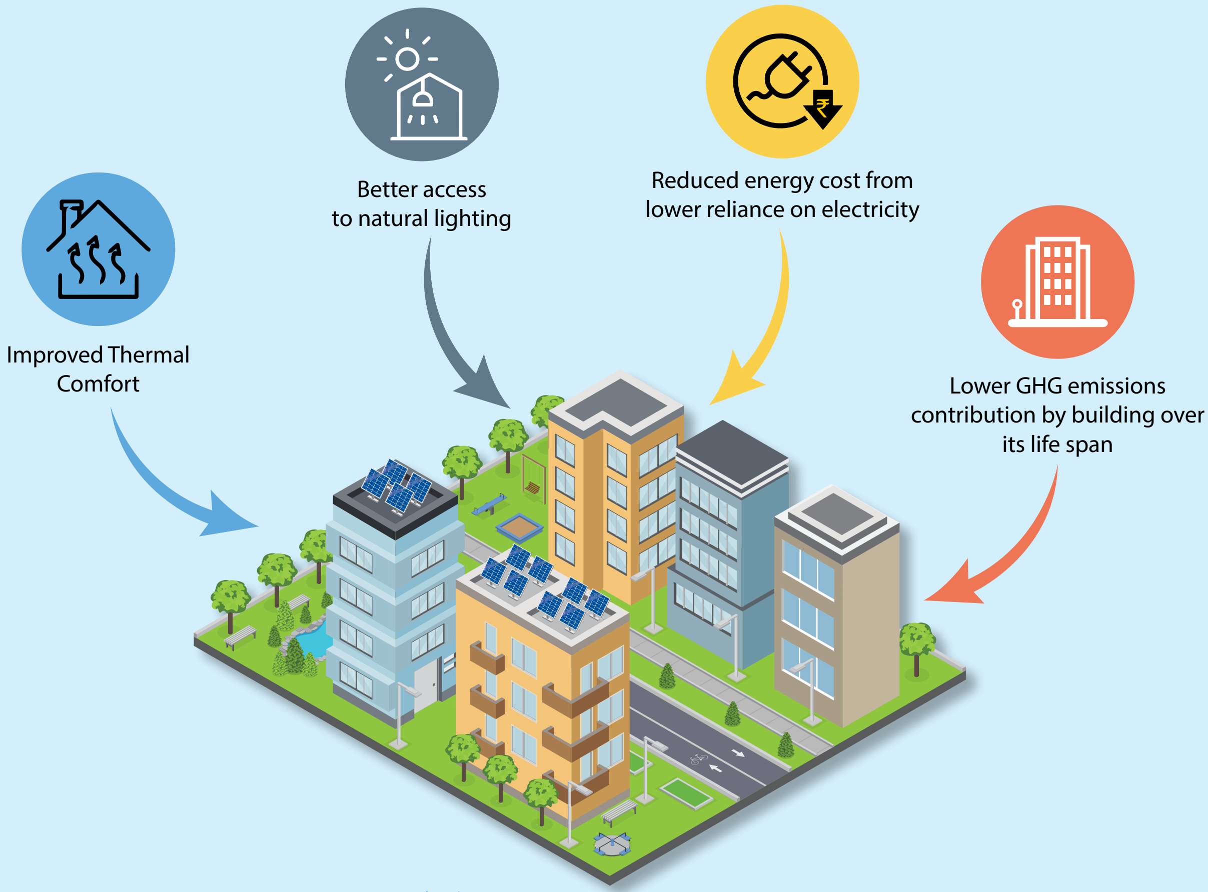
Building Efficiency Accelerator

Guidelines for
Energy Efficient and Climate Responsive Homes in Nagpur

SEPTEMBER 2020



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Prepared under the Building Efficiency Accelarator Project. The Building Efficiency Accelerator (BEA) is one of the six accelerators of energy efficiency under the Sustainable Energy for All (SE4ALL) initiative of the UN.

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List of Abbreviations

BEA	Building Efficiency Accelerator
SE4ALL	Sustainable Energy for All
UN	The United Nations
NMC	Nagpur Municipal Corporation
NSSCDCL	Nagpur Smart and Sustainable City Development Corporation Limited
WRI	World Resources Institute
ICLEI	International Council for Local Environmental Initiatives
EDS	Environment Design Solutions Pvt. Ltd.
SHGC	Solar Heat Gain Coefficient
GF	Glazing factor
VLT	Visual Light Transmittance
R	Thermal Resistance
U – value	Thermal Conductance
ECBC-R	Energy Conservation Building Code - Residential
SRI	Solar Reflectance Index
IGBC	Indian Green Building Council
RCC	Reinforced Cement Concrete
LED	Light Emitting Diode
BEE	Bureau of Energy Efficiency
TFL	Fluorescent Tube Lamps
GRIHA	Green Rating for Integrated Habitat Assessment
VFD	Variable Frequency Drives
CFL	Compact Fluorescent Lamp
PV	Photovoltaic
OHT	Overhead Tank
MNRE	Ministry of New and Renewable Energy
EMI	Equated Monthly Instalment
COP	Coefficient of Performance
NZEB	Net or nearly zero energy buildings
RES	Renewable Energy Sources
USGBC	United States Green Building Council
LEED	Leadership in Energy and Environmental

Background

Building Efficiency Accelerator (BEA) Program

The Building Efficiency Accelerator (BEA), one of the six accelerators of energy efficiency under the Sustainable Energy for All (SE4ALL) initiative of the UN, assists sub-national governments in improving the energy efficiency of buildings within their jurisdictions to reduce energy costs, create new market opportunities and reduce the GHG emission associated with them. This multi-sectoral public-private collaboration aims to accelerate the process of adoption of best-practice policies and implementation of building efficiency projects in cities across the world, with the goal of doubling the rate of energy efficiency improvement in the building sector by 2030. Further information on the BEA is available at www. buildingefficiencyaccelerator.org

Nagpur's Building Efficiency Actions under the BEA Deep-Dive Engagement

Nagpur city joined the BEA Initiative in April 2018 to become one of 50+ partner cities of the BEA. Given the city's intent to advance building efficiency adoption, Nagpur was selected as a deep-dive city and received assistance through the BEA on identifying building energy efficiency actions, developing work plans and implementing policies, projects and tracking methods to fulfil its BEA commitments.

The Nagpur Municipal Corporation (NMC) and Nagpur's Smart City SPV, Nagpur Smart and Sustainable City Development Corporation Limited (NSSCDCL), are both partners to the BEA engagement in the city, with NSSCDCL coordinating project implementation from the city's side. This BEA deep-dive technical assistance was implemented by ICLEI-Local Governments for Sustainability, South Asia (ICLEI South Asia) with the support of World Resources Institute (WRI), an organization that leads global coordination of the BEA.

Key Activities undertaken in Nagpur under the BEA Deep-Dive Engagement Include:

- Review of designs of two buildings, proposed to be built under the 'Home Sweet Home' affordable housing scheme of about 1,000 dwelling units, as part of Nagpur's Smart City project. The design review identified suitable design measures/solutions that can be adopted to enhance building energy performance as well as thermal comfort levels of inhabitants.

- Preparation of a technical guideline to support development of energy efficient housing in the city. This guideline provides energy efficient measures which can be adopted by various stakeholders in Nagpur across the stages of design and construction of future homes.

- Benchmarking of energy consumption in 10 public and 10 commercial buildings (hotels). Conduct of energy audits in public, commercial as well as residential buildings to identify suitable energy conservation measures and demonstrate the potential for energy savings; establishing a basis for adoption of energy conservation measures in Nagpur's different building typologies in the future.

About this document

This Guideline for Energy Efficient and Climate Responsive Homes has been customized for Nagpur city and presents locally adoptable principles and energy efficient measures across the stages of design while constructing for new housing in Nagpur. This Guideline can be handily used by NMC and NSSCDCL officials to promote energy efficient housing with reduced environmental and climate impact and without compromising comfort levels, be it by inclusion of suggested energy efficiency measures for future affordable housing projects or in the modification of local building regulations. This guideline is a living document which can be updated by NMC and NSSCDCL as required to respond to increasing ambition and market conditions, in consultation with local stakeholders, experts, and partners.

Who All Can Use the Guidelines?

The Guidelines for construction of Energy Efficient and Climate Responsive Homes are prepared to make the process of creating energy efficient homes easier for a range of different groups.

For homeowners, the Guidelines help explain the process of designing and building sustainably. The guideline covers both general overview and specific topics, Building Efficiency Guideline is designed to help homeowners create a climate responsive sustainable home.

For Architects and Designers, the Guidelines provide a comprehensive overview of sustainable design principles and strategies including detailed information on a range of different topics. One can use it as a design support tool; or share it with clients to familiarise them with the options available.

For developers or builders, especially the many who play a role in design as well as construction, the Guidelines have relevant design advice. It is also consists of useful detail on procurement of materials and products, lighting, mechanical system, and renewable energy systems. These guidelines can be shared with clients to familiarise them with the options available.

This technical guideline document has been prepared through close collaboration of NSSCDCL, NMC, ICLEI South Asia team and technical experts from Environment Design Solutions Pvt. Ltd. (EDS) who were engaged for this assignment, with the support of WRI.

The project team appreciates the vision and leadership of NSSCDCL and NMC to advance energy efficiency in the city's building stock through targeted actions, including through this guideline. We are grateful for all the guiding contributions and support extended by Honourable Mayor, Municipal Commissioner, departments and officers of the NSSCDCL and NMC, without which this guideline would not have been possible. We are extremely thankful to Dr. Ramnath Sonawane, Ex-CEO, NSSCDCL, Mr. Mahesh Moroney, CEO (In-Charge), NSSCDCL, and Mr. Devendra Mahajan, Ex-General Manager, Environment Division, NSSCDCL, and the NSSCDCL team for their guidance during the project. Support of the BEA and the WRI team to this exercise is kindly appreciated.

Team and City Departments Involved

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NSSCDCL and NMC: Environment Division, Infrastructure Division, Mobility Division, Town Planning department, Nagpur Smart City project management unit, Project Architect- Home Sweet Home project

Disclaimer

Chapter 1 – Introduction

The **Guidelines for Energy Efficient and Climate Responsive Homes in Nagpur** are formulated to help individuals, Architects, and designers in creating comfortable home with low impact on the environment and healthier spaces to live in.

Home is important in so many ways. It is a place to unwind, relax and spend quality time with family and friends. It is also likely to be the biggest investment one makes. Decisions about one's home have consequences for future living costs and quality of life. Collectively, such decisions contribute to the bigger picture and can help to create more vibrant, connected, and sustainable towns and cities. In such rapidly changing times, smart investment decisions demand smart thinking about new issues. When one is planning building new home it is easy to focus on the short term, but features that enhance resale value, improve comfort, and reduce bills are worth paying for.

The Guidelines for Energy Efficient and Climate Responsive Homes in Nagpur is a comprehensive guide to the design principles and features that add value to home and reduce its environmental impact. Many of them come at no additional cost. They just require the right 'know how' at the right stage of building project. Others may add cost but also add lasting value and help to 'future-proof' home against rising energy costs.

Each section in the **Guideline** covers a sustainability theme, such as passive design or energy. A sustainable home needs to address all these themes in tandem. The principles and ideas in each section can be applied to any home – individual or multi-storied residences. Each section also includes recommendations and Nagpur specific strategies that can be implemented at various stages of project – design stage, selection of building materials and allied building use products.

Chapter 2 – Climate Responsive Design

Over long periods of time, by trial and error, vernacular building solutions (buildings based on local conditions) evolved, and they all contain elements of climate responsive design. We build today for the reason we have always built — to make safe, healthy shelters that protect us from the elements and keep us comfortable. However, cheap accessible fossil energy sources and the abundance of technology and new materials have encouraged us to solve building problems differently in recent times. Unfortunately, some of these methods may be compromising the ability of our planet to sustain us in the long or even medium term. The new challenge is to use our technology to minimise environmental impact, while continuing to improve the comfort and performance of the homes we create.

A great majority of Indians currently live in homes that work against the climate, not with it. These homes are too hot or too cold, waste energy and are comparatively expensive to run. Most homes use far more electricity than necessary and are being made of materials that damage our health and the environment. Using good design principles can save energy and money, while creating a more enjoyable and comfortable home.

Importance of Climate Responsive Design

'Climate Responsive Design' is design that takes advantage of the climatic parameters: Sun, Wind and Light, to maintain a comfortable and conducive indoor environment. Passive design can reduce or eliminate the need for secondary heating or cooling, which accounts for about 40% (or much more in some climates) of energy use in the average Indian home.

The importance of climate responsive design cannot be overstated. Paying attention to the principles of good climate responsive design suitable for climate effectively 'locks in' thermal comfort, low heating and cooling bills, and reduced greenhouse gas emissions for the life span of home.

Climate responsive design utilises natural sources of heating, cooling, and daylight such as the sun and cooling breezes. It is achieved by appropriately orientating building on its site and carefully designing the building envelope (roof, walls, windows, floors), and selecting right material for construction.

The most economical time to achieve good passive design is when initially designing and constructing building. However, substantial renovations to an existing home can also offer a cost-effective opportunity to upgrade thermal comfort — even small upgrades can deliver significant improvements.

Several different and interrelated strategies contribute to good Climate responsive design, each of them is subject of sections in this guideline. Climate responsive design strategies vary with climate, and strategies which are specific to the Nagpur region are captured in this guideline.

Chapter 3 – Climate of Nagpur

Identification of Climate

Climate responsive design ensures that the occupants remain thermally comfortable with minimal auxiliary heating or cooling in the climate where they are built. India has five climate zones, each having its own climatic characteristic that determine the most appropriate design objectives and design responses. Identifying Nagpur's climate zone and gaining an understanding of the principles of thermal comfort will help one in making informed design choices while making one's home. Nagpur falls under composite climate as identified by National Building Code.

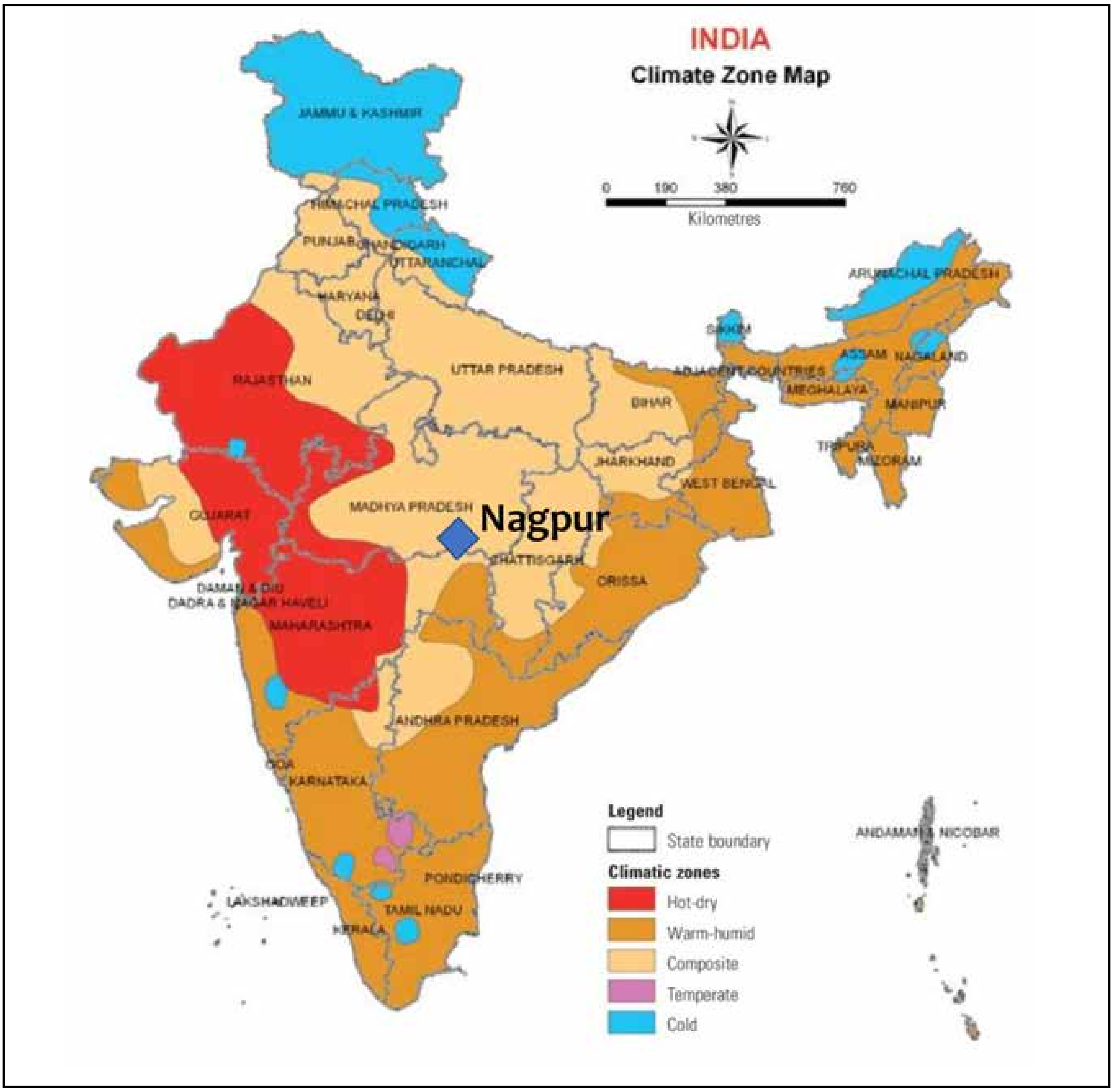


Figure 1: Climate Zones of India - National Building Code 2005

Composite climate is characterized by the following:

- The maximum daytime temperature in summers is in the range of 32 – 43 °C, and night-time temperatures are from 27 to 32 °C. In winter, the values are between 10 to 25 °C during the day and 4 to 10 °C at night.
- The relative humidity is about 20 – 25 % in dry periods and 55 – 95 % in wet periods.
- Rainfall in this zone varies between 500 – 1300 mm per year.
- A variable landscape and seasonal vegetation.
- The intensity of solar radiation is very high in summer with diffuse radiation amounting to a small fraction of the total. In monsoons, the intensity is low with predominantly diffuse radiation.
- This region receives strong winds during monsoons from the south-east and dry cold winds from the north-east. In summer, the winds are hot and dusty. The sky is overcast and dull in the monsoon, clear in winter and frequently hazy in summer.
- Generally, composite regions experience higher humidity levels during monsoons than hot and dry zones. Otherwise most of their characteristics are similar to the latter. Thus, the design criteria for climate responsive designs are to reduce heat gain by providing shading, to promote heat loss by ventilation and that maximising cross ventilation is desirable in the monsoon period.

