INTEGRATED GREEN DESIGN

for Urban & Rural Buildings
in Hot-Dry Climate Zone
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Central Public Works Department
India, a fast developing country, is required to balance the utilisation of resources with the simultaneous need for preserving the environment. To prevent rapid growth from irreversibly degrading the environment and a consequent decay in the quality of life, there is a need to explore options that are low on energy and water use, on pollution and on cost. The planning, construction and utilisation of buildings has to also take options into account.

While the work on sustainable buildings has begun in right earnest, there is scope to do more. While the government and private buildings are gradually adopting practices of energy and environmental efficiency, for these to rapidly bring about visible change, the effort of the entire construction industry which is creating our infrastructure is needed. Since a large part of the built environment is dealing with buildings such as individual residences, schools, health centres, small commercial centres, amongst others, these also need to be included in the sustainable building movement. The cumulative effect of such buildings can make a significant impact on the environmental footprint.

The creation of this manual brings the concept of integrated green design to the common person, wherein certain generic principles and easy to implement methodologies are made available. Architects and engineers who are important decision makers of this construction process will have a much needed ready reckoner with this publication.

I congratulate the Central Public Works Department in bringing out this guide and look forward to the widespread application of the principles.

Shri Kamal Nath
Minister of Urban Development
Government of India
The challenges of growth are many and complex. With development the aspirations of the people are rising. There are competing demands on natural resources such as water and land and on power. Over and above all this are the increasingly evident impacts of global warming induced climate change, wherein temperatures are rising.

India’s 2011 Census provides some interesting data that reveals development trends and offers planning opportunities. It shows that one in every third Indian now lives in an urban environment. While the number of million plus cities has shot up to 53 from 35 in 2001, the smaller cities are growing much faster than the larger ones that have a million plus population. The Census houses have increased from 25 crore to 33 crore, of which a third are in urban areas. The challenge then is to meet the necessary and basic needs of all, while maintaining levels of comfort, of using natural resources sustainably and with, minimum impact on the environment. This calls for making simple yet effective and locally relevant changes in the way we develop and construct in our urban and rural habitats, enabling us to reduce our resource consumption. The sheer numbers on widespread adoption will help provide the desired impact.

The publication and widespread dissemination of this simple yet effective user friendly guide on integrated green design for small structures in the hot-dry climate zones in the country by the Central Public Works Department, Ministry of Urban Development, marks another milestone in the journey of reducing our ecological footprints in the urban and rural living spaces, in a manner that will continue, if not enhance comfort levels. I look forward to the adoption of options offered.

Dr Sudhir Krishna
Secretary
Ministry of Urban Development
Government of India
India is a country with diverse ecological zones that range from mountains to valleys, dry lands to flood plains and from coastal regions to plateaus. To create infrastructure under these diverse conditions that meet the needs of the people, comply to set norms and standards, use resources and materials that are easily available and with minimum are impact on the environment call for constant innovation and experimentation and engagement with stakeholders.

Over the past several years, the Central Public Works Department (CPWD) has taken significant efforts to move towards the creation of sustainable infrastructure through the adoption of a multi-pronged approach. For example, CPWD is a stringent follower of ECBC [Energy Conservation Building Codes], NBC (National Building Code) and Ministry of Environment and Forests regulations on energy conservation and protection of the environment. The organisation’s voluntary efforts and commitments towards sustainability has now transformed into a mandatory and holistic approach, with the declaration that all future buildings to be constructed by CPWD will be minimum 3 star GRIHA rated green buildings. Moving a step further, few buildings being constructed by CPWD are being targeted for highest green building rating i.e. 5 star GRIHA rating after completion.

Our Training Institute at Ghaziabad, has been identified as a centre for excellence in green building initiatives and is imparting training to engineers and architects all over the country and facilitating dissemination of knowledge and technologies among experts in the field.

This guide on integrated green design for buildings in the hot-dry zone is another milestone in this journey. The individual impact of each building may be small. But the cumulative effects of integrating environment concerns right from site selection and its orientation, planning, resource and utilisation, to operation and maintenance, and reaching to buildings constructed by all - rural and urban areas - will add up to a considerable reduction of the ecological footprint.

This practical guide is simple and easy to adopt. The widespread dissemination that has been planned to reach out to various players in the construction industry will go a long way in its adoption across hot-dry climatic zone, adding to our efforts in reducing environmental impact while meeting the needs of the people.

We look forward to your feedback and experiences on using this publication.

Ashok Khurana
Director General
Central Public Works Department
Ministry of Urban Development
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What is a Green Building?

A green building is one which, as compared to a conventional building, has the following properties:

1. Uses less water
2. Is energy efficient
3. Conserves natural resources
4. Generates less waste
5. Provides healthier spaces for occupants

WHY GO GREEN?

- Global warming is leading to a rise in temperatures and extreme weather effects.
- Land for building is scarce & Greenfield areas are being depleted to make buildings. The Buildings being made are both energy intensive in construction and usage.
- In case of the environment around buildings, the air is polluted, fresh water is scarce and many water sources are polluted. There is also an increase in energy usage to compensate for the above.
- Deteriorating health of building occupants due to sick building syndrome arising from non-natural and potentially toxic materials.
- Increasing energy use for other utilities like transportation due to sprawling cities & towns.
- Large scale depletion of non-renewable energy resources.
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Site Context and Environment

How we build is influenced by, and in turn also influences our surrounding natural environment and its components i.e. atmosphere, biosphere, lithosphere and hydrosphere. This forms our “site context”. Responding to this context in building design is essential for a holistic green design approach.

(A) THE SUN & OUR CLIMATE
Building orientation, layout and renewable energy choices

(A) CLIMATE & LOCAL MATERIAL
availability influences
Building material choice

(H) RAINFALL PATTERN & GROUND CHARACTER
influences Rainwater harvesting potential

(H) GROUNDWATER LEVEL
influences Building water supply & Rainwater harvesting methods

(H) SOLAR PATH, WIND PATTERNS & PREVALENT TEMPERATURES
influences creation of architectural spaces like courtyards / verandahs and helps plan passive cooling features

(L) EXISTING & PROPOSED VEGETATION
influences Building layout to promote shading and passive cooling

(L) LANDFORM
influences building layout to minimize cut & fill on-site

(H) SURFACE WATER
influences Building water use pattern, waste water disposal method & methods for passive cooling / harnessing water energy

(A) ATMOSPHERE

(L) LITHOSPHERE

(B) BIOSPHERE

(H) HYDROSPHERE

Regenerative design is of higher value than just efficient green design. This can be termed a “better-than-before” scenario. For. e.g.

A barren site with water flowing away from it

Recharging water and planting to improve local ecology forms a regenerative approach

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The Indian sub-continent can be broadly categorized into five regions with distinct climates. These climate zones, as shown in the adjoining map, warrant special provisions in each to aid in the functional design of buildings with respect to human thermal comfort and hence energy efficiency. The table below shows the distinct climatic features of the hot-dry climate zone, which is the focus of these guidelines.

<table>
<thead>
<tr>
<th>Climatic features</th>
<th>Situation in Hot-Dry Climate</th>
<th>Generic corresponding strategy</th>
<th>Page Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical landscape &amp; vegetation</td>
<td>Sandy / rocky ground with little vegetation; Low water level</td>
<td>- Preserve vegetation and conserve water</td>
<td>see pg. 12,13,31</td>
</tr>
<tr>
<td>Solar radiation</td>
<td>Intense (800 - 950 W/m²)</td>
<td>- Shade building especially open as they admit maximum solar radiation - Solar energy generation</td>
<td>see pg. 14-19, 29</td>
</tr>
<tr>
<td>Mean Temp.</td>
<td></td>
<td>- Prevent solar access in summer but allow in winters - Insulate building to prevent conduction of heat indoors during the day time</td>
<td>see pg. 7-9, 23-26</td>
</tr>
<tr>
<td>Summer midday</td>
<td>40º - 45º C</td>
<td>- Prevent solar access in summer but allow in winters - Insulate building to prevent conduction of heat indoors during the day time</td>
<td>see pg. 7-9, 23-26</td>
</tr>
<tr>
<td>Summer night</td>
<td>20º - 30º C</td>
<td>- Prevent solar access in summer but allow in winters - Insulate building to prevent conduction of heat indoors during the day time</td>
<td>see pg. 7-9, 23-26</td>
</tr>
<tr>
<td>Winter midday</td>
<td>5º - 25º C</td>
<td>- Prevent solar access in summer but allow in winters - Insulate building to prevent conduction of heat indoors during the day time</td>
<td>see pg. 7-9, 23-26</td>
</tr>
<tr>
<td>Winter night</td>
<td>0º - 10º C</td>
<td>- Prevent solar access in summer but allow in winters - Insulate building to prevent conduction of heat indoors during the day time</td>
<td>see pg. 7-9, 23-26</td>
</tr>
<tr>
<td>Diurnal variations</td>
<td>15 - 20º C</td>
<td>- Prevent solar access in summer but allow in winters - Insulate building to prevent conduction of heat indoors during the day time</td>
<td>see pg. 7-9, 23-26</td>
</tr>
<tr>
<td>Mean relative humidity</td>
<td>Very low (25 - 40 %)</td>
<td>- Can use evaporative cooling where water is available</td>
<td>see pg. 21</td>
</tr>
<tr>
<td>Annual rainfall</td>
<td>Low &lt;500mm / yr</td>
<td>- Harvest rainwater for use in dry spells</td>
<td>see pg. 30</td>
</tr>
<tr>
<td>Winds</td>
<td>Dust laden local winds often developing into sandstorms</td>
<td>- Prevent wind infiltration; Avoid wind-induced ventilation during overheated times</td>
<td>see pg. 21</td>
</tr>
<tr>
<td>Sky conditions</td>
<td>Cloudless skies with high solar radiation causing glare</td>
<td>- Prevent direct radiation ingress and glare into rooms</td>
<td>see pg. 20</td>
</tr>
</tbody>
</table>

The Integrated Green Design (IGD) approach looks at a building in stages of its planning and design from the broader issues to the details. Each stage within the IGD approach fulfills one or more of the five ‘Green’ building imperatives.

**STAGES OF PLANNING & DESIGN**

**Sustainable Site Planning**
Utilizing existing infrastructure, laying out building blocks to benefit from existing landform, sunpath and wind while minimizing damage to prevalent soil, flora, water and air quality.

**Materials**
Choosing materials which are local, durable, utilize waste, have low embodied energy content, use less water for processing and help insulate the building.

**Appropriate Landscaping**
Planting the right way to conserve water and improve micro-climate.

**Building Energy Use**
Efficient electricity usage and usage of clean energy.

**Building Water Use**
Saving water through efficient fixtures and augmenting water through rain water harvesting & waste water treatment.

**Building Design Details**
Detailing building fenestration design and construction details to promote shading, insulation and heat loss.
The IGD approach starts not from the site layout but from site selection. While not possible in all cases, wherever possible efforts must be made to choose an appropriate site for the proposed use of the building. This would result in less damage of virgin land and less energy expenditure in ‘developing’ a site. For buildings within large campuses, selecting an appropriate plot within is equally important.

**SITE SELECTION**

**AVOID NATURAL DRAINAGE LINES**
- Especially important in sloped sites.
- Obstructing natural drainage lines would involve energy use to drain out storm water or risk site flooding.

**READY ACCESS TO EXISTING INFRASTRUCTURE**
- Electricity supply
- Water supply
- Public transport
  Helps reduce need for new infrastructure

**COMPACT ACCESS ROADS AND UTILITIES**
- Improve efficiency of movement and feasibility of common maintenance on campuses
- Reduce paved areas on site and consequently reduce heat gain
- Connecting to adjacent structures for common services & access road would reduce servicing costs and improve walkability

**COMPACT CLUSTER PLANNING**
Cluster based planning of the building blocks within campuses results in more compact utilities network, reduces damage to existing environment and promotes walkability. Sharing spaces, services and creating a medium-rise, high density development complements this.

One block shades the other

Shaded spaces

Possibility of future expansion reduces need for encroaching on greenfield sites

POSSIBLE FUTURE EXPANSION
- Flexibility to encroach on greenfield sites
- Shaded spaces
Sustainable Site Planning

Best Possible Orientation of Typical Existing Planforms

N-S orientation can be used in creative ways to generate a variety of built and open spaces.

Orient Building Long Faces Along N-S

Low sun angle on east and west. Difficult to shade in summer.

Minimum radiation on the north side allowing large windows for excellent day lighting.

High sun angle in summer on the south side. Hence easy to shade.

Seasonal variation in solar altitude

Exposure variation summer / winter

Low sun angle in winter allows welcome solar access.
Sustainable Site Planning

PLANFORM

TYPICAL EXISTING PLANFORMS IN ASCENDING ORDER OF PERIMETER- TO - AREA (P/A) RATIO

In the hot-dry climate a smaller perimeter-to-area ratio (P/A) would result in less area exposed to radiation and lesser conduction heat gains.

Greater the perimeter-to-area ratio, greater is the heat gain by the building.

Planforms with greater P/A ratio may be applied in certain cases to include features like water bodies & vegetation which can modify the micro-climate. The intermediate spaces can also be effective as interaction spaces.

Cooled wind is welcome

Wind for night ventilation is welcome
Most concepts in hot, dry climate focus on decreasing heat gain but adequate daylight is also important. Depending upon the building use, choosing an appropriate planform and proper activity zoning at the initial design stages can ensure heat gain reduction and optimum daylighting.

This approach is useful in placing service spaces like toilets/storage areas/staircase at locations where they can act as thermal barriers. The effect of an unfavorable plan orientation can also be reduced to some extent by zoning.
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**Sustainable Site Planning**

**BUILDING TYPES**

- **Detached**
  - High exposure to radiation and wind
  - Hence shading through various building elements is vital
  - New buildings should be placed as close as possible to existing buildings for possibility of shading one another.

- **Row**
  - Solar gains are reduced due to common walls
  - Relevant for barracks and housing.

- **Courtyard**
  - Courtyards are important for daylight & ventilation and has a cultural significance too
  - Ventilation in hot dry climate is useful if the air is cool. Thus the courtyard should
    - be proportioned to be mostly shaded, and / or
    - contain cooling elements like trees, soft paving and water bodies if water is available.

**LOW-RISE VS. HIGH RISE**

- **Low-rise**
  - Higher footprint area
  - Foundation embodied energy is more as multiple floors are not sharing the foundation.
  - Lesser footprint
  - Could be optimum in terms of total energy and shading

- **High-rise**
  - Least footprint
  - Higher service energy to move resources and people up and down.

**Courtyard effect in traditional settlements**

Variable sizes create temperature-pressure differential & can induce cross ventilation.

**Typical modern courtyards**

Courtyard Height: Width (H/W) ratio almost 1:4. Hence courtyard not shaded and no courtyard effect

Possible strategies include:
- Cooling the courtyard by shading (H/W ratio nearing 1:1).
- Shading by verandahs / covered passages or by vegetation.
CONSTRUCTION STAGE PRACTICES

- Preserve existing trees with tree guards, etc. And protect their roots from excavation and material storage.

- Information board about safety and ‘green’ practices and emergency contact numbers.

- Waste bins for segregating construction waste.

- Site roads paved with gravel or brickbats to prevent dust rising up.

- Appropriate workers’ facilities for resting/toilets/Creche.

- Segregated material storage to reduce waste & for easier handling. Covered storage where necessary.

- Pre-planned movement path for materials & labour.

- Sedimentation tank to collect & reuse surface flow or rainwater. Explore possibility of using treated water for construction.

- Strict delineation of excavated/affected area on site from the unaffected areas.

- Electrical lines separated/elevated vis-a-vis human/material movement.

- Boards/barriers to reduce air pollution and spread of waste materials, loose soil from site.

- CONSERVATION OF FERTILE TOP SOIL ON DELINEATED SPACE
  - Temporary plants to hold top soil for later use in landscaping.
  - Max. 40 cm. Top soil.
  - Geo textile/other sheet separating top soil from sub soil.
  - Pre-existing sub-soil.
Landscaping for Improving Occupant Comfort

PLANNING PLANTATION

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Reduction of paved areas and use of pervious paving reduces UHI effect and improves groundwater recharge. Such paving can be used in walkways, pavements, vehicular roads within the site, ramps, etc.

ALBEDO: refers to surface reflectivity of various materials. Higher the albedo, more reflective the material.
- Dark surfaces: 0.1 - 0.3
- White-coloured (e.g. white-washed) surfaces: 0.7 - 0.8
- High reflective paints: 0.8 - 0.9
- White ceramic tiles: 0.7
- Heat resistant terrace tiles: 0.7

PROMOTING GROUNDWATER RECHARGE

Preserve existing vegetation as they are a 'free' micro-climate modifier. Promote native species needing less water.

Trees help in shading:
- Trees close to building on the west and closely spaced for shading
- Trees close to building on the east with moderate spacing help in shading
- Deciduous trees on the south side for shading in summer and solar access in winter

Trees prevent infiltration of dust laden hot summer winds

Trees act as noise and dust barrier

Trees prevent infiltration of dust laden hot summer winds

Preserve existing vegetation as they are a 'free' micro-climate modifier. Promote native species needing less water.

Concrete grid paver
Sand compact sub-base
Gravel
Compact sub-soil base

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- High reflective paints: 0.8 - 0.9
- White ceramic tiles: 0.7
- Heat resistant terrace tiles: 0.7
Use of native, low water consuming species, reduction of exotic species & lawns and an efficient irrigation system reduces water consumption.

**LIST OF SOME NATIVE SPECIES FOUND IN THE HOT-DRY CLIMATE ZONE, INDIA**

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Type</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ronjh</td>
<td>Acacia leucophloea</td>
<td>Tree; Deciduous</td>
<td>Native. <strong>Hardy species.</strong> Can grow in the rocky and sandy soils of this zone. Spreading feathery foliage. 12m mature height.</td>
</tr>
<tr>
<td>Khejri</td>
<td>Prosopis cineraria</td>
<td>Tree; Deciduous</td>
<td>Native. <strong>Adaptable to the harsh conditions of this zone.</strong> Droopy feathery foliage. 12m mature height. State tree of Rajasthan.</td>
</tr>
<tr>
<td>Ker</td>
<td>Capparis aphylla</td>
<td>Shrub; Deciduous</td>
<td>Native. <strong>Almost leafless with beautiful flowers</strong> but with wide spreading roots. 4m mature height.</td>
</tr>
<tr>
<td>Dhau</td>
<td>Anogeissus pendula</td>
<td>Tree; Deciduous</td>
<td>Native. <strong>Known as the ‘habitat specialist’ of the Aravalli hills.</strong> 10 - 15m mature height.</td>
</tr>
<tr>
<td>Khair</td>
<td>Acacia catechu</td>
<td>Small tree; Deciduous</td>
<td>Native. 5m mature height.</td>
</tr>
<tr>
<td>Baheda</td>
<td>Terminalia bellirica</td>
<td>Large tree; Deciduous</td>
<td>Native except for the desert areas. Massive dome shaped crown with broad leaves. <strong>20 - 40m mature height.</strong></td>
</tr>
<tr>
<td>Salai</td>
<td>Boswellia serrata</td>
<td>Tree; Deciduous</td>
<td>Native. Light spreading crown with droopy branches. <strong>Drought and frost resistant.</strong> Has medicinal usage. 9 - 15m mature height.</td>
</tr>
<tr>
<td>Kankera</td>
<td>Maytenus emarginata</td>
<td>Small Tree; Deciduous</td>
<td>Native. <strong>Can have large oval crown.</strong> Considered sacred. 5m mature height.</td>
</tr>
<tr>
<td>Desi Babool</td>
<td>Acacia nilotica</td>
<td>Tree; Deciduous</td>
<td>Native. <strong>Spreading, open, feathery crown.</strong> 10m mature height.</td>
</tr>
<tr>
<td>Ber</td>
<td>Ziziphus mauritiana</td>
<td>Small Tree; Deciduous</td>
<td>Native. Dense spreading crown. 8m mature height. <strong>Also cultivated for its fruit.</strong></td>
</tr>
<tr>
<td>Farash</td>
<td>Tamarix articulata</td>
<td>Tree; Evergreen</td>
<td>Native. Fast growing. <strong>Salinity tolerant.</strong> 10m mature height.</td>
</tr>
<tr>
<td>Rohida</td>
<td>Tecomella undulata</td>
<td>Tree; Deciduous</td>
<td>Native. <strong>Loose, open crown.</strong> 8m mature height.</td>
</tr>
<tr>
<td>Neem</td>
<td>Azadirachta indica</td>
<td>Tree; Semi-evergreen</td>
<td>Drought tolerant. <strong>Good shade tree.</strong> 12m mature height.</td>
</tr>
<tr>
<td>Bouganvillea</td>
<td>Bougainvillea glabra</td>
<td>Shrub; Deciduous</td>
<td>Good for dry areas. <strong>Low water usage once established.</strong> 4 - 6m mature height.</td>
</tr>
<tr>
<td>Peelu</td>
<td>Salvadora persica</td>
<td>Small Tree; Evergreen</td>
<td>Native in hot, arid areas with water availability. <strong>Tolerant of saline soils.</strong> 7m mature height.</td>
</tr>
<tr>
<td>Bada Peelu</td>
<td>Salvadora oleoides</td>
<td>Small tree; Evergreen</td>
<td>Native in hot, arid areas in dry water courses. 5m mature height.</td>
</tr>
<tr>
<td>Thor</td>
<td>Euphorbia neriifolia</td>
<td>Shrub; Deciduous</td>
<td>Native to dry rocky areas. Spiny, succulent plant. 4m mature height.</td>
</tr>
<tr>
<td>Gondi</td>
<td>Cordia gharaf</td>
<td>Small tree; Deciduous</td>
<td>Native but scarce. 6m mature height.</td>
</tr>
<tr>
<td>Bui</td>
<td>Aerva tomentosa</td>
<td>Herb</td>
<td>Native. <strong>Good soil binder.</strong></td>
</tr>
<tr>
<td>Guggal</td>
<td>Commiphora wightii</td>
<td>Small tree; Deciduous</td>
<td>Native. <strong>Tolerant of poor soil.</strong> Endangered. 4m mature height.</td>
</tr>
<tr>
<td>Jujube</td>
<td>Ziziphus zizyphus</td>
<td>Small tree; Deciduous</td>
<td>Native. <strong>5 - 10m mature height.</strong></td>
</tr>
<tr>
<td>Sewan</td>
<td>Lasiurus sindicus</td>
<td>Grass</td>
<td>Native to the Thar desert. Perennial. <strong>Good soil binder.</strong></td>
</tr>
</tbody>
</table>
**Building Design**

**SHADING STRATEGIES FOR BUILDING & OPENINGS**

Shading is the most important building design strategy for comfort in the hot-dry climate. Shading of openings like windows is very important and in any case the Window-Wall-Ratio (WWR) should not be more than 60%. Effective day lighting is possible with a much lower WWR.

**Shading of window and wall surface by jaali screens.**

**Shading of building surface by vegetation**

**Shading of building surface by surface texture**

**Shading of building surface by architectural projections**

Jharokhas are an architectural heritage of the region and provide effective shading. A Jharokha window on the south also cuts out the east-west sun.

**Besides shading, utilizing Double Glazed Units (DGUs) help insulate the window panel and reduces large heat ingress which would otherwise enter the living space.**

**Light shelves help in deeper penetration of daylight into the room & uniform distribution of daylight of lighting.**

**ORIENTATION BASED SHADING STRATEGIES**

Larger windows could be placed on the north facade as direct solar radiation is least on this facade. Radiation from low sun during peak summers can be cut off by small vertical shades.

Windows must be small on the east and west sides and must be adequately shaded.

Larger windows can be placed on the south side as it is relatively easier to shade the south side from the high summer sun with a horizontal sun-shade. This can also allow desirable winter sun.

On the west closely spaced vertical shades cut out the low evening sun. As the heat built up during the day is already present, minimization of openings is desirable.
Shading from the sun and well designed shading devices are a primary need in the hot-dry climate. It is well established that a majority of the solar heat gain comes from radiation through openings. When designing shading devices for windows, the required horizontal and vertical shadow angles need to be established. They are dependent on both the orientation of the window plane and the sun path.

**Horizontal shadow angle (HSA: characterizes the vertical shading device)**
This is the horizontal angle between the normal of the window pane or the wall surface and the current sun azimuth angle. It is relevant for designing vertical shading devices such as fins.

**Vertical shadow angle (VSA: characterizes the horizontal shading device)**
This is the angle that a virtual plane containing the bottom two points of the wall/window and the centre of the Sun makes with the ground when measured normal to the window plane. It is required when designing horizontal shading devices such as overhangs.

**CALCULATING HSA & VSA FROM SUNPATH DIAGRAM**
E.g. Sun path Diagram of Jodhpur, Rajasthan (26.29° N, 73.03° E). The following diagram is also called a stereographic projection which showcases the movement lines of the sun relative to a location on earth.

\[
\begin{align*}
HSA &= \text{solar azimuth} - \text{window orientation} \\
VSA &= \tan^{-1}\left( \frac{\tan(\text{solar altitude})}{\cos(HSA)} \right)
\end{align*}
\]
Building Design

SUNPATH DIAGRAMS OF CITIES IN THE HOT-DRY CLIMATE ZONE

Kota, Rajasthan (25.18° N, 75.83° E)  Ahmedabad, Gujarat (23.03° N, 72.62° E)
SUNPATH DIAGRAMS OF CITIES IN THE HOT - DRY CLIMATE ZONE

Aurangabad, Maharashtra (19.87° N, 75.33° E)

Solapur, Maharashtra (17.68° N, 75.92° E)
**Building Design**

**FENESTRATION SHADING DEVICE DESIGN**

Example of shading device design on south and west facades of building located in Jodhpur, Rajasthan (26.29° N, 73.03° E)

**STEP 1**
Determine the cut-off dates i.e. the over-heated period of the year when the window is to be completely shaded. During this period the date of longest and shortest sun-path is recorded, i.e. the two extremities of the sun-path.

In Jodhpur, for e.g., the cut-off dates are taken as 1st April to 31st August. Within this period, the longest sun path is recorded on 21st June and the shortest sun path on 1st April.

**STEP 2**
Determine the start and end times representing the times of day between which full shading is required for different facades. It should be kept in mind that the closer to sunrise and sunset these times are, the exponentially larger the required shade.

In Jodhpur, for e.g.,

**West facade = 12 noon - 5pm**
The shades for this face are designed for the longest sun path within the over-heated period i.e. 21st June.

**South facade = 11am - 5pm**
The shades for this face are designed for the shortest sun path (sun travels low in the sky) within the over-heated period i.e. 1st April.

These two periods together avoid direct sun completely in the overheated period.

**STEP 3**
Look up the sun position using sun-path diagrams to obtain the azimuth and altitude of the sun at each time on the designated day for facades of different orientations.

In Jodhpur, for e.g., from the sun path diagram

Sun position 5pm, 21st June = -77.4° or 282.6° Azimuth / 31.5° Altitude (for designing shading device for the west facade)

Sun position 1pm, 1st April = -165.7° or 194.3° Azimuth / 69.5° Altitude (for designing shading device for the south facade)

Similarly, the sun positions are recorded for every half hour interval on the designated day for facades of different orientations.
**Effective Shading Device Design**

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Effective Shading</th>
</tr>
</thead>
<tbody>
<tr>
<td>South</td>
<td>Fixed horizontal device or window recessing.</td>
</tr>
<tr>
<td>West and East</td>
<td>Vertical device/louvers (possibly moveable). East / West faces are difficult to shade with fixed shades as the sun is very low. Hence only small windows are recommended. External moveable shades/ rollable blinds are more effective than fixed shades. These also help preserve the view from the windows.</td>
</tr>
<tr>
<td>North side</td>
<td>Generally not required except from low evening sun in peak summer when the sun path is long and hits the North from the side. Cutting this out can be is achieved by vertical shades.</td>
</tr>
</tbody>
</table>

**Step 4**
Calculate HSA and VSA at different times during designated period for each facade. We need to design a shading device for the lowest possible VSA (horizontal shade) and the lowest possible HSA (vertical shade).

**Example**

In the west facade, one can design vertical shades for which the HSA is calculated. The lowest HSA is found to be at 2:30 pm (0.5°). Designing for this HSA would result in very large shades. Hence the shading device is designed for an intermediate sun position. The HSA at 1:30 pm and 5 pm is about 12°. But at 5 pm, the altitude angle of the sun is less (31.5°) and the facade can be shaded by vegetation. Hence, in this case the shades will be designed for the sun position at 1:30 pm.

Sun position 1:30 pm, 21st June = -101.3° or 258.7° Azimuth / 78.2° Altitude

HSA = solar azimuth - window orientation
    = 258.7 - 270 = -11.3°

In the south facade, we shall design horizontal shades for which the VSA is calculated. The lowest VSA is found to be at 1 pm (70.1°). (These shades are designed for the lowest sun path within the overheated summer period. The sun path is lower in winter but during this period solar ingress is preferable)

Sun position 1 pm, 1st April = -165.7° or 194.3° Azimuth / 69.5° Altitude

HSA = solar azimuth - window orientation = 194.3 - 180 = 14.3

VSA = tan⁻¹(tan(solar altitude) / cos(HSA))
    = tan⁻¹(tan(69.5) / cos(14.3)) = 70.1°

**Step 5**
Calculate required depth of shade.

**Example**

For west facade

Shading by single vertical shade is not feasible as the shade depth becomes prohibitive. Hence the width is subdivided and several louvres are designed. If 6 divisions are created, i.e. effective width to be shaded is 250mm

\[
\text{Depth (d)} = \frac{\text{width}}{\tan (\text{HSA})}
\]

\[
= \frac{250}{\tan (11.3°)}
\]

= 1250mm

This depth can be reduced much further by designing the louvers at an angle. As mentioned earlier, on the west facade fixed shades will not shade the window at all times. Movable louvers or shading by trees could be better.

For south facade

Depth (d) derived as 650mm

\[
\text{Depth (d)} = \frac{\text{Height}}{\tan (\text{VSA})}
\]

\[
= \frac{1800}{\tan (70.1°)}
\]

\[
= 650mm
\]

If two horizontal louvres are used then,

Depth (d) derived as 300mm

\[
\text{Depth (d)} = \frac{\text{Height}}{\tan (\text{VSA})}
\]

\[
= \frac{850}{\tan (70.1°)}
\]

\[
= 300mm
\]
D A Y L I G H T  D I S T R I B U T I O N
An integrated design approach utilizes indirect radiation for daylighting and avoids the heat of direct radiation.

**Room & Opening dimensions for appropriate daylighting**

![Diagram of room and opening dimensions](image)

Total daylighted area for window = 2H x (W + 2m)

NBC also recommends that the window area should be at least 15% of the floor area of the room.

**LIGHTSHELVES / SHADING DEVICES**
Since in the hot, dry climate a compact building approach would reduce the sky dome available for daylighting, daylight penetration can be enhanced by use of lightshelves.

**DISTANCE BETWEEN BUILDINGS FOR DAYLIGHTING**
Ideally for daylight penetration, the lowest floor windows should subtend a maximum angle of 22.5° with the top of the adjacent building / object. But for regulating heat radiation, a closer fit would help.

---

**REFLECTANCE OF INTERNAL FINISHES**
For better daylight distribution, the reflectance of the internal surfaces should be higher. Secondly, full height partitions to be minimized in favour of open office plans where more people can share the natural light & ventilation from a window.

**REFLECTANCE OF COMMON SURFACE FINISHES & COLOURS**

<table>
<thead>
<tr>
<th>Typical finishes of surfaces</th>
<th>Reflectance</th>
</tr>
</thead>
<tbody>
<tr>
<td>White wash</td>
<td>0.7 - 0.8</td>
</tr>
<tr>
<td>Cream colour</td>
<td>0.6 - 0.7</td>
</tr>
<tr>
<td>Light green</td>
<td>0.5 - 0.6</td>
</tr>
<tr>
<td>Light blue</td>
<td>0.4 - 0.5</td>
</tr>
<tr>
<td>Light pink</td>
<td>0.6 - 0.7</td>
</tr>
<tr>
<td>Dark red</td>
<td>0.3 - 0.4</td>
</tr>
<tr>
<td>Medium grey</td>
<td>0.3</td>
</tr>
<tr>
<td>Cement terrazzo</td>
<td>0.25 - 0.35</td>
</tr>
<tr>
<td>Brick</td>
<td>0.4 - 0.5</td>
</tr>
<tr>
<td>Vegetation (mean value)</td>
<td>0.25</td>
</tr>
</tbody>
</table>
Passive cooling strategies need to be incorporated at the design initiation stage based on the planned organization of spaces in the building. This will ensure minimum HVAC loads even if any active cooling systems are desired.

**Evaporative cooling**
Evaporative cooling works well in the hot-dry climate as humidity is low in this zone. But water availability needs to be checked.

**Night ventilation**
Night ventilation works well in this climatic zone as diurnal variations are high. In this process, buildings are ventilated at night when ambient temperatures are lower to resist heat build-up.

**Earth berming**
Earth berming reduces outside air infiltration, keeps temperatures cool in summer and warm in winter as the earth’s temperature at a depth of a few meters remains almost stable throughout the year. Berms may cover a part of the ground floor, sometimes entire buildings, provided daylight and ventilation requirements are taken care of. Needs adequate water-proofing measures. Basements are similarly cool and preferred spaces.

**Earth Air Tunnel System**
This system is viable if the ground below has good thermal capacity, for e.g. soil with adequate water content. The design basics generally followed are (from various existing systems):
- Pipe depth 4m
- Pipe diameter 0.3 to 0.7m
- Distance between pipes 3m centre-to-centre
- Pipe length depends of air volume required.

**Thermal mass**
A building envelope with higher thermal mass will retard heat transfer from the exterior to the interior during the day. When temperatures fall at night, the walls re-radiate the thermal energy back into the night sky. Extensively used in traditional buildings in the region.
### Materials

#### HIERARCHY OF SELECTION CRITERIA

- **A)** Minimum environmental damage during extraction
- **B)** No harmful effluents into environment in installation & usage
- **C)** Local materials to reduce transportation energy
- **D)** Durability & longevity
- **E)** Response of material to climate in creating comfort
- **F)** Lower embodied energy (EE) in creation of material
- **G)** Ability to reuse with minimum processing

How green a material might be, depends on the selection criterion applied. In utilizing these 8 selection criterion (from A to G) although all are important, but the priority needs to be given for the upper one than the lower one if one needs to choose between the two. See example in boxes which illustrate the criterion in more detail.

**Stones from sustainable mines:** The sustainable mining framework of the Govt. of India enunciated better mining practices, less air pollution, reuse of mine waste and mine land.

**Reuse of mine waste,** like use of stone dust and chips to make concrete blocks. Also helps reduce air & land pollution.

**Salvaged timber,** reused wood, particle boards etc. reduce use of new wood & saves trees.

**EEV of flyash block** = 2.32 MJ / brick
EEV of stabilised earth block = 2.79 MJ / brick Even though a flyash block has lesser EEV, it is more efficient only if it travel less than 50 km.

EEV of Material 1 = 90 MJ / sq.m; Life = 80 yrs.
EEV of Material 2 = 72 MJ / sq.m; Life = 40 yrs.
2x durability of Material 2 means 1/2 energy for extraction, processing, installation & disposal

**PPC has lower embodied energy due to fly ash content which is waste from thermal power plants. It can be used in both structural concrete and plaster mortar.**

**Stabilised earth block** has less embodied energy vis-a-vis bricks as bricks use higher energy for firing.
EEV of CSEB = 138 MJ / sq.m of wall
EEV of brick = 681MJ / sq.m of wall

**Waste glass** is used in the manufacture of glass. Used marble chips used in the manufacture of terrazzo reduce embodied energy.

**UPVC windows are more insulating than Aluminium windows**

Iron is superior to Aluminium in terms of ease with which it can be recycled and reutilized. But recyclability (as different from recycled) is a future hope which might not fructify.
**Integrated Green Design (IGD) for Urban & Rural buildings, Hot-Dry Climate Zone**

**MATERIAL PROPERTIES**

**Embodied energy (EE):** It is the sum of all the energy required to produce a material, considered as if that energy was incorporated or ‘embodied’ in the material itself. Units MJ / kg or MJ / m³. (M = Megajoules)

(Note: Values used in this document do not include the energy of transporting materials to site which will vary based on location.)

**Thermal mass:**
Thermal mass is the ability of a material to absorb heat energy. This heat storing capacity of building materials helps achieve thermal comfort conditions by providing a time delay to the flow of heat. High density materials, like concrete, brick and stone have high thermal mass. Thermal mass is most appropriate for climates with a diurnal variation of more than 10°C.

**Thermal insulation:**
Thermal insulation is the reduction of heat transfer through a material. Heat flow is a consequence of contact between objects of differing temperatures. Insulation reduces thermal conduction thus reducing unwanted heat loss or gain.

The insulating capability of a material is measured with thermal conductivity (k). Low thermal conductivity is equivalent to high insulating capability (R-value).

**Thermal mass & Thermal insulation in Hot-Dry Climate:**
High thermal mass materials, without insulation, can radiate heat all night during a summer heatwave, or absorb all the heat produced on a winter night.

Use of insulation with low thermal mass materials will not be effective in keeping indoor temperatures comfortable. It can trap heat within the building envelope.

High mass construction with high insulation levels is the most effective strategy to reduce heat gains and should be used with proper shading. In the hot-dry climate, insulation should be on the external side with the high mass material on the inside, protecting it from the summer sun.

**Thermal conductivity (k):** Property denoting a material’s inherent ability to conduct heat. It is an intrinsic material property and is temperature dependant. Unit: W/m.K

**Thermal transmittance (U-value):** Property denoting a material’s ability to conduct heat. It is the inverse of R-value. Unit: W/m².K

**Thermal resistance (R-value):** Property denoting a material’s resistance to heat. It is dependent on temperature and the thickness of the material. Unit m².K/W

**Relationship between k, R-value & U-value:**
- R-value = thickness of material (d)/ k
- U-value = 1/ R-value

**Note:** Value used are indicative & may vary slightly based on exact material property.

**MATERIAL VALUE TABLE**

<table>
<thead>
<tr>
<th>Material</th>
<th>R value (m².K/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>230mm thk. Brick wall</td>
<td>0.38</td>
</tr>
<tr>
<td>300mm thk. Stone wall</td>
<td>0.08</td>
</tr>
<tr>
<td>300mm thk. AAC wall</td>
<td>0.28</td>
</tr>
<tr>
<td>230mm thk. FALG wall</td>
<td>0.96</td>
</tr>
<tr>
<td>75mm thk. Rockwool</td>
<td>1.56</td>
</tr>
<tr>
<td>50mm thk. XPS</td>
<td>1.73</td>
</tr>
<tr>
<td>50mm thk. EPS</td>
<td>1.39</td>
</tr>
<tr>
<td>50mm thk. PUF</td>
<td>2.08</td>
</tr>
<tr>
<td>75mm thk. inverted kulhar in lime concrete</td>
<td>0.30</td>
</tr>
<tr>
<td>25 - 100mm air cavity</td>
<td>0.18</td>
</tr>
</tbody>
</table>

**EMBODIED ENERGY TABLE**

<table>
<thead>
<tr>
<th>Material</th>
<th>Embodied Energy (MJ / m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>230mm thk. Red clay Brick wall</td>
<td>681.95</td>
</tr>
<tr>
<td>300mm thk. Stone wall</td>
<td>630.00</td>
</tr>
<tr>
<td>300mm thk. AAC wall</td>
<td>215.70</td>
</tr>
<tr>
<td>230mm thk. FALG wall</td>
<td>201.94</td>
</tr>
<tr>
<td>50mm thk. XPS</td>
<td>142.50</td>
</tr>
<tr>
<td>50mm thk. PUF</td>
<td>151.50</td>
</tr>
<tr>
<td>50mm thk. EPS</td>
<td>66.45</td>
</tr>
</tbody>
</table>

**Surface Air Film resistances:**
- Outside surface (vertical) = 0.04 m².K/W
- Inside surface (vertical) = 0.13 m².K/W
- Outside surface (horizontal) = 0.06 m².K/W
- Inside surface (horizontal) = 0.16 m².K/W

(Integrated Green Design (IGD) for Urban & Rural buildings, Hot-Dry Climate Zone)
REDUCING HEAT INGRESS THROUGH WALL

The choice of materials must optimize between the insulation provided & the embodied energy of the material based on its local availability.

### WALL ASSEMBLY 1
300mm thk. stone wall + 12mm plaster one side
EE= 644 MJ / m²
R value= 0.27 m².K/W

### WALL ASSEMBLY 2
230mm thk. brick wall + 12mm plaster both sides
EE= 711 MJ / m²
R value= 0.59 m².K/W

### WALL ASSEMBLY 3
230mm thk. brick wall in rat-trap bond + 12mm plaster both sides
EE= 365 MJ / m²
R value= 0.70 m².K/W

### WALL ASSEMBLY 4
230mm bk.wall + 70mm air cavity + 115mm brick Wall + 12mm plaster both sides
EE= 1052 MJ / m²
R value= 0.95 m².K/W

### WALL ASSEMBLY 5
230mm thk. brick wall in rat-trap bond + 12mm plaster both sides
EE= 365 MJ / m²
R value= 0.70 m².K/W

### WALL ASSEMBLY 6
230mm FAL G + 70mm air cavity + 115mm FAL G + 12mm plaster
EE= 318 MJ / m²
R value= 1.80 m².K/W

### WALL ASSEMBLY 7
20mm stone cladding + 300mm AAC + 12mm plaster
EE= 272 MJ / m²
R value= 2.27 m².K/W

### WALL ASSEMBLY 8
230mm bk.wall + 50mm XPS + 115mm bk. Wall + 12mm plaster both sides
EE= 1194 MJ / m²
R value= 2.51 m².K/W

### WALL ASSEMBLY 9
3D Eco wall: 50mm shotcrete + 100mm EPS +50mm shotcrete (reinforced with wiremesh)
EE= 470 MJ / m²
R value= 3.00 m².K/W

---

**R-value calculation example:**

Wall assembly 5: 300mm thk. stone wall + 70mm air cavity + 115mm brick Wall + 12mm plaster both sides

<table>
<thead>
<tr>
<th>Material</th>
<th>Resistance: R-value (m².K/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside air film</td>
<td>0.04</td>
</tr>
<tr>
<td>300mm thk. stone</td>
<td>0.08</td>
</tr>
<tr>
<td>70mm air cavity</td>
<td>0.18</td>
</tr>
<tr>
<td>115mm thk. brick wall</td>
<td>0.19</td>
</tr>
<tr>
<td>12mm plaster</td>
<td>0.02</td>
</tr>
<tr>
<td>Inside air film</td>
<td>0.13</td>
</tr>
</tbody>
</table>

**R value of the wall assembly:**

Sum of the component R-values = 0.64 m².K/W

ECBC recommended R value for wall assembly = 2.27 m².K/W

Add-on insulation should be judiciously used especially in the case of non-conditioned buildings with cost constraints and need to keep embodied energy low.
**REDUCING HEAT INGRESS THROUGH ROOF**

### (A) REFLECT

Heat gains can be reduced by using roof finishes with high solar reflective index (SRI). Examples of high SRI materials include china mosaic, white cement tiles, reflective paints etc. ECBC mandates a minimum SRI of 0.7.

### (B) SHADE

Shading the roof also reduces heat gain. For e.g. partial shading by pergolas, bamboo frame, overhanging creepers, Photo-voltaic panels.

### (C) INSULATE

**ROOF ASSEMBLY 1** (EE excluding that of 100mm RCC slab = 506.44 MJ / m²)

RCC slab + 50mm (avg. thickness) brickbat coba + 20mm cement mortar finish

EE = 185 MJ / m²

R value = 0.39 m².K/W

**ROOF ASSEMBLY 2**

RCC slab + 75mm mud phuska + 20mm cement mortar finish

EE = 36 MJ / m²

R value = 0.40 m².K/W

**ROOF ASSEMBLY 3**

RCC slab + 75mm Inverted earthen pot in lime concrete + 20mm cement mortar finish

EE = 74 MJ / m²

R value = 0.60 m².K/W

**ROOF ASSEMBLY 4**

RCC slab + 75mm brick laid at intervals of 230mm c/c + brick tile covering + 20mm cement mortar finish

EE = 300 MJ / m²

R value = 0.60 m².K/W

**ROOF ASSEMBLY 5**

RCC slab + 100mm PUF + waterproofing + Marble crazy

EE = 419 MJ / m²

R value = 4.48 m².K/W
MATERIAL USAGE: GOOD PRACTICES

- Possibility of thermal bridging
  - Continuous cavity reduces possibility of thermal bridging
  - 20mm stone jamb for windows. The reduced thickness minimizes thermal bridging
  - 300mm thk. stone wall
  - 115mm thk. brick wall

- Jaalis in the roof parapet allows air movement over the hot roof surface comparatively cooling it down in day-time and increase speed of heat loss in night-time
- Avoid thermal bridging by taking insulation below parapet wall and meeting with wall insulation on the exterior of the walls
- Placing insulation outside the wall is better as it increases the time lag of the wall assembly & prevents heat ingress at source
- Metal ties will act as thermal bridge. Plastic ties better
- Detail to overlap AAC wall on beam to minimize thermal bridging through beam
- Storage space
**Materials**

**Ferro cement**
(EE= 111 MJ / m²)
A versatile form of RCC possessing unique properties of strength and durability. Made up of rich cement mortar and wire mesh reinforcement, it has a high ratio of strength to weight. A cost-effective material, it also enables faster construction and has lower embodied energy compared to conventional RCC due to its thin section & minimization of steel.

**CLC (Cellular Lightweight Concrete) & AAC (Aerated Autoclaved Concrete) Blocks**
(EE= 215 MJ / m² for wall thickness 300mm)
CLC and AAC blocks are air-cured lightweight concrete with fly-ash as a major ingredient. The difference lies in the process of generation of air bubbles. In CLC the air bubbles are generated in the form of a foam while in AAC they are produced from a reaction that uses aluminum powder.

These light-weight blocks reduce structural steel requirement and provides higher thermal insulation. As it uses fly-ash which is a waste material it leads to substantial material saving and has lower embodied energy.

**Perforated Brick Masonry**
These are high strength hollow bricks with 50-60 percent perforations. These perforations act as sound and heat insulators and saves materials.

**Pre-stressed Slab**
This helps in reduction of section of slab. Pre-stressed slabs are up to 25% lighter than conventional RCC slabs due to a reduction in section size.

**Sandstone Roofing**
(EE= 196 MJ / m²) An extensively used material, this consists of 25mm thick stone blocks on pre-cast RCC beams or iron sections.

**3D Eco Wall**
(EE= 470 MJ / m²)
This wall assembly consists of a 100mm EPS panel finished with 50mm shotcrete on both sides, reinforced by wiremesh. The 200mm thk. panel saves space and provides excellent insulation. This may be used both for walling & roofing.

The EPS can be reduced to 100mm for interior walling.

**GEOPOLYMERS**
Geopolymers are a class of synthetic aluminosilicate materials with potential use essentially as a replacement for Portland cement. Fly ash based geopolymer concrete has superior strength and mortar / plaster made from it does not require curing. GPC (GeoPolymer Cements) use a host of waste and virgin materials in feedstock. Besides Structural Concrete, GPC can be used also for Building Blocks and Paver Blocks.

Please note: The embodied energy values are indicative. They do not include transportation energy to deliver material on-site. Values will vary as per exact construction detail utilized.

**FALG (Fly Ash- Lime Gypsum) Blocks**
(EE= 202 MJ / m² for 230 thk wall) These blocks require less mortar, plastering can be avoided, are cost effective and environment-friendly as it avoids use of fertile top soil.

**Pre-cast Stone Blocks**
Blocks manufactured using waste stone pieces of various sizes with lean cement concrete.

**CSB (Compressed Stabilised Earth Blocks)**
(EE= 138.6 MJ / m² for 230mm thk. wall) Blocks made of mud stabilised with 5% cement lime and compacted in block-making machines without firing. Compressive strength equal to red clay fired bricks.
Building Energy Efficiency

ORDER OF STRATEGIES FOR ENERGY EFFICIENCY

A. Control amount of heat reaching building:
- Building orientation, shading by projections, vegetation etc. (see pg. 14)
- Insulation (see pg. 24,25,26)

B. Minimize carriage of heat through building skin:
- Passive cooling strategies (for non-AC buildings) (see pg. 21)
- Low energy HVAC technologies (for AC buildings)

C. Reduce internal heat gain and improve daylight (for detailed design refer to daylighting code SP41)
- Usage of fixtures and appliances with low equipment power density and with efficient BEE rating.
- Keep outdoor equipment like window ACs in shade to improve efficiency
- Use efficient artificial lighting

D. Cooling the building through:
- Passive cooling strategies (for non-AC buildings) (see pg. 21)
- Low energy HVAC technologies (for AC buildings)

ARTIFICIAL LIGHTING EFFICIENCY

1) Use of optimum Lighting Power Density (LPD): It is the amount of electrical power used to illuminate a space. (Expressed in Watts per unit of area)

<table>
<thead>
<tr>
<th>Application Area</th>
<th>LPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building entrance with canopy</td>
<td>13 W/m² of canopied area</td>
</tr>
<tr>
<td>Building entrance without canopy</td>
<td>90 W/m door width</td>
</tr>
<tr>
<td>Building exit</td>
<td>60 W/m door width</td>
</tr>
<tr>
<td>Building facades</td>
<td>2 W/m² of vertical facade area</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Indoor LPD of common building types (ECBC 2007)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building type</td>
</tr>
<tr>
<td>Residential</td>
</tr>
<tr>
<td>Office</td>
</tr>
<tr>
<td>Dining facility</td>
</tr>
<tr>
<td>Clinic</td>
</tr>
<tr>
<td>School</td>
</tr>
<tr>
<td>Hostel</td>
</tr>
</tbody>
</table>

2) Selection of efficient lighting fixture on the basis of efficacy (ratio of lumen output to energy input)

<table>
<thead>
<tr>
<th>Lamp efficacy of different lamps</th>
<th>Type</th>
<th>Lamp wattage (W)</th>
<th>Ballast power loss</th>
<th>Total Power (W)</th>
<th>Lamp flux (lumen)</th>
<th>Efficacy (lumen / W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent</td>
<td>100</td>
<td>-</td>
<td></td>
<td>1340</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>TL-D 36W</td>
<td>36</td>
<td>4</td>
<td>40</td>
<td>3250</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>TL5 HE 14W</td>
<td>14</td>
<td>2</td>
<td>16</td>
<td>1350</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>TL5 HE 28W</td>
<td>28</td>
<td>2</td>
<td>30</td>
<td>2900</td>
<td>97</td>
<td></td>
</tr>
<tr>
<td>CFL 18W</td>
<td>18</td>
<td>4</td>
<td>22</td>
<td>1200</td>
<td>54</td>
<td></td>
</tr>
</tbody>
</table>

3) Use of controls where possible like master switches, timers, occupancy sensors etc.
RENWABLE ENERGY FOR ELECTRICITY GENERATION

With the high solar radiation available in the hot, dry climate zone, it is highly recommended to use solar energy to meet at least some part of the building’s electricity demand. The simplest way to generate solar energy is by using stand-alone photo-voltaic (PV) systems with or without storage battery.

SOLAR PHOTO-VOLTAICS INSTALLATION

The ideal orientation for optimal performance of a solar cell is at an angle equivalent to the latitude of the place of installation. Area required for generation of 1 kWp electricity is on an average 12 m² for 15% efficiency panels.

POSSIBILITIES OF PV PANEL PLACEMENT

Typical hot water consumption in different buildings (varies as per local criterion)

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>100 litres / day / family</td>
</tr>
<tr>
<td>Office</td>
<td>4 litres / person / day</td>
</tr>
<tr>
<td>Hostel</td>
<td>30 litres / person / day</td>
</tr>
<tr>
<td>Dispensary</td>
<td>30 litres / bed / day</td>
</tr>
</tbody>
</table>

FLATPLATE COLLECTOR (FPC) VS. EVACUATED TUBE COLLECTOR (ETC)

ETC, though more expensive, is generally more efficient due to better heat absorption and less heat losses. The circular tubes also allow better sun tracking and are better suited for hard water.

Commonly, units are available for 200 litres per day, 500, 1000 and more.

Integrated Green Design (IGD) for Urban & Rural buildings, Hot-Dry Climate Zone
# RAINWATER HARVESTING (RWH)

Water conservation and reuse is of utmost priority in the hot-dry climate.

## Strategies for Water Efficiency

- **Reduce water demand**
- **Reduce potable water use**
- **Rainwater harvesting and recharge augment local water resource**
- **Treatment and reuse of wastewater reduces need for extra municipal water / ground water**

## Run-off Co-efficients for Various Surfaces

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Run-off Co-efficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roofs conventional concrete</td>
<td>0.95</td>
</tr>
<tr>
<td>Concrete / Kota paving</td>
<td>0.95</td>
</tr>
<tr>
<td>Gravel</td>
<td>0.75</td>
</tr>
<tr>
<td>Brick paving</td>
<td>0.85</td>
</tr>
<tr>
<td>Vegetation</td>
<td>0.2 - 0.3 (depending on slope)</td>
</tr>
<tr>
<td>Turf slopes (Lawn)</td>
<td>0.25 - 0.45 (depending on slope)</td>
</tr>
</tbody>
</table>

## Rainwater Harvesting Potential

\[
\text{Catchment area (m}^2\text{)} \times \text{Annual rainfall (m)} \times \text{Surface run-off co-efficient}
\]

A thumb rule for estimating tank size is to store 15 minutes of peak rainfall. So, if peak rainfall = 90mm/hr., then in 15 minutes rainfall = 22.5mm

Hence, \((22.5\text{mm} \times \text{collection area} \times \text{run-off co-efficient})\) would be the optimum tank size for storage.

## Cascade System RWH for Rainwater Reuse

- Rainwater from 2nd terrace collected & used on the lower floor.
- Rainwater from 1st terrace collected and used for irigation etc.

## Comparison Between Direct Rainwater Use & Recharge Into Groundwater

<table>
<thead>
<tr>
<th>Direct Use</th>
<th>Recharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used if rainfall frequent</td>
<td>Used if rainfall infrequent</td>
</tr>
<tr>
<td>Used if groundwater table is high</td>
<td>Used if groundwater table is low to augment groundwater resource</td>
</tr>
</tbody>
</table>

## Precautions to Be Taken While Harvesting Rainwater
- Filtration and first flush system essential to prevent entry of contaminants
- Cleaning of tank at the beginning of summer and winter rainfalls

## Rainwater Harvesting For Multiple Blocks

Multiple buildings within a cluster can have a common rainwater harvesting system.
Zero discharge is possible by creative treatment and reuse of water, thus reducing load on municipal drains.

TECHNOLOGIES FOR SMALL STAND-ALONE PROJECTS:

(A) IMPROVED SEPTIC TANK

- Primary treatment (Septic tank)
- Secondary treatment (Anaerobic baffled tank reactor)
- Tertiary treatment (Reed bed system / Planted gravel filter)

(B) EFFECTIVE MICRO-ORGANISMS

Effective micro-organisms (EM) system has anaerobic organisms introduced to waste water after primary treatment to remove organic content. Using EM reduces sludge in the secondary treatment.

LOCATION:

The treatment systems can be located within the setbacks around the building depending upon the space availability.

DEWATS system can be incorporated longitudinally within the setback. If more space is available, further treatment can be incorporated like polishing ponds.

Multiple buildings can combine their water treatment systems. In a campus, this is all the more feasible.

(C) DECENTRALIZED WASTEWATER TREATMENT SYSTEM (DEWATS)

- Primary treatment (Septic tank)
- Secondary treatment (Anaerobic baffled tank reactor)
- Tertiary treatment (Reed bed system / Planted gravel filter)
Modifying Existing Buildings

STRATEGIES FOR MODIFYING SMALL SCALE EXISTING BUILDINGS

(A) ADD-ON INSULATION ON WALL AND ROOF
Insulation can be added on to the wall and roof, as shown in the examples, to reduce heat ingress into the building.

Insulation added on existing roof
RCC slab + 50mm sloping screed + 75mm XPS + china mosaic
R value = 2.97 m².K/W

Insulation below-deck possible & usually the case in existing buildings but preventing heat ingress from outside is preferable.

(B) ENERGY AUDITS for replacing existing electrical fixtures with efficient ones. This includes...
- Lighting fixtures with higher lumen output and lower heat output
- Lighting fixtures with electronic ballasts
- Other efficient appliances as per the ECBC 2007

(C) WINDOW RETROFITTING involves
- Cleaning out blocked openings which afford natural light
- Shading the window glazing to prevent heat ingress by add-on projections on East, West and South sides
- Adding light shelves, in the interior or exterior, for better daylight distribution

(D) SHADING
- Using spaces like courtyards for add-on shading features. For e.g. adding a shaded porch into the courtyard helps shade the building surface and openings.
- Shading the window ACs also helps provide better performance.

(E) ADD-ON COOLING DEVICES
Passive cooling devices, which consume less energy as compared to air-conditioners, can be incorporated into the building even at a later date. For e.g. Desert coolers / Evaporative coolers

Use of desert coolers is another way of evaporative cooling. Adequately placed coolers can affect the temperatures of large contiguously ventilated spaces.
Temporary structures are frequently used for site offices, temporary installations and additional building area requirements, and in many cases they are air conditioned as well. For these to be energy efficient certain options are available as follows.

**INSULATED STEEL PANELS:**
These are similar to insulated cement panels except for the facing material. These lightweight panels also result in better airtightness, and are reusable.

**INSULATED CEMENT BOARD PANELS:**
These panels ensure higher insulation. These lightweight panels can be reused, thus reducing overall embodied energy. Stone and timber finishes are also available for insulated panels.

**ASSEMBLED TEMPORARY STRUCTURE:**
Better insulation in temporary structures can also be achieved by introducing insulation between cement boards. The insulation and boards are supported on a steel framework.

**AERATED CEMENT SOLID WALL PANELS:**
These have good insulation properties. Additionally, flyash used in both the aerated cement core and the cement board ensures that the embodied energy also remains low.
ABBREVIATIONS:

AAC: Autoclaved Aerated Concrete
CLC: Cellular Lightweight Concrete
CSEB: Compressed Soil Earth Blocks
DEWATTS: Decentralised Water Treatment System
ECBC: Energy Conservation Building Code
EE: Embodied Energy
EEV: Embodied Energy Value
EM: Effective Micro-organisms
EPS: Expanded Polystyrene
ETC: Evacuated Tube Collector
FALG: Fly-Ash Lime Gypsum
FPC: Flat Plate Collector
HVAC: Heating, Ventilation and Air Conditioning
HSA: Horizontal Shadow Angle
IGD: Integrated Green Design
LPD: Lighting Power Density
NBC: National Building Code
P/A Ratio: Perimeter-to-Area Ratio
PPC: Portland PozzolanaCement
PUF: Polyurethane Foam
SPV: Solar Photo-voltaic
UPVC: Unplasticised Polyvinyl Chloride
VOC: Volatile Organic Compound
VSA: Vertical Shadow Angle
WWR: Window-to-Wall Ratio
XPS: Extruded Polystyrene
UHI: Urban Heat Island

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Mukund Joshi
Chief Engineer, NZ-III, CPWD