulation Levels

LEVEL	λ [(W/m. °C)]
Very Good	0.02 - 0.06
Good	0.06 - 0.1
Medium	0.1 - 0.5
Bad	0.5 - 1
Very Bad	Above 1

The value of Lamda (λ), row and Cp are average values generally used in thermal calculation.

Data Source: GERES. LEC Integration Design Manual

Insulation Level



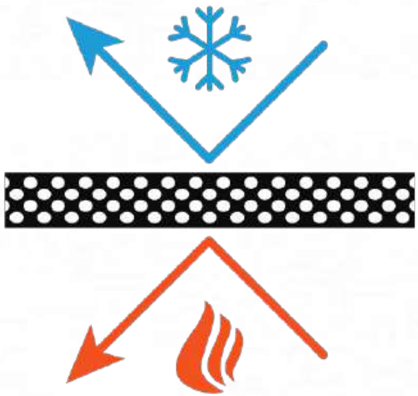
Thermal Insulation Level *(Base Stone = 01)*

INSULATION LEVEL	MATERIALS	λ [(W/m. ₒC)]
Very Good Insulators	Polyurethane	0.032
	Polystyrene	0.04
	Rockwool	0.04
	Glasswool	0.04
Good Insulators	Sawdust	0.07
	Straw	0.08-0.12
	Wood shavings	0.1
	Plastic Bottles	0.1
Medium Insulators	Plywood	0.14
	Wood	0.18
	Cardboard	0.2
Bad Insulators	Rammed Earth	0.9
	Mud	0.9
Very Bad Insulators	Concrete	1.8
	Stone	2.5-3

Insulation Level of Usual materials.

Data Source: GERES. LEC Integration Design Manual

Thermal Mass Level



Thermal Mass Level of Different Material

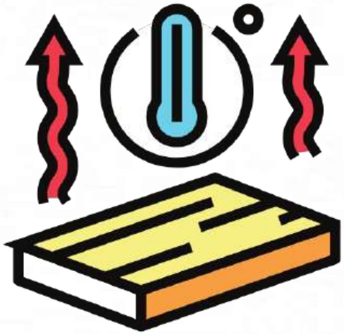
THERMAL MASS LEVEL	MATERIALS	ρ (kg/m³)	Cp (J/kg °C)]	ρ Cp (kJ/ m³ °C)]
Very Bad	Rockwool	0.032	25	23
	Polystyrene	0.04	25	34.5
	Glasswool	0.04	60	36.6
	Polyurethane	0.04	30	40.5
	Straw	0.07	75	105
Medium to Bad	Wood	0.08-0.12	420	630
Good	Rammed Earth	0.1	1800	1548
	Mud	0.1	1800	1548
Very Good	Concrete	0.14	1800	2592
	Stone	0.18	2400	2632

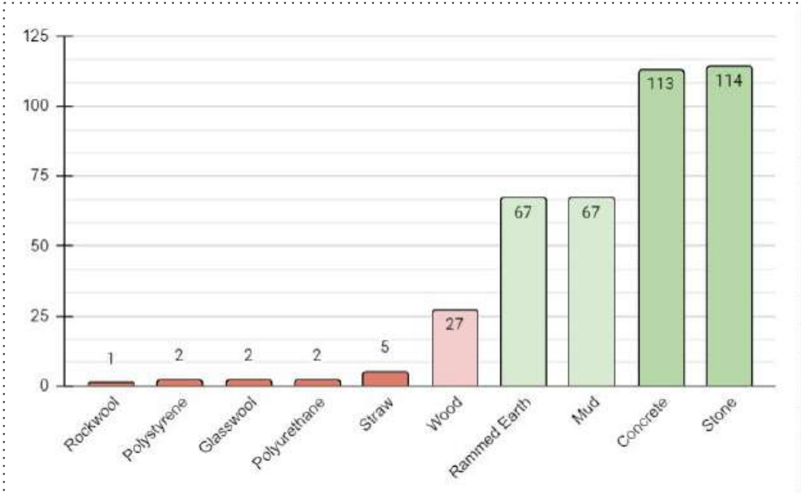
where;

ρ - Density of the Material. Cp - Specific Heat capacity of the Material, & ρ.Cp -Volumetric Heat Capacity

