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ARCHITECTS ANONYMOUS
DEVELOPING A PARTICIPATORY, USER-FRIENDLY PLATFORM TO GENERATE REGION-SPECIFIC CLIMATIC BUILDING DESIGN STRATEGIES FOR THE ‘ANONYMOUS ARCHITECT’

A Thesis in
Architecture
by
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ABSTRACT

Current public discourse around energy conservation in buildings revolves around a ‘top-down’ approach that is centered around green building rating systems and energy codes. Aside from the debate of whether these systems and codes are themselves efficient enough is perhaps the larger question of the sheer number of buildings that ‘slip’ through these regulations, particularly in the residential sector, which is not only the largest building typology by area and energy consumption, but is by and large unorganized and little regulated from an energy perspective. This situation is even more critical in fast-developing countries like India, in which it is projected that more than three-fourths of the buildings that will exist by 2030 have not yet been built. The majority of these residential buildings are built by clients (the ‘anonymous architect’) using stock designs from contractors that rarely take into account the climate of the region, which is the key component towards achieving energy efficiency. Even for the anonymous architect who is energy-conscious but unfortunately does not have the resources to consult specialized professionals; there is a distinct lack of existing research in the form of a user-friendly, open-source platform that can generate region-specific climatic building design strategies which can then enable him/her to request changes to the contractor’s stock designs. Accordingly, this research uses technology such as Geographic Information Systems (GIS) and web-design tools to generate these design strategies in a participatory, ‘bottom-up’ platform - one that can be easily accessed even from the anonymous architect’s smartphone.
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1.1. SUSTAINABLE DEVELOPMENT

The Brundtland Commission defined sustainable development as “development which meets the needs of current generations without compromising the ability of future generations to meet their own needs” (UN World Commission on Environment & Development: Brundtland Commission, 1987). This definition cleverly captures aspects of what are now known as the three pillars of sustainability – social, economic and environmental sustainability (Fig. 1). In other words, true sustainable development must integrate and find a balance between economic growth, societal development and environmental preservation.

Now, let us examine the performance metrics of these three ‘pillars’ over time:

1.1.1. SOCIETY

One of the most common quantitative measurement factors of societal development is the Human Development Index (HDI) published by the United Nations Development Programme (UNDP) which includes factors such as life expectancy, education and the standard of living (Noorbakhsh, 1998). It is fairly obvious from Fig. 2 that the overall HDI value, as well as the Education and Health index values for most countries have only seen a continuous upward trend over the past few decades.
1.1.2. ECONOMY

Real Gross Domestic Product (GDP) per capita is an inflation-adjusted measurement of economic growth that also factors in the differences in the purchasing power of currencies (Kravis, Heston & Summers, 1978). Fig. 3 is notable for two reasons - it shows that despite economic crises such as the Great Depression, at a macro level, there has been true economic growth in terms of the purchasing power of an individual. The second notable aspect is that the graph demonstrates that the real GDP per capita remained fairly constant until the Second Industrial Revolution in the latter half of the 19th century, after which people around the world saw economic growth at a rate not seen before.
1.1.3. ENVIRONMENT

The “Kaya Identity” is an equation that measures environmental impact by human factors and is expressed as \( F = P \times (G/P) \times (E/G) \times (F/E) \), in which \( F \) = the global CO2 emissions from human sources, \( P \) = global population, \( G \) = world GDP and \( E \) = global energy consumption (Kaya & Yokobori, 1997). Fig. 4 shows the global CO2 emissions from the burning of fossil fuels between 1751 and 2012, which indicates the recent exponential increase in CO2 emissions, commonly identified as the main cause of global warming (Lashof & Ahuja, 1990).
Another notable aspect in Fig. 4 is that the initial rise in CO2 emissions coincided with the Second Industrial Revolution - therefore, while the latter half of the 19th Century contributed to an enhanced quality of life (the social aspect of sustainability) and more purchasing power for individuals (the economic aspect of sustainability), it had a detrimental effect on our planet (the environmental aspect of sustainability). The rapid increase in emissions over the past few decades as seen in Fig. 4 - even after we were aware of the fact that this is the leading cause of global warming and climate change - indicates that there is an urgent need for a systemic change in our current strategies towards environmental sustainability.

The first step towards exploring a solution is to look back at the factors that cause this increase in the global CO2 emissions (the ‘F’ in the Kaya Identity); namely global population (P), affluence (world GDP – ‘G’) and global energy consumption (E). While there is no doubt that solutions need to be found regarding the stabilization of world population and reducing the average per capita consumption of resources etc., these are factors that are outside the purview of this architectural research. The focus of this project will instead be to analyze factor ‘E’, the global energy consumption, in terms of its sources and patterns, and propose a solution that can contribute to an overall reduction in energy consumption, which in turn would reduce global CO2 emissions (‘F’).
1.2. ENERGY CONSUMPTION - THE GLOBAL SCENARIO

The pattern of global energy consumption (Fig. 5) shows that until the time of the Second Industrial Revolution, energy was produced largely from biomass-based sources. Fossil fuel-based energy consumption begun with the use of coal in the latter half of the 19th century and showed a dramatic rise with the use of new sources such as oil in the period of unparalleled prosperity after the Second World War in the mid-20th century.

![Fig. 5 - Global energy consumption, 1850-2010](http://planetsave.com/2014/09/16/what-is-climate-change-video/)

The clear synergy between global energy consumption (Fig. 5) and CO2 emissions (Fig. 4) means that along with commitments towards non-fossil fuel-based energy production (a medium-to-long term strategy), countries also have to post-haste implement energy conservation measures that can produce immediate and lasting impact on reducing CO2 emissions and consequently, environmental degradation. The countries for whom this initiative is most critical are the United States, China and India - the combined annual CO2 emissions of these three countries (Fig. 6) is alone responsible for more than half of the world’s CO2 emissions (Emission Database for Global Atmospheric Research, 2014).
However, the greenhouse gas emissions of the United States has already peaked, and the country has committed to a reduction of 26-28% of its 2005 level by 2025. Similarly, China has committed to reduce its CO2 emissions growth and peak by 2030 (United Nations Framework Convention on Climate Change, 2015). On the other hand, India’s CO2 emissions are expected to increase at a rate faster than any other country in the world. Fig. 7 is a conservative estimate that indicates how the Energy Information Administration (EIA) expects India’s CO2 emissions to soar through until 2040 and possibly beyond.
Therefore, it is imperative that an alternative approach needs to be identified for energy conservation in the Indian context in order to reduce a majority of future CO2 emissions.

1.3. ENERGY CONSUMPTION PATTERNS IN INDIA

1.3.1. BY SECTOR

Now, let us analyze India’s energy consumption patterns by its three major, distinct sectors - Buildings, Industry and Agriculture - in order to understand the greatest potential for energy reduction. With as much as 50% of the population employed in the agriculture sector, it consumes 24% of all energy produced in India (Fig. 8). The building sector and the Industrial sector account for 31% and 45% of energy production respectively (Central Statistics Office, 2015).

![Fig. 8 - 2015 Energy consumption by sector, India](Image by author based on data from the Central Statistics Office, Government of India)

The Industrial sector accounts for the largest energy share as India is considered a ‘fast-developing’ economy. However, over time, as it transitions to a ‘developed’ economy, it is anticipated that the building sector would see the fastest growth - an estimated 75% of buildings that will exist in India by 2030 have not been built yet (Global Buildings Performance Network, 2015). For example, a similar sector-wise energy analysis for a ‘developed’ economy like the U.S. (Fig. 9) indicates that the building sector consumes a majority of energy produced in the country.
Another important reason to focus on energy conservation in the building sector is that unlike the other sectors, buildings typically have a ‘lock-in’ period for around 50 years. Retrofitting a building to make it more energy-efficient is an expensive affair, unlike the industrial, transportation or agricultural sectors in which it is prudent to replace machinery or technology in a much shorter time-period.

If we examine the building sector further in terms of the typology of buildings, it can be observed that commercial buildings consume only 9% of the overall energy production whereas residential buildings consume 22%, which is almost one-fourth of all energy produced in India (Fig. 10).

Examining this sector of residential energy consumption further; it is noteworthy that despite the rapid increase in new building floor area, only 4% of energy is spent in the construction of these new buildings (Fig. 11) – as a result, an estimated 18% of
all energy consumed in India is for the operation and maintenance of residential buildings.

Fig. 11 – Indian residential energy consumption - construction vs operation & maintenance Image by author based on data from the Central Statistics Office, Government of India

1.3.2. SUMMARY

This segment – operation and maintenance energy of residential buildings in India – is one that is little regulated from an energy perspective, because taken individually, residences are typically too small and too numerous to be logistically covered under a mandatory energy code. Taken together, however, this sector has a huge impact on the overall energy consumption and by extension, on the carbon emissions of India, the third largest emitter country in the world.

Therefore, the broad focus of this research will be to propose and develop a new model for the reduction of the foreseeable energy consumption in the operation and maintenance of residential buildings in India.

1.4. AN OVERVIEW OF THE INDIAN RESIDENTIAL BUILDING SECTOR

To better develop this alternative model for energy conservation, it is crucial to analyze and understand the existing patterns of residential development in India.

Dhar, Pathak and Shukla (2013) estimate that India’s population will grow at a compounded rate of 1% per annum between 2010 and 2030. This implies that its population will increase from 1.25 billion in 2013 to approximately 1.5 billion in 2030 (Fig. 12).
This massive population growth would further exacerbate the existing shortage of 18.78 million housing units in urban India (Fig. 13) as estimated by the Ministry of Housing and Urban Poverty Alleviation (2011), and could possibly lead to a shortage of 38 million housing units by 2030 based on current trends.
1.4.1. THE SUBURBAN SPRAWL

This large-scale increase in population and consequently the need for housing has predictably led to suburban sprawl around many Indian cities such as Bangalore and Gurgaon (Fig. 14), which have seen a population increase of 250% between 1991 and 2011.

![Fig. 14 - Suburban sprawl in Bangalore (left) and Gurgaon (right)](source: Satellite imagery extracted by author from Google Maps)

Sudhira, Ramachandra and Jagadish (2004) used GIS and remote sensing techniques in their study of urban sprawl near Mangalore, Karnataka; and note that urban sprawl due to population growth is seen as one of the major threats towards sustainable development in India. Their study determined that almost two-thirds of housing zones in Mangalore can be classified as low-density (3 to 4 dwelling units per acre).

The individual unit of this suburban sprawl is typically a low-height single-family home, for which the annual carbon emissions are 25% more than a comparable housing unit in a medium-density (12 to 16 dwelling units per acre) development (Chakrabarti, 2013).

1.4.2. SUMMARY

Therefore, as the need for energy conservation is the greatest in single-family homes among the different housing typologies; this thesis will specifically focus on developing a new model for the reduction of energy consumption in the operation and maintenance of single-family homes in India.
2.1. ENERGY CONSERVATION MEASURES

Around the world, there are two broad approaches towards energy conservation in buildings—mandatory codes that are typically formulated by governments, and voluntary rating systems developed by various organizations. The 'green building movement' is one that "grew out of the general concerns of the environmental impact of rapid development in the 1960s and the 70s, the energy crisis of the 70s, and after the 'sick building scares' (poor indoor air quality) in the 80s; more and more people began to ask whether architecture could have a more positive effect on people and planet" (Hosey, 2014). Governments moved quickly to find a solution - in the U.S., ASHRAE standards were adopted into local building codes; while in India, the Bureau of Energy Efficiency (BEE) was set up by the government to "prescribe energy conservation building codes for efficient use of energy and its conservation in buildings" and "amend the energy conservation building codes to suit the regional and local climatic conditions" (The Energy Conservation Act, 2001).

2.1.1. MANDATORY CODES: India’s mandatory energy code, the Energy Conservation Building Code (ECBC), was formulated by the Bureau of Energy Efficiency and formally launched by the Government of India in May 2007. Evans, Shui and Somasundaram (2009) summarize the ECBC, which sets compliance standards for building energy conservation - they note that currently, the code applies only to buildings that have a connected load greater than 100 kW or contract demand greater than 120 kVA. In practice, these ECBC compliance requirements are mandatory only for buildings with air-conditioned areas above 1000 m². In principle, the ECBC also applies to large residential buildings that are above these thresholds, but the current national policy priority is only to enforce it for commercial buildings (Rawal and Shukla, 2014). This implies that currently, India does not have a mandatory energy code that applies to the residential sector, which as mentioned previously, accounts for 22% of the overall energy consumption of the country.
2.1.2. VOLUNTARY SYSTEMS: In terms of a voluntary approach towards building energy conservation, there are two main ‘green building’ rating systems in India – LEED (Leadership in Energy and Environmental Design), promoted by the Indian Green Building Council (IGBC) and GRIHA (Green Rating for Integrated Habitat Assessment), developed by The Energy Resources Institute (TERI) and promoted by the Ministry of New and Renewable Energy (MNRE). Both GRIHA and LEED have certification fees that vary depending on the floor area and typology of the project. While these rating systems can be credited for spreading awareness about ‘green buildings’ among the general public, there has been criticism about whether they really do “provide a definitive standard for what constitutes a green building” as claimed in the GRIHA manual (The Energy Resources Institute, 2011).

For example, Vyas and Jha (2012) in their comparative assessment of different green building assessment systems, including LEED-India and GRIHA, argue that in the context of a large, ‘developing’ country like India, two major categories - climate and life-cycle cost - are ignored by both these systems. In his essay ‘Turning Down the Global Thermostat’, Architect Edward Mazaria (2003) criticizes rating systems because “LEED-type programs can actually be damaging because they shift decisions about sustainability out of the realm of design at the workplace and put it in a separate, purely technical category.” These rating systems typically come into play in an architectural project when it is well into the design phase, during which the ability to impact reduces and the cost of changes increase. This is procedurally similar to the MacLeamy curve (Fig. 15) - in order to reduce the ‘operation and maintenance’ energy of a project, the greatest effort in terms of sustainability strategies should be at the design stage, which these rating systems largely fail to address.
Fig. 15 - A modified MacLeamy curve for a ‘green building’ - to have the greatest impact on energy and to reduce the cost of changes, most effort should be put into the design phase of the project

Image by the author based on the ‘MacLeamy curve’ by Patrick MacLeamy

Aside from the qualitative debate of whether these systems assist in the development of a ‘green building’ or not is the larger quantitative question of how much impact these systems have made in terms of real numbers. Smith (2015) has analysed the characteristics and spatial distribution of LEED-India and GRIHA projects in India. While LEED-India has a total number of 445 projects, out of which 199 are residential; GRIHA has rated 89 residential projects out of a total of 365 - there are no available statistics in terms of how many of these rated residential projects were single-family homes. Therefore, in spite of dominating public discourse (Fig. 16) about ‘green buildings’ and sustainability, it is safe to assume that these two rating systems have ‘rated’ a negligible fraction of single-family homes, let alone the overall building stock in India.
2.1.3. SUMMARY

The analysis shows that there is a massive segment of energy consumption in India – the 22% for the residential sector – that has been inadequately addressed. Single-family homes in particular ‘slip through the cracks’, and even recent research on the residential sector by organizations such as the Global Buildings Performance Network (GBPN), still recommend a ‘top-down’ approach in terms of introducing a specific energy code for residential development (Rawal & Shukla, 2014). Enforcing such a code for single-family homes will also be a huge logistical challenge for a large ‘developing country’ like India, where some stages of the construction process are still unregulated.