Climatic Characteristics

Nagpur is a large city in the central Indian state of Maharashtra. The city lies on the Deccan plateau of the Indian Peninsula and has a mean altitude of 310.5 meters above sea level. Nagpur is located at the coordinates 21.14° N, 79.08° E

In Nagpur, summers are extremely hot, with May being the hottest and most uncomfortable month. Winter lasts from November to January, during which temperatures drop below 10 °C. The summer season experiences hot winds, reaching wind speeds of up to 10m/s, flowing predominantly from the West direction. The average number of heat wave days occurring in Nagpur in the Summer months of March, April & May is 0.5, 2.4 and 7.2 days respectively. May is the most uncomfortable and hottest month. During the preceding spring season, winds are the warmest and flow from predominantly the North - West directions. Cold winds blow in the winter from the North-East.

Sun Movement

Sun path diagram can be used to determine the sun's position in terms of altitude and azimuth for any day of the year. It can be used by designers to shade or expose certain parts of building to Sun. For Nagpur it can be understood that the sun is at low angle during the winters and to the south of east-west axis. During summer, its path is at high angle and slightly north to the east west axis. The alteration in path affects solar radiation penetration patterns during different seasons and consequently, heat gain and loss in a building. Buildings should be shaded during summer to decrease direct solar gains. Overhangs should be appropriately designed to shade opening due to lower solar angles which contribute to glare.

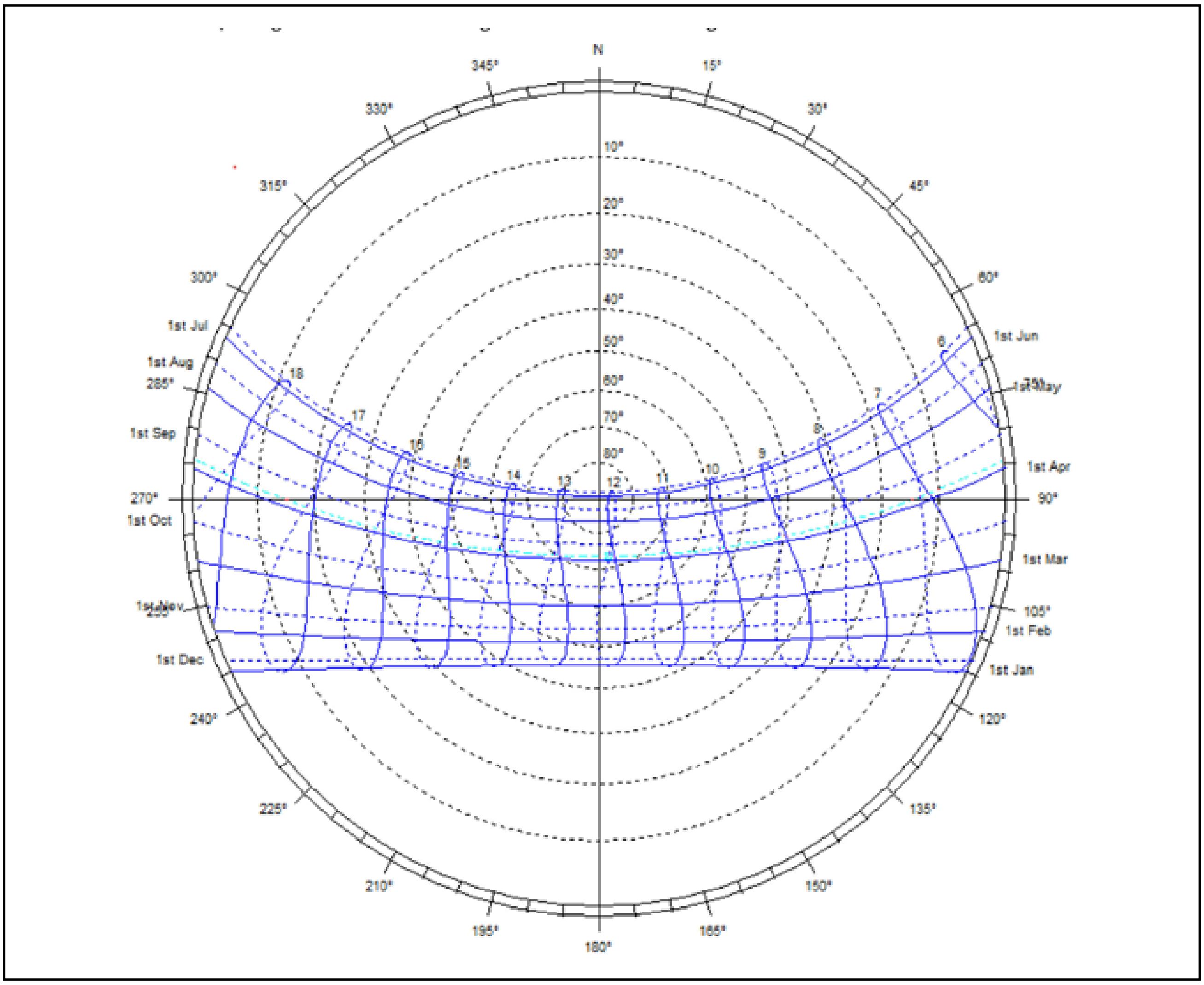


Figure 2: Sun Path for Nagpur

Temperature

Nagpur shows distinct variation in temperatures throughout the year. The temperature for Nagpur increases steadily till May which is the hottest month, and January being the coldest month.

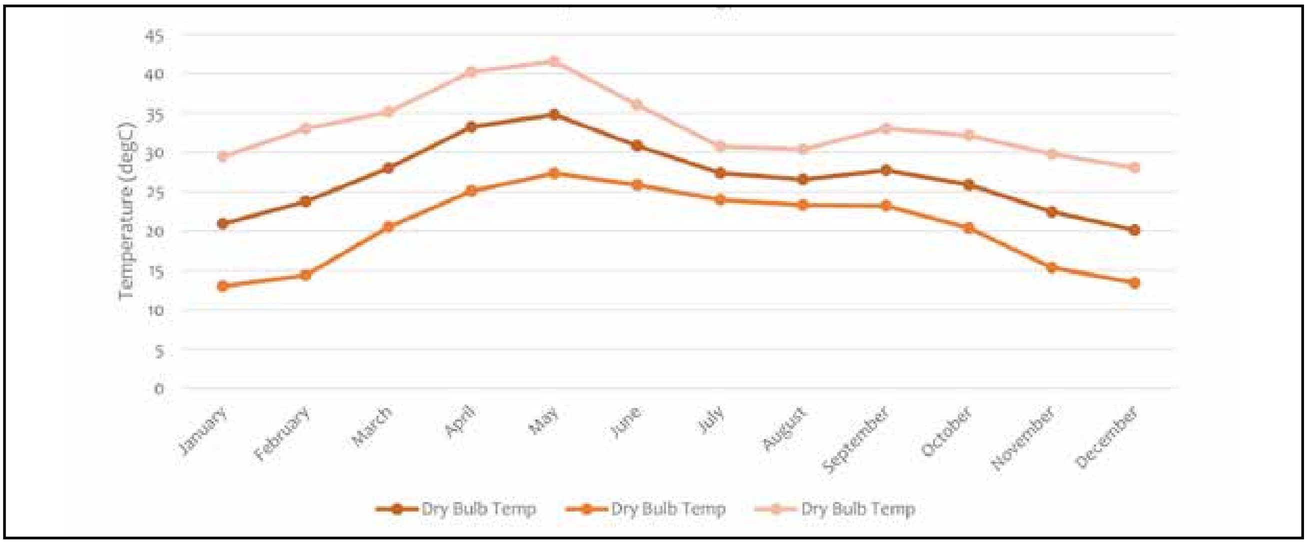


Figure 3: Temperature of Nagpur

Rainfall

The average total annual rainfall for Nagpur is nearly 1075 mm. The rainfall generally increases from the west to the east in the district. The south-west monsoon usually reaches the district in the second week of June. The rainfall during the period, June to September constitutes about 90% of the annual total, July being the month with the highest rainfall.

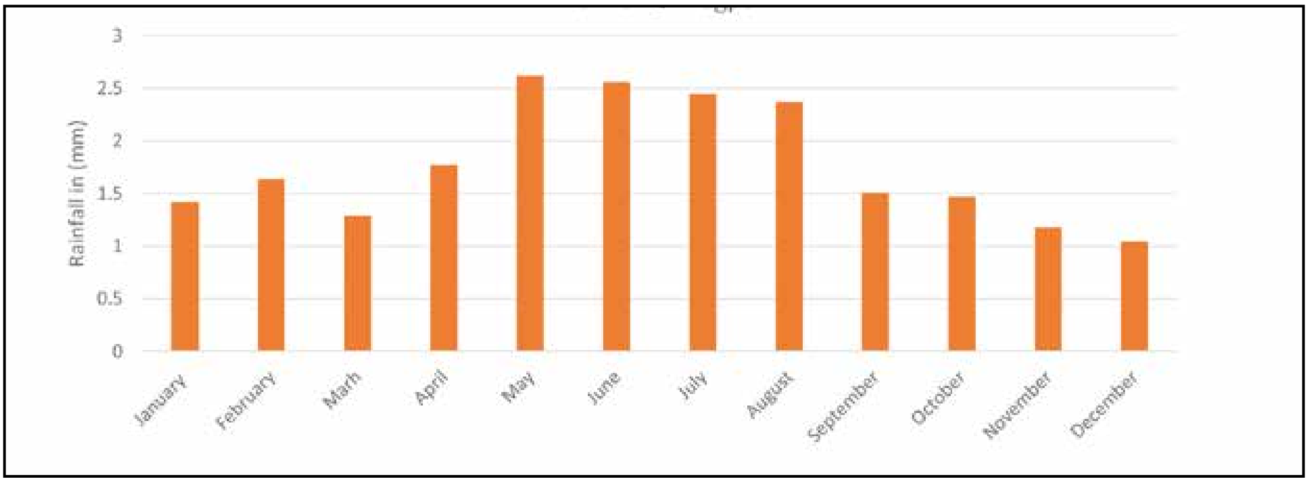


Figure 4: Rainfall of Nagpur

Humidity

Except during the monsoon season when the humidity is high, the air is generally dry. The summer season is the driest part of the year when the relative humidity goes down to 20% or less particularly in the afternoons.

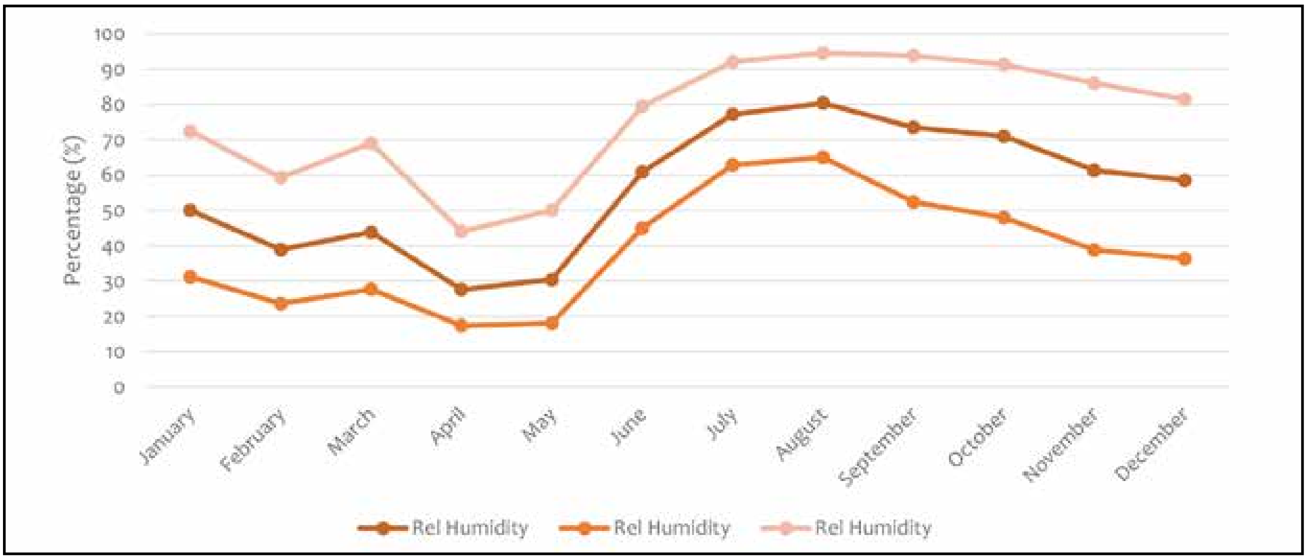


Figure 5: Humidity of Nagpur

Wind Speed and Direction

Wind with higher speed are experienced in the months of April and July.

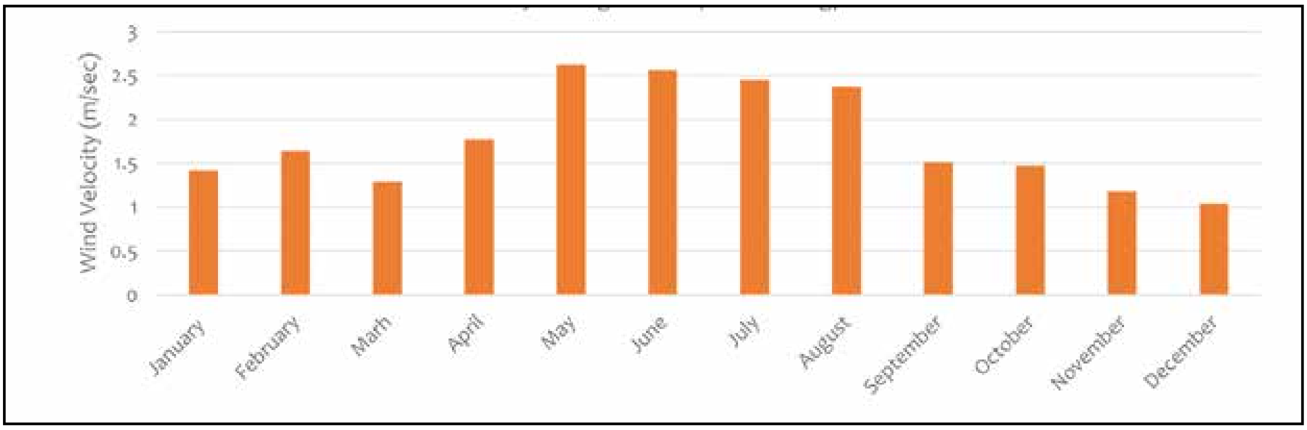


Figure 6: Daily Average Wind Speed for Nagpur

Wind Direction

Figure 7 shows the annual wind direction for Nagpur. Maximum frequency of the wind comes between North and West direction. High temperature winds also flow from the same direction.

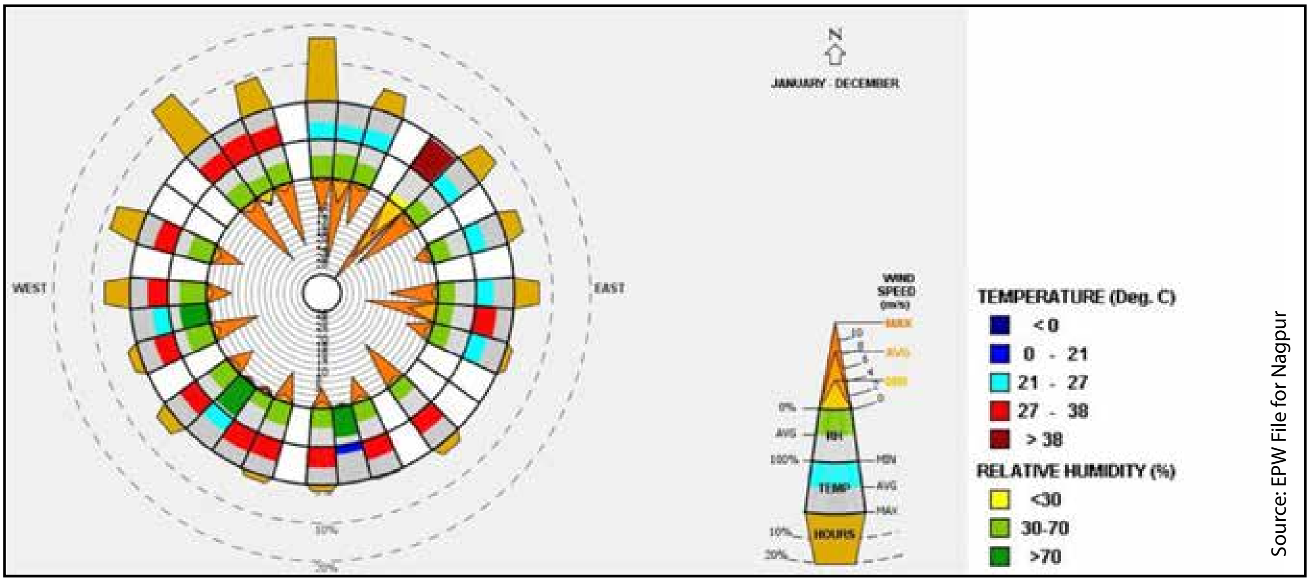


Figure 7: Annual Wind Flow for Nagpur

Figure 8 shows wind direction for the Summer season, predominantly the hot winds flows between North and West direction. High speed hot winds flow from Northwest direction, it is important to block these hot winds.

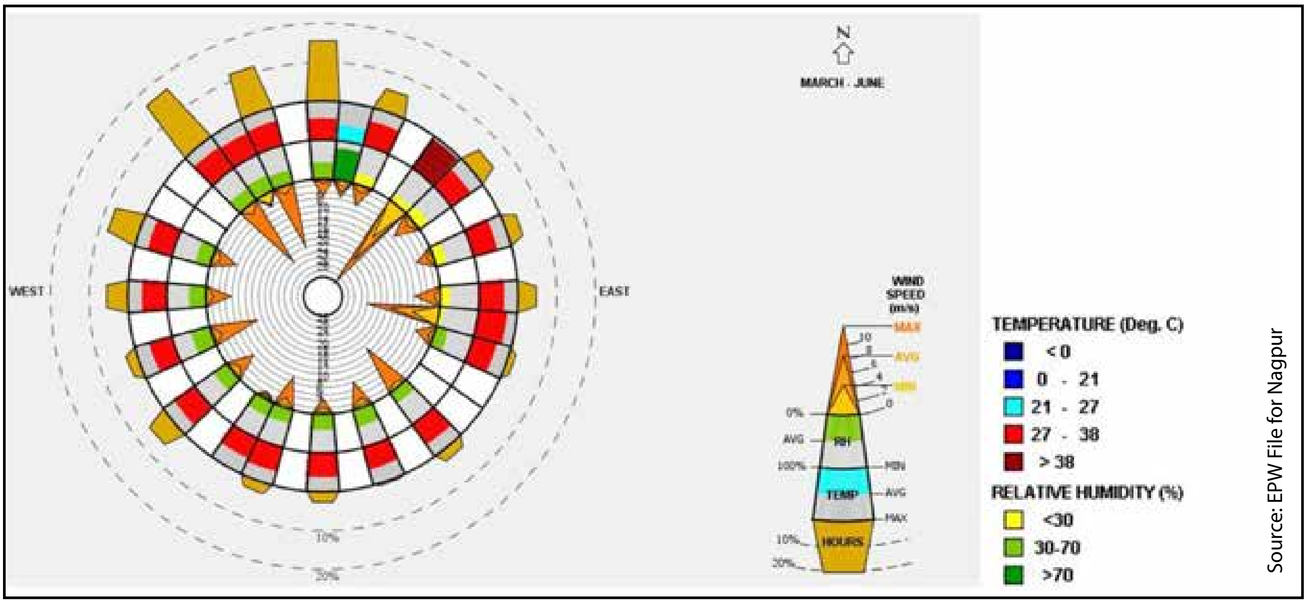


Figure 8: Summer Season - Wind Direction for Nagpur

Figure 9 shows wind direction for Winter season, predominantly the cold winds flow between Northwest and Northeast direction. High speed cold winds blow from North, blocking these winds is important.

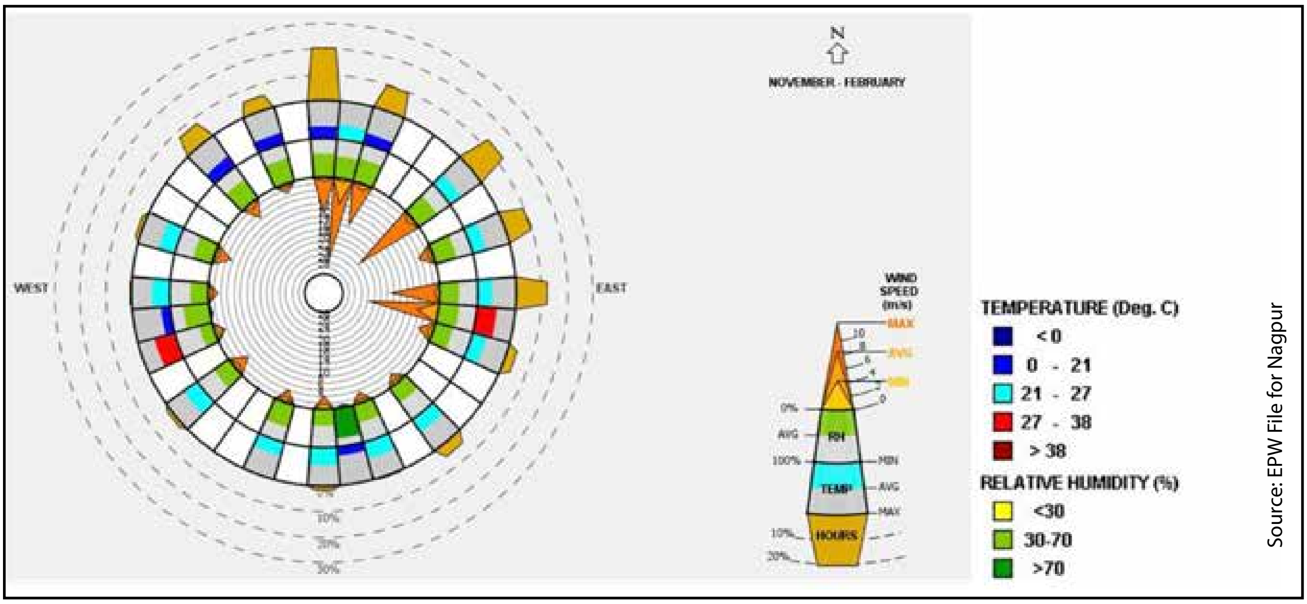


Figure 9: Winter Season - Wind Direction for Nagpur

Figure 10 shows wind direction for monsoon season, predominantly the wind flows between Northwest and West. Windows should be oriented strategically so as to facilitate ventilation.

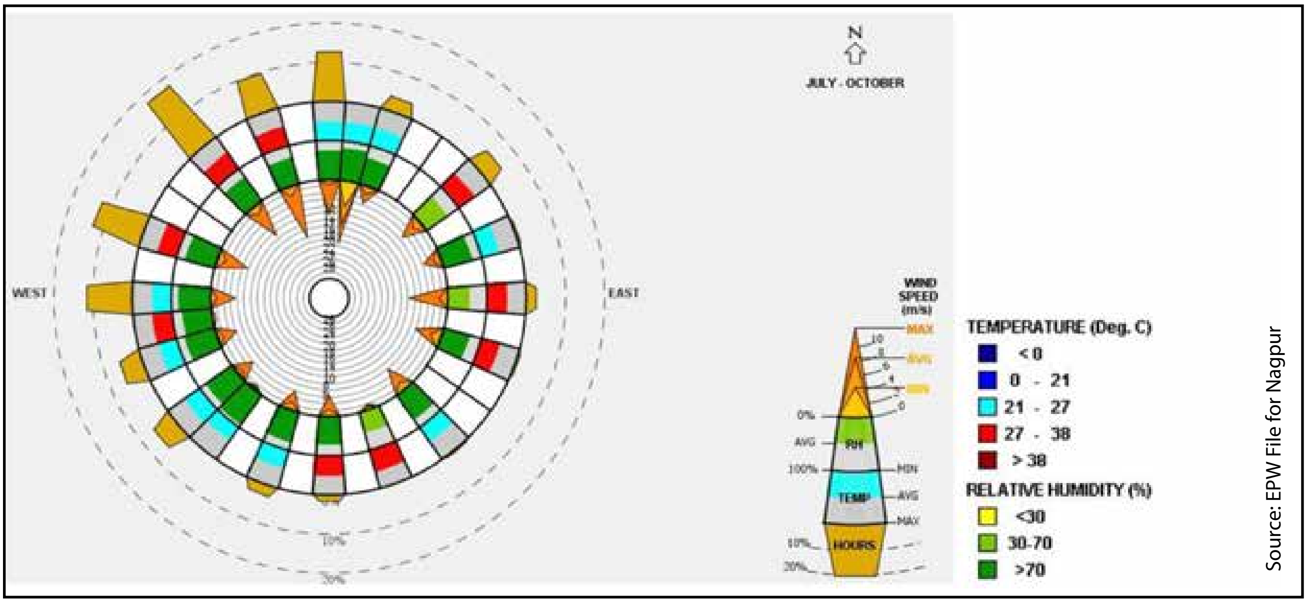


Figure 10: Monsoon Season - Wind Direction for Nagpur

Passive Design Strategies for Nagpur

Passive solar techniques involve methods of collecting, storing, distributing, and controlling thermal energy flow by means of natural principles of heat transfer. Passive systems have no separate devices for collecting and storing energy, nor any mechanical means for transporting heat. Instead, they make use of the energy available in the immediate environment and effect energy exchanges through natural processes.

For Nagpur in summer season, desirable lower indoor temperatures can be achieved by shading the windows with appropriate shading devices or by vegetation. Choosing appropriate building materials for walls and roof can largely contribute in delaying the indoor heat ingress, during Summer season. By allowing winter sun indoors and appropriate selection of building materials for walls and roof, comfort conditions in winter season can be met. Windows should be strategically placed so as increase the wind flow for monsoon season. Use of ceiling fans can also facilitate wind movement indoors.

Chapter 4 – Climate Responsive Design Strategies for Nagpur

Form and Orientation

Climate Responsive strategies related to form and orientation are the two most important strategies for reducing energy consumption and improving thermal comfort for occupants of a building. It has a large impact on the amount of sun falling on surfaces, daylighting, and direction of winds. Climate responsive design goals can be easily met by harnessing sun and prevailing winds which are largely impacted by building form and its orientation. These strategies are one-time interventions and their potential benefits should not be missed. Building designs vary according to context of its location and climate. However, the underlying principle remains the same, maximising amount of solar radiation in winter and minimizing the amount in summers.

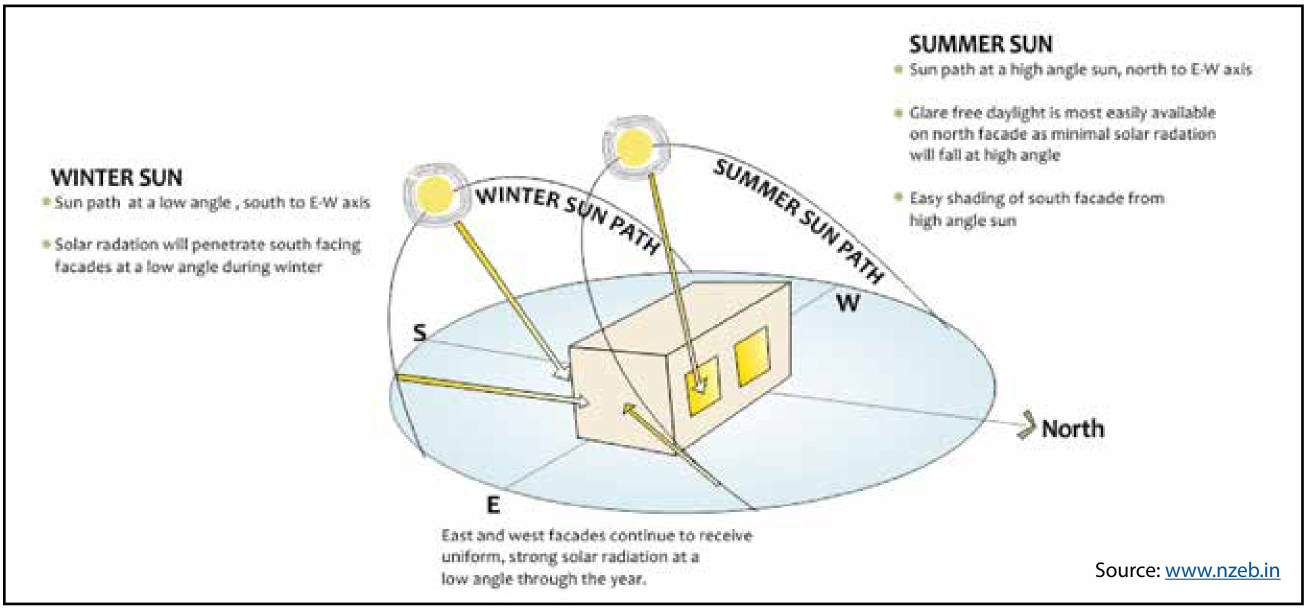


Figure 11: Seasonal changes in sun path and impact on incident solar radiation

For composite climate like Nagpur, it is recommended to orient a rectangular form (see below possible combinations in figure 3) with a longer facade along the north, this will allow less exposure to the low angles harsh west sun. It will also provide glare free light in summer from north without shading and winter sun penetration from the south.

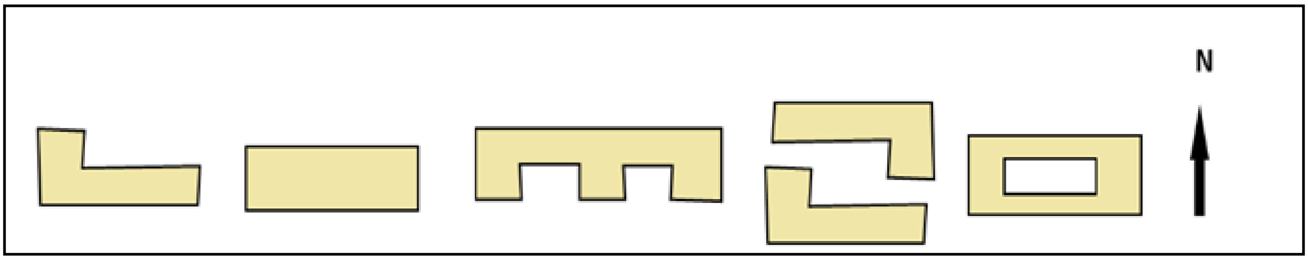


Figure 12: Longer axis of the building along with North and South

The total surface area exposed should be kept at a minimal, this will restrict the solar ingress into the building. One of the strategy is to optimise the surface to volume(S/V) ratio of the building to be as low as possible in order to minimize heat gain (compact plans have greater thermal efficiency, e.g. a square plan is more thermally efficient than a rectangular one). It is recommended to have a compact form with lower surface area and surface volume ratio.

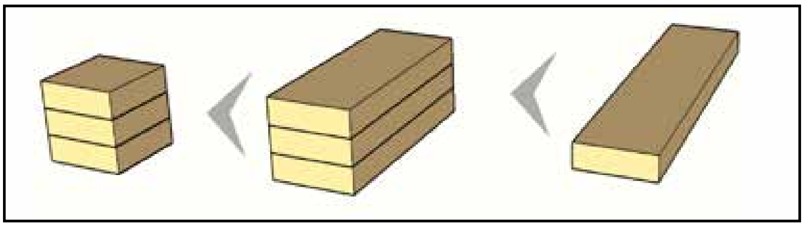


Figure 13: Compact plan to minimize heat gain

If site has multiple buildings, they should be arranged in ascending order of their heights and be built on slits to allow ventilation.

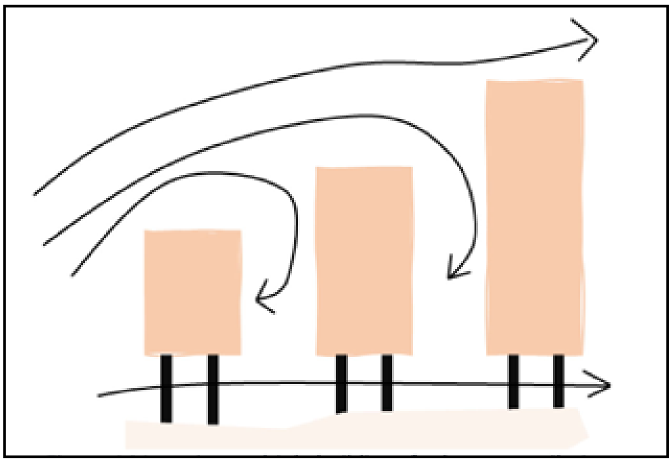


Figure 14: Locating multiple buildings for better ventilation

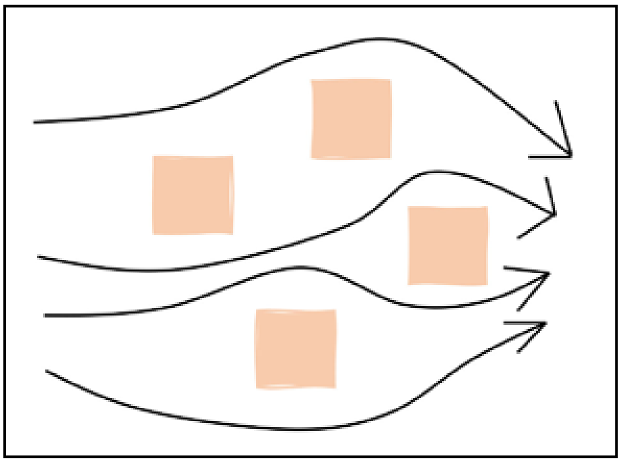


Figure 15: Staggered planning to enhance ventilation

Strategies for cooling buildings in Nagpur:

1. Orient long facades of buildings along north- south to reduce direct solar exposure.
2. Buildings should be oriented with their longer axis aligned perpendicular to the prevailing winds to facilitate maximum airflow and cross ventilation through the building.
3. Buildings that feature a courtyard orienting the courtyard 45° from the prevailing wind maximizes wind flow into the courtyard and enhances cross ventilation in the building.
4. Compact plans are desirable where the surface area exposure should be as low as possible to minimize heat gain.
5. A square plan with a courtyard would be very effective, for an individual home.
6. Buffer spaces like staircases, storerooms can be located in east and west orientation and should be shaded by landscape.

Natural Ventilation

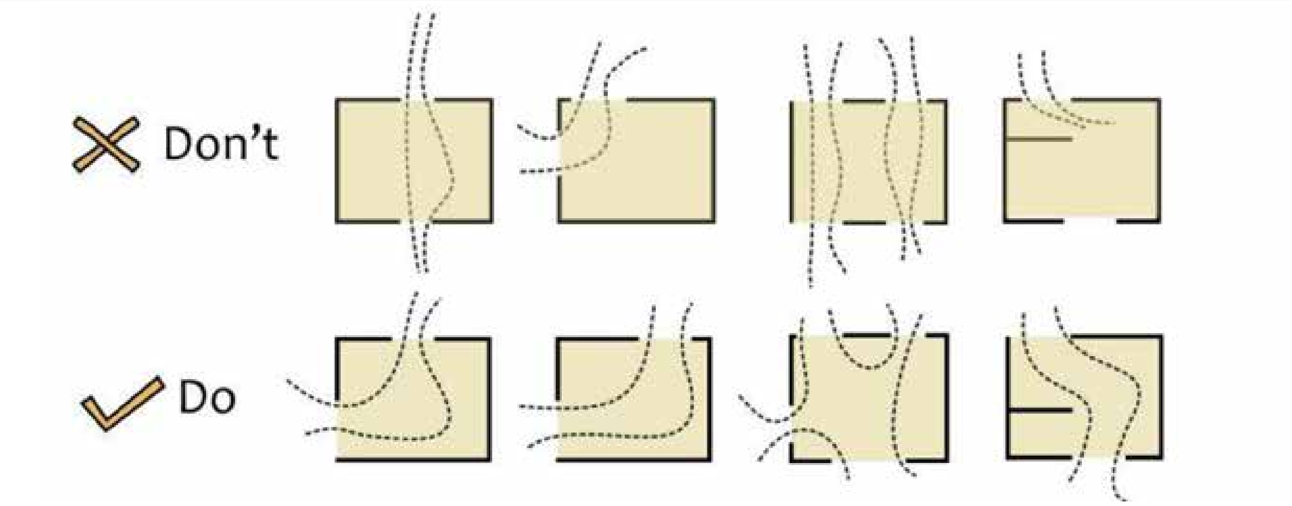
Air movement is the most important element of comfort, especially for individual homes. Passive design measures can be judiciously used to influence movement of outside air into the home by bringing in fresh air.

Various natural ventilation strategies can be adopted such as appropriate orientation and form, openings in building envelope (windows, doors, and ventilators), operable windows, internal space planning, etc. Other advanced ventilation techniques include courtyard effect, stack effect, evaporative cooling and air earth tunnels systems can be utilised effectively in Nagpur.

Cross Ventilation

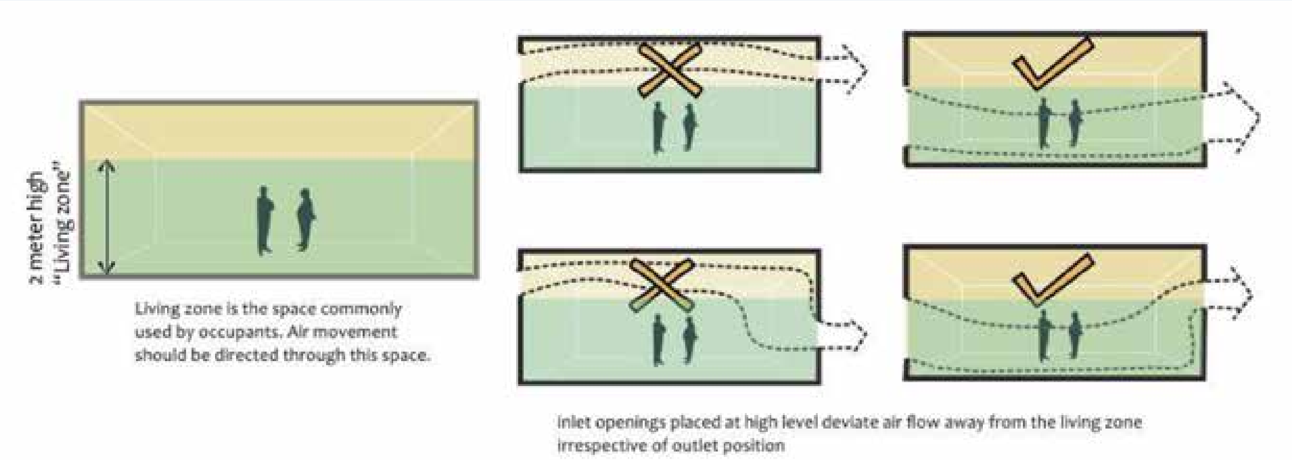
Without outlet openings, there may be no effective air movement through a building, even in the case of strong winds. The location of the openings and interior partitions in both plan and section influence the route of the air flow through the room. It is important that openings be located so that air movement is sensed at the occupant level. If the openings are all located near the ceiling or all near the floor the maximum air velocity will not occur in the occupied zones which are usually at 1 to 6 feet above the floor. If the openings are mid-height in the wall or if some are high and some are low, then higher velocity will occur in the occupied zone.

How to locate windows in homes?



Source: https://nzeb.in/knowledge-centre/passive-design/natural-ventilation/

Figure 16: Window placement in plan



Source: https://nzeb.in/knowledge-centre/passive-design/natural-ventilation/

Figure 17: Window placement in sectional plane

How much openable area is enough for effective natural ventilation?

For Naturally ventilated homes where external air is used for ventilation, guidelines for openable window-to -floor area from Eco-Niwas Samhita 2018 (Energy Conservation Building Code for Residential Buildings) can be referred to design appropriate opening sizes to ensure ventilation. The code defines minimum openable window- to-floor area ratio that is required for effective ventilation, which is the ratio of all openable area in a dwelling unit to carpet area. Ensuring minimum window openings helps in ventilation, improvement in thermal comfort, and reduction in cooling energy.

Strategies for natural ventilation in Nagpur:

1. Opening should be placed perpendicular to wind direction to facilitate ventilation in monsoon season.
2. Hot summer winds and cold winter winds should be blocked.
3. Residences can be oriented 0° to 30° with respect to the prevailing wind direction, preferably orientating longer facades of the building towards predominant wind direction.
4. If the space has only one façade exposed to the exterior, it is preferred to provide at least 2 windows on the façade. Windows should be staggered rather than being aligned (refer above figure 17).

5. Use appropriate window design to facilitate natural ventilation. The openable area of a window predominantly ensures natural ventilation. For, example net openable area for casement window is 90%, whereas for sliding (2 panes) it is 50%.

Advanced Ventilation Techniques

Some ventilation techniques that can be utilised effectively in Nagpur are introduced in the following sections.

Courtyard Effect

Courtyard buildings were developed in an era when air-conditioning was not present. Courtyard buildings were an integral part of Indian architecture. The courtyard has social, cultural, religious, and environmental benefits.

Courtyards have been traditionally used in hot and dry climates, for example in Rajasthan in India. However, for a composite climate like Nagpur it can be effectively used to ger desired effect during peak summers and winters. During hot weather in the daytime, the interiors of the courtyards get heated up due to direct incident sun and reflected radiation from opposite walls heating up the relatively cooler air inside the courtyard. The rising heated air is replaced by cooler air from relatively cooler air.

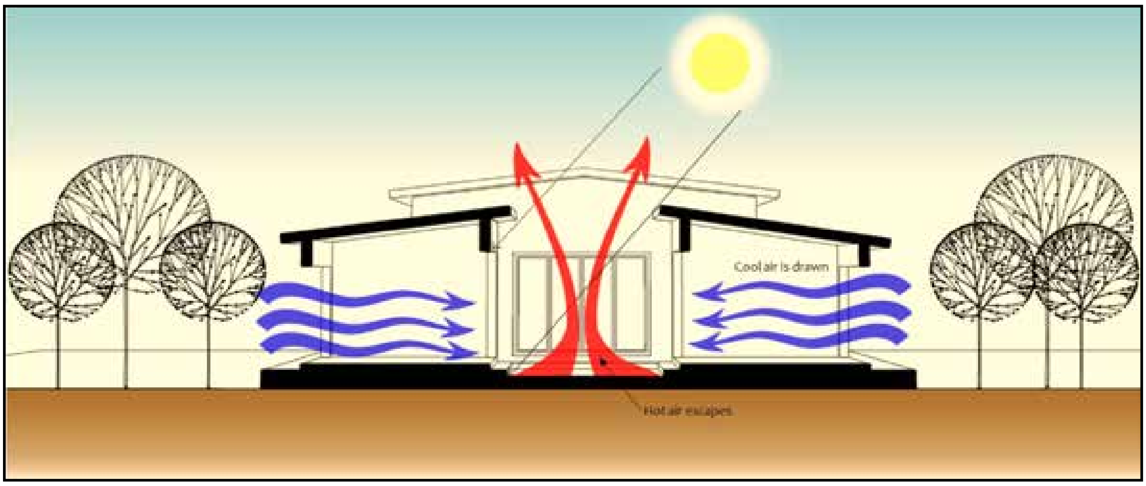


Figure 18: Daytime operations of Courtyard

After sunset, the warm air of the courtyard, which was heated directly by the sun and indirectly by the warm wall surfaces, rises and is gradually replaced by the already cooled night air from above. This cool air accumulates in the courtyard in laminar layers and seeps into the surrounding rooms, cooling them. In the morning, the air of the courtyard, which is shaded by its four walls, and the surrounding rooms heat slowly and remain cool until late in the day when the sun shines directly into the courtyard. The warm wind passing above the house during the day does not enter the courtyard but merely creates eddies inside. In this way, the courtyard serves as a reservoir of coolness.

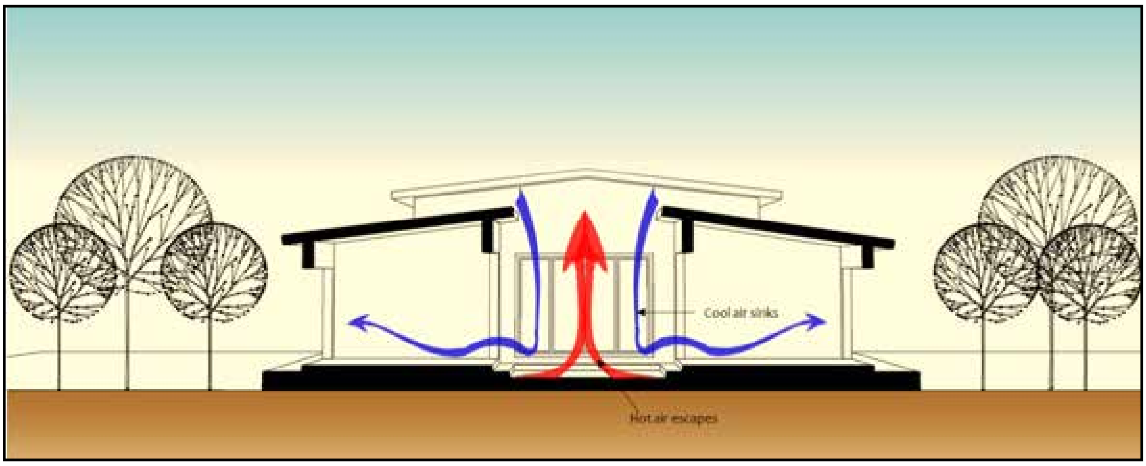


Figure 19: Night-time Operations of Courtyard

Stack Effect

Stack effect occurs in tall buildings, typically at places with vertical passages such as stairwells, elevators, or shafts. Stack effect works on temperature differentials within the building. When air inside a building is warmer than the outside air, the warmer less dense air rises. Stack ventilation takes advantage of this effect, in which the inside warm and light air escapes from the high vents of the stack, in turn drawing colder & denser outside air throw opening at the lower level. Longer stacks typically increases airflow. Stack effect can be enhanced by selecting the material for stack, in the below example the top section of the stack is made up of glass to increase the temperatures within the stack which in turn facilitates faster movement of air.

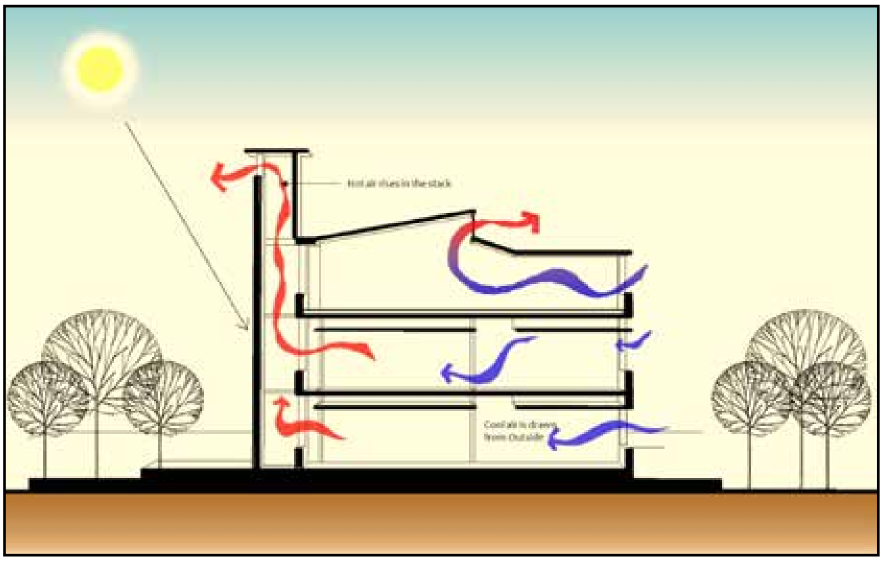


Figure 20: Stack Effect

Earth Air Tunnels

Earth air tunnel or earth air heat exchanger is a pre-cooling or pre-heating system which consists of a tunnel at reasonable depth below the ground surface. A wind tower is connected to the underground tunnel, which runs from the bottom of the wind tower to the basement of the building. The wind tower catches the wind which is forced down the tower into the tunnel. The temperature of the tunnel, being lower than that of the ambient temperature, cools the air before it is circulated into the living space. In winter, the temperature of the air tunnel is higher than the ambient temperature and hence warms the air passing through it. To reduce the underground temperature, the ground can be shaded using vegetation and can be wetted by sprinkling water. This water seeps through and dampens the tunnel walls. Consequently, air from the tunnel is evaporatively cooled as it passes through the tunnel. Another variation possible is to use buried pipes instead in place of tunnel.

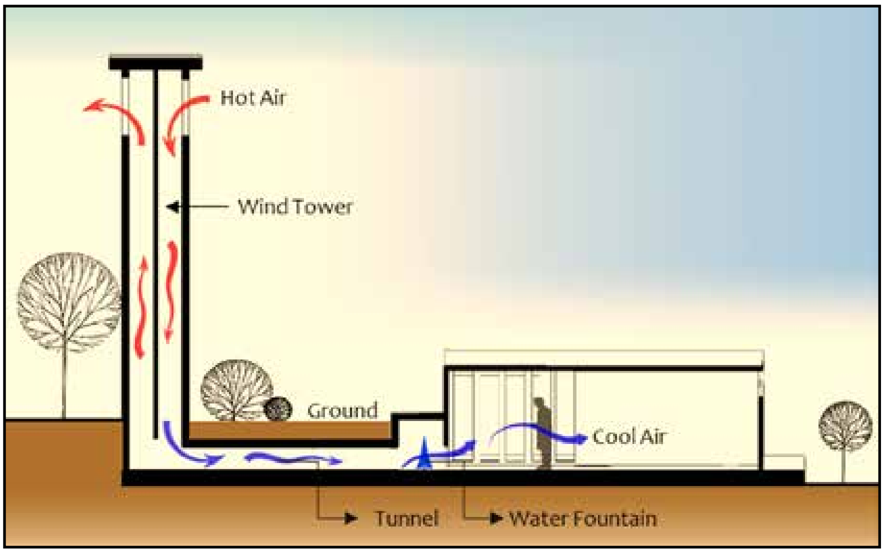
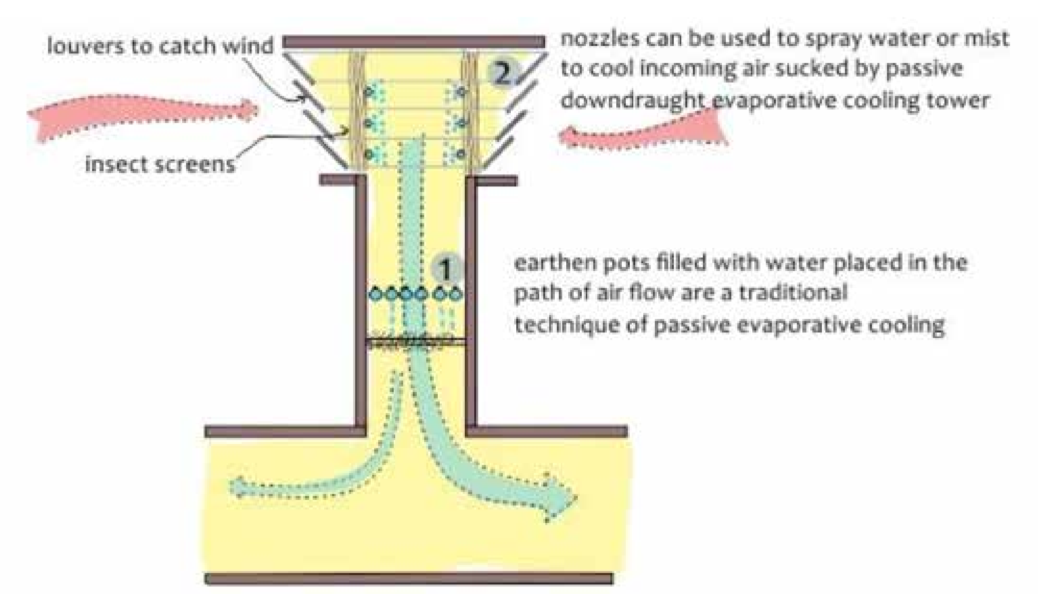


Figure 21: Earth Air Tunnel

Evaporative Cooling

Evaporative cooling is a process that uses the effect of evaporation as a natural heat sink. Evaporative cooling can be passive or hybrid. Where evaporation occurs naturally it is called passive evaporation. A space can be cooled by passive evaporation where there are surfaces of still or flowing water, such as basins or fountains. This phenomenon is largely witnessed in systems such as desert coolers in most Indian households.

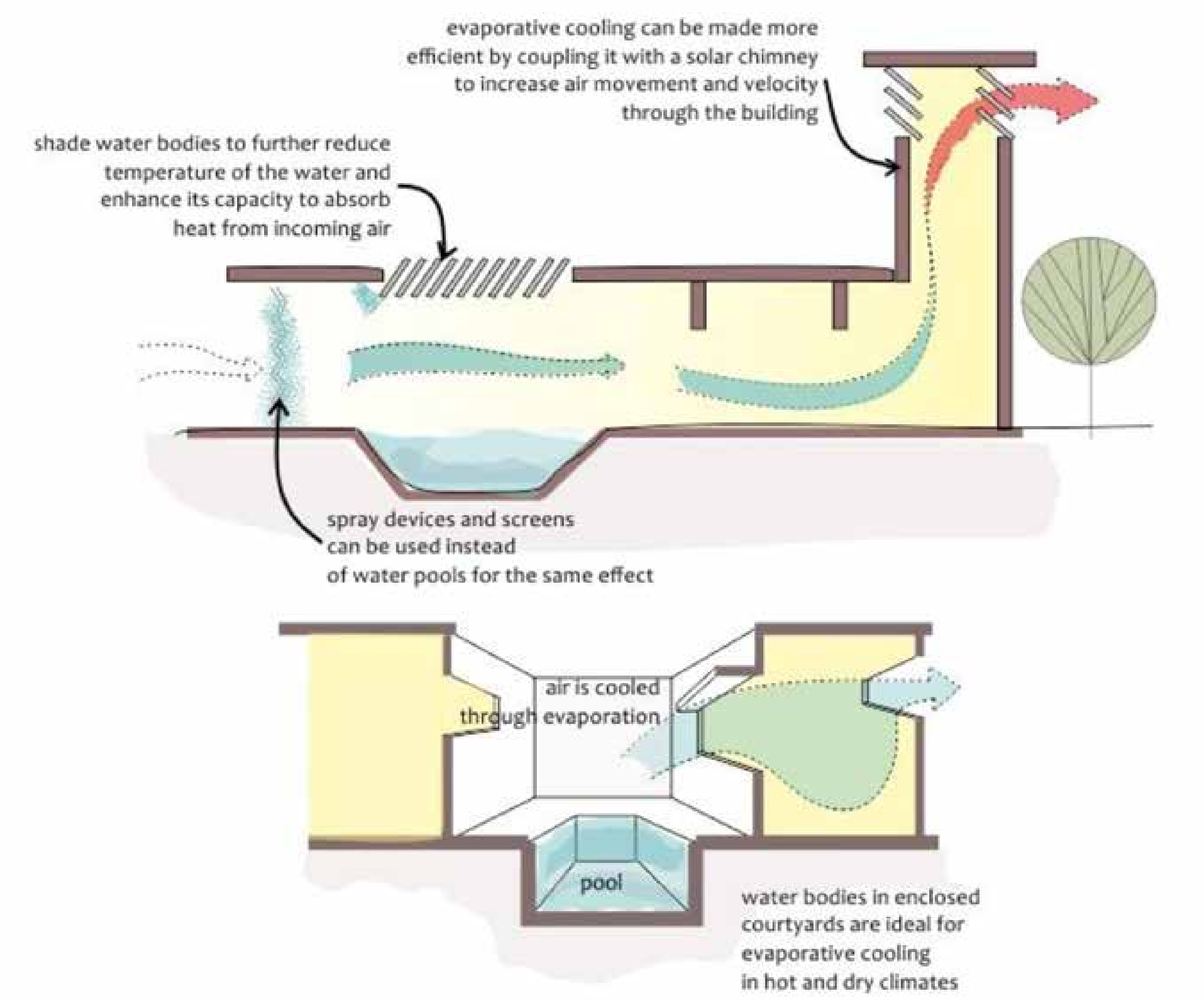
Passive downdraught towers catch hot ambient air through wind scoops at the top. This air is cooled either through mechanical systems like nozzle sprays or through passive systems like water filled vessels. The heavy cool air sinks to the bottom zone of habitable spaces. Efficiency depends on the temperature differential between the warm outside air and cool air inside the tower.



Source: https://nzeb.in/knowledge-centre/passive-design/evaporative-cooling/

Figure 22: Passive Downdraft Tower

Pools, ponds, and water features immediately outside windows or in courtyards can pre-cool air entering the house. As water evaporates it draws large amounts of heat from surrounding air. Where evaporation must be controlled by means of some mechanical device, the system is called a hybrid evaporative system.



Source: https://nzeb.in/knowledge-centre/passive-design/evaporative-cooling/

Figure 23: Example of Evaporative cooling

Shading

Direct sun can generate the same heat as a single bar radiator over each square metre of a surface, but effective shading can block up to 90% of this heat. Effectively shading a residence and its outdoor spaces leads to reduced summer temperatures, improved comfort and also reduced energy. A variety of shading techniques can help, from fixed or adjustable shades to trees and vegetation, depending on the building's orientation. Along with glazing type and size of the fenestration, shading devices are equally important in limiting heat gain from outside through radiation. External and internal shading devices can thus be used as an essential solution for achieving energy efficiency.

The most important factor in the design of external shading device is the orientation of the opening and the incident solar radiation on it. Impact of seasonal variation in the sun path (and incident solar radiation) is linked to the orientation. For Nagpur, during the winter season, Sun's path is at a low angle and, slightly to the south of east and west. In summer, sun path is at a high angle and, to the north of east and west. So, shading for south openings in the south must allow penetration of the low angle sun for heat gain during winter but must block the same during summer. For opening in north, shading is needed only to prevent penetration of the high sun angle during summers.

Solar radiation on east and west facing openings does not vary much by the seasonal variations in the sun path. They receive uniform solar radiation, while compared to north and south facing openings, which receive higher solar radiation through the year.

How to design effective shading devices for Nagpur?

Shading devices are required to block the unwanted Sun during the summer season. Direct sun falling on the glass of the window easily penetrates indoors as short-wave radiation and can easily travel through glass, due to the nature of the material.

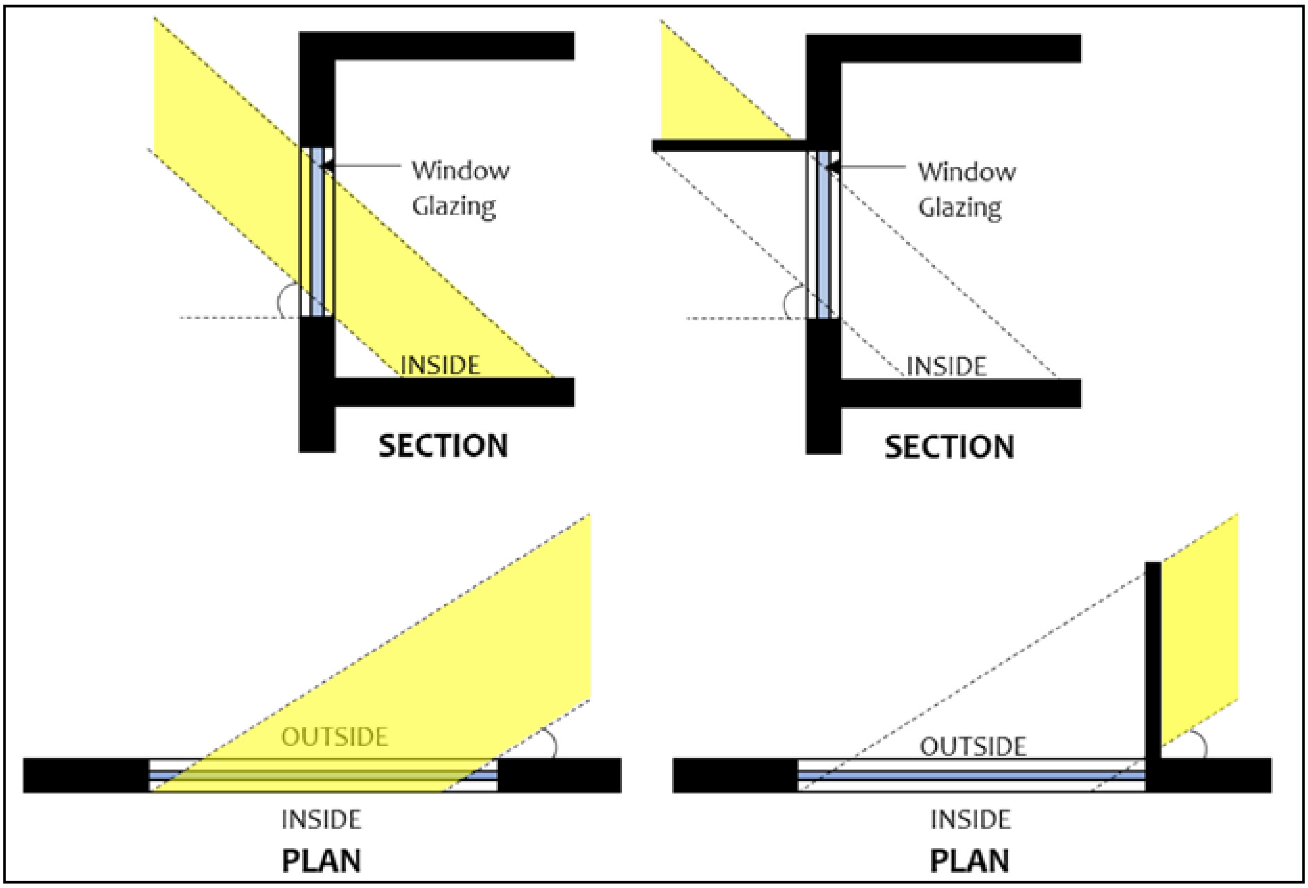


Figure 24: Overhang and Vertical Fins effectively block solar radiation

Depth and type of shading device is largely influenced by the solar angles and orientation.

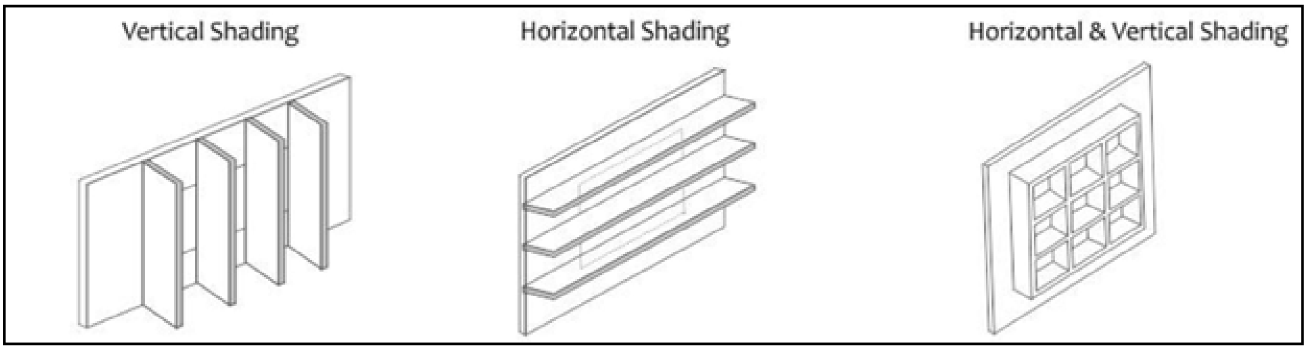
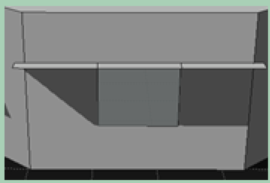
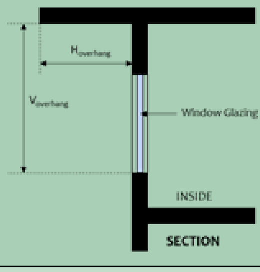
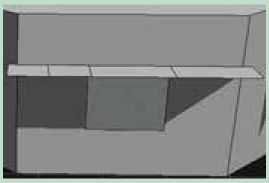
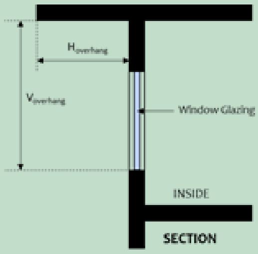
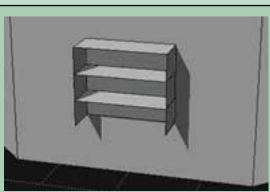
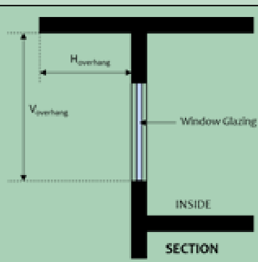
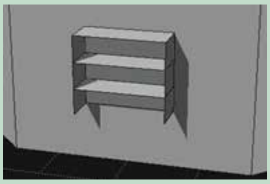
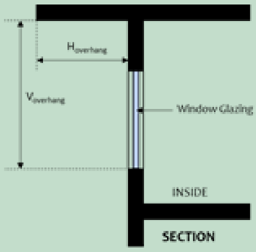
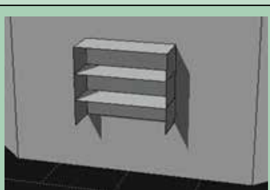
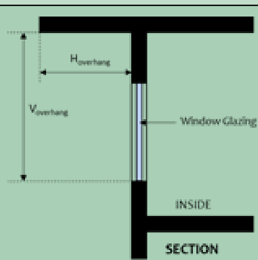


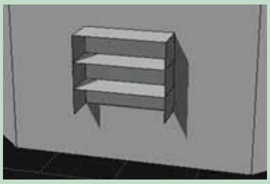
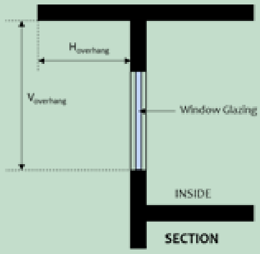
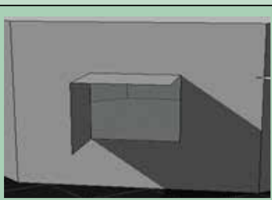
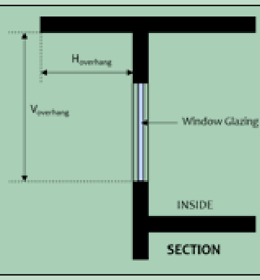
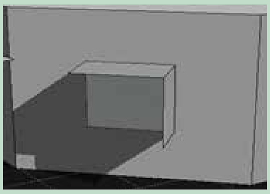
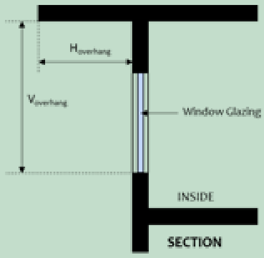
Figure 25: Types of Shading devices

The vertical and horizontal shading devices effectively work to cut off the direct solar angles on the windows.

Based on the geographic location of Nagpur, and the corresponding movement of the sun, the horizontal overhangs and vertical fins, or a combination of both, can be optimized to block the unwanted solar radiation. For an orientation, a certain type of shading device can be better suited to perform against solar ingress than others. The optimum shading assembly for each orientation is as below.

Table 1: Shading device design for each orientation

Orientation	Type of shading device	Size of horizontal or vertical shading device	
North	 Single Overhang		H overhang = 0.217 x V overhang
South	 Single Overhang		H overhang = 0.458 x V overhang
East	 Multiple overhang + Vertical fin		H overhang = 1.2 x V overhang If the dimension of the overhang is not practical, total dimension can be evenly distributed to smaller practical dimensions and distributed over the fenestration Vertical Fin Depth = H overhang
West	 Multiple Overhang + Vertical fin		H overhang = 1.075 x V overhang If the dimension of the overhang is not practical, total dimension can be evenly distributed to smaller practical dimensions and distributed over the fenestration Vertical Fin Depth = H overhang
South - East	 Multiple Overhang + Vertical		H overhang = 1.125 x V overhang If the dimension of the overhang is not practical, total dimension can be evenly distributed to smaller practical dimensions and distributed over the fenestration Vertical Fin Depth = H overhang

Orientation	Type of shading device	Size of horizontal or vertical shading device	
South - West	 Multiple Overhang + Vertical fin		H overhang = 1.083 x V overhang If the dimension of the overhang is not practical, total dimension can be evenly distributed to smaller practical dimensions and distributed over the fenestration Vertical Fin Depth = H overhang
North - East	 Overhang + Vertical fin		H overhang = 0.842 x V overhang Vertical Fin Depth = H overhang
North - West	 Overhang + Vertical fin		H overhang = 0.658 x V overhang Vertical Fin Depth = H overhang

To, block the Sun a combination of strategies is required to be used to achieve desired indoor environment.

The strategy includes not only designing the right size of shading devices but also selecting right glass specification. Solar Heat Gain Coefficient (SHGC) of glass is the key factor which should be identified while selecting glass, which impacts the amount of solar radiation travelling indoors. This combined strategy works effectively and can drastically reduce the heat ingress indoors.

Eco – Niwas Samhita 2018, Section 3.2 and Annexure 7, provides guidelines for calculating the Equivalent SHGC which can help designers select the right glass type based on its properties and provides guidance in designing right size of shading devices.

Strategies for designing shading devices for Nagpur:

1. Buildings should be oriented with the longer sides in North- South orientation.
2. South-facing windows are the easiest to shade. Horizontal shading devices are most effective as they can block sunrays in summer and admit sunrays in winter.
3. East and West facing windows are difficult to shade and should be avoided. If East- and West-facing windows exists, they are best shaded with a combination of horizontal and vertical shading devices.
4. For buildings with low height deciduous trees can be planted on strategic locations in the east and west to reduce summer overheating while allowing desirable winter solar gains.
5. An extended roof in form of canopy, balcony can provide shade to the entire north and south wall from the noon sun
6. Minimal shading is required on the north side. Vertical fins or Internal blinds can be used to cut low evening summer sun.
7. Semi-outdoor spaces such as balconies (2.5m – 3m deep) can provide shade and protect interior spaces from overheating and climatic variations.

8. If no exterior shading is possible, a lower solar heat gain coefficient (SHGC) for the window glazing is a must.

Daylighting

Daylighting is a design strategy to use light from the sun, to illuminate interiors of homes. Presence of natural light in an occupied space brings a sense of wellbeing, increases awareness of the surrounding and increases energy saving potential with reduced dependence on artificial light. Appropriate use of windows, skylights, clerestories, and other apertures in the dwelling unit provide means to harvest daylight.

It should however be noted that more sunlight entering the building, more internal heat gains are expected. Thus, care must be taken to place the fenestration appropriately. Daylighting is an integral part of Climate responsive design strategies and should be addressed from early design phase to lower energy consumption and provide enhanced daylight indoors.

How to ensure adequate daylighting indoors?

IGBC Green Homes Rating Version3.0 (For Multi-dwelling Residential Units), Residential Health and Wellbeing (RHW)-Mandatory Requirement 1 RHW credit 1 Enhanced Daylighting, provides a guideline for ensuring adequate daylight achievement indoors based on the types of space. This guideline can be used in early design stage to ensure adequate daylight is available for all spaces of a home. Glazing factor (GF) is a straightforward approach and requires simple inputs like total area of window, floor area and Visual Light Transmittance (VLT)of glass to confirm compliance. Minimum glazing factors should be achieved for each space independently.

Table 2: Glazing Factor required for different Spaces

Type of Space which are regularly occupied by residents	Glazing Factor (GF)*
Living	1
Bedroom / Study room	1
Kitchen	2

* For other spaces* which are not listed in the above table, a minimum glazing factor of 1 should be achieved.

Glazing Factor Calculation

$$\text{Glazing Factor} = \frac{\text{Window Area (sqmts)}}{\text{Floor Area (sqmts)}} \times \text{Actual Visible Transmittance of Glazing} \times \text{Constant} \times 100$$

Constant Values:

Windows on wall	0.2
Window on roof (skylight)	1.0

Floor area – floor area of individual space which is to be evaluated

VLT of glass – to be input in percentage; if manufacturer data states VLT of glass as 0.6, input 60% in calculations

Based on the above equation minimum window area is derived to achieve required glazing factor for different kind of spaces, assuming VLT of glass as 60%.

Table 3: Window area required for different room sizes and location

Window Area (Sqft)	Floor area (sqft)	Window location
3.5	20	Kitchen Window on wall
7	40	
14	80	
18	100	

Window Area (Sqft)	Floor area (sqft)	Window location
9	100	Living /Bedroom/ Study room Window on wall
13	150	
17	200	
21	250	
5	300	Living /Bedroom/ Study room Window on roof
6	350	
7	400	
8	450	
9	500	

VLT of glass indicates the potential of using daylight. Ensuring minimum VLT helps in improving daylighting, thereby reducing the energy required for artificial lighting. However, while selecting VLT for glass, it is important to also understand the Window – to – Wall ratio, as both these factors are equally important while making the glass selection. Eco- Niwas Samhita 2018, Section 3.2, provides guidelines for minimum visible light transmittance (VLT) requirement for specific Window- to – Wall ratio, which can be a good reference to help Architects and designer select the appropriate glass properties.

Strategies for daylighting in Nagpur:
1. Larger and taller residences should have thinner floor plates to maximize daylighting potential from side windows.
2. Large residences can get daylight into more spaces by having central courtyards or atria or having other cut-outs in the building form.
3. Focus should be given to increase uniformity of light spread through equal distribution of windows on façade and using reflective colours indoor.
4. Increasing the height of each storey will allow for higher windows also helps pull daylight further into the dwelling unit.
5. There is a direct relationship between the height of the window and the depth of daylight (Typically adequate daylight will penetrate 1.5 times the height of the window).
6. Use light-coloured interior surfaces to reduce luminance contrast and improves coverage.

Building Materials

Walls, windows, and the roof form the skin of the building which are exposed to climatic elements. Indoor environment is impacted largely on how the skin of the building responds to climatic elements. Selection of building skin with appropriate material properties, insulation, and colour based on climatic and functional requirements can reduce the number of hours when heating or cooling is required to maintain comfort.

Understanding building physics is important to make right selections while selecting building skin elements. The amount of heat that flows through a buildings skin is due to a temperature difference between inside and outside and is a function of the magnitude of that difference, the resistance to heat flow by the skin materials. Because heat flows from hot to cold, if the inside is warmer than the outside, the heat will flow outwards. If the inside is cooler than the outside, the heat will flow inward.

The rate of heat flow through the building materials is usually described in terms of resistance (R). R is the number of hours needed for 1 Watt to flow through one square meter of skin given a temperature difference of 1-degree Celsius. The reciprocal of R, the U- value, is the number of Watts that will flow through one square meter of building skin in one hour given a temperature difference of 1-degree Celsius.

Impact of U Value on cooling load indoor temperatures and cooling load

The cooling load is the amount of heat energy that would be needed to be removed from a space (cooling) to maintain the temperature in acceptable range. The cooling load is largely impacted by the construction materials used for building. Lower cooling loads indicate that, relatively, the dwelling will require less cooling to maintain comfortable conditions. Lower thermal loads correspond to lower electricity usage. Below stated example explains how cooling load as well indoor temperatures vary by using different walling materials.

Figure 26: Proposed plan for LIG building for Home Sweet Home Program

The proposed building is G+11 residential structure with 2 floors of slit parking. Various wall assembly parameters are assigned to the external walls and simulation was conducted on the dwelling units to assess the performance of the external walls and the roof. The building envelope combinations of increase in thermal mass, addition of insulation and creating an air cavity were identified to be tested on a Building Energy Analysis software – DesignBuilder.

Table 4: Cases considered for thermal performance of envelope material

Case	Wall Parameters		Roof	
	Specification	U value (W/m².k)	Specification	U value (W/m².k)
Case 1	160mm RCC (MIVAN Tech)	3.52	100mm RCC Slab + 50mm Brick Coba	3.45
Case 2	160mm RCC + 50mm XPS insulation	0.539	100mm RCC Slab + 50mm Brick Coba + 25mm PUF	0.85
Case 3	200mm AAC Block	0.754	100mm RCC Slab + 50mm Brick Coba + 25mm PUF	0.85
Case 4	200mm AAC Block + 50 mm XPS insulation	0.361	100mm RCC Slab + 50mm Brick Coba + 25mm PUF	0.85
Case 5	Rat Trap Bond (65mm Brick + 100mm Airgap + 65mm Brick)	1.75	100mm RCC Slab + 50mm Brick Coba + 25mm PUF	0.85

The cooling load analysis for above cases is as below:

Table 5: Cooling Load analysis

Case	Wall + Roof - Cooling Load (kW)
Case 1	404
Case 2	97
Case 3	91
Case 4	64
Case 5	229

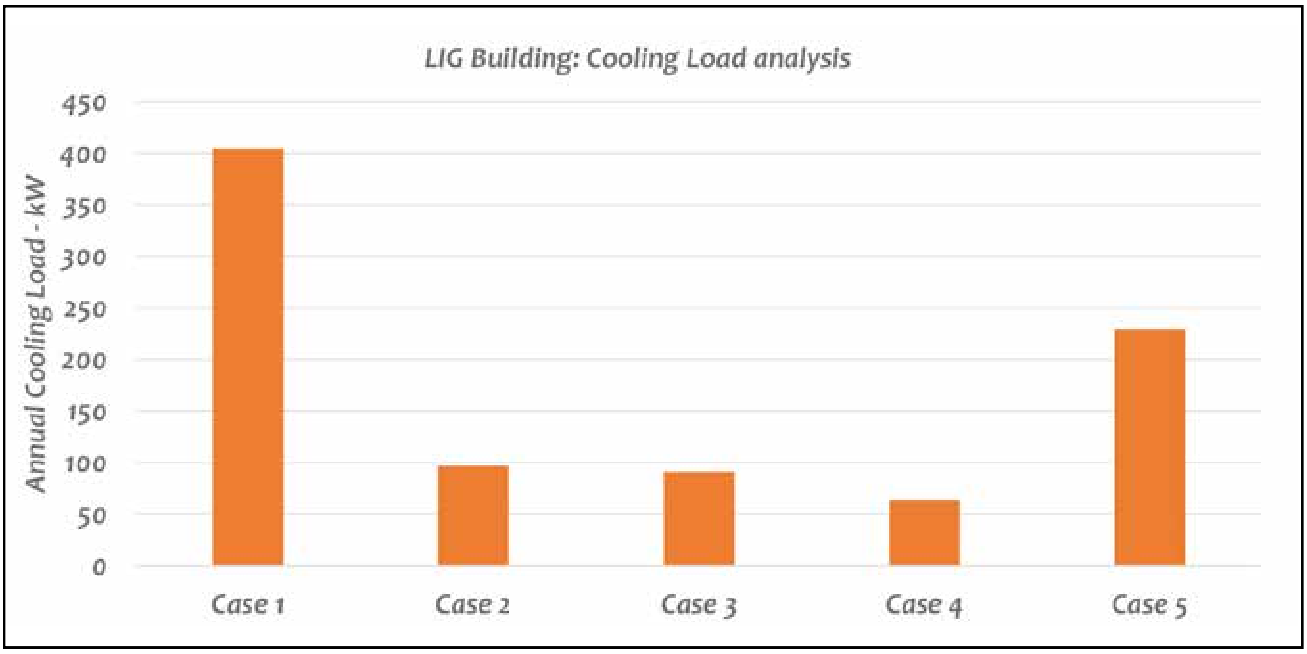


Figure 27: Cooling load analysis of proposed LIG building, Nagpur

From the above analysis it is understood that case 4 i.e. 200mm AAC Block + 50 mm XPS insulation performs better than all other building envelope and results in minimum cooling load for the building in study.

The analysis of the indoor air temperature performed for summer design day resulted in following:

Table 6: Indoor Temperature analysis

Case	Average Indoor Temp (Daytime) °C	Average Indoor Temp (Night-time) °C
Case 1	38.77	37.46
Case 2	37.51	36.47
Case 3	38.37	37.01
Case 4	37.37	36.30
Case 5	37.75	36.82

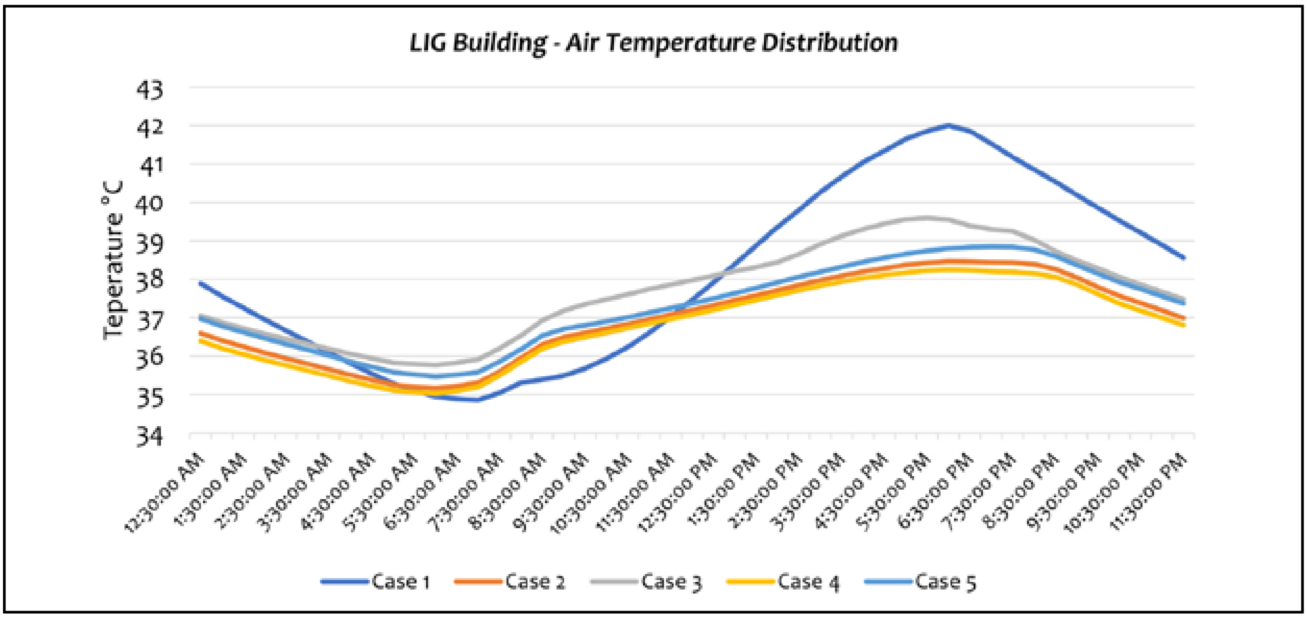


Figure 28: Internal temperature trend for different materials

From the above graph, it is understood that case 4 results in lower indoor temperatures during day and night-time, when compared with other building envelope configurations.

We thus understand that, while selecting construction materials U – value of the material is very critical. As different construction materials may have different U – values, it is required to approach this subject with a better understanding rather than just selecting material with higher U value. In a building/ home all components of the building envelope (windows, walls, glass) and roof are exposed to heat, hence a holistic approach of achieving better building performance is required over selecting individual envelope components, based on its thermal performance. Eco- Niwas Samhita 2018 is the Energy Conservation Building Code - Residential (ECBC-R) (Part I: Building Envelope) which has been prepared to set minimum building envelope performance standards to limit heat gains (for cooling dominated climates) and to limit heat loss (for heating dominated climates), as well as for ensuring adequate natural ventilation and daylighting potential, and is a holistic approach of designing homes. The code provides necessary guidelines to meet building performance based on climate zone and same can be used by Architects and designers while building design and selecting construction materials, in Nagpur.

Below table highlights different kind of wall material and insulation material used in walling systems which are conventionally used and corresponding U value & approximate cost.

Table 7: U value and approximate cost for materials used for walling systems

Category	Size (mm)	U-value (W/m^2K)	Density (kg/m^3)	Approx Cost (Rs./ sq. mt)
Brick wall (designation 5) designation 7.5)	115	6.26	1922.16	1162.69
	230	3.13	1922.16	1814.44
	345	2.09	1922.16	2466.24
Cement Stabilized Brick Wall	125	5.20	1922.16	1162.69
	250	2.60	1922.16	1814.44
	375	1.73	1922.16	2466.24
Fly Ash Brick Wall (designation 7.5)	100	5.40	1569.76	1080.66
	200	2.70	1569.76	1650.39
	300	1.80	1569.76	2220.11
Hollow Concrete Block Wall	200	1.82	1265.42	1403.30
	300	1.21	1265.42	1987.10
Insulated Block Wall	200	0.40	1374.34	2497.75
	300	0.27	1374.34	3628.75
Autoclaved Aerated Concrete Block Wall	100	1.40	549.90	1149.64
	200	0.70	549.90	1788.34
	300	0.47	549.90	2426.94
Extruded polystyrene (XPS)	25	1.12	34.92	926.81
	50	0.56	50.94	1246.22
	75	0.37	66.96	1565.63
	100	0.28	82.97	1885.04
Expanded polystyrene (thermocole) (EPS)	25	1.52	28.83	752.58
	50	0.76	44.85	897.77
	75	0.51	60.87	1042.96
	100	0.38	76.89	1188.14
Polyurethane Density-36±2Kg/3	25	0.93	24.03	1132.39
	50	0.47	40.05	1450.64
	75	0.31	56.06	1800.26
	100	0.23	72.08	1925.70

Category	Size (mm)	U-value (W/m²K)	Density (kg/m³)	Approx Cost (Rs./ sq. mt)
Bonded Mineral wool (Rock/ glass wool)Density-64Kg/m³	25	1.36	63.91	1085.65
	50	0.68	79.93	1208.19
	75	0.45	95.95	1330.73
	100	0.34	111.97	1453.27
Glass fibre and mineral fibre	25	1.32	72.08	1081.59
	50	0.66	88.10	1200.06
	75	0.44	104.12	1318.53
	100	0.33	120.14	1437.00

Below table highlights different kind of insulation material used in roofing systems which are conventionally used and corresponding U value & approximate cost.

Table 8: U value and approx. cost for materials used for roofing systems

Category	Size (mm)	U-value (w/m²K)	Density (kg/m³)	Approx Cost (Rs/unit)
Extruded polystyrene (XPS)	25	1.13	34.92	497.28
	50	0.57	50.94	816.70
	75	0.38	66.96	1136.11
	100	0.28	82.97	1455.52
Expanded polystyrene (thermocole) (EPS)	25	1.52	28.83	323.06
	50	0.76	44.85	468.25
	75	0.5	60.87	613.43
	100	0.38	76.89	758.62
Polyurethane Density-36±2Kg/3	25	0.84	24.03	795.79
	50	0.42	40.05	1114.04
	75	0.28	56.06	1463.65
	100	0.21	72.08	1589.09
Bonded Mineral wool (Rock/ glass wool) Density-64Kg/m3	25	1.16	63.91	205.82
	50	0.58	79.93	328.36
	75	0.387	95.95	450.89
	100	0.2	111.97	573.43
Glass fiber and mineral fiber	25	1.32	72.08	201.75
	50	0.66	88.10	320.23
	75	0.44	104.12	438.70
	100	0.33	120.14	557.17

Below table highlights glass material which are conventionally used and corresponding U value & approximate cost.

Table 9: U value and approximate cost for glass

Make	Model no	Coating type	Performance category	Solar factor (SHGC)	U-Value (W/sq.m-K)	Cost (Rs/m²)
Pilkington	Solar E Clear	clear	High	0.53	2.80	1100
Pilkington	Pilkington K Glass / Energy advantage	tinted	High	0.71	2.80	1050
Pilkington	Solar-E II EverGreen	tinted	High	0.32	2.85	1200

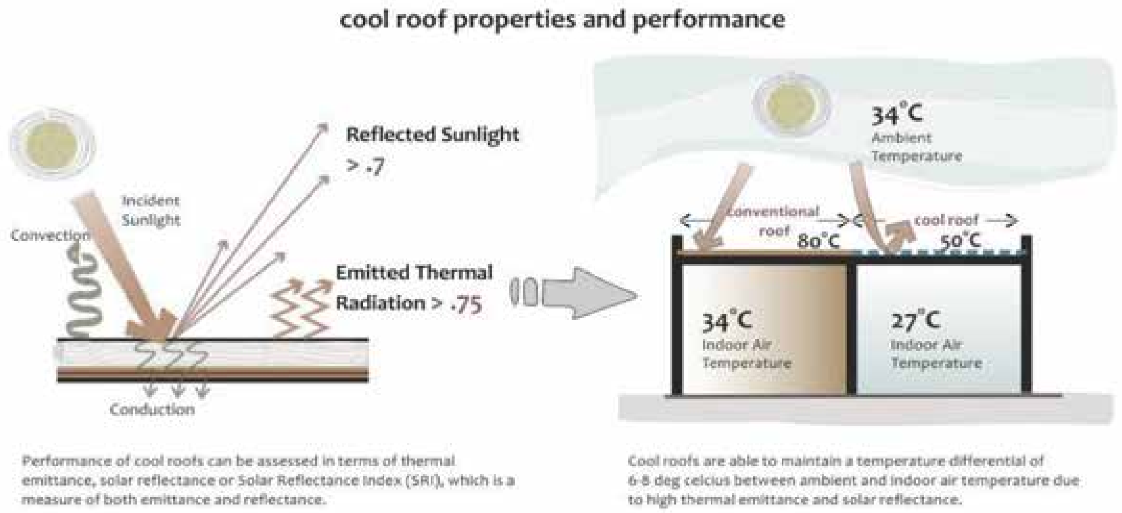
Make	Model no	Coating type	Performance category	Solar factor (SHGC)	U-Value (W/sq.m-K)	Cost (Rs/m²)
Pilkington	Solar-E II Grey	tinted	High	0.34	2.85	1150
Pilkington	Eclipse Advantage Clear	clear	High	0.62	3.01	1000
Pilkington	Eclipse Advantage Bronze	tinted	High	0.46	3.01	1100
Pilkington	Eclipse Advantage EverGreen	tinted	High	0.37	3.01	1100
Saint Gobain	SG 43	clear	High	0.14	3.6	1350
Saint Gobain	SG 28	clear	High	0.28	3.72	1450
AIS	Ecosense Enhance Ivory	Clear	High	0.34	4.5	1200
Pilkington	Clear	clear	Low	0.82	5.27	800
Pilkington	Bronze	tinted	Low	0.62	5.27	800
AIS	Ecosense Enhance Spring	Clear	Low	0.64	5.4	1200
AIS	Ecosense Enhance Marine	tinted	Low	0.48	5.4	1200
AIS	Sunshield Icy Clear	Clear	Low	0.65	5.4	1200
Saint Gobain	SG 46	clear	Low	0.54	5.6	1250
Saint Gobain	SG 71	clear	Low	0.50	5.7	900
AIS	Ecosense Enhance Nectar	Clear	Mid	0.45	4.8	1200
AIS	Ecosense Enhance Indigo	tinted	Mid	0.38	4.9	1200
Saint Gobain	SG 34	clear	Mid	0.50	5.00	1350
Saint Gobain	SG 35	tinted	Mid	0.39	5.00	1350
Saint Gobain	SG 44	clear	Mid	0.29	5.2	1350
Pilkington	EverGreen	tinted	Mid	0.53	5.27	800
AIS	Ecosense Enhance Snow	Clear	Mid	0.38	5.4	1200
AIS	Ecosense Enhance Cove	tinted	Mid	0.36	5.4	1200
AIS	Ecosense Enhance Pine	tinted	Mid	0.35	5.4	1200
AIS	Sunshield Leaf Green	tinted	Mid	0.34	5.4	1200
AIS	Sunshield Oceanic Blue	tinted	Mid	0.42	5.4	1200
Saint Gobain	SG 55	tinted	Mid	0.40	5.6	1000
Pilkington	Emerald Green with Reflite coating	tinted	Mid	0.28	5.70	900
Saint Gobain	SG 75	tinted	Mid	0.35	5.7	900

Strategies to select building material for Nagpur:

1. For low rise developments i.e. single or double storied buildings, adding insulation on the roof is important to reduce the heat gain from roof. Green roofs can be installed as a part of insulation
2. For multi storied building adding insulation on the walls is more important than adding on the roof. This is because the roof area is far less as compared to the wall area which are exposed to environment.
3. Alternative construction technology and materials can be used to delay heat transfer like cavity walls, rat trap bond methodology.
4. Eco Niwas Samhita 2018, Table 7 of Part I: Building Envelope guideline can be used while selecting materials for walls, glass, and roof.

Cool Roof

A cool roof is one that reflects most of the incident sunlight and efficiently emits some of the absorbed radiation back into the atmosphere, instead of conducting it to the building below. Thus, the roof literally stays cooler, with lower surface temperatures, keeping the building at a cooler and more constant temperature. The term, 'cool roof' refers to the outer layer or exterior surface of the roof which acts as the key reflective surface. These roofs have higher solar reflectance than a typical roof surface. The term 'cool roof' includes an extensive array of roof types, colours, textures, paints, coatings, and slope applications.



Source: www.nzeb.in

Figure 29: Cool Roof Properties and Performance

Solar Reflectance Index

Though most roofing materials have a fairly high thermal emittance, in order to accurately determine a roofing product's 'coolness', or its ability to shield the building beneath it from heat, both solar reflectance and thermal emittance must be measured. A high emittance value alone will not result in a cool roof nor will a high reflectance value alone. The Solar Reflectance Index (SRI), which incorporates both solar reflectance and emittance in a single value, quantifies how hot a surface would get relative to standard black and standard white surfaces.

Cool roofs can be selected from a wide variety of materials and colours and can be advantageously applied to almost any building or roof type. Moreover, cool roofs are a viable option for both new and existing building applications. For new buildings, the incremental cost of adding cool roofs is minimal, or, at times, none.

While selecting the roofing material, colour, finish etc, one can refer any of the following guidance:

According to ECBC 2017 cool roof requirement, roofs with slopes less than 20° shall have an initial solar reflectance of no less than 0.60 and an initial emittance no less than 0.90. Solar reflectance shall be determined in accordance with ASTM E903-96 and emittance shall be determined in accordance with ASTM E408-71 (RA 1996).

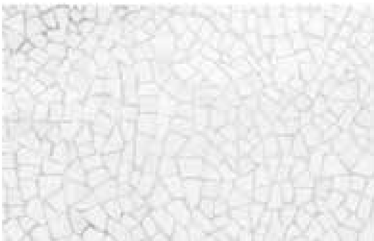
The IGBC Green Homes version 3 requires exposed roof areas should meet minimum Solar Reflective Index (SRI*) values for different roof types as below:

Table 10: Solar Reflectance Index (SRI) values for roof types

Roof Type	Slope	SRI
Low-sloped roof	< 1:6	78
Steep-sloped roof	> 1:6	29

Table 11: Solar Reflective Index (SRI) for some of the standard roofing materials

Materials	Typical Solar Reflective Index (SRI)
Gray Asphalt Shingle	22
Unpainted Cement tile	25
Light Gravel on Built – Up roof	37
White – Coated gravel on Built-up roof	79
White Cement Tile	90
White Coating – 2 coats, 20 mm	107



Green Roof

A green roof is a roof surface, flat or pitched, that is planted partially or completely with vegetation and a growing medium over a waterproof membrane. They may be 'extensive' and have a thin growing medium (up to 200mm deep) with 'groundcover' vegetation, or 'intensive' and have soil over 200mm deep supporting vegetation up to the size of trees.

Green roofs or roof gardens can be used as they help to reduce heat loads in a building. The additional thickness of the growing medium provides extra thermal insulation. The green cover lowers ambient temperatures through evapotranspiration. Green roofs can be categorised as intensive, extensive and modular blocks. The biggest difference is with respect to the depth of soil and resultantly, the type of vegetation that can be supported in each of the types. Soil depth in intensive green roofs is at least 300mm, in extensive roofs about 25 to 125 mm, and in modular blocks about 100mm. Roof structures have to be sturdy for supporting green roofs as these impose greater dead weights than normal roofs.

Strategies for designing roofs for Nagpur:

1. Cool roofing materials includes use of well-graded broken pieces of glossy glazed tiles (broken china mosaic), modified bitumen with plastic and a layer of reinforced material.
2. Reinforced Cement Concrete (RCC) roof topped with elastomeric cool roof coating or simply finished with broken white glazed tiles, also qualifies as Cool roof.
3. Customized concrete and clay tiles may be obtained in white, increasing the solar reflectance to about 70 percent (compared to 20-30 percent range for red tile).
4. Roof insulation can be added to concrete roof.
5. Terrace garden can be created based on green roof guidelines, above.
6. Solar panels can be installed at the roof level to reduce the flow of heat from roof to floor below.

Chapter 5 – Selection of Energy Efficient Lighting Systems, Equipment and Appliances

As the size of buildings increases, the opportunity for total daylighting or passive solar heating and cooling decreases. This is because large buildings are more complex, more difficult to predict and guarantee the performance, and the criteria used to judge their performance become more restrictive. Also, in current situation residents largely rely on artificial lighting and air conditioners, to achieve desired comfort in day to day life. These supplemental systems should not be the final step in design, as they largely impact the overall energy performance of the building. Rather, they should be regarded as just one more item on the schematic design stage, to be accounted for before proceeding to the next level of detail in design. There lies a huge opportunity to save electrical energy by selecting systems like lamps, room air conditioners, water heaters, refrigerators colour television, etc which not only are efficient but also save money by reducing electricity bills.

Artificial Lighting design

Light plays an essential role in our ability to perceive the world around us; the lighting system plays a critical role in how we perceive a space and can even influence how we act in that space. Lighting can affect performance, mood, morale, safety, security, and decisions. While creating a space various lighting technique can be used such as downlighting, wall washing, cove lighting, up lighting, silhouetting etc to create a specific ambience. However, it is equally important to understand how the designed lighting will impact the overall energy consumption. Lighting in homes consumes 8-15% of the average household electricity budget, although this can differ depending on the lighting technologies used, lighting design and user behaviour. Efficient and well-designed lighting can make for significant energy savings.

Harvesting Daylight

Maximising the use of daylight should be the first step of design so that electric lighting is not required during daylight hours. Then, create a lighting design strategy that meets the needs in the most efficient way, including daylight design. Above section of the guidelines provides guidance on designing a daylit space.

Lamp Selection

The lighting design process in its most basic form requires identifying a task and then providing a light source that will provide proper quantity and quality of light for the task. The fixture protects the light source, connects it to the power source and distributes its light. The first step in the selection of lamp is to select the range of lamps satisfying the quality requirements such as energy use (total wattage), amount of light emitted (lumen output) , colour and temperature properties, glare, lamp life etc. and then select the lamp which has the highest efficacy within the group.

Luminous Efficacy of the lamp can be calculated by using data from Manufacturer i.e. the lamp lumen output and wattage.

Luminous efficacy (lm/W) = lamp lumen output / total lamp wattage

Total lamp wattage = rated lamp wattage + (% loss from ballast x rated lamp wattage)

Types of Lamps

Light Emitting Diodes (LEDS)

LEDs (light emitting diodes) are basically solid-state devices like a semiconductor or circuit chip – there is no filament like an incandescent bulb, and no gas like fluorescent bulbs. LED light fittings are typically made up of several LEDs combined. These are very energy-efficient with low heat output and are extremely long lasting – between 15,000–30,000 hours and more in some cases, compared to around 1000–2000 for incandescent bulbs. While LEDs should ideally be used in every room in the house, their long lifespan is especially useful in stairwells and other locations where bulbs are difficult to change.

The LED lighting market has seen huge development in recent years, and now LED bulbs are available to replace incandescent or compact fluorescent bulbs in most existing fixtures and fittings, including spotlights and downlights. Some LEDs are dimmable, and LED lights that produce a warm white light are available.

The Bureau of Energy Efficiency (BEE) website https://www.beestarlabel.com/SearchCompare has an inventory of numerous LED lamps which are categorised based on make & model number, wattage and Star Rating. While selecting lamps for new home or while making significant renovation, these are a good option.

Fluorescent lamps

A fluorescent lamp is typically a low-pressure mercury-vapor gas-discharge lamp that utilises fluorescence to produce visible light. Fluorescent lamps are very energy-efficient, using as little as 20% of the energy to provide the same light output as an incandescent lamp are long lasting (up to 10,000 hours) can provide light in a range of colours.

Fluorescent tube lamps (TFL) are available in straight or circular styles and require special fittings. These lamps are accompanied with a ballast, with respect to energy savings perspective electronic ballasts should be used as they are more energy efficient, longer lasting, start the lamp quicker, produce less flicker and are dimmable, however are more expensive. The Bureau of Energy Efficiency (BEE) website https://www.beestarlabel.com/SearchCompare has an inventory of numerous TFL's which are categorised based on make & model number, wattage, colour temperature and Star Rating.

Compact fluorescent lamps are similar to fluorescent lamps but can fit into conventional screw-fitting light sockets. They come in a range of styles – stick, globe, circular, square and can replace incandescent light bulbs in most light fittings. These have an integral ballast and should be concealed within a fitting to minimise glare.

They may not be able to be used with dimmers or sensors and electronic switches.

Lighting Controls

Lights can be controlled to shut off when there is ample daylight available or the space is unoccupied. While this can be done manually most common automatic controls such as dimmers, motion, occupancy sensors, photosensors and timers can be also used to reduce energy consumption.

Dimmer Controls

Dimmer controls provide variable indoor lighting. When lightbulbs are dimmed, it reduces their wattage and output, which helps save energy. Dimmers are inexpensive and provide some energy savings when lights are used at a reduced level. They also increase the service life of lightbulbs significantly. Dimming ballast can be used with compatible TFL's and LED lamps which can provide greater energy savings as compared to a conventional TFL's and LED lamps.

Sensor Controls

Motion or Occupancy sensors turn lights on automatically when someone comes in to a space and turns lights off (either by movement or after a set period of time) when the person leaves potentially saving energy. These sensors use a small amount of power by being on standby, but this is much less than lights that are left on continuously. Motion sensors can be effectively used for outdoor lights in residential complex which will automatically turn outdoor lights on when they detect motion and turn them off a short while later. They are very useful for outdoor security and utility lighting. Photosensors turn lights on when the room or outdoor is not daylit. Photosensors can be used to prevent outdoor lights from operating during daylight hours, which can save energy.

Timer Controls

Timers can be used to turn on and off outdoor and indoor lights at specific times. This saves energy by ensuring that lights are not left on indefinitely, but they can also cause safety issues if the light goes off without warning. Timer controls can be programmable to specific use, for example switching lights on only during certain times of the day. However, they can be used effectively in combinations with other controls. For example, the best combination for aesthetic lighting may be a photosensor that turns lights on in the evening and a timer that turns the lights off at late night hour.

Energy Efficient Lighting Design

Energy-efficient lighting design can be achieved when all aspect of lighting design work in tandem i.e utilisation of daylight, providing required illumination where needed, selecting appropriate lighting fixtures, turning off artificial lights when not needed, maintaining light coloured finishes of ceiling, walls and furnishings.

Strategies for energy efficient lighting

1. Install fluorescent or LED light fixtures for all ceiling- and wall-mounted fixtures that will be on for more than 2 hours each day, such as kitchen and living room, bathroom, and other higher-demand locations.
2. Install all lighting fixtures in outdoor spaces and indoor common areas with a minimum luminous efficacy of 75 lumen/watt, reference Criterion8, GRIHA Affordable Housing Manual v.1
3. Automatic controls must be provided for 100% of outdoor lights, reference Criterion8, GRIHA Affordable Housing Manual v.1
4. Use BEE Star labelled lighting fixtures.
5. Use occupancy sensors for automatically turning on and off lights as needed, these can be used for storage areas.
6. Use timers and other controls to turn decorative lighting on and off.
7. Consider light wall colours to minimize the need for artificial lighting.
8. Use LED or fluorescent lights with timer control for outdoor lighting in small residences.
9. Consider flood lights with combined photosensors and motion sensors in the place of other security lighting options, large residential complexes.
10. Use solar LED streetlight wherever applicable.

Pumps and Lifts

In multi-storeys residential complexes common services including lifts, water pumping systems contribute largely towards energy consumption, along with common area lighting. Their lies a huge opportunity to save energy required for pumping and lift in the range of 25% - 30%.

Pumps

Typically, in a multi-storey building, water is received from the municipal water supply to a ground-level reservoir and is then pumped to an overhead reservoir located at the roof level. The water is then distributed to individual dwelling unit. In low rise building traditionally this supply of water was done by using gravity until recently hydro pneumatic pumping system are being utilized in high rise residential complexes. The electricity consumption of the water pumping systems depends upon size and type of pump, motor type and control, and piping design. While selecting the pumping system for multi storey residential complex, design guidelines formulated by Bureau of Energy Efficiency (BEE) for Energy Efficient Multi- Storey Residential Buildings can be used which ensures reduced energy consumption.

Pumped Gravity System

- Select pump so that the head and flow parameter for the 'Duty Point' matches with that of the 'Best Efficiency Point' of the pump.
- Design piping so as to reduce frictional losses
- Use variable frequency drives (VFDs) on pump motors.

Hydro-Pneumatic System

- Install VFDs for all pumps

Lift

There are two main types of lifts used in residential buildings I.e. hydraulic lifts and traction lifts. Traction lifts can be classified further as geared, gearless, and machine room-less lifts. Electricity is consumed during the operation of lifts and during the stand-by mode. Electricity consumption largely depends upon the type of lift, controls for electric motors, type of braking system, and type & control of lighting and ventilation systems in the lift car. While selecting the lift for multi storey residential complex, design guidelines formulated by Bureau of Energy Efficiency (BEE) for Energy Efficient Multi- Storey Residential Buildings can be used which ensures reduced energy consumption.

Measures to reduce standby electricity consumption

- Use LED or CFL for the lighting of the lift car
- Avoid dark interiors in the lift car
- Use high efficiency motors for the ventilation of the lift car
- Provide auto switch-off for lights and ventilation fan

Measures to reduce running electricity consumption

- Use of VFDs in motors
- Lifts with gearless systems
- Incorporation of regenerative braking

Household Equipment and Appliances

Household appliances and equipment account for about 33% of energy consumption and about 45% of greenhouse gas emissions in the average household. Careful selection of appliances and equipment can save money and reduce environmental impact without compromising lifestyle.

Commonly used household equipment and appliances

- Television
- Refrigerator
- Home entertainment
- Microwave
- Dishwasher
- Appliances related to cooking – food processor, Grinder, electric kettle etc
- Air Conditioners
- Ceiling Fans
- Pumps
- Motors
- Room Heaters
- Water Heaters
- Computer monitors

The Bureau of Energy Efficiency (BEE) initiated the Standards & Labelling programme for equipment and appliances in 2006 to provide the consumer an informed choice about the energy saving and thereby the cost saving potential of the relevant marketed products. The energy efficiency labelling programs under BEE are intended to reduce the energy consumption of appliance without diminishing the services it provides to consumers. BEE's website is comprehensive and lists down all compliant equipment, appliances, room air conditioners, lamps and many more items, which are categorised based on their energy performance i.e from 1 Star – 5 Star. One has multiple options to choose from, right from energy consumption to make and model number of a product. These products should be reviewed while making selection for new home or during refurbishments.

BEE's Star labelled equipment and appliance are follows:

1. Ceiling Fan
2. Colour Television
3. Computer
4. Direct Cool Refrigerator
5. Distribution Transformer
6. Domestic Gas Stove
7. Frost Free Refrigerator
8. Room Air Conditioners (Fixed Speed)
9. Room Air Conditioners (variable Speed)
10. General Purpose Industrial Motor
11. Monoset Pump
12. Openwell Submersible Pump Set
13. Stationary type water heater
14. Submersible Pump Set
15. TFL
16. Washing Machine (Semi/Top load/front load)
17. LED Lamps
18. Chillers
19. Microwave Oven

Strategies for selection of equipment and appliances

1. Choose equipment or appliance that is the right size for your needs.
2. Use the highest BEE star rating possible and 3 star rated appliances at a minimum

Chapter 6 – Renewable Energy Technologies

Renewable Energy Technologies

Renewable energy is collected from renewable resources. It originates from natural sources or processes that are constantly replenished. For example, sunlight or wind keep shining and blowing, even if their availability depends on time and weather. With increasingly innovative and less expensive technologies, it is easier to install renewable energy generation systems even at an individual home, that would convert the solar/wind energy into different forms of utilities like electricity or hot water.

Renewable Energy systems for Home

At residential level Solar energy can be trapped to produce both electricity and hot water for day to day use. Recent advancement in Solar PV technologies and various support provided by the Government have made installation of PV panels lucrative in the residential sector.

Solar PV to Electricity

Solar photovoltaics are a combination of panels containing several solar cells which convert the incident solar energy into usable electricity. These panels can be placed at any place which receives abundant amount of sunlight. Solar electricity generation system can be installed on an independent house or multi-storeyed residential building. Solar electricity generation consists of components to produce electricity, convert generated direct current into alternating current, that can be used by equipment installed in the building, and store excess generated electricity, that can be used in night. The primary components of the system are Solar PV panels, Inverter, Storage Batteries.

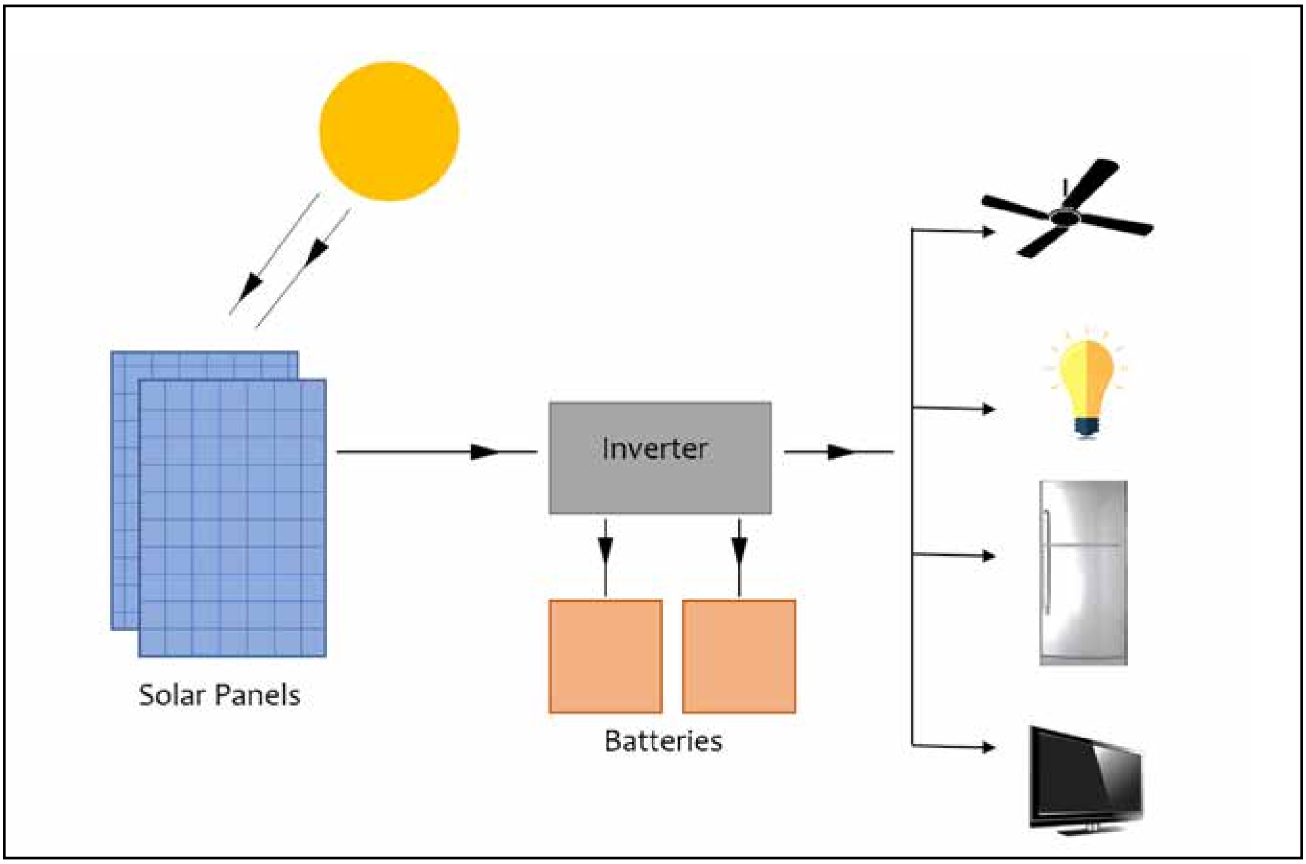


Figure 30: Components of Solar PV System

For individual residential units Solar PV installation can ideally offset 100% of the electricity consumption due all electrical loads. For example, the Solar Rooftop calculator demonstrates that by installing a 2kW of solar plant which requires area of approx. 200 sqft, 100% of electricity demands can be met with and ROI of approximately 6.25 years. For large multi storey residential complexes PV installation can largely offset electricity consumption of common utilities like common area and outdoor lighting, pumping loads etc.

Location of PV Panels

The general rule for solar panel placement is solar panels should face true south for 'fixed' or non-tracking types of Solar PV systems. Usually this is the best direction because solar panels will receive direct light throughout the day. However, it may also be beneficial to have a slight rotation away from due south, facing slightly south-west. South-West turn allows the solar panels to produce more electricity during evening hours when more appliances are expected to be operating.

The angle or tilt of a solar panel is also an important consideration. The angle that a solar panel should be set at to produce the most energy each year is determined by the geographical latitude. A general rule for optimal annual energy production is to set the solar panel tilt angle equal to the geographical latitude, for Nagpur it would 21.64°.

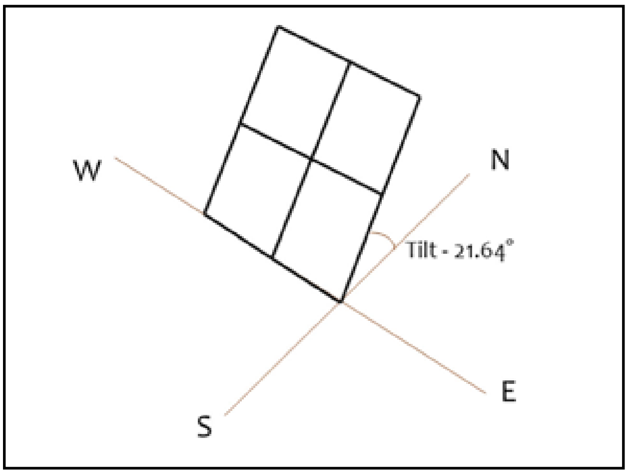


Figure 31: Angle of Tilt for Nagpur

Strategies for installing PV Panels for Nagpur

1. PV panels can be placed at the terrace of homes or multi storied residential buildings. Space required for 1 kW of solar PV installation is in the range of 7 – 10 sq. m.
2. Wall space of approximate size 3 feet X 3 feet is required for inverter and an AC disconnect.
3. A clear area of width 3 feet is also required in front of the system for maintenance.
4. PV panels result in an additional dead load of 30 – 40 kg/sq.m. on the building. The structure of the building should be sufficiently designed to accommodate the additional load.
5. Solar trackers can also be installed to orient the panels towards the sun.
6. Shading effect of any future expansion of nearby buildings and growth of trees should be analysed before finalizing the location of PV panels.

The performance of Solar panels gets impacted due to shadow casted by taller structures ideally, they should receive uninterrupted and direct sun rays for better performance.

In the below example, by relocating the overhead tank (OHT) to the Northern corner all possible chances of shadowing the PV panels are eliminated, allowing direct Southern sun exposure to the PV panels for better performance.

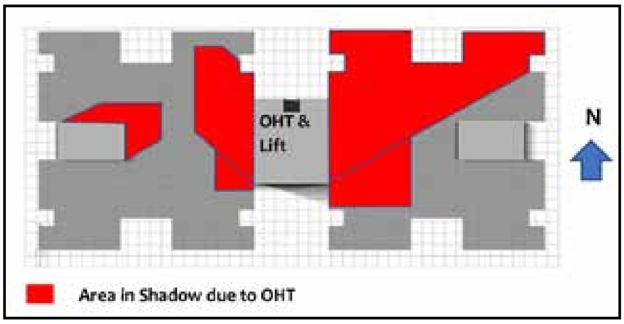


Figure 32: Terrace layout with OHT in centre of the floor

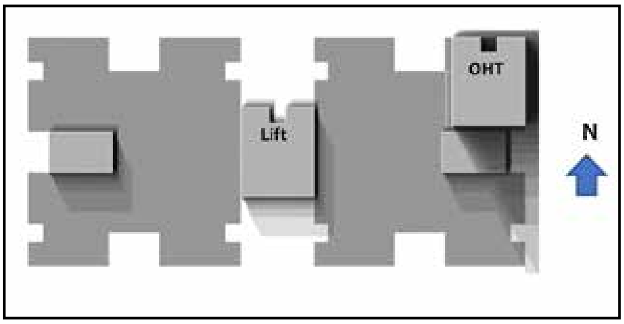


Figure 33: Relocation of OHT to maximize solar exposure for PV panels

Solar Rooftop Calculator

Before planning on the installation of Solar PV system one can find out the approximate cost of the system, Solar PV capacity to be installed based on the available area by using simple tool which is developed by the Ministry of New and Renewable Energy (MNRE) https://solarrooftop.gov.in/rooftop_calculator

The calculator provides homeowner an understanding of the cost implication of installing a Solar PV system based on key input parameters like area available for Solar PV installation on roof or the size of PV Solar Panel Capacity one wants to install. It also provides feasible Plant size based on the Budget a homeowner may have for installation of PV panels.

Simple Payback Calculation for Upscale Home (3-4 Occupants)

Average Electricity Bill per month	2000	Rs
Average Electricity bill for 1 year	24,000	Rs
Total units consumed per month	200	kWh
Assuming a Solar plant of 2 kWp is installed with approximate monthly consumption is 200 kWh. This plant size will be able to offset the monthly electricity demand of the home (area required for PV – 200 sqft)		
Approximate cost of 2kW plant	1,50,000	Rs
Simple Payback for PV plant installation of 2 kW = (1,50,000/ 24,000)	~ 6.25	Years

The high initial cost of solar PV system is becoming easier to address. For residences and housing societies, loans are available at low EMIs under MNRE directive to banks to treat rooftop solar as a priority sector for lending.

Solar Hot Water System

Solar hot water systems use roof mounted solar collectors to absorb energy from the sun to heat water which flows to a storage tank. Majorly two types of Solar Hot Water systems are widely used – flat plate panels and evacuated tube collectors.

Most solar hot water systems use solar collectors or panels to absorb energy from the sun. Water is heated by the sun as it passes through the collectors. It then flows into an insulated storage tank for later use. The storage tank is usually fitted with an electric booster that heats the water when sunlight is insufficient.

Location of Solar Hot Water system

The general rules of locating plate collector for Solar Hot water system are like PV panel location for electricity generation. The plate collectors should be facing South so that the sun rays fall perpendicular to the collector. The angle of tilt should be equivalent to the latitude of the location, in case of Nagpur it should be 21.64°.

Solar Water Heating System Configurations

Individual system for a home or a dwelling unit within a multi storey residential complex
In this kind of configuration, a separate solar water heating system is available for home or each dwelling unit with the solar hot water system installed at the roof of the building. A hot water pipeline is individually drawn for each dwelling unit, in multi storey residential complex. The advantage of this configuration is that it ensures equal distribution of hot water to each of the dwelling unit and maintenance and service of the individual system is borne by each flat. This system is usually used only for buildings up to four storeys.

Community type system
In this kind of configuration, a large solar water heating system that can provide hot water to the entire multi storey residential complex is installed on the roof. The hot water from the system is supplied through a common pipe network. This configuration occupies less area of the roof than the individual type configuration, and it is generally used for buildings with three or more storeys. However, in the community type configuration, proper arrangements need to be made for efficient back-up heating, ensuring equal hot water sharing among the flats, and ensuring instant hot water supply for the lower floors.

Sizing of hot water system
The requirement of hot water varies from person to person. However, it is estimated that the average hot water requirement per person per day in an average household in India is around 40 liters. Following two tables show the hot water requirement for different applications in Indian households.

Water consumption pattern in high end bungalows	**Liters (per person)**
Bathing	80
Wash basin	20
Kitchen wash	15
Clothes wash	10
Water consumption pattern in high end residential flats	
Bathing	60
Wash basin	10
Kitchen wash	15
Clothes wash	10
Water consumption pattern in average residential flats	
Bathing	40
Wash basin	10
Kitchen wash	15
Clothes wash	10

From the above table the total hot water demand for an average residential flat with 4 occupants for bathing purpose is 160 litres of hot water. While sizing for solar hot water systems, heat losses occurring in pipes and mixing of cold water with the hot water in the hot water tank is to be considered. Considering a heat loss factor of 20% for average residential flat in city area, hot water requirement will be 192 litres. If hot water is used regularly, a 150 liter tank is more than sufficient. It is always advisable to have the storage tank of a little higher capacity to avoid overheating during summer season. For a per day 160 litres of hot water (at 40°C) hot water a storage tank of 150-250 litres will suffice along with a collector area of 2 square meters.

Strategies of installing Plate Collectors for Nagpur

1. Plate collectors can be placed at the terrace of homes or multi storied residential buildings, with direct exposure to sun rays. Storage tank can be located in any available area on terrace, it does not require direct solar exposure.
2. 2 square meters of plate collector can typically produce 160 litres of hot water at 40C.
3. Plate collectors result in an additional dead load based on type of system selected. The structure of the building should be sufficiently designed to accommodate the additional load.
4. Shading effect of any existing tall structure like overhead tanks, future expansion of nearby buildings and growth

of trees should be analysed before finalizing the location of Plate collectors.

5. Roof spaces of a 12-storey residential building is usually sufficient to install a solar water heating system that can meet around 75% of the annual energy required for heating water.
6. For buildings that are more than 12 storeys, the amount of hot water generated through solar energy decreases, and for a 24-storey building 40%–50% of the annual hot water requirement could be met.
7. To be effective, the design of solar water heating systems should be done carefully to incorporate suitable provisions to deal with equal distribution of hot water, back-up heating, and instant supply of hot water on lower floors.

Heat Pump Water Heaters

Heat pump water heaters use electricity to move heat from one place to another instead of generating heat directly. Therefore, they can be two to three times more energy efficient than conventional electric resistance water heaters. To move the heat, heat pumps work like a refrigerator in reverse. Heat Pump water heater can save more than 70% of electricity when compared to a normal electric water heater. Heat Pump water heaters are efficient than electric water heaters and have higher COP (Coefficient of Performance) as compared to electric water heaters. The COP ranges from 3.6 – 4.

Heat Pump Water Heater can be installed in a bathroom, balcony, kitchen, etc virtually anywhere in the home without affecting the outlook of the building. It draws heat from air (atmosphere) so that the heater continues to supply hot water in all weather conditions irrespective of the water heater location.

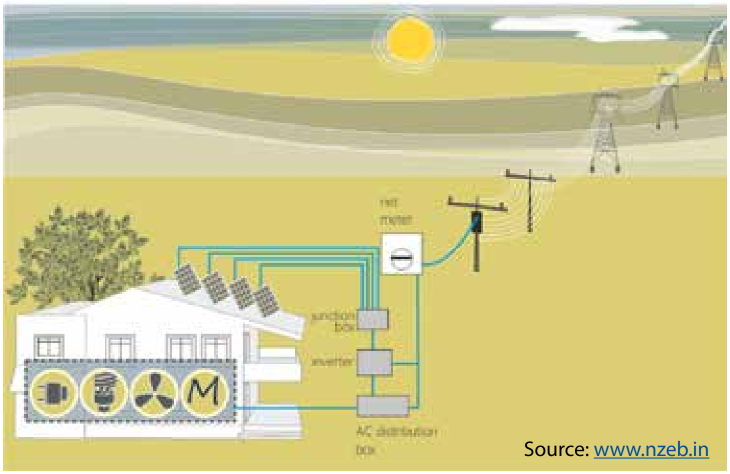
Comparative analysis of Heat Pump water heater and Electric water heater

Table 12: Heat Pump Vs Electric Water Heater

Parameters	Heat Pump Water heater	Electric Water heater
Operating Cost (%)	28	100
Place of installation	Any place	Any place
Source of Energy	2/3 from atmosphere (renewable)+1/3 from electrical power	Electrical power
Temperature of Hot water	55°C	60-70°C
Climatic constraints	None (works throughout the year)	None (works throughout the year)

Net Metering

Solar powered homes or multi-storeyed residences can either use the generated energy within the building for use or get connected to the larger electrical grid, as supplied by power provider. Electric utilities allow homeowners to only pay the difference between the grid-supplied electricity consumed and what they have produced – a process called net metering. For example, if a residential customer has a Solar PV system on the roof, it may generate more electricity than the home uses during the day. If the home is net-metered, the electricity meter will run backwards to provide a credit against what electricity use exceeds the system's output, throughout the day. Customers are only billed for their "net" energy use. On average, only 20-40% of a solar energy system's output ever goes into the grid, and this exported solar electricity serves nearby customers' loads.



Source: www.nzeb.in

Figure 34: Net-Metering

Advantages of Net Metering

1. Savings in Energy bills - If the amount of energy generated by the homeowner's system is more than the amount of energy consumed, in this way the homeowner gets a control over the electricity bills.
2. Eliminates the need for battery storage and backup inverter- Unlike off- grid Solar PV systems, homeowners do not require battery storage systems while using net metering since the extra power is stored by the utility grid itself. It also eliminated the need for inverters since the electricity grid also acts as a backup inverter.
3. Inexpensive and low maintenance – Since solar panels primarily are low maintenance, the main parts of a PV system that require maintenance would be battery and inverter. However, through net metering these components can be eliminated and would further decrease the maintenance requirements.

How to avail Net Metering in Nagpur

Under MERC net metering regulations, 2015 guidelines for the consumers desiring connectivity of roof-top solar PV system with MSEDCL's network are formulated as follows:

1. Any new or existing consumer is eligible to install solar rooftop system for captive use.
2. The LT/HT consumer in MSEDCL's area who intends to install a solar PV system less than 1 MW to cater all or part of their own electricity load requirement is eligible for getting connectivity of roof-top solar PV system with MSEDCL's Network which includes consumer catering to a common load such as housing society. https://www.mahadiscom.in/consumer/solar-rooftop-net-metering/
3. Such solar generation system may be owned and operated by the consumer itself or by third party leasing such system to the consumer.
4. The variation in the capacity of the solar PV system shall be allowed within a range of 5%

Procedure for application for connectivity of roof-top solar PV system with DISCOMs network

The standard procedure for availing the net metering facility for the solar rooftop projects in Maharashtra is as follows:

Step 01
Submit application along with application fees

Step 02
Technical feasibility study by Discom

Step 03
Approval by Discom

Step 04
Submission of Work completion report Applicant to Discom

Step 5
Tetsing and Commissioning of system by Discom and installation of Net meter

Step 6
Net metering connection agreement between consumer nd Discom

Step 7
Synchronisation of Rooftop Solar PV system withdistribution network

Chapter 7 – Net Zero Energy Buildings

Net Zero Buildings

Net or nearly zero energy buildings (NZEB) are highly efficient buildings with extremely low energy demand, which is met by renewable energy sources. Such buildings produce as much energy as they consume, accounted for annually. In order to achieve their net zero energy goals, NZEBs must first sharply reduce energy demand using energy efficient technologies, and then utilize renewable energy sources (RES) to meet the residual demand. In such buildings, efficiency gains enable the balance of energy needs to be supplied with renewable energy technologies. This is the most logical approach to reach NZEB goal.

Beyond this very general definition, a number of more specific definitions and terms have been put forth to better capture the specifics of how NZEB performance is achieved and measured. These specific definitions reflect the differences in priorities and perspectives among the diverse set of parties interested in NZEB buildings—for example, emphasis on demand-side versus supply-side technologies or a focus on onsite energy use versus carbon emissions—and can have an impact on design decisions (Torcellini et al. 2006).

Definitions of NZEB are critical in determining the path to zero energy goals, and significantly influence design choices of architects and building owners. Appropriateness of definitions to a project vary according to project goals and values of the designer and building owner, making it essential for them to understand which definition will suit their purpose best.

Metric to Define NZEB

Metrics is one the integral elements of the NZEB definition framework, which decide NZEB definitions. The four main metrics, corresponding to the four definitions are site energy, source energy, carbon emissions and energy cost. NZEB metrics can measure energy in its primary and secondary form, environmental implications of energy use through emissions and cost of energy. Primary energy is raw or source fuel for producing heat and electricity. It could also be termed as energy embodied or captured in fuels. Secondary energy is the energy product derived from primary energy, like grid supplied electricity. Each metric has its benefits and drawbacks. Source energy and carbon emissions metrics are complex because they require complex conversion factors as energy use of the building is weighed against its impact at the source of generation and delivery distance. Conversely, they enable compensation of effect of building energy use on national or regional energy resources and environment. Site energy and energy cost are simpler to evaluate but both cannot be used for energy accounting beyond the site.

Building Rating System Targeting NZEB

Green building certification for building recognizes projects that implement various sustainability strategies including, reduced contributions to climate change, beneficial impacts on water resources, biodiversity, health and well-being, regenerative material resource cycles, social equity, and quality of life. To further enhance this recognition various Green Building Rating Systems have introduced Rating System with an aim towards NZEB including ambitions targets for Net Zero Water and Waste.

The Indian Green Building Council (IGBC) has developed the 'Net-Zero Energy Rating', which provides a structured guideline to achieve NZE buildings in India including residential sector. USGBC has developed LEED Zero, a complement to LEED that verifies the achievement of net zero goals **LEED Zero Carbon** and **LEED Zero resources**, https://www.usgbc.org/programs/leed-zero The TRUE Zero Waste Certification system enables facilities to define, pursue and achieve their Zero Waste goals, cutting carbon emissions and supporting public health https://true.gbci.org/. Case studies for various NZEB projects can be found on https://nzeb.in/case-studies/

Solar Heat Gain Coefficient (SHGC): SHGC is the fraction of incident solar radiation admitted through non-opaque components, both directly transmitted, and absorbed and subsequently released inward through conduction, convection, and radiation.

U Value: Thermal transmittance (U value) is the heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on either side. Unit of U value is W/m2 .K. The U value for a wall/roof/glazing indicates its ability to transfer heat through conduction.

Visible Light Transmittance (VLT): VLT is the ratio of the total transmitted light to the total incident light. It is a measure of the transmitted light in the visible portion of the spectrum through a material.

Window-to-Wall Ratio (WWR): WWR is the ratio of the window components area to the envelope area of home.

References

Net Zero Energy Buildings https://nzeb.in/

Eco Niwas Samhita https://www.beeindia.gov.in/sites/default/files/ECBC_BOOK_Web.pdf

Indian Green Building Certification – Green Homes Version 3 https://igbc.in/igbc/html_pdfs/events/IGBC%20Green%20Homes%20Rating%20System%20Ver%203.0.pdf

GRIHA https://www.grihaindia.org/sites/default/files/pdf/Manuals/griha-abridged-manual.pdf

BEE Design Guidelines for Energy Efficient Multi story Residential buildings

https://beeindia.gov.in/sites/default/files/Design%20Guideline_Book_0.pdf

Practical guidebook for Implementing Smart Technologies and Clean Energy Projects in Existing High Rise Residential Apartments

https://www.mahaurja.com/meda/data/energy_conservation/pdf/smart%20technology%20guide%20book.pdf

Maharashtra State Electricity Distribution Co. Ltd. https://www.mahadiscom.in/consumer/solar-rooftop-net-metering/

User Handbook on Solar Water Heaters https://www.undp.org/content/dam/india/docs/user%E2%80%99s_handbook_on_solar_water_heaters.pdf

Bureau of Energy Efficiency (BEE) Star Labelled https://www.beestarlabel.com/

Maharashtra Energy Development Agency https://www.mahaurja.com/meda/

Comfortable Low Energy Architecture https://www.new-learn.info/packages/clear/index.html

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Annexure: Definition of terms used

Solar Heat Gain Coefficient (SHGC): SHGC is the fraction of incident solar radiation admitted through non-opaque components, both directly transmitted, and absorbed and subsequently released inward through conduction, convection, and radiation.

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