Data Source: GERES. LEC Integration Design Manual

Thermal Mass Level

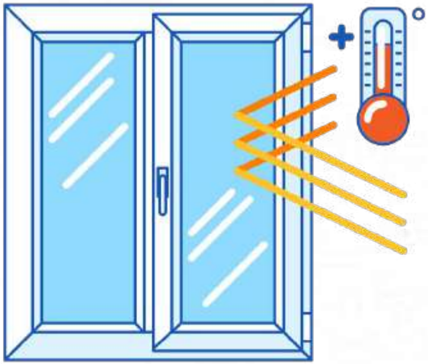




Thermal Mass Level of Different Material *(Base Rockwool - 01)*

Data Source: GERES. LEC Integration Design Manual

Thermal Conductance Level



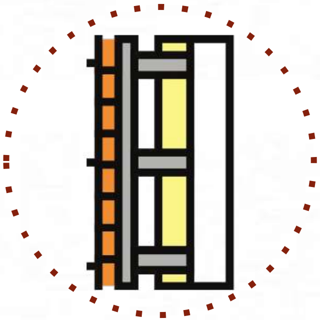
Thermal Conductance Level

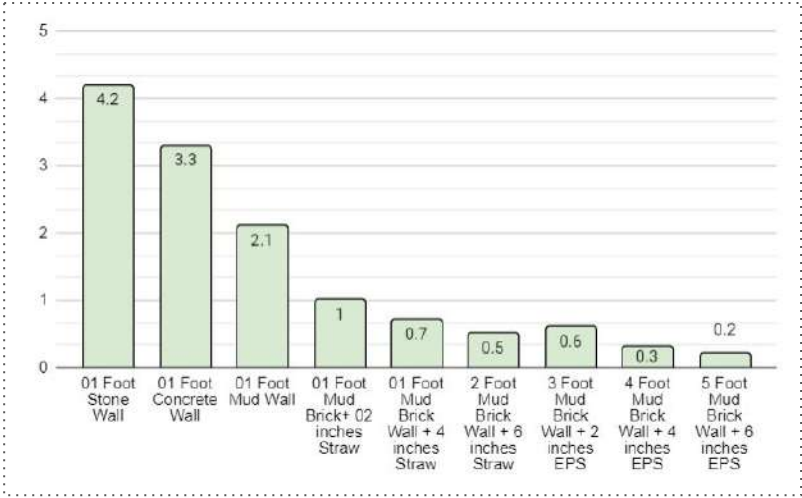
LEVEL	Uwall [W/m³ °C)]
Very Good	Above 2
Good	0-0.4
Medium	0.4-0.8
Bad	0.8-1.5
Very Bad	Above 3

Uwall - Thermal conductance of a wall in [W/m³ °C)]

Data Source: GERES. LEC Integration Design Manual

Thermal Conductance Level



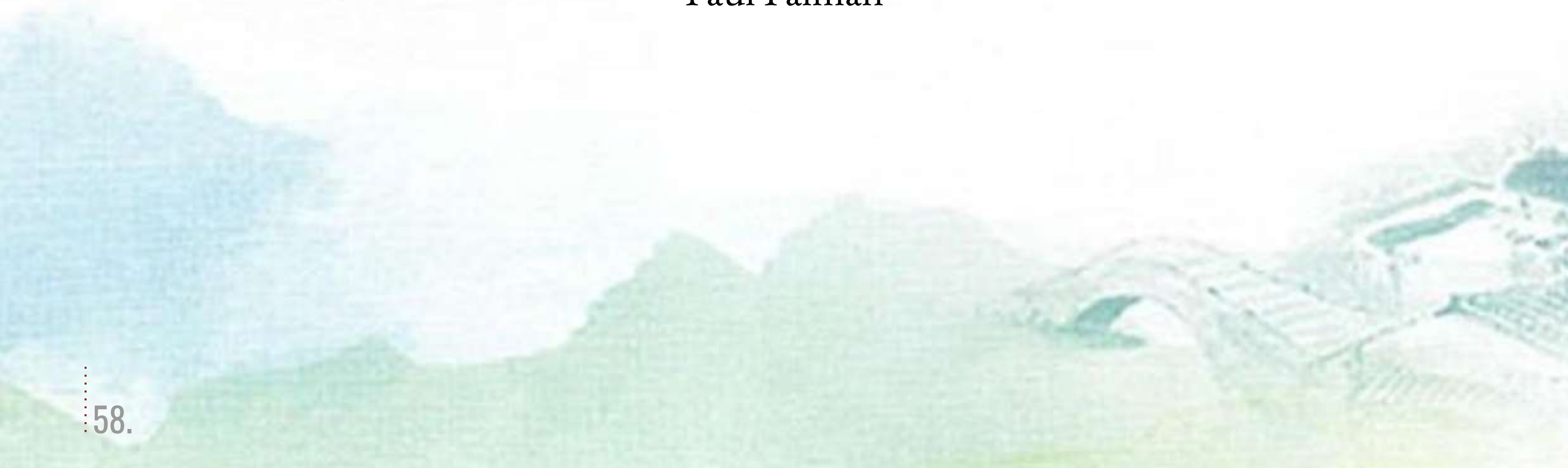


Thermal Conductance Level of different walls

Data Source: GERES. LEC Integration Design Manual

Let the sun be our guiding light, warming our homes and hearts with the embrace of passive solar design.

~ Paul Palman ~



08 Checklist for your PSHB.

Let's do a self-assessment for our building by checking different parameters. (such as; materials, maintenance, site anlaysis)

Checklist for Best Implementation

SR. NO.	PARAMETERS	STATUS		RATE
		Yes	No	SCALE (0-10)
10	**Safety and codes**			
A	Compliance with local building codes and regulations			
B	Fire safety and emergency procedures			
C	Hazard and risk assessment			
11	**Materials and Equipment**			
A	Quality of materials and equipment used			
B	Product certifications and warranties			
C	Commissioning and Testing			
12	**Monitoring and Evaluation**			
A	Measuring energy performance			
B	Identifying areas for improvement and upgrades			
13	**Materials and Equipmen**			
A	Quality of materials and equipment used			
B	Product certifications and warranties			
C	Commissioning and Testing			
14	**Monitoring and Evaluation**			
A	Measuring energy performance			
B	Identifying areas for improvement and upgrades			

Checklist for Best Implementation

SR. NO.	PARAMETERS	STATUS		RATE
		Yes	No	SCALE (0-10)
1	**Site Analysis**			
A	Orientation of the building			
B	Topography and shading			
C	Climate data			
D	Building usage and occupancy patterns			
2	**Building Design**			
A	Insulation			
B	Window placement and sizing			
C	Building envelope			
D	Solar thermal and electrical systems			
E	Ventilation			
3	**Solar Collectors**			
A	Collector			
B	Size and orientation			
C	Efficiency and performance			
4	**Storage and Distribution**			
A	storage system			
B	Size and capacity			
C	Distribution method			

Checklist for Best Implementation

SR. NO.	PARAMETERS	STATUS		RATE
		Yes	No	SCALE (0-10)
A	Automatic or manual controls			
B	Temperature and humidity sensors			
C	Automated shading			
6	**Maintenance and Monitoring**			
A	Preventive maintenance schedule			
B	Monitoring and data recording			
C	Troubleshooting and repair procedures			
7	**Safety and codes**			
A	Compliance with local building codes and regulations			
B	Fire safety and emergency procedures			
C	Hazard and risk assessment			
8	**Building Controls**			
A	Automatic or manual controls			
B	Temperature and humidity sensors			
C	Automated shading			
9	**Maintenance and Monitoring**			
A	Preventive maintenance schedule			
B	Monitoring and data recording			
C	Troubleshooting and repair procedures			

09 Annexure

Miscellaneous Information pertaining to the design of Passive Solar Buildings. This includes but is not limited to: Comprehensive list of districts with their climate zones; HDD and CDD data for important cities

Annexure 1: Major Districts and Their Climate Zones

State/UT	District	Climate Zone (ECBC)
Jammu and Kashmir	All Districts	Cold
Ladakh	Leh, Kargil	Cold
Himachal Pradesh	Chamba, Kinnaur, Kullu, Lahaul Spiti,Shimla	Cold
	Bilaspur, Hamirpur, Kangra, Mandi, Sirmaur, Solan, Una	Composite
Uttarakhand	Almora, Bageshwar, Champawat, Chamoli, Pithoragarh, Rudraprayag, Uttarkashi	Cold
	Dehradun, Haridwar, Nainital, Pauri, Udham Singh Nagar	Composite
	Tehri	Cold and Composite
West Bengal (Hill)	Darjeeling	Warm and Humid
Sikkim	East Sikkim,North Sikkim, West Sikkim, South Sikkim	Cold
Manipur	All Districts	Warm and Humid
Tripura	All Districts	Warm and Humid
Assam	Karbi Anglong, Dima Hasao (North Cachar hills)	Warm and Humid

The Climate Zone Finder Tool will assist you in finding the climate zone for any district in India https://ecbc.in/climatezonefinder

Annexure 1: Major Districts and Their Climate Zones

State/UT	District	Climate Zone (ECBC)
Meghalaya	East Garo Hills, East Jaintia Hills, East Khasi Hills, North Garo Hills, South Garo Hills, South West Garo Hills, South West Khasi Hills, West Garo Hills, West Jaintia Hills, West Khasi Hills	Warm and Humid
	Ri Bhoi	Cold
Mizoram	All Districts	Warm and Humid
Arunachal Pradesh	Tawang, Kamle, Kra Daadi, Kurung Kumey, Upper Siang, Upper Subansiri, West Siang	Cold
	Anjaw, , Changlang, Dibang Valley, East Siang, Lepa Rada, Lohit, Longding, Lower Dibang Valley, Lower Siang, Lower Subansiri, Namsai, Tirap, Papum Pare	Warm and Humid
	Central Siang, East Kameng, West Kameng	Cold, Warm and Humid*
Nagaland	Dimapur, Kiphire, Kohima	Warm and Humid
	Longleng, Mokokchung	Cold
	Mon	Cold, Warm and Humid*
	Noklak, Peren, Phek, Tuensang, Wokha, Zunheboto	Warm and Humid

The Climate Zone Finder Tool will assist you in finding the climate zone for any district in India ttps://ecbc.in/climatezonefinder . *Climatic variations within district. Data Source: ECBC Climate zone finder tool

Annexure 2
Daily Heating degree Demand per day

State/UT	Major Town/ Cities	Annual Average HDD (Degree C-d)		Annual Average CDD (Degree -d)
		Below 10° C	Below 18° C	Above 18° c
Uttarakhand	Pithoragarh	47.97	834.64	921.11
	Almora	10.30	548.73	1,415.43
	Gangotri/Bagori	3,464.13	6,480.85	0.00
	Joshimath	1,550.48	4,116.22	0.01
	Mussoorie	64.43	930.25	965.20
Himachal Pradesh	Kaza	5,209.79	8,240.10	0.00
	Shimla	51.21	526.53	1,728.51
Jammu and Kashmir	Gulmarg	987.02	2,740.68	237.53
	Srinagar	1,390.75	3,403.06	82.12
Ladakh UT	Kargil	4,261.48	7,196.78	0.00
	Leh	4,717.03	7,692.52	0.00
	Nubra Valley	721.64	978.94	0.00

Data Source: Average of Annual Values from 1981-2021, from Data Access Viewer, NASA

Annexure 2
Daily Heating degree Demand per day

State/UT	Major Town/ Cities	Annual Average HDD (Degree C-d)		Annual Average CDD (Degree -d)
		Below 10° C	Below 18° C	Above 18° c
Manipur	Imphal	0.10	279.09	1,258.03
Assam	Guwahati	987.02	2,740.68	237.53
Arunachal Pradesh	Itanagar	0.00	40.06	267.98
	Ziro	28.04	887.29	709.91
Meghalaya	Shillong	9.99	684.61	683.78
Mizoram	Aizawl	44.71	82.67	1,906.55
Nagaland	Kohima	0.00	82.32	1,949.65
Sikkim	Gangtok	1,180.12	3,764.98	0.00
Tripura	Agartala	0.00	27.16	2,749.37

Data Source: Average of Annual Values from 1981-2021, from Data Access Viewer, NASA

About the Institute

G.B. Pant National Institute of Himalayan Environment (NIHE) was established in 1988-89 as an Autonomous Institute of the Ministry of Environment, Forest & Climate Change (MoEF&CC), Government of India. The Institute has been identified as focal agency to advance scientific knowledge, evolve integrated management strategies, demonstrate their efficacy for conservation of natural resources, and ensure environmentally sound development in the entire Indian Himalayan Region (IHR).

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ISBN: 978-93-340-3505-6