2.2. TYPICAL DESIGN PROCESS

The thumb rule that only 2% of buildings built worldwide are designed by architects (Dendra, 2011) applies to the Indian context as well; in fact this number might well be even less in a ‘developing country’ where 68% of the population still lives in rural areas. When it comes to smaller building units such as single-family homes, the architect is an even more peripheral player in the design and construction process in the larger context. Therefore, even if the architectural community comes together and follows higher standards of energy-efficiency in the design process for the residential sector, it would still only make a marginal difference overall.
2.2.1. THE ‘STOCK DESIGN’ APPROACH

In India, as is the case in the rest of the world, the typical building design process for residences is contractor-dominated. Most houses are built by these contractors who also design the building, or as in the majority of cases, offer a variety of ‘stock designs’ from which the client selects the one that gets built.

The past decade has also seen a gradual replacement of the contractor’s role as a designer or as a source of these stock designs with the proliferation of websites that offer similar resources. Because of a wider range of design options and the ability to easily narrow down architectural designs that fit one’s required programmatic requirements (Fig. 17); there is a complete transition of the designer’s role in a typical single-family home project from the contractor to the client (the ‘anonymous architect’) in these websites.

![Search Your Dream Home](http://www.gharplanner.com/)

Fig. 17 - A screenshot from a typical ‘stock designs’ website showing the various services offered and the ability to search for options based on programmatic requirements


The contractor’s role in the process is now therefore just that of a builder, as the complete drawing package – concept plans (Fig. 18), elevations, working drawings, structural details, electrical and plumbing drawings, and even a cost estimate – is available with these websites (‘Gharplanner’, 2016).
2.2.2. ENVIRONMENTAL IMPLICATIONS

However, the larger implication of this ‘stock design’ approach is that this process completely alienates the building’s relationship to the climate and context of the site. This would negatively impact building energy conservation efforts, because this ‘one size fits all’ approach is similar to that of the green building rating systems - in a large country like India, which has multiple climatic zones, this ‘stock design’ process effectively means that passive solar design concepts - which can reduce the energy consumption of a building by 50-80% (Architecture 2030) - are bypassed. In fact, India’s climate offers a tremendous potential for energy conservation by passive design for residences, because space conditioning patterns are very different from those in, for example, the US. For example, in most regions, residences typically do not need to be ‘sealed’ to prevent air leaks as there is no requirement for heating.
An analysis by Rawal and Shukla (2014) of the energy consumption patterns (Fig. 19) in the Indian residential sector reveals that the majority of energy use (62%) is from ceiling fans (for cooling & ventilation) and lighting. Appropriate orientation and fenestration design can increase daylight penetration and reduce cooling loads by a large extent for most months of the year – note that air conditioning accounts for only 7% of a residence’s energy use in India.

Therefore, the need of the hour is to develop an alternative platform that can be used to deliver passive design strategies that can be applied to the standard acontextual ‘stock design’ approach for single-family homes in India.

2.3. KEY FINDINGS

Current approaches towards energy conservation in India have been ‘top-down’ in nature – whether it be the government’s mandatory ECBC or the two popularly used voluntary green building systems, LEED-India and GRIHA – separating the signal from the noise is crucial if we are to make a real difference in terms of facts on the ground. This ‘trickle-down’ model has proven to be an unsustainable, unstable one (Fig. 20) as it has been applied only for a fraction of the overall building stock in the country. Further, in the context of the residential sector and specifically single-family homes, there is a vacuum in terms of a coherent strategy to address energy conservation. Taking into consideration the vast scale, the projected rate of growth, and the challenges of enforcing regulations for India’s fast-developing residential sector; an alternative ‘bottom-up’ approach to the housing-specific energy code recommended by think-tanks needs to be explored.
- one that simply uses available technology and existing knowledge in a different manner to be able to reach out to a larger audience.

![Diagram](image)

Fig. 20 - Current vs Proposed model of building energy conservation

While this is just a hypothesis, and it is not claimed that this will be a panacea for India’s projected energy-related challenges in the housing sector; there is undoubtedly a case for a different approach - even for an energy-conscious and environmentally responsible client who might unfortunately not have the access to specialized professionals; there are currently very few available opportunities to easily access relevant passive building design information in order to make informed, energy-related decisions to modify the ‘stock design’ of his/her home.
3.1. PRECEDENT STUDIES

As the first step towards developing the proposed ‘bottom-up’ platform that can provide passive design strategies in a manner that can be easily accessed and understood by even laypeople; similar open-source precedents were analyzed. This analysis was done to get answers to multiple crucial questions:

1) What should be the overarching ‘principles’ of this platform, keeping in mind the objective of open access to all?
2) What should be the process of generating the content of the platform, i.e. the passive solar strategies? And how can the content of this platform be relevant across the vastly different climatic conditions in India?
3) What would be the best way to disseminate this information so as to reach the widest audience? What should the interface and the content look like?

Two open-source platforms were studied in detail – the ‘2030 Palette’ by Architecture 2030 and ‘Climate Consultant’ by the Energy Design Group at the University of California, Berkeley. These two platforms were selected because they have alternate strengths and weaknesses in almost all aspects – in terms of methodology, accessibility, content and user experience design - and therefore play a vital role in the comprehensive development of the proposed platform.

3.1.1. ARCHITECTURE 2030 PALETTE

The 2030 palette was developed by Architecture 2030, a non-profit think tank that addresses climate change through building design solutions. Founded by Architect Edward Mazaria in 2002 as part of his architecture practice, the organization came into the limelight when Mazaria ‘redrew’ the energy consumption pie chart and determined that buildings accounted for almost 50% of energy use in the US (Mazaria, 2003). The organization has a range of initiatives and programs such as the 2030 Palette, 2030 Districts and the AIA+ 2030 education series with the overarching goal of achieving carbon-neutral built environments by 2030.

The 2030 Palette was launched in 2013 as an internet platform “providing a set of guiding principles and actions for creating low-carbon and adaptable built environments worldwide” (Architecture 2030, 2013).
The 2030 Palette is simply a series of environmental design strategies organized in a hierarchical manner (Fig. 21) as ‘tags’ (the type of strategy) and ‘scales’ (the scale at which the strategy can be applied). There are five ‘scales’ of strategies – regions (e.g. inundation mapping or habitat corridors), city/town (urban infill, heat island mitigation etc.), district (residential densities, street networks etc.), site (e.g. solar access, constructed wetland) and the smallest scale, building (direct gain heat storage, solar shading etc.). Within each of these scales, ‘tags’ classify the strategies further into their objectives – for example, the building scale has four tags – lighting, heating, cooling and whole building. This systematic organization enables a user with some knowledge about the design process and the terminologies used to quickly organize relevant strategies.

In terms of the organizational layout for each strategy (Fig. 22), there are three main components – a short descriptive text that occasionally provides specific guidelines, a set of images that show how the respective strategy has been implemented, and a series of ‘swatches’ (other strategies) that are related to the selected strategy.
Fig. 22 – Organizational layout of each design strategy in the 2030 Palette - related strategies, images and a description
Source: http://www.2030palette.org/swatches/view/stack-ventilation/british_high_commission_colombo_11.jpg

**PROS**

The standout feature in the 2030 Palette is its accessibility – being a simple website, anyone with an internet connection can have complete access to all its features. The layout is fairly simple as well, and the pictorial focus for each strategy makes it attractive for anyone to easily understand the concept. The strategies also cannot be mistaken by a layperson to be ‘prescriptive’ in nature, because there are multiple images of the application of the strategy in environments of different scales and style. Although the information presented is quite simple, the ‘tools and resources’ section at the end of each strategy provides external links to further details regarding the strategy in case an in-depth understanding is desired.

**CONS**

The 2030 Palette is quite simply a repository of information about passive building strategies - therefore, there is no distinction at even the site and building-level ‘scales’ about which climates the respective strategy could be applicable for. This
would make it difficult for the ‘anonymous architect’ (the client) who might not, for example, be able to make subtle distinctions such as the importance of cooling by ventilation in addition to cooling by shading in warm-humid climates. Also, all the strategies are ‘best-case scenarios’ and therefore do not provide alternative solutions in case of external constraints – for example, a client with a site elongated along the north-south axis in a hot climate would not know what the second-best option could be (lesser windows on the east and west walls / a ‘staggered’ façade for self-shading etc.)

3.1.2. CLIMATE CONSULTANT

The Climate Consultant program is a part of a series of free tools developed by the Energy Design Group led by Dr. Murray Milne at the Department of Architecture, University of California – Los Angeles. Apart from Climate Consultant, the group has also developed HEED: Home Energy Efficient Design (a simple program that compares the energy performance of a house with the California energy code baseline), and open access courses about climate responsive design and how to read climatic data.

ORGANIZATION

Initially developed as a Master’s thesis by Yun S. Kim, Climate Consultant has undergone various iterations over the years with the objective of helping architects, builders, contractors, homeowners and students visualize and understand climatic data and its influence of building design (Milne, Liggett & Al-Shaali, 2007). The program uses EPW (Energy Plus Weather) data files – which have to be downloaded and installed - of a location to visualize its specific climatic data and generate design recommendations. The basic climatic characteristics of the location – temperature, radiation and humidity – are represented in a simple bar graph format (Fig. 23) in the beginning; followed by more complex and interactive analyses such as the psychrometric chart, wind speed & direction graph, and sun shading chart.
Fig. 23 - Visual representation of the temperature range of the location (the horizontal grey band represents comfort hours) Image generated from Climate Consultant

However, the most important feature of Climate Consultant comes at the very end of the program – a series of climatic building design strategies that are specific to the location’s climate. These strategies are represented as very simple black-and-white images accompanied by a short descriptive text (Fig. 24).

Fig. 24 - Region-specific climatic building design strategies expressed as simple images Image generated from Climate Consultant

Use plant materials (bushes, trees, ivy-covered walls) especially on the west to minimize heat gain (if summer rains support native plant growth)

Traditional passive homes in hot humid climates used light weight construction with openable walls and shaded outdoor porches, raised above ground
**PROS**

The ability to synthesize complex data into simple visual graphs and sketches makes Climate Consultant engaging and user-friendly. There are also a few design tools in the program – for example, the sun shading chart also has a shading calculator to design window overhangs and side fins to eliminate direct solar gain through the window as shown in Fig. 25.

![Sun shading chart with the shading calculator to design the window overhang and side fins](Image generated from Climate Consultant)

However, the most important aspect in Climate Consultant is that it is climate-specific in nature, and the climatic design strategies are expressed in a predominantly visual format. These recommendations are also arranged in a hierarchical manner, with the strategies that make the most difference to thermal comfort being displayed at the top of the list.

**CONS**

Climate Consultant is not easily accessible for a layperson without knowledge of the building design and construction process. The program itself, as well as the EPW file for the location needs to be downloaded and installed on a computer - this limits the ‘reach’ of the platform and its accessibility. Another problem is the lack of EPW files for many locations outside of the United States such as the fast-developing Indian cities of Coimbatore and Gurgaon, which have a population of ~1 million.
3.2. DESIGN CONSIDERATIONS FOR PROPOSED PROGRAM

Currently, most platforms have the climatic design information presented in a manner such that it is either not very intuitive or not specific enough to be useful to the anonymous architect. These programs also typically target professionals in the building design and construction process, when it is clear that clients play a much larger role in the design process of smaller building units such as single-family homes. In summary, there is a clear potential to develop a platform that learns from the weaknesses and incorporates the strengths (accessibility, clarity and climatic specificity) of both the 2030 Palette and the Climate Consultant programs. Based on the background information presented earlier and the precedent analysis, the following guidelines have been framed for the development of the program:

3.2.1. PRINCIPLES

Open-source / Free to use: To be able to reach the maximum number of people
User-friendly: So it can be used by a layperson with no architectural knowledge
Engaging: To sustain user interest
Easily accessible: To avoid the hassle of downloading files / installing software
Predominantly visual: To avoid jargon and convey concepts clearly

3.2.2. CONTENT

Climate-specific: The passive design recommendations have to be relevant to the client’s site location. Further, there needs to be a robust analysis to generate each design strategy – one that takes into account the Indian social and economic context. A study of the vernacular architecture and / or high-performance buildings in each climatic region would be helpful to identify these time-tested ‘common threads’ between multiple buildings in the same climate.

Simplicity: The description of each strategy should be jargon-free, and should include external links to any specific architectural terminology

3.2.3. PLATFORM

The illusion of specificity: Although the design strategies will be relevant for the entire climatic region; giving users the ability to select their specific site will engage
them better. Geographic Information Systems (GIS) tools could be used to make the site selection process intuitive and interesting.

Non-prescriptive, visual approach: It needs to be clear that these climatic design strategies are only meant to be suggestions and are non-prescriptive - this is because this program should not be mistaken for one that generates architectural designs. Similarly, sometimes there might be factors (views, etc.) other than the climate of the region that influence the building design. Therefore, the predominant visual representation of these strategies should not look like a ‘finished product’, but more of a composite visual style that focusses on how the strategy is applied and how it works.

Easy accessibility: The program needs to be accessible by the maximum number of people, and a website is therefore the best platform currently. Similarly, the program should be able to be used on the smallest display unit available - the ubiquitous smartphone. With 55% of the 220 million + smartphone users in India using their phones for banking or finance (We Are Social, 2014), this would be an ideal platform as the client could sit across the table with the contractor/ builder and request modifications to the stock designs.
This chapter describes in detail the process used to arrive at the region-specific climatic building design strategies for the different climatic regions of India. India’s vast area and topographical features have meant that various climatic zones exist in the country; and the first step towards generating passive design concepts was to identify an appropriate model of climate zone classification. This was then followed by an exhaustive study of vernacular architecture and other exemplars in each climatic region to identify the common passive design recommendations that are specific to that region.
4.1. PHYSIOGRAPHICAL FEATURES OF INDIA

Much of the administrative boundaries of India are defined by natural features, with the Arabian Sea on the west, the Bay of Bengal on the east, and the Himalayan mountain ranges along the North (Fig. 26). Subrahmanyam (2016) notes that “India’s present-day relief features have been superimposed on three basic structural units: the Himalayas in the north, the Deccan (peninsular plateau region) in the south, and the Indo-Gangetic Plain in between.” The internal boundaries of India’s states and territories was generated along linguistic lines following the States Reorganization Act of 1956 (indiacode.nic.in).

![Fig. 26 - The Geographic map of India](http://www.lahistoriaconmapas.com/atlas/nepal-maps/geographic-map-of-india.htm)

B. Dey (1990) notes that the contrasts in the areal variations of temperature and rainfall are very remarkably different across India - as the seventh largest country in the world, this consequently means that very different climatic zones exist across the country.
4.2. CLIMATE CLASSIFICATION MODELS

The first step towards generating region-specific climatic design recommendations is to identify an appropriate climate classification model that takes into account the different climatic variables that impact the energy performance of a building. Four climate classification models – Koppen, Trewartha, NBC (National Building Code), and Bansal – were studied in detail and are summarized below:

4.2.1. KOPPEN

Fig. 27 - The Koppen climate classification of India
Developed by Dr. Wladimir Koppen in 1900, with minor modifications in 1918 and 1936, the Koppen model (Fig. 27) continues to be the most widely used climate classification model over a century later (Peel, Finlayson and McMahon, 2007). The roots of Koppen’s classification lie in his background in plant sciences and in his belief that native vegetation is the best expression of the climate of a region (Wilcock, 1968). Koppen’s classified the climatic zones of India into nine categories:

1. Amw (Monsoon type with short dry winter season)
2. As (Monsoon type with dry season in high sun period)
3. Aw (Tropical Savannah type)
4. BShw (Semi-arid Steppe type)
5. BWhw (Hot desert type)
6. Cwg (Monsoon type with dry winters)
7. Dfc (Cold, Humid winters type with shorter summer)
8. Et (Tundra Type)
9. E (Polar Type)

However, it is to be noted that the Koppen system is a broad, worldwide classification system and appears to have some discrepancies when juxtaposed with the actual geographical features of India - B. Dey (1990) argues that this becomes obvious when one notes that almost the entire northern part of the country from west to east is classified as ‘Monsoon type with dry winters’ (Cwg) when this includes diverse geographical regions such as The Great Indian Desert in the west and the lush tropical forests of the north-east.

**4.2.2. TREWARTHA**

Glenn Thomas Trewartha rectified some of these deficiencies and modified the Koppen classification system in 1966, with further updates in 1980 (Belda, Holtanova, Halenka & Kalvoa, 2014). As per Trewartha’s classification (Trewartha, 1968), there are seven distinct climatic zones (Fig. 28) in India:

1. Am (Tropical Monsoon type)
2. Aw (Tropical wet and dry or Savannah type)
3. Bs (Semi-arid or Steppe type)
4. BSh (Tropical and Sub-tropical desert type)
5. BWh (Middle latitude desert type)
6. Caw (Sub-tropical humid type)
7. H (Undifferentiated highlands/ Mountain type)
The Trewartha system of climate classification corresponds to the geographical regions of India in a far more satisfactory manner than the Koppen system. However, it is to be kept in mind that some of the problems associated with Koppen - that is a generalized classification model and is based off the vegetation patterns of a region which might not necessarily be appropriate for building design - still persist with the Trewartha classification system.
4.2.3. National Building Code

The National Building Code (2005) of India identifies five distinct climate zones on the basis of mean monthly values of maximum temperature and relative humidity percentages (Fig. 29). It is to be noted that these climatic zones have been identified specifically for the purpose of designing buildings in India, unlike the Koppen and Trewartha classification systems which are more general in terms of both the geography and the scope of use.

Fig. 29 - The climate classification of India based on the National Building Code
The five distinct climatic zones identified in the National Building Code are:

1. Hot-Dry (Temperature above 30ºC and Relative Humidity below 55%)
2. Warm-Humid (Temperature above 30ºC and Relative Humidity above 55%, or Temperature above 25ºC and Relative Humidity above 75%)
3. Temperate (Temperature between 25-30ºC and Relative Humidity below 75%)
4. Cold (Temperature below 25ºC and all values of Relative Humidity)
5. Composite (Regions that do not fall under any of the above categories for six months or more in a year)

A region is deemed Hot-Dry, Warm-Humid, Temperate or Cold if their corresponding values of Temperature and Relative Humidity are valid for six months or more in a year. For example, a region will be classified as Hot-Dry if it exhibits a mean monthly maximum temperature above 30ºC and a relative humidity value of less than 55% for only 6 months, and experiences other temperatures and relative humidity values for the rest of the year.

The NBC classification model is therefore based on two main factors - temperature and relative humidity - which predominantly influence heat exchange between the human body and the surroundings (Moore, 1993). However, two climatic factors that influence building design - precipitation and solar radiation - are not taken into account. For example, the vernacular design of buildings in Cold & Cloudy climates are markedly different from those in Cold & Sunny climates as indirect heat gain is the main strategy in the former while direct gain is the primary strategy in the latter. Therefore, it would be better if there is an alternative model that takes into account these factors as well.

4.2.4. BANSAL

Dr. N.K. Bansal published his climate classification model (Fig. 30) in 1995 on the basis of observations of temperature, relative humidity, precipitation and solar radiation (expressed as number of clear days) made at 233 weather stations across India (Bansal & Minke, 1995). Six distinct climate zones were identified as follows:

1. Hot-Dry (Temperature above 30ºC, Relative Humidity below 55%, greater than 20 clear days, and precipitation levels less than 85mm)
2. Warm-Humid (Temperature above 30ºC, Relative Humidity above 55%, lesser than 20 clear days, and precipitation levels greater than 85mm)
3. Moderate (Temperature between 25-30°C, Relative Humidity below 75%, lesser than 20 clear days, and precipitation levels greater than 85mm)

4. Cold and Cloudy (Temperature below 25°C, Relative Humidity greater than 55%, lesser than 20 clear days, and precipitation levels greater than 85mm)

5. Cold and Sunny (Temperature below 25°C, Relative Humidity lesser than 55%, greater than 20 clear days, and precipitation levels lesser than 85mm)

6. Composite (Regions that do not fall under any of the above categories for six months or more in a year)
Therefore, the Bansal classification model uses climatic variables that predominantly influence human comfort (temperature and relative humidity) as well as those that have an impact on passive building design (precipitation and solar radiation levels).

4.2.5. SUMMARY
The Bansal climate classification system has been chosen as the basis for the development of the ‘Architects Anonymous’ platform because of the following reasons: 1) as mentioned before, it factors in human comfort as well as building design variables, 2) it is based on data from a comparatively larger sample size - 233 weather stations across the country, and 3) it has been exhaustively vetted and forms the basis of a number of other publications including those produced by The Energy Research Institute (TERI) and the Ministry of New and Renewable Energy (MNRE) of the Government of India.

4.3. DERIVATION OF CLIMATIC DESIGN STRATEGIES

4.3.1. PROCESS
To derive climatic design strategies specific to each climate zone, existing documentation of various examples of vernacular architecture and other buildings that have exemplary energy performance were analyzed in detail. The decision to study vernacular architecture to generate contemporary passive building design strategies was taken due to a variety of reasons. Koenigsberger, Ingersoll, Mayhew and Szokolay (1974) note that “traditional building forms of the rural tropics often include sound solutions of climatic problems. Given the technological limitations and the always overriding considerations of safety, some of these solutions must be considered ingenious, and there can be no doubt that they deserve careful study”. Singh, Mahapatra and Atreya (2009) suggest that vernacular architecture “addresses the local climatic constraints and shows maximum adaptability and flexibility”, and that the design of these buildings is the outcome of generations of traditional knowledge based on a trial and error approach.

Multiple examples from each climatic zone were analyzed to eliminate specific cultural or aesthetic factors that are not relevant to the research, and only the ‘common threads’ (which invariably turned out to be climatic responses) were documented. For example, over the course of the research about the warm-humid climatic region, vernacular buildings from the north-east as well as from the
southern tip of India were analyzed to understand how they responded to the common need for heat loss by convection even though they were located thousands of kilometers apart. For ease of understanding, the climatic design strategies that were derived from this analysis has been grouped under four categories – Form & Orientation, Envelope, Zoning and miscellaneous strategies.

While the study of vernacular architecture has helped generate the climatic design strategies pertaining to all the four categories listed above, more recently-built exemplars have also been studied mainly to determine strategies pertaining to construction materials, methods and technology. For representative purposes, only two exemplars (one vernacular and one more recently-built) have been described in detail for each climatic zone.

A few terms that are specific to building science will be used in following chapter - the contextualized definitions / descriptions of these terms (from Bansal, Minke & Hauser, 1994) are listed below for easier comprehension:

**Thermal Storage:** Thermal capacity effects in materials result in the time delay as well as damping of the parameters in the environment - as a result, there are temperature differences between the materials and the environment around them. This effect can be utilized for space cooling and heating.

**Convection:** The heat transfer phenomenon that occurs because of material particiles of a body moving in space and carrying heat from one part to another.

**Direct Gain:** A passive solar design concept in which solar radiation is transmitted through a glazed surface and falls on inside building surfaces to be absorbed and converted into heat.

**Indirect Gain:** A passive solar design concept in which solar radiation is absorbed, converted into heat, and transmitted by a thermal storage wall into the living space.

**Conduction:** A phenomenon in which the heat exchange takes place directly between the neighboring particles of the material; the heat is passed on from one particle to another.

**Heat Reflectivity Reduction:** If the surfaces of the building are painted with such colors that reflect solar radiation (in order to have minimum absorption), the heat flux transmitted into the building is reduced considerably.
Thermal Comfort: A combination of six parameters – air temperature, mean radiant temperature, relative humidity, air speed, metabolic rate and clothing insulation – that determines what conditions are comfortable for the occupants.

Temperature Swing: The variation between a high temperature and a low temperature that occurs during the same day.

Window-Wall Ratio: The net glazing area (excluding mullions etc.) divided by the gross exterior wall area.

Thermal Right-Sizing: The concept of reducing the volume of conditioned space to the appropriate or optimum size in order to reduce energy consumption.
CHARACTERISTICS: Regions that have a mean (all monthly values) temperature of greater than 30ºC (86ºF), relative humidity of less than 55%, precipitation levels of less than 85mm, and 20 or more clear / sunny days for more than 6 months in a year are classified as Hot-Dry climates. Other aspects of this region include relatively flat, sandy or rocky ground conditions; scarce vegetation, a low water table and dust laden winds that occasionally develop into sandstorms (Bansal & Minke, 1995). Much of the western states of Rajasthan & Gujarat, and portions of Maharashtra, Karnataka, Telangana and Andhra Pradesh are considered Hot-Dry regions.
Arvind Krishnan recorded the thermal performance of indigenous habitats in the Hot-Dry region of Rajasthan (Krishnan, 1996) using on-site monitoring equipment and analyzed time-lag and decrement factor evaluations and airflow characteristics among other observations. Some of the broad observations from the study are:

**ORIENTATION / FORM:** The typical havelis or traditional houses of the region are ‘row-houses’ oriented with the longer sides facing North-South and feature a central courtyard. Building facades are shaded by balconies, chajja (sun shade) projections, and also mutual shading by neighboring buildings as a result of the dense, compact settlement form.

**ENVELOPE:** Almost the entire urban fabric of Jaisalmer is built using locally available light yellow sandstone (Fig. 31) which helps in reducing heat gain by absorption. The use of thick walls and floors also serve to attenuate the harsh outdoor conditions which are typically in excess of 40°C (104°F) in the summer, while the courtyard and the openings on the shorter facades facilitate ventilation providing greater sensible comfort.

**ZONING:** Being ‘row-houses’, the generic house in Jaisalmer is considered to not have any heat input/output along the longer walls as they are ‘shared’ with the neighboring house and not exposed to the elements. Instead, the central courtyard and the shorter facades become the avenues through which the entry...
of light and ventilation occur. Zoning based on use-pattern can also be observed with the living spaces - which are typically used during the day - sunken to utilize the earth's insulating properties.

Fig. 32 - Summer temperature profile of typical (Vyas) house, Jaisalmer, India
Source: Krishan, A. (1996)

SUMMARY: The thermal performance observations (Fig. 32) reinforce the effectiveness of the passive design of the havelis; with the building observed in detail recording an indoor temperature fluctuation of not more than 3°C in the ground floor when the outdoor temperature fluctuation was in the order of 15°C, while the maximum indoor temperature was 8 to 9°C lower than the corresponding outdoor temperature.

Similar passive solar concepts - mutual shading, massive walls, openings predominantly facing the north-south direction etc. - can be observed in the University guest house (Fig. 33) located in Jodhpur (another Hot-Dry climatic region) designed by Architect Vinod Gupta and built in 1988.
Fig. 33 - Ground Floor plan (top), Site plan (left) and section (right) of the University guest house, Jodhpur, India
Source: Bansal, Hauser & Minke 1994

The transverse section of the building also shows the function of the wind tower with a wet screen to aid in the evaporative cooling of the building and the partial berming of some of the spaces to reduce temperature fluctuations. The heavily insulated roof (100mm / 4” lime terracing + cinder filling on terracotta pots + 100mm / 4” stone slab), the massive buff colored exterior stone masonry construction (up
to 400mm / 16” thick), and the wooden window frames insulate the building by reducing solar heat transmission to the interior (Bansal, Hauser & Minke 1994). Monitoring results of the building show that some of the rooms are up to 10ºC cooler in the summer and 8ºC warmer in the short winter than the corresponding outdoor temperature (Majumdar, 2001).

**DESIGN STRATEGIES FOR HOT-DRY CLIMATES**

The following design strategies for buildings in hot-dry regions have been compiled based on the comparative study of exemplars:

**Table 1 - Design strategies for Hot-Dry climates**

<table>
<thead>
<tr>
<th>HOT-DRY CLIMATES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The overall passive design goal for hot-dry climates would be to maintain a cooler indoor temperature by reducing direct solar heat gain through appropriate solar orientation, shading design and sizes of openings</td>
<td></td>
</tr>
<tr>
<td><strong>ORIENTATION / FORM</strong></td>
<td></td>
</tr>
<tr>
<td>1. Orient the longer walls of the building to face north and south, and locate the majority of the windows (adequately shaded) on the north-facing walls to reduce solar heat gain</td>
<td></td>
</tr>
<tr>
<td>2. If the north-south building orientation is not possible due to site conditions, at least try to locate the majority of the windows (adequately shaded) on the north-facing walls to reduce solar heat gain</td>
<td></td>
</tr>
<tr>
<td>3. Right-size the building by making it compact (by reducing ceiling height to 8 feet, reducing floor area etc.) to reduce the volume of conditioned space</td>
<td></td>
</tr>
<tr>
<td>4. Design a shaded courtyard (with vegetation and/or an overhanging roof) and sprinkle water (conserved through a rain water collection system) during the summer to promote evaporative cooling</td>
<td></td>
</tr>
<tr>
<td>5. In case of sloping sites, berm or partially berm the building to utilize the earth’s insulating properties</td>
<td></td>
</tr>
<tr>
<td>6. Consider constructing the building / parts of the building slightly below the ground level to utilize the earth’s insulating properties</td>
<td></td>
</tr>
<tr>
<td><strong>ENVELOPE</strong></td>
<td></td>
</tr>
<tr>
<td>7. Use a reflective exterior finish on the roof surface such as recycled chipped china mosaic tiles and a ‘filler-slab’ system on the interior to reduce solar heat gain</td>
<td></td>
</tr>
<tr>
<td>8. Construct thick exterior &amp; interior walls to insulate from solar heat gain</td>
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</tr>
<tr>
<td>9. Minimize the sizes of windows (particularly on the west and south-facing walls) to reduce solar heat gain</td>
<td></td>
</tr>
<tr>
<td>10. Provide high-insulation glazing for all the windows (if not, at least for the windows on the south and west facing walls) to reduce solar heat gain</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>If high-insulation glazing is not feasible, a low-cost alternative is to provide pre-cast jalis or operable wooden shutters in front of the window to reduce solar heat gain</td>
</tr>
<tr>
<td>12.</td>
<td>Design the north and south-facing window overhang (sunshade / chajja) width to shade the window glazing throughout the year</td>
</tr>
<tr>
<td>13.</td>
<td>Use insulated steel or wooden window frames to reduce the conduction of solar heat to the interior spaces</td>
</tr>
<tr>
<td>14.</td>
<td>Provide small openings near the top of the staircase to allow hot air to escape and promote ventilation</td>
</tr>
<tr>
<td>15.</td>
<td>Use lighter colored finishes of construction materials on the outside of the building to reduce solar heat gain</td>
</tr>
<tr>
<td>16.</td>
<td>Locate the open plan interior spaces (for example, Living-Dining-Kitchen) along the ‘cooler’ north-south axis</td>
</tr>
<tr>
<td>17.</td>
<td>Locate auxiliary spaces such as the store, toilets and stairs on the east or west to act as buffer spaces, but ensure there are ‘pockets’ of openings to facilitate ventilation</td>
</tr>
<tr>
<td>18.</td>
<td>Locate the sleeping spaces on the north or east, which are the ‘cooler’ zones of the building in the night, when they are most likely to be used</td>
</tr>
<tr>
<td>19.</td>
<td>Build a higher compound wall along the windward side to shield the building from hot wind</td>
</tr>
<tr>
<td>20.</td>
<td>Locate/design the building such that the exterior walls are shaded by overhanging roofs, neighboring buildings or vegetation to reduce solar heat gain</td>
</tr>
<tr>
<td>21.</td>
<td>Provide a roof-top solar water heating system to utilize solar heat and conserve water heating energy throughout the year</td>
</tr>
<tr>
<td>22.</td>
<td>Use light shelves (located on the outside of the wall line) on the south-facing wall to distribute daylight deeper into the building</td>
</tr>
<tr>
<td>23.</td>
<td>Design a ceiling profile (such as a vault) if necessary to provide effective reflectivity of daylight into the building</td>
</tr>
</tbody>
</table>
Orient the longer walls of the building to face north and south, and locate the majority of the windows (adequately shaded) on the north-facing walls to reduce solar heat gain (try to avoid south and west-facing windows).

If the north-south building orientation is not possible due to site conditions, at least try to locate the majority of the windows (adequately shaded) on the north-facing walls to reduce solar heat gain (try to avoid west-facing windows).
Right-size the bedrooms and the service areas by making them compact (by reducing ceiling height to 8 feet, reducing floor area etc.) to reduce the volume of conditioned space.

Design a shaded courtyard (with vegetation and/or an overhanging roof) and sprinkle water (conserved through a rain water collection system) during the summer to promote evaporative cooling.

In case of sloping sites, berm or partially berm the building to utilize the earth's insulating properties.

In case of sloping sites, berm or partially berm the building to utilize the earth's insulating properties.
Consider constructing the building or parts of the building slightly below the ground level to utilize the earth’s insulating properties.

Use a reflective exterior finish on the roof surface such as recycled chipped china mosaic tiles and a ‘flier slab’ system on the interior to reduce solar heat gain.

Design thick exterior and interior walls to insulate the building in the summer and retain heat gain in the winter.

Design thick exterior and interior walls to insulate the building in the summer and retain heat gain in the winter.
Provide high-insulation glazing for all the windows (if not, at least for the windows on the south and west facing walls) to reduce solar heat gain.

If high insulation glazing is not feasible, a low-cost alternative is to provide pre-cast jalousie or operable wooden shutters in front of the window.
Design the north and south-facing window overhang (sunshade / chajja) width to shade the window glazing throughout the year.

Use insulated steel or wooden window frames to reduce the conduction of solar heat to the interior spaces.

Provide small openings near the top of the staircase to allow hot air to escape and promote ventilation.

Use lighter colored finishes of construction materials on the outside of the building to reduce solar heat gain.
Locate the open plan interior spaces (for example, Living Dining Kitchen) along the ‘cooler’ north-south axis.

Locate auxiliary spaces such as the store, toilets and stairs on the east or west to act as buffer spaces, but ensure there are ‘pockets’ of openings to facilitate ventilation.

Locate the sleeping spaces on the north or east, which are the ‘cooler’ zones of the building in the night, when they are most likely to be used.

Locate and design the building such that the west-facing and east-facing exterior walls are shaded by overhanging roofs, neighboring buildings or vegetation.
Build a higher compound wall along the windward side to shield the building from hot wind.

Provide a roof-top solar water heating system to utilize solar heat and conserve water heating energy throughout the year.

Use light shelves (located on the outside of the wall line) on the south facing wall to distribute daylight deeper into the building.

Design a ceiling profile (such as a vault) if necessary to provide effective reflectivity of daylight into the building.
DEMONSTRATION

The sample stock plan shown below was accessed from a website that offers stock designs based on the client’s programmatic requirements - number of bedrooms, bathrooms, parking spaces, and so on. Note the caption below the image – “Get your free copy of this plan and go to any builder you wish” – this captures in a nutshell the need for a program like ‘Anonchitect’ in today’s environment.

As a test-case, let us assume that this stock plan is purchased by a client in Ahmedabad, a city with a hot-dry climate (based on the Bansal classification). Using the climatic design strategies suggested for hot-dry climates, the stock plan has been modified as can be seen below. Note that apart from the switch between the alfresco space and the bedroom on the south-west; large scale
changes have not been made to the layout as it is assumed that the client had selected the earlier stock plan based on aesthetic considerations etc. The modifications that can be observed from the plans are: the relocation of the alfresco space as a buffer on the hotter south-west corner of the site, the thicker wall envelope, the reduction of window sizes on the south-facing walls (to reduce solar heat gain), and the increase of window sizes on the north-facing walls (for glare-free lighting. Also note that instead of the large south-facing windows for the bedrooms, two smaller windows have been provided for each bedroom for cross-ventilation and for the better distribution of natural light. Changes that are not reflected in the plan, but are considered in the energy model are the modified window overhang depths based on the climatic design recommendations.

An energy analysis study was carried out on both these plans in the BEopt software to determine the effectiveness of the Anonchitect design strategies. The image below shows the comparison in energy consumption of the modified plan against
the standard stock design - it can be observed that there is an estimated reduction of approximately 12% in the modified design. The annual energy related costs for the stock plan design was $1286 as opposed to $1204 for the modified design.

The modest reduction in energy use in the modified design could perhaps be because of the limitations of the software, as the impact of a number of design recommendations could not be modelled or evaluated in it. In particular, aspects of site design - such as using the earth as an insulating material, or landscaping on the south and west sides of the building etc. - which would make a significant difference to energy consumption, could not be evaluated. Similarly, certain finer details - such as the type of window frames, or creating small openings at the top of the stairwell to aid stack effect - could not be modelled or evaluated either.

Perhaps what is important is that even in a fairly superficial modification in the floor plan (as is the case above), there is a clear reduction in energy consumption, which translates into not just cost savings for the client; but more importantly, a reduction in carbon emissions - from 6.6 to 5.8 metric tons annually - which has the potential to be a significant step towards achieving targets for carbon emissions reduction if institutionalized or implemented on a large scale.
4.3.3. WARM-HUMID CLIMATES

**Characteristics:** Regions that have a mean (all monthly values) temperature of greater than 30°C (86°F), relative humidity greater than 55%, precipitation levels greater than 85mm, and less than 20 clear/sunny days for more than 6 months in a year are classified as Warm-Humid climates. This region is otherwise characterized by a relatively flat topography with abundant vegetation, intense radiation on clear days, and high humidity levels and low diurnal temperature variations that cause great discomfort if there is no air movement (Bansal & Minke, 1995). The districts along India’s vast coastline which contain a number of highly populated
areas and much of the North-Eastern states are characterized as Warm-Humid regions.

Singh, Mahapatra and Atreya (2009) used the adaptive approach as classified in ASHRAE standard 55/2004 to undertake a detailed survey and to conduct field tests and thermal sensation vote of the occupants of 150 vernacular buildings in the North-Eastern states of India. Some of the broad observations from the study of the buildings in the warm-humid region are:

**ORIENTATION / FORM:** While the houses did not have a specific orientation (possibly due to site conditions), they typically exhibited a linear form (Fig. 34) with windows on all sides to promote ventilation throughout the building.

**ENVELOPE:** The porous nature (window to wall ratio of 0.216) of the envelope can be observed in Fig. 34, with openings at two levels - large windows and ‘jalis’ to promote ventilation at the body level, and smaller openings just below the ceiling to remove the warm air by convection. A highly reflective galvanized tin sheet formed the top layer of the roof with a large overhang and chajjas protecting the openings from direct solar gain.

Fig. 34 - House in Tezpur selected for long-term monitoring
Source: Singh, Mahapatra and Atreya (2009)
ZONING: The buildings in the region were characterized by an ‘open’ interior layout and courtyard to facilitate ventilation and provide relief from the high humidity levels. The living space in the selected house was located on the cooler north zone with a screened verandah that extended the space on pleasant days.

SUMMARY: The temperature profiles recorded by Singh, Mahapatra and Atreya (2009) of the outside and the inside of the Tezpur house show that the indoor temperature was always lower than the outdoor temperature; and for an outdoor temperature swing of 15ºC (January), 19ºC (April), 12ºC (July) and 12ºC (October), the corresponding indoor temperature swing was 10ºC, 9ºC, 7ºC and 6ºC.

Dili, Naseer and Varghese (2010) have conducted quantitative and qualitative evaluations of similar vernacular houses in Kerala – another warm-humid climatic region - and have observed that for an outdoor diurnal variation of 12ºC (from 22ºC to 34ºC), the corresponding indoor variation was only 4ºC (from 26ºC to 30ºC, which is within the comfort range for the corresponding levels of Relative Humidity). It was also observed that there is no time lag between the indoor and the outdoor peak temperature because of the light-weight construction materials used.

The form and orientation of the ‘Vikas’ community housing project (Fig. 35) in Auroville - designed by Satprem Mani and completed in 2000 - displays a nuanced approach towards the need for solar shading, daylighting and ventilation.

Fig. 35 - Site plan of the Vikas community, Auroville
Source: Auroville Earth Institute (2005)
The linear floor plan with most of the openings facing north and south (also the predominant wind direction – refer Fig. 35) serve to minimize solar heat gain as these openings are shaded by vertical and horizontal ‘fins’ throughout the year. These fins also serve to channelize the wind through the living spaces, and light shelves in the windows provide glare-free daylighting to the interior despite the recessed nature of the openings (Fig. 36).

Fig. 36 - South façade showing the vertical and horizontal ‘fins’ for shading and ventilation
Source: Auroville Earth Institute (2005)

The wooden frames for these openings are not only a low-cost alternative to Aluminum or UPVC frames, but also have better insulation properties - the U-value for a whole window with wooden frames is consistently lower than a comparable window with, for example, aluminum frames (EnergyGuide, 2010). The building is also located such that vegetation on the west and the east sides help in reducing solar gain; and ‘supports’ have been designed and installed specifically to facilitate the growth of ‘climbing plants’ to provide shade (Fig. 36). Water management measures include solar pumps and water heating systems, a biological wastewater treatment plant (Fig. 35), and a rainwater harvesting system that prevents run-off even during the monsoon season.
The following design strategies for buildings in warm-humid regions have been compiled based on the comparative study of exemplars:

### Table 2 - Design strategies for Warm-Humid climates

<table>
<thead>
<tr>
<th>Warm-Humid Climates</th>
</tr>
</thead>
<tbody>
<tr>
<td>The overall passive design goal for warm-humid climates would be to maintain a cooler indoor temperature by ensuring air movement, and reducing direct solar heat gain through appropriate shading design.</td>
</tr>
</tbody>
</table>

**Orientation / Form**

1. Orient the longer walls of the building to face north and south, and locate the majority of the windows (adequately shaded) on the north and south-facing walls to reduce solar heat gain.

2. If the north-south building orientation is not possible due to site conditions, at least try to locate the majority of the windows (adequately shaded) on the north and south-facing walls to reduce solar heat gain.

3. Design a long, narrow floor plan for the building to maximize cross-ventilation.

4. If a long, narrow floor plan is not feasible, consider designing a courtyard or design an atrium space with small openings near the top to allow for hot air to escape and promote ventilation.

5. Consider raising the building on ‘stilts’ (particularly if the soil is wet/moist) to minimize dampness and maximize natural ventilation underneath the building to increase heat loss.

**Envelope**

6. Promote wind movement over the roof by creating small openings at the bottom of the parapet wall or by having a jali parapet wall to reduce solar heat gain.

7. Provide high-insulation glazing for all the windows (if not, at least for the windows on the south and west facing walls) to reduce solar heat gain.

8. If high-insulation glazing is not feasible, a low-cost alternative is to provide pre-cast jalis or operable wooden shutters in front of the window.

9. Design the north and south-facing window overhang (sunshade / chajja) width to shade the window glazing throughout the year.

10. Use insulated steel or wooden window frames to reduce the conduction of solar heat to the interior spaces.

11. Provide small openings near the top of the stairwell to allow hot air to escape and promote ventilation.

12. Use jalis or louvered openings in the wall along the wind direction to facilitate continuous ventilation.

13. Use lighter colored finishes of construction materials on the outside of the building to reduce solar heat gain by absorption.
**ZONING**

14. Design open plan interior spaces (for example, Living-Kitchen-Dining) to facilitate cross-ventilation. Operable walls, screens or louvered doors can be used to separate these spaces if visual privacy is a concern.

15. Locate these open plan interior spaces along the ‘cooler’ north-south axis.

16. Locate auxiliary spaces such as the store, toilets and stairs on the east or west to act as buffer spaces, but ensure there are ‘pockets’ of openings to facilitate ventilation.

17. Locate the sleeping spaces on the sides facing the wind direction; if this is not possible, locate them on the north or east, which are the ‘cooler’ zones of the building.

18. Provide screened, shaded outdoor buffer spaces such as a verandah or patio on the south and/or west facades to prevent insect problems but still allow ventilation.

**MISC.**

19. Locate/design the building such that the west-facing and east-facing exterior walls of the house are shaded by overhanging roofs, neighboring buildings or vegetation; but ensure that these do not obstruct the predominant wind direction.

20. Provide a roof-top solar water heating system to utilize solar heat and conserve water heating energy throughout the year.

**LIGHTING**

21. Use light shelves (located on the outside of the wall line) on the south-facing wall to distribute daylight deeper into the building.

22. Design a ceiling profile (such as a vault) if necessary to provide effective reflectivity of daylight into the building.
GRAPHIC REPRESENTATION OF DESIGN STRATEGIES

Orient the longer walls of the building to face north and south, and locate the majority of the windows (adequately shaded) on the north and south-facing walls to reduce solar heat gain.

If the north-south building orientation is not possible due to site conditions, at least try to locate the majority of the windows (adequately shaded) on the north and south-facing walls to reduce solar heat gain.
Design a long, narrow floor plan for the building to maximize cross-ventilation.

If a long, narrow floor plan is not feasible, consider designing a courtyard or design an atrium space with small openings near the top to allow for hot air to escape and promote ventilation.

Consider raising the building on ‘talls’ (particularly if the soil is wet/moist) to minimize dampness and maximize natural ventilation underneath the building to increase heat loss.

Promote wind movement over the roof by creating small openings at the bottom of the parapet wall or by having a jali parapet wall to reduce solar heat gain.
Provide high insulation glazing for all the windows (if not, at least for the windows on the south and west facing walls) to reduce solar heat gain.

If high-insulation glazing is not feasible, a low-cost alternative is to provide pre-cast jalis or operable wooden shutters in front of the window.
Design the north and south-facing window overhang (sunshade/chajja) width to shade the window glazing throughout the year.

Use jalis or louvered openings in the wall along the wind direction to facilitate continuous ventilation.

Use insulated steel or wooden window frames to reduce the conduction of solar heat to the interior spaces.

Provide small openings near the top of the staircase to allow hot air to escape and promote ventilation.
Use lighter colored finishes of construction materials on the outside of the building to reduce solar heat gain.

Design open plan interior spaces (for example, Living-Dining-Kitchen) to facilitate cross-ventilation. Operable walls, screens or louvered doors can be used to separate these spaces if visual privacy is a concern.

Locate the open plan interior spaces (for example, Living-Dining-Kitchen) along the 'cooler' north-south axis.

Locate auxiliary spaces such as the store, toilets and stairs on the east or west to act as buffer spaces, but ensure there are 'pockets' of openings to facilitate ventilation.
Locate the sleeping spaces on the north or east, which are the ‘cooler’ zones of the building in the night, when they are most likely to be used.

Locate/design the building such that the west-facing and east-facing exterior walls are shaded by overhanging roofs, neighboring buildings or vegetation.

Provide screened, shaded outdoor buffer spaces such as a verandah or patio on the south and/or west facades to prevent insect problems but still allow ventilation.

Provide a roof-top solar water heating system to utilize solar heat and conserve water heating energy throughout the year.
Use light shelves (located on the outside of the wall) on the south-facing wall to distribute daylight deeper into the building.

Design a ceiling profile (such as a vault) if necessary to provide effective reflectivity of daylight into the building.
CHARACTERISTICS: Regions that have a mean (all monthly values) temperature between 25ºC (77ºF) - 30ºC (86ºF), relative humidity of less than 75%, precipitation levels typically greater than 85mm, and less than 20 clear / sunny days for more than 6 months in a year are classified as Moderate climates. Other aspects of this region include a relatively hilly or a high plateau type terrain with fairly abundant vegetation. True to the name, climatic conditions in moderate climates are generally within the comfort range, and require very little passive design interventions in the built environment (Bansal & Minke, 1995). Few regions in India
are classified as Moderate, the most populated being the areas around the cities of Bangalore in Karnataka and Pune in Maharashtra.

Mili Majumdar in Energy Efficient Buildings in India (2001) studies in detail the residence for Mary Mathew in Bangalore, designed by Mathew & Ghosh architects. Reducing direct solar gain and providing adequate ventilation to alleviate thermal discomfort are the most efficient strategies for a building in a moderate climate like Bangalore. Some of the broad observations from Majumdar’s study of the Mary Mathew residence are:

**ORIENTATION / FORM:** A linear form with its longer sides facing North-South (Fig. 37) reduces solar heat gain while ensuring glare-free lighting throughout the day, and a garden court provides ventilation due to convection.

![Fig. 37 - View of South façade, Mary Mathew residence, Bangalore](Source: Mathew & Ghosh Architects)

**ENVELOPE:** A low-cost, low embodied-energy approach was taken in the envelope design – a granite rubble foundation system, load-bearing brick walls, and a roof system of precast hollow terracotta curved panels with nominal concrete and Galvanized Iron reinforcement were used. Minimal openings were created on the western and south-western side of the house (Fig. 37) to reduce direct solar gain, and the exterior and interior surfaces were predominantly white in color to improve heat reflectivity off the building surfaces.

**ZONING:** Most of the service spaces such as the toilets, pantry, kitchen and the maid’s quarters – which are not regularly occupied during the day – are located on the south-west to act as a buffer for the main living spaces. The courtyard
extends the living spaces on pleasant days, while the bedrooms are located on the ‘cooler’ northern side of the site.

**SUMMARY:** According to Mili Majumdar (2001), the passive design features ensure that air-conditioning systems are not required to condition the house even in the summer; consequently, the electricity consumption is a low 240 units / month, while in the winter it is 160 units / month. The solar water heating system located on the roof (seen in Fig. 37) helps in reducing energy consumption for water heating purposes, while the efficient daylighting design also implies that there is no requirement for artificial lighting before 5:00 - 5:30pm in the winter and 6:00 - 7:00pm in the summer.

Bansal and Minke’s (1995) documentation (Fig. 38) of a vernacular house near Bangalore also exhibits several similar characteristics such as the reduction of solar gain - by orienting the larger openings and the bedrooms to the north, by shading the east and west walls by neighboring buildings, and by ensuring adequate shading of windows on the north and south walls by projecting roof slabs. In a low-rise structure, there is a need to insulate the roof to reduce solar heat transfer to the interior, and this is achieved by the use of stone slabs with lime insulation.
DESIGN STRATEGIES FOR MODERATE CLIMATES

The following design strategies for buildings in moderate climates have been compiled based on the comparative study of exemplars:

Table 3 - Design strategies for Moderate climates

<table>
<thead>
<tr>
<th>MODERATE CLIMATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>While the climatic conditions in Moderate regions are within the comfort zone for most of the year (because of which orientation/form aspects are not as crucial as they are in the case of other climates), reducing direct solar heat gain through appropriate shading design is useful to maintain a cooler indoor temperature during the summer</td>
</tr>
<tr>
<td>1. Promote wind movement over the roof by creating small openings at the bottom of the parapet wall or by having a jali parapet wall to reduce solar heat gain</td>
</tr>
<tr>
<td>2. Minimize the sizes of windows, particularly west-facing ones, to reduce solar heat gain in the summer and decrease internal heat loss in the winter</td>
</tr>
<tr>
<td>3. Design the north-facing window overhang (sunshade / chajja) width to shade the window glazing throughout the year</td>
</tr>
<tr>
<td>4. Design the south-facing window overhang (sunshade / chajja) width to shade the window glazing on the south-facing wall during the summer and allow the sun into the room during the winter</td>
</tr>
<tr>
<td>5. Use insulated steel or wooden frames for windows and glazing which would insulate the building better</td>
</tr>
<tr>
<td>6. Use lighter colored finishes of construction materials on the outside of the building to reduce solar heat gain, and also on the inside of the building to distribute daylight deeper into the living spaces</td>
</tr>
<tr>
<td>7. Locate the open plan interior spaces (for example, Living-Dining-Kitchen) along the ‘cooler’ north-south axis</td>
</tr>
<tr>
<td>ZONING</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
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<tr>
<td>Locate auxiliary spaces such as the store, toilets and stairs on the</td>
</tr>
<tr>
<td>east or west to act as buffer spaces, but ensure there are ‘pockets’</td>
</tr>
<tr>
<td>of openings to facilitate ventilation</td>
</tr>
<tr>
<td>Locate the sleeping spaces on the north or east, which are the</td>
</tr>
<tr>
<td>‘cooler’ zones of the building in the night, when they are most likely</td>
</tr>
<tr>
<td>to be used</td>
</tr>
<tr>
<td>Create shaded semi-outdoor spaces such as verandahs or patios to act</td>
</tr>
<tr>
<td>as extended living spaces during the pleasant months of the year</td>
</tr>
<tr>
<td>Locate/design the building such that the west-facing and east-facing</td>
</tr>
<tr>
<td>exterior walls are shaded by overhanging roofs, neighboring buildings</td>
</tr>
<tr>
<td>or vegetation to reduce solar heat gain</td>
</tr>
<tr>
<td>Provide a roof-top solar water heating system to utilize solar heat</td>
</tr>
<tr>
<td>and conserve water heating energy throughout the year</td>
</tr>
<tr>
<td>Use light shelves (located on the outside of the wall line) on the</td>
</tr>
<tr>
<td>south-facing wall to distribute daylight deeper into the building</td>
</tr>
<tr>
<td>Design a ceiling profile (such as a vault) if necessary to provide</td>
</tr>
<tr>
<td>effective reflectivity of daylight into the building</td>
</tr>
<tr>
<td>Incorporate light wells facing south near the north and east sides</td>
</tr>
<tr>
<td>of the building to get daylight without losing heat by creating large</td>
</tr>
<tr>
<td>north or east facing windows</td>
</tr>
</tbody>
</table>
Promote wind movement over the roof by creating small openings at the bottom of the parapet wall or by having a jali parapet wall to reduce solar heat gain.

Minimize the sizes of windows, particularly west-facing ones, to reduce solar heat gain in the summer and decrease internal heat loss in the winter.

Design the north-facing window overhang (sunshade/chaija) width to shade the window glazing throughout the year.

Design the south-facing window overhang (sunshade/chaija) width to shade the window glazing on the south-facing wall during the summer and allow the sun into the room during the winter.
Design the south-facing window overhang (sunshade / chajja) width to shade the window glazing on the south-facing wall during the summer and allow the sun into the room during the winter.

Use insulated steel or wooden window frames to reduce the conduction of solar heat to the interior spaces.

Use lighter colored finishes of construction materials on the outside of the building to reduce solar heat gain.

Locate the open plan interior spaces (for example, Living, Dining, Kitchen) along the ‘cooler’ north south axis.
Locate auxiliary spaces such as the store, toilets and stairs on the east or west to act as buffer spaces, but ensure there are ‘pockets’ of openings to facilitate ventilation.

Locate the sleeping spaces on the north or east, which are the ‘cooler’ zones of the building in the night, when they are most likely to be used.

Create shaded semi-outdoor spaces such as verandahs or patios to act as extended living spaces during the pleasant months of the year.

Locate design the building such that the exterior walls are shaded by overhanging roofs, neighboring buildings or vegetation to reduce solar heat gain.
Provide a roof-top solar water heating system to utilize solar heat and conserve water heating energy throughout the year.

Use light shelves (located on the outside of the wall line) on the south facing wall to distribute daylight deeper into the building.

Design a ceiling profile (such as a vault) if necessary to provide effective reflectivity of daylight into the building.

Incorporate light wells facing south near the north and east sides of the building to get daylight without losing heat by creating large north or east facing windows.
4.3.5. COLD-CLOUDY AND COLD-SUNNY CLIMATES

**Characteristics:** As per Bansal & Minke’s classification (1995), both Cold-Cloudy and Cold-Sunny regions have a mean monthly temperature of less than 25°C, but this is where the similarity ends. Cold-Cloudy regions have a relative humidity that varies between (all monthly values for at least 6 months in a year) 70 and 80%, precipitation levels greater than 85mm and have less than 20 clear / sunny days; whereas Cold-Sunny climates have consistently low relative humidity values that vary between 10 to 50%, precipitation levels generally less than 85mm and have greater than 20 clear / sunny days. The regions that exhibit both these climatic types have highland / mountainous terrains with occasionally intense winds. Solar
radiation is generally diffuse in Cold-Cloudy climates while it is intense with a low percentage of diffuse radiation in Cold-Sunny climates, which is the key difference to the passive building strategies in these regions. Large parts of the northern Indian states of Jammu & Kashmir, Himachal Pradesh and Uttarakhand, and the hill-stations in other parts of the country are characterized as Cold-Cloudy or Cold-Sunny regions.

Among the projects studied in detail to generate the climatic design recommendations for Cold-Cloudy and Cold-Sunny climates, two representative examples have been discussed below – the traditional houses (Fig. 39) in parts of North-East India (Cold-Cloudy) and the Druk White Lotus School in the Cold-Sunny desert region of Ladakh in Northern India.
Some of the broad observations from the study of exemplars in cold regions are:

**ORIENTATION / FORM:** Singh, Mahapatra and Atreya (2011) observed that most vernacular buildings in the Cold-Cloudy regions, where possible, were sited on south-facing slopes of hills and mountains to maximize solar gain. Similarly, the buildings in the Druk White Lotus School are also oriented with the longer walls facing North-South (Fig. 40). In Cold-Cloudy regions, buildings are typically compact, with a low ceiling height and a minimum surface-volume ratio to maximize solar heat gain in the day and minimize internal heat loss in the night. In Cold-Sunny climates however, a favorable south-facing orientation (as can be seen in the Druk White School) takes precedence over the need for a minimum surface-volume ratio as direct gain is a more effective passive solar strategy in these regions.

**ENVELOPE:** Where possible, many features were common to both climates - the use of massive stone blocks in wall construction to minimize heat loss at night, a composite of locally available materials like wood, cane and bamboo for floors and ceilings, and a tight envelope construction to minimize air infiltration. However, the major difference between the two climates is that while in Cold-Cloudy regions, the openings are small on all sides of the building - Singh, Mahapatra and Atreya
(2011) observed an overall window-wall ratio of 0.108 – as indirect gain strategies are far more effective; in Cold-Sunny regions direct gain systems are far more efficient, therefore the entire southern wall is sometimes glazed (as in the case of the Druk White Lotus School) for maximum solar gain. In both regions, window overhangs are rarely used, although roof overhangs are not uncommon to protect the walls from rain.

**ZONING:** Singh, Mahapatra and Atreya (2011) noted that wind protection was an important strategy in Cold-Cloudy climates; and a verandah typically served as an ‘air-lock’ or a buffer space between the main rooms of the house and the exterior elements. The central location of the kitchen was also crucial in the vernacular architecture of the region, as it also served as an internal heat source. Bedrooms were small in size and typically located on the south so as to receive the late afternoon / evening solar heat gain.

**SUMMARY:** The temperature profiles recorded by Singh, Mahapatra and Atreya (2009) of the outside and the inside of the house in Cherrapunjee show that for an outdoor temperature swing of 16°C (January), 19°C (April), 10°C (July) and 7°C (October), the corresponding indoor temperature swing was 11°C, 10°C, 7°C and 7°C (Fig. 41), which lies in the permissible range for naturally ventilated buildings.

![Fig. 41 - Comparative (Indoor vs Outdoor) temperature profiles of Cherrapunjee house](source)

Similarly, the temperature monitoring (Fig. 42) of the residences (indicated as a dotted line) in the Druk White Lotus School show the thermal performance of the
space in the late winter when outdoor temperatures drop below zero degrees Celsius in the night but remain steady (between 15 and 20ºC) inside the building.

Fig. 42 - Comparative (Indoor vs Outdoor) temperature profiles of Druk White Lotus School
Source: Galeazzl, Francesca (2009)

DESIGN STRATEGIES FOR COLD-CLOUDY AND COLD-SUNNY CLIMATES

The following design strategies for buildings in cold-cloudy and cold-sunny regions have been compiled based on the comparative study of exemplars.

Table 4 - Design strategies for Cold-Cloudy and Cold-Sunny climates

<table>
<thead>
<tr>
<th>COLD-CLOUDY / COLD-SUNNY CLIMATES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ORIENTATION / FORM</strong></td>
</tr>
<tr>
<td>1. Orient the longer walls of the building to face north and south, and locate the majority of the windows on the south-facing wall to increase solar heat gain</td>
</tr>
<tr>
<td>2. If the north-south building orientation is not possible due to site conditions, at least try to locate the majority of the windows on the south-facing wall to increase solar heat gain</td>
</tr>
<tr>
<td>3. Right-size the building by making it compact (by reducing ceiling height to 8 feet, reducing floor area etc.) to reduce the volume of conditioned space</td>
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<tr>
<td><strong>COLD CLOUDY</strong></td>
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<tr>
<td><strong>ENVELOPE</strong></td>
</tr>
<tr>
<td>4. In case of sloping sites, berm or partially berm the building to utilize the earth’s insulating properties</td>
</tr>
<tr>
<td>5. Consider constructing the building/parts of the building slightly below the ground level to utilize the earth’s insulating properties</td>
</tr>
<tr>
<td>6. Construct thick exterior and interior walls to retain solar and internal heat</td>
</tr>
<tr>
<td>7. Design a ‘heat collector wall’ (large window or glazing) on the south-facing wall to increase solar heat gain</td>
</tr>
<tr>
<td>8. Design a thick mass wall behind the south-facing glazing to increase solar heat gain</td>
</tr>
<tr>
<td>9. Minimize the sizes of windows on the north, east and west-facing walls of the building to reduce heat loss by air infiltration</td>
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<tr>
<td>10. Minimize the percentage of overall window area to 10% or less of the overall wall area to reduce internal heat loss</td>
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<tr>
<td>11. Provide high-insulation glazing for windows on the north and east-facing walls to reduce internal heat loss, and have clear glazing (single-pane) for windows on the west and south-facing walls for maximum solar heat gain</td>
</tr>
<tr>
<td>12. If high-insulation glazing is not feasible, a low-cost alternative is to provide operable wooden shutters in front of the window</td>
</tr>
<tr>
<td>13. Design the north and south-facing window overhang (sunshade/chajja) width to a minimum extent only to provide rain protection, but allow the sun to heat the interior spaces throughout the year</td>
</tr>
<tr>
<td>14. Use insulated steel or wooden window frames to reduce the loss of internal heat to the exterior environment</td>
</tr>
<tr>
<td>15. Use a ‘high thermal storage’ flooring material such as concrete or stone flooring, or a dark colored carpet particularly in the rooms on the south and west sides of the building to increase solar heat gain</td>
</tr>
<tr>
<td>16. Use darker colored finishes of construction materials on the outside of the building to increase solar heat gain</td>
</tr>
<tr>
<td>17. Use heavy curtains to cover the glazing during the night in order to prevent heat loss from the interior to the exterior</td>
</tr>
<tr>
<td>18. Create a false ceiling under the main roof, or a ventilated attic with insulation such as Rockwool or glass wool to retain solar heat gain and reduce internal heat loss</td>
</tr>
<tr>
<td><strong>ZONING</strong></td>
</tr>
<tr>
<td>19. Locate the open plan interior spaces (for example, Living-Dining-Kitchen) along a north-south axis with the living room preferably facing south to utilize solar heat gain</td>
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<tr>
<td>20. Locate auxiliary spaces such as the storage, toilets and stairs on the east or north or along the wind direction to act as ‘buffer spaces’ and protect the living areas</td>
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<td>27.</td>
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<td>28.</td>
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</table>
Orient the longer walls of the building to face north and south, and locate the majority of the windows on the south-facing wall to increase solar heat gain in winter.

If the north-south building orientation is not possible due to site conditions, at least try to locate the majority of the windows on the south-facing walls to increase solar heat gain in winter.
Right-size the building by making it compact (by reducing ceiling height to 8 feet, reducing floor area, etc.) to reduce the volume of conditioned space.

In case of sloping sites, berm or partially berm the building to utilize the earth's insulating properties.

In case of sloping sites, berm or partially berm the building to utilize the earth's insulating properties.

Consider constructing the building / parts of the building slightly below the ground level to utilize the earth's insulating properties.
Construct thick exterior and interior walls to retain solar and internal heat.

Design a 'heat collector wall' (large window or glazing) on the south facing wall to increase solar heat gain.

Design a thick mass wall behind the south-facing glazing to increase solar heat gain.
Minimize the sizes of windows on the north, east and west-facing walls of the building to reduce heat loss by air infiltration.

Minimize the percentage of overall window area to 10% or less of the overall wall area to reduce internal heat loss.

Provide high-insulation glazing for windows on the north and east-facing walls to reduce internal heat loss.

Provide high-insulation glazing for windows on the north and east-facing walls to reduce internal heat loss.
If high-insulation glazing is not feasible, a low-cost alternative is to provide pre-cast jalis or operable wooden shutters in front of the window.

Provide clear glazing (single-pane) for windows on the west and south facing walls for maximum solar heat gain.
Design the south-facing window overhang (sunshade/chajja) width to a minimum extent only to provide rain protection, but allow the sun to heat the interior spaces throughout the year.

Use insulated steel or wooden window frames to reduce the conduction of solar heat to the interior spaces.

Use a 'high thermal storage' flooring material such as concrete or stone flooring, or a dark coloured surface particularly in the rooms on the south and west sides of the building to increase solar heat gain.

Use darker colored finishes of construction materials on the outside of the building to increase solar heat gain.
Use heavy curtains to cover the glazing during the night in order to prevent heat loss from the interior to the exterior.

Create a false ceiling under the main roof, or a ventilated attic with insulation such as rockwool or glasswool to retain solar heat gain and reduce internal heat loss.

Locate the open plan interior spaces (for example, Living-Dining-Kitchen) along a north-south axis with the living room preferably facing south to utilize solar heat gain.

Locate auxiliary spaces such as the store, toilets and stairs on the east or north or along the wind direction to act as “buffer spaces” and protect the living areas.
Locate the sleeping spaces on the south or west sides of the floor plan to take advantage of the afternoon and evening solar heat gain.

Provide a protected entrance (air-lock) to reduce the infiltration of cold air into the main living spaces.

Create shaded semi-outdoor spaces such as verandahs or patios facing the winter wind direction to ‘protect’ the living spaces from the cold winter winds and to act as extended living spaces during the pleasant summer.

Create shaded semi-outdoor spaces such as verandahs or patios facing the winter wind direction to ‘protect’ the living spaces from the cold winter winds and to act as extended living spaces during the pleasant summer.
Build a higher compound wall along the windward side to shield the building from cold wind.

Try to ensure that the south and west facing walls are not shaded by any obstructions such as overhanging roofs, neighboring buildings, or vegetation.

Use light shelves (located on the inside of the wall line) on the south facing wall to distribute daylight deeper into the building.

Incorporate light walls facing south near the north & east sides of the building to get daylight and heat instead of creating north or west-facing windows.
4.3.6. COMPOSITE CLIMATES

**Characteristics:** Bansal & Minke (1995) define Composite regions as those that do not fall within the definitions of any of the other climatic regions for six months or more in a year. Other aspects of this region are variable landscapes with rapid seasonal changes in vegetation, variable precipitation levels between 500 and 1300mm per year, temperatures ranging from 43°C in the summer to 4°C in the winter, and overcast sky conditions between July through September (monsoon months) & clear conditions during the other months of the year. Much of the central ‘heartland’ states of India such as Uttar Pradesh, Madhya Pradesh, Bihar and Jharkhand are considered Composite regions.
The Civil Lines duplex (Fig. 43) designed by architect Ashok B. Lall and completed in 1999 in the composite climatic region of Delhi is a model for climatic design in an environment which sees large climatic swings over the year - therefore, buildings have to minimize solar gain in the summer, promote ventilation during the monsoon months, and maximize solar gain in the winter.

**ORIENTATION / FORM:** A compact, self-shading form with the longer facades facing north-south with expandable living spaces is most commonly found in composite climatic regions. In the Civil Lines duplex (Fig. 43), it can also be observed that most of the openings face north-south, while the east-west facades are relatively ‘opaque’ to protect them from the summer wind and intense solar radiation. The cross-section (Fig. 44) of the duplex also demonstrates another crucial climatic design strategy - earth-bemming - which helps in maintaining a cooler indoor temperature in the summer and a warmer indoor temperature in the winter.

**ENVELOPE:** Mili Majumdar (2001) notes that in the Civil Lines duplex, one of the innovative passive design features is the thicker envelope on the eastern and western walls to reduce solar heat gain - these walls consist of a 30mm thick polyurethane board insulation sandwiched between a 115mm thick brick wall on
the interior face and a terracotta jali whose cavities are rendered with cement sand mortar. These walls therefore not only help reduce solar gain, but also form a decorative exterior façade. The roofs also have a similar insulation sandwiched between the RCC slab below and a broken china mosaic finish above, which helps in reflecting sunlight and reducing solar gain during the long summer months. The cross-section also illustrates the thoughtful design for the south-facing facades & spaces of the duplexes - while the overhangs protect the spaces from the summer sun; they are designed to allow the winter sun (Fig. 44) to heat the entire living space on the first floor, which are double-height in volume to facilitate this.

![Winter section along the North-South axis of the Civil Lines duplex](Source: ashokblallarchitects.com)

The architect also notes that the use of low-embodied energy materials such as the massive terrazzo stone (for the walls) and the wood work which were reclaimed from old bungalows was not only a decision taken for reinforcing the desired aesthetic, but also because they addressed social and environmental sustainability principles (Lall, 2011). All the door and window frames that interact with the exterior environment are made of wood (Fig. 45) because of the better insulation properties of the material, and are also designed with double-rebates to control the infiltration of hot air in the summer and cold air in the winter.

**ZONING:** The bedrooms in the Civil Lines residence are located either on the cooler North-east portion of the site or have openings only along the northern facade. The
common spaces (Living-Dining-Kitchen) are buffered by auxiliary spaces on the east and west, and are continuous along the north-south axis with openings on either side. This helps in minimizing solar heat gain in the summer (because of the absence of west-facing openings and adequate shading on the south), promotes cross-ventilation in the monsoon months (because of the open-plan and the double-height living space which aids in stack ventilation), and also increases solar heat gain in the winter (because of the unique cross-section discussed earlier). Buffer spaces like the toilets and the storage were oriented on the east and west sides of the house to minimize heat gain in the regularly occupied spaces during the longer summer season.

![Image](https://ashokblallarchitects.com)

Fig. 45 - Double-height living space (left) and the shaded court of the residence (right)
Source: ashokblallarchitects.com

The outdoor court also acts a passive design concept with the deciduous trees (Fig. 45) like the Peepal providing shade during the summer and extending the living spaces during the comfortable periods of the year. The daylighting strategy is also best seen in the cross-section (Fig. 44) which illustrates the porous nature of the envelope on the north and south facades, which also have light-shelves and balconies that provide diffused light to the interior spaces.

**SUMMARY:** Mili Majumdar (2001) notes that the thermal performance of the residence was remarkable for the type of climate it is situated in – except for the very hot months of May, June and July (when the average maximum temperatures are about 41°C); the indoor temperatures were in the range of 20-28°C when the corresponding outdoor temperatures varied between 10-35°C. In the hot-humid months of May, June & July, air-conditioning was required for about 60% of the daytime hours between 9am – 6pm.
Bansal and Minke’s (1995) documentation (Fig. 46) of a vernacular house in Saliar village near the composite climatic region of Dehradun also exhibits several similar characteristics such as the inward looking form with organized around a court, overhangs for openings that minimize solar gain in the summer and allow the winter sun during the day, the massive walls that balance temperature fluctuations, and the thermal insulation of the roof that reduces heat transmission to the interior in the summer and decreases heat loss in the winter.
### DESIGN STRATEGIES FOR COMPOSITE CLIMATES

The following design strategies for buildings in composite climates have been compiled based on the comparative study of exemplars:

**Table 5 - Design strategies for Composite climates**

<table>
<thead>
<tr>
<th>COMPOSITE CLIMATES</th>
<th>ORIENTATION / FORM</th>
</tr>
</thead>
<tbody>
<tr>
<td>The overall passive design goal in composite climates would be to reduce solar heat gain in the summer (which is longer in duration) and decrease heat loss in the winter</td>
<td>1. Orient the longer walls of the building to face north and south, and locate the majority of the windows (adequately shaded) on the north and south-facing walls to reduce solar heat gain</td>
</tr>
<tr>
<td></td>
<td>2. If the north-south building orientation is not possible due to site conditions, at least try to locate the majority of the windows (adequately shaded) on the north and south-facing walls to reduce solar heat gain</td>
</tr>
<tr>
<td></td>
<td>3. Right-size the bedrooms and the service areas by making them compact (by reducing ceiling height to 8 feet, reducing floor area etc.) to reduce the volume of conditioned space</td>
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<tr>
<td></td>
<td>4. Design a shaded courtyard (with vegetation and/or an overhanging roof) and sprinkle water (conserved through a rain water collection system) in summer to promote evaporative cooling</td>
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<td></td>
<td>5. In case of sloping sites, berm or partially berm the building to utilize the earth’s insulating properties</td>
</tr>
<tr>
<td></td>
<td>6. Consider constructing the building / parts of the building slightly below the ground level to utilize the earth’s insulating properties</td>
</tr>
</tbody>
</table>
| **ENVELOPE** | 7. Use a reflective exterior finish on the roof surface such as recycled chipped china mosaic tiles and a ‘filler-slab’ system on the interior to reduce solar heat gain  
8. Design thick exterior and interior walls to insulate the building in the summer and retain heat gain in the winter  
9. Minimize the sizes of windows, particularly west-facing ones, to reduce heat gain in summer and decrease internal heat loss in winter  
10. Provide high-insulation glazing for all windows to reduce solar heat gain in the summer and reduce internal heat loss in the winter  
11. If high-insulation glazing is not feasible, a low-cost alternative is to provide operable wooden shutters in front of the window  
12. Design the north and south-facing window overhang (sunshade / chajja) width to shade the window glazing during the summer, but allow the sun into the room during the winter  
13. Use insulated steel or wooden window frames to reduce the conduction of solar heat to the interior spaces  
14. Use lighter colored finishes of construction materials on the outside of the building to reduce solar heat gain  
15. Use heavy curtains to cover the glazing during the night in order to prevent heat loss from the interior to the exterior |
| **ZONING** | 16. Locate the open plan interior spaces (for example, Living-Dining-Kitchen) along the ‘cooler’ north-south axis  
17. Locate auxiliary spaces such as the store, toilets and stairs on the east or west to act as buffer spaces, but ensure there are ‘pockets’ of openings to facilitate ventilation  
18. Locate the sleeping spaces on the north / east, which are the ‘cooler’ zones in the night, when they are most likely to be used  
19. Locate/design the building such that the west-facing and east-facing exterior walls are shaded by overhanging roofs, neighboring buildings or vegetation |
| **MISC.** | 20. Plant deciduous vegetation such as Gulmohur, Peepal, Silk Cotton or Teak trees in front of the south & west-facing walls that will provide shade in the summer & allow the sun to heat the building in the winter  
21. Create shaded semi-outdoor spaces such as verandahs or patios facing the winter wind direction to ‘protect’ the living spaces from the cold winter winds and to act as extended living spaces during the milder times of the year  
22. Provide a roof-top solar water heating system to utilize solar heat and conserve water heating energy throughout the year |
| **LIGHTING** | 23. Use light shelves (located on the outside of the wall line) on the south-facing wall to distribute daylight deeper into the building  
24. Design a ceiling profile (such as a vault) if necessary to provide effective reflectivity of day-light into the building |
GRAPHIC REPRESENTATION OF DESIGN STRATEGIES

Orient the longer walls of the building to face north and south, and locate the majority of the windows (adequately shaded) on the north and south-facing walls to reduce solar heat gain.

If the north-south building orientation is not possible due to site conditions, at least try to locate the majority of the windows (adequately shaded) on the north and south-facing walls to reduce solar heat gain.

SECTION

SECTION
Right: size the bedrooms and the service areas by making them compact (by reducing ceiling height to 8 feet, reducing floor area etc.) to reduce the volume of conditioned space.

Design a shaded courtyard (with vegetation and/or an overhanging roof) and sprinkle water (conserved through a rainwater collection system) during the summer to promote evaporative cooling.

In case of sloping sites, berm or partially berm the building to utilize the earth’s insulating properties.
Consider constructing the building / parts of the building slightly below the ground level to utilize the earth's insulating properties.

Use a reflective exterior finish on the roof surface such as recycled chipped china mosaic tiles and a 'slab' system on the interior to reduce solar heat gain.

Design thick exterior and interior walls to insulate the building in the summer and retain heat gain in the winter.

Design thick exterior and interior walls to insulate the building in the summer and retain heat gain in the winter.
Minimize the sizes of windows, particularly west-facing ones, to reduce heat gain in summer and decrease internal heat loss in winter.

Provide high-insulation glazing for all windows to reduce solar heat gain in the summer and reduce internal heat loss in the winter.

Plan: Winter

Summer Section

Provide high-insulation glazing for all windows to reduce solar heat gain in the summer and reduce internal heat loss in the winter.

Winter Section

Detail A

High Insulation Glazing

Wall
If high-insulation glazing is not feasible, a low-cost alternative is to provide pre-cast jalis or operable wooden shutters in front of the window.

Design the north and south-facing window overhang (sunshade / chaajja) width to shade the window glazing during the summer, but allow the sun into the room during the winter.
Use insulated steel or wooden window frames to reduce the conduction of solar heat to the interior spaces.

Use lighter colored finishes of construction materials on the outside of the building to reduce solar heat gain.

Use heavy curtains to cover the glazing during the night in order to prevent heat loss from the interior to the exterior.

Locate the open plan interior spaces (for example, Living Dining Kitchen) along the ‘cooler’ north south axis.
Locate auxiliary spaces such as the store, toilets and stairs on the east or west to act as buffer spaces, but ensure there are ‘pockets’ of openings to facilitate ventilation.

Locate the sleeping spaces on the north or east, which are the ‘cooler’ zones of the building in the night, when they are most likely to be used.

Locate/design the building such that the west-facing and east-facing exterior walls are shaded by overhanging roofs, neighboring buildings or vegetation.

Plant deciduous vegetation such as Gulmohur, Peepal, Silk Cotton or Teak trees in front of the south & west-facing walls that will provide shade in the summer & allow the sun to heat the building in the winter.
Plant deciduous vegetation such as Gulmohur, Peepal, Silk Cotton or Teak trees in front of the south & west-facing walls that will provide shade in the summer & allow the sun to heat the building in the winter.

Create shaded semi-outdoor spaces such as verandahs or patios facing the winter wind direction to protect the living spaces from the cold winter winds and to act as extended living spaces during the pleasant summer.

Provide a roof-top solar water heating system to utilize solar heat and conserve water heating energy throughout the year.
Use light shelves (located on the outside of the wall line) on the south-facing wall to distribute daylight deeper into the building.

Design a ceiling profile (such as a vault) if necessary to provide effective reflectivity of daylight into the building.
4.4. COMPILATION OF CLIMATIC DESIGN STRATEGIES

In this section, a compilation of passive design strategies for all the climatic zones has been presented comparatively to understand how some passive concepts apply across different climatic zones and to understand the differences between them. This was also an intermediate step between the ‘content development’ and the ‘program development’ parts of the project as it helped clarify the number of graphic representations that needed to be generated. The short text for each design strategy has been kept jargon-free, and the few specific words (light shelf, thermal mass, right-size etc.) will have links in the website to their descriptions.

4.4.1. HEATING STRATEGIES

The first compilation of passive heating concepts is presented below. Of particular note are the direct / indirect gain strategies discussed previously regarding the cold-sunny and cold-cloudy climates, and the heating strategies pertaining to the composite climatic regions:

Table 6 - Comprehensive list of passive heating strategies for the six different climates H-D (Hot-Dry), W-H (Warm-Humid), COM (Composite), C-S (Cold-Sunny), C-C (Cold-Cloudy) & MOD (Moderate); the colors relate to their respective colors in the comprehensive Bansal climatic classification map presented in the next chapter

<table>
<thead>
<tr>
<th>HEATING STRATEGIES</th>
<th>H-D</th>
<th>W-H</th>
<th>COM</th>
<th>C-S</th>
<th>C-C</th>
<th>MOD</th>
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<tbody>
<tr>
<td>ORIENTATION / FORM</td>
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<tr>
<td>Orient the longer walls of the building to face north</td>
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<td>and south, and locate the majority of the windows on</td>
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<td>the south-facing wall to increase solar heat gain</td>
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<td>If the north-south building orientation is not</td>
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<td>possible due to site conditions, at least try to</td>
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<td>facing walls to increase solar heat gain</td>
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<td>Right-size the building by making it compact (by</td>
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<td>reducing ceiling height to 8 feet, reducing floor</td>
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<td>area etc.) to reduce the volume of conditioned space</td>
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<td>In case of sloping sites, berm or partially berm the</td>
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<td>building to utilize the earth’s insulating properties</td>
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<td>Consider constructing the building / parts of the</td>
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<td>building slightly below the ground level to utilize</td>
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<td>the earth’s insulating properties</td>
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<td>Construct thick exterior and interior walls to retain solar and internal heat</td>
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<td>Design a ‘heat collector wall’ (large window or glazing) on the south-facing wall to increase solar heat gain</td>
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<tr>
<td>Design a thick mass wall behind the south-facing glazing to increase solar heat gain</td>
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<tr>
<td>Minimize the sizes of windows on the north, east and west-facing walls of the building to reduce heat loss by air infiltration</td>
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<tr>
<td>Minimize the percentage of overall window area to 10% or less of the overall wall area to reduce internal heat loss</td>
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<tr>
<td>Provide high-insulation glazing for windows on the north and east-facing walls to reduce internal heat loss, and have clear glazing for windows on the west and south-facing walls for maximum solar heat gain</td>
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<tr>
<td>If high-insulation glazing is not feasible, a low-cost alternative is to provide operable wooden shutters in front of the glazing</td>
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<tr>
<td>Design the north and south-facing window overhang (sunshade / chajja) width to a minimum extent only to provide rain protection, but allow the sun to heat the interior spaces throughout the year</td>
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<tr>
<td>Use insulated steel or wooden window frames to insulate the building better</td>
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<tr>
<td>Construct thick interior walls to retain heat gain from internal and external sources</td>
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<tr>
<td>Use a ‘high thermal storage’ flooring material such as concrete or stone flooring, or a dark colored carpet particularly in the rooms on the south and west sides of the building to increase solar heat gain</td>
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<tr>
<td>Use darker colored finishes of construction materials on the outside of the building to increase solar heat gain</td>
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<tr>
<td>Use heavy curtains to cover the glazing during the night in order to prevent heat loss from the interior to the exterior</td>
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<tr>
<td>Create a false ceiling under the main roof, or a ventilated attic with insulation such as Rockwool or glass wool to retain solar heat gain and reduce internal heat loss</td>
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<tr>
<td><strong>ZONE</strong></td>
<td><strong>Requirement</strong></td>
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<tr>
<td>Locate the open plan interior spaces (for example, Living-Dining-Kitchen) along a north-south axis with the living room preferably facing south to utilize solar heat gain.</td>
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<tr>
<td>Locate auxiliary spaces such as the storage, toilets and stairs on the east or north or along the wind direction to act as ‘buffer spaces’ and protect the living areas.</td>
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<tr>
<td>Locate the sleeping spaces on the south or west sides of the floor plan to take advantage of the afternoon and evening solar heat gain.</td>
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<tr>
<td>Provide a protected entrance (air-lock) to reduce the infiltration of cold air into the main living spaces.</td>
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<tr>
<td>Create shaded semi-outdoor spaces such as verandahs or patios facing the winter wind direction to ‘protect’ the living spaces from the wind and to act as extended living spaces during the pleasant times of the year.</td>
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<tr>
<td>Construct a higher compound wall on the windward side to shield the building from cold wind.</td>
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<tr>
<td>Try to ensure that the south and west facing-walls are not shaded by any obstructions such as overhanging roofs, neighboring buildings or vegetation.</td>
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<tr>
<td>Provide a roof-top solar water heating system to utilize solar heat and conserve water heating energy throughout the year.</td>
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### 4.4.2. LIGHTING STRATEGIES

The second, smaller compilation of passive lighting concepts is presented below. Note how the difference in light shelf location between climates that require heating and those that require cooling – in cold climates, where the maximum solar radiation needs to fall on the building envelope, the light shelves need to be located on the inside of the wall line (and not as an exterior projection) in cold so as to not shade the wall surface / glazing below.
4.4.3. COOLING STRATEGIES

The third and final compilation of passive cooling concepts is presented below. Of particular note are the subtle differences between the climatic regions in order to arrive at the same end goal – for example, while most of the strategies for hot-dry climates focus on cooling by reducing solar heat gain, in warm-humid climates the greater focus is on cooling through convection / ventilation:

Table 8 - Comprehensive list of passive cooling strategies

<table>
<thead>
<tr>
<th>COOLING STRATEGIES</th>
<th>H-D</th>
<th>W-H</th>
<th>COM</th>
<th>C-S</th>
<th>C-C</th>
<th>MOD</th>
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<tbody>
<tr>
<td>ORIENTATION / FORM</td>
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<tr>
<td>Orient the longer walls of the building to face north and south, and locate the majority of the windows (adequately shaded) on the north and south-facing walls to reduce solar heat gain</td>
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<tr>
<td>If the north-south building orientation is not possible due to site conditions, at least try to locate the majority of the windows (adequately shaded) on the north and south-facing walls to reduce solar heat gain</td>
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<tr>
<td>Orient the longer walls of the building to face north and south, and locate the majority of the windows (adequately shaded) on the north-facing walls to reduce solar heat gain</td>
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<tr>
<td>If the north-south building orientation is not possible due to site conditions, at least try to locate the majority of the windows (adequately shaded) on the north-facing walls to reduce solar heat gain</td>
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<tr>
<td>Design a long, narrow floor plan for the building to maximize cross-ventilation</td>
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<tr>
<td>If a long, narrow floor plan is not feasible, consider designing a courtyard or an atrium space with small openings near the top to allow for hot air to escape and promote ventilation</td>
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<tr>
<td>Right-size the building by making it compact (by reducing ceiling height to 8', reducing area etc.) to reduce volume of conditioned space</td>
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<tr>
<td>Right-size the bedrooms and the service areas by making them compact (by reducing ceiling height to 8 feet, reducing floor area etc.) to reduce the volume of conditioned space</td>
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<tr>
<td>Design a shaded courtyard (with vegetation and/or an overhanging roof) and sprinkle water (conserved through a rain water collection system) during the summer to promote evaporative cooling</td>
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<tr>
<td>In case of sloping sites, berm or partially berm the building to utilize the earth’s insulating properties</td>
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<tr>
<td>Consider constructing the building / parts of the building slightly below the ground level to utilize the earth’s insulating properties</td>
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<tr>
<td>Consider raising the building on ‘stilts’ (particularly if the soil is wet/moist) to minimize dampness and maximize natural ventilation underneath the building to increase heat loss</td>
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<tr>
<td>Minimize the sizes of windows (particularly on west &amp; south-facing walls) to reduce heat gain</td>
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<tr>
<td><strong>ENVELOPE</strong></td>
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<tr>
<td>Minimize the sizes of windows, particularly west-facing ones, to reduce heat gain in summer and decrease internal heat loss in winter</td>
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<tr>
<td>Provide high-insulation glazing for all the windows (if not, at least for the windows on the south and west-facing walls) to reduce solar heat gain</td>
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<tr>
<td>If high-insulation glazing is not feasible, a low-cost alternative is to provide pre-cast jalis or operable wooden shutters in front of the glazing</td>
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<tr>
<td>Design the north and south-facing window overhang (sunshade / chajja) width to shade the window glazing throughout the year</td>
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<tr>
<td>Design the north and south-facing window overhang (sunshade / chajja) width to shade the window glazing during the summer, but allow the sun into the room during the winter</td>
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<tr>
<td>Use insulated steel or wooden window frames to reduce the conduction of solar heat to the interior spaces</td>
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<tr>
<td>Provide small openings at the top of the stairwell to allow hot air to escape &amp; promote ventilation</td>
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<tr>
<td>Construct thick exterior &amp; interior walls to insulate from solar heat gain</td>
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<tr>
<td>Construct thick exterior and interior walls to insulate the building in the summer and retain internal heat in the winter</td>
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<tr>
<td>Use a reflective exterior finish on the roof surface such as recycled chipped china mosaic tiles and a ‘filler-slab’ system on the interior to reduce solar heat gain</td>
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<tr>
<td>Promote wind movement over the roof by creating small openings at the bottom of the parapet wall or by having a jali parapet wall to reduce solar heat gain</td>
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<tr>
<td>Use jalis or louvered openings in the wall along the wind direction to facilitate continuous cross-ventilation</td>
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<tr>
<td>Use lighter colored finishes of construction materials on the outside of the building to reduce solar heat gain</td>
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<tr>
<td>ZONING</td>
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<tr>
<td>Design open plan interior spaces (for example, Living-Kitchen-Dining)</td>
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<td>to facilitate cross-ventilation. Operable walls, screens or louvered</td>
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<td>doors can be used to separate these spaces if visual privacy is a</td>
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<td>concern</td>
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<tr>
<td>Provide screened, shaded outdoor buffer spaces such as a verandah or</td>
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<td>patio on the south and/or west facades to prevent insect problems but</td>
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<td>still allow ventilation</td>
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<tr>
<td>Locate the open plan interior spaces (for example, Living-Dining-Kitchen) along the ‘cooler’ north-south axis</td>
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<tr>
<td>Locate auxiliary spaces such as the store, toilets and stairs on the</td>
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<td>east or west to act as buffer spaces, but ensure there are ‘pockets’</td>
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<td>of openings to facilitate some ventilation</td>
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<tr>
<td>Locate the sleeping spaces on the north / east, which are the ‘cooler’</td>
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<td>zones in the night, when they are most likely to be used</td>
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<td>Locate the sleeping spaces on the sides facing the wind direction;</td>
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<td>if this is not possible, locate them on the north or east, which are</td>
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<td>the ‘cooler’ zones of the building</td>
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<td>Build a higher compound wall along the windward side to shield the</td>
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<td>building from hot wind</td>
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<td>Locate/design the building such that the exterior walls are shaded</td>
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<td>by overhanging roofs, neighboring buildings or vegetation to reduce</td>
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<td>solar heat gain</td>
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<tr>
<td>Plant deciduous vegetation such as Gulmohur, Peepal, Silk Cotton or</td>
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<td>Teak trees in front of the south &amp; west-facing walls that will</td>
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<td>provide shade in the summer &amp; allow the sun to heat the building in</td>
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<td>the winter</td>
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5.1. GEOGRAPHIC INFORMATION SYSTEMS (GIS)

5.1.1. BACKGROUND

One of the simplest definitions of GIS was provided by Jeffrey Star and John Estes in their book ‘Geographic Information Systems: An Introduction’ (1990) – “A Geographic Information System (GIS) is an information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is both a database system with specific capabilities for spatially referenced data, as well as a set of operations for working with data.” GIS applications are programs that allow users to analyze spatial information, create new layers of data and publish the results. GIS applications have now gone beyond their traditional use for cartography, and now involve complex operations such as navigation systems, crime analysis, habitat conservation etc. – similarly, there is immense potential to use GIS applications in the design of our built environment.

5.1.2. RATIONALE

There were three main reasons behind the decision to use GIS applications in the project - the first, and most important, was that it could be used to generate a visual medium (a map) that the anonymous architect could use for the ‘site location’ process instead of downloading and installing an EPW (EnergyPlus Weather) data file of the location in a program as in the case of Climate Consultant. The second advantage is that the ‘raw material’ (base maps, administrative boundaries etc.) to be used in the GIS application are all open-source and easily available online; and with a strong community of developers, the content will only get enriched over time (more details in the base map etc.). The third reason is that GIS is a scalable and expandable system - for example, in this project GIS is currently used to process only the broad macro-level climatic zone classification; but in the future, it can also be used to add other related layers of information such as micro-climate modifiers - water bodies, heat islands etc.
5.1.3. PROCESS

The first step in this process was to re-organize (Fig. 47) the boundaries of the Bansal climate classification map (Fig. 30) based on the administrative extents of the districts of India. Although this would mean that there would be some approximation, the benefits of this will be immense - instead of being based on ‘imaginary lines’, this re-organization will now mean the climate classification is based on a ‘real’ administrative boundary. As mentioned earlier, the scalability and expandability of the GIS system will help incorporate additional layers of information such as the local building codes of the district etc.

Fig. 47 - The Bansal climate classification map reorganized by author along district-level administrative boundaries
The GIS application ArcMap 10.3.1 by ESRI (Environmental Systems Research Institute) was then used to generate the climate classification map (Fig. 48) in a GIS system. Two main ‘attributes’ were added to each Indian district – namely the colors for each climate zone; and then for each climate zone, the URL (link) of the webpage of the respective climate’s strategies.

Fig. 48 - The reorganized Bansal climate classification recreated in ESRI ArcMap 10.3.1

This GIS document was then published online to the ESRI ArcGIS website, where a crucial part of the ‘Architects Anonymous’ platform was integrated – the image on the left in Fig. 49 shows the published map with a 50% opacity for the climate layers; and the image on the right is how the final map would appear to the user – with the climate classification layers completely transparent. This was done because it is crucial that the user feels comfortable with the aesthetics and navigation of the map – in other words, this map, with the climate layers ‘hidden’ would look very
similar to, for example, a google maps interface, which is commonly used by people for navigation purposes.

The final version of the site selection map would appear as it does on the left in Fig. 50 – the anonymous architect can either enter the address of the building site, or simply zoom in and click on the location of the site. This would result in a ‘pop-up’ window that requests for a confirmation of the site location, which would then lead to the webpage of the climatic region in which the selected site is located.
This GIS integration is a crucial part of the program, as it helps simplify the complex ‘climate-specificity’ aspect of the Climate Consultant, and generates a very simple, user-friendly ‘front-end’ site selection interface for the anonymous architect.
5.2. REPRESENTATIONAL STRATEGY

5.2.1. OBJECTIVES
The broad objectives considered for the representation of each design strategy were: 1) A predominantly visual character to sustain user interest; 2) Simplicity and clarity – this is not only because of the assumption of the user as a layperson, but also because the small ‘real-estate’ if the concept needs to be conveyed through a smartphone; and 3) non-prescriptive in nature – as mentioned earlier, the strategies should not look like a ‘finished product’, but focus instead on representing how the strategy is applied and convey action where possible.

5.2.2. PRECEDENTS
The positive aspects from three different exemplars served to guide the creation of the visual style. Francis D.K. Ching’s sketches (Fig. 51, above left) convey aspects of scale through the use of human figures and objects, the sketches in Sun, Wind and Light (2001) seem more ‘non-prescriptive’ and convey ‘actions’ or processes in the form of lighting and ventilation patterns etc., and 3) BIG Architects’ conceptual diagrams often involve the interplay of color and symbols to reinforce the concept.
5.2.3. SYNTHESIS

These ideas were then synthesized in an iterative process to develop the representational style of the design strategies. The elements of scale in D. K. Ching’s sketches were incorporated into the ‘sketchy’ nature of the ‘Sun, Wind and Light’ illustrations, and finally post-processed to integrate BIG’s use of color and iconography to stimulate visual interest (Fig. 52).
5.2.4. PROCESS

1. The outline is conceptualized and pencilled within a 2.5”x2.5” square tile (the estimated size of the image when viewed on a smartphone). Sketch is then inked, scanned, and ‘cleaned’ in Photoshop.

2. Basic, standardized colors and material patterns are then applied.

3. The concept of the strategy is then visually represented – in this case, it is a light shelf to distribute daylight deeper into the building. Orientation cues, if any, are also added to generate the final image.

Fig. 53 - Sketch development
There are various scales (Fig. 54) of these climatic design strategies – from site to building element details, and therefore each type of strategy (form / massing, plans, sections and details) has a standardized set of elements and colors in order to have a continuous, coherent narrative through the program.

Fig. 54 - Sample images of different types of sketches - Form / massing (Left above), Plans (Right above), Section (Left below) and Detail (Right below)
5.3. WEB-DESIGN

5.3.1. OBJECTIVES

The final step in the development of the platform was to put together the GIS map and the compilation of the strategies into the website. The broad guidelines in this phase of the project were: 1) the website had to be intuitive and easy to navigate, and 2) it should not be a ‘closed-loop’ system, and instead have links to relevant external sources where needed. The name of the website, anonchitect.com, was driven by the need to retain the core idea of the project – the client as an anonymous architect in the design and construction process.

5.3.2. PROCESS

Generally speaking, there are two broad ways to design a website – a graphic, ‘drag-and-drop’ type process with preset templates (for example, Wix or Wordpress); or the more difficult code-based process, but with greater control over the end result. However, the product used, ‘Adobe Muse’, tries to bridge the gap between those two options – it retains greater control over the behavior & appearance of elements similar to a code-based process, but in a graphic, ‘drag-and-drop’ manner with an interface not dissimilar to other Adobe products such as Photoshop.

The overall organization of the website was fairly simple to storyboard - a linear, step-by-step process to guide the user and incrementally introduce concepts of climatic design. This is because the working assumption was that the client would not have any prior knowledge about the building design and construction process.

The webpage for each climate’s design strategies was generated first, because the URLs of these pages were what was added as an ‘attribute’ for the respective climates in the ArcMap GIS program.
5.3.3. NAVIGATION

1. SPLASH PAGE
The splash page would have a short slideshow (using the images from Fig. 56) that explains to the user how they could apply the program.

2. HOME PAGE
The home page introduces the anonymous architect to the intent and the suggested use-case (modify stock designs) of the program. The simple navigation features of the website are explained here as well.
3. SITE SELECTION

The site selection page is the embedded GIS map, the interface of which looks very similar to the standard Google maps. The user can either click on the location of the building site or simply enter the address in the search bar.

4. CLIMATE CHARACTERISTICS

This page mentions the type of climate the site is located in, and gives a brief overview of the climate’s characteristics. A small note about the most important passive design concept (heating / cooling) for that climate acts a segue to the next page.
5. CLIMATIC DESIGN STRATEGIES
The main part of the program, this page contains the climatic design strategies arranged in the order of importance. Each strategy consists of a short descriptive text anchored to a large image that aids in the quick assimilation of the strategy.

6. FURTHER RESOURCES
The final page provides links to other helpful resources such as the Architecture 2030 Palette, a catalogue of eco-friendly products and materials etc.
6.1. PLANNED USE CASE SCENARIO

1. Clients who cannot access an architect with expertise in climatic design visit a contractor to pick a ‘stock design’

2. They then use their smartphones to visit the Anonchitect website to determine climatic design strategies relevant to their site

3. On the basis of these relevant climatic strategies, they then ask the contractor to modify the stock design selected earlier

4. The modified design is then constructed with an enhanced response to the climate & context of the region

Fig. 56 - Planned use case of the Anonchitect website
Images 1, 2 & 3: Photo by Dhaval Chheda; Image 4: http://mtstandard.com/home-page/
6.2. NEXT STEPS

Currently, Anonchitect is at a ‘beta’ stage - the next step would be to integrate more opportunities for interaction between the anonymous architect and the program, which would help increase user engagement and offer scope for collaboration between multiple users (Fig. 57). Currently, alternative strategies are presented in addition to the ‘optimum’ or best-case strategy (for example, refer to the ‘orientation’ strategy for the different climates - there is always a ‘second-best’ alternative to the preferred building orientation). However, this process needs to be streamlined (because currently the user views both the best-case and the alternative approach) by including an option where the user could override (a simple ‘yes’ or ‘no’ selection box) each suggested best-case strategy and progress through the program without having to view any irrelevant alternative strategies.

![Flowchart of the next stage of program development](image)

Another simple way to improve interactivity is to offer users the opportunity to create an anonchitect account, which they could then use to select and save just those design strategies that are feasible for their site, which could then be exported in a printable format, shared on social media etc. This process could happen when more strategies are added in the next round of content development. The intent for the next layer of climatic design strategies would be to progress from the current classification at a climate zone level to something more regional – for example, based on latitudes, shading angles could be designed and very specific numbers provided for sunshade depth etc. Another possibility is to include ‘operation and
maintenance’ strategies, which would help people to appropriately use the building they have designed with the design strategies.

6.3. POTENTIAL DISSEMINATION STRATEGIES

Organizations such as The Energy Resources Institute (TERI) and the Global Buildings Performance Network (GBPN) are leading think-tanks in India that have the institutional expertise to not only collaborate with and enhance the AA platform, but also have existing community outreach programs that can be tapped into for easier and faster dissemination to the prospective ‘Anonymous Architects’.

The Indian government’s new mantra is to promote “m-governance” as a solution for de-centralizing citizen services (Mobile Seva, 2016) - this program also directly aligns with those goals, and if institutionalized, can have the potential to reach out to a massive audience. There is a strong case to be made for the Ministry of New and Renewable Energy (MNRE) to adopt and develop this platform to offset some of the projected exponential growth in energy consumption because of schemes such as the ‘Housing for All’, which is estimated to add 20 million affordable housing units by 2022.

Another strategy worth exploring would be to incrementally involve the other ‘players’ in the building industry so as to not ‘replace’ the roles of any of these professionals, but rather make all their roles simpler – for example, while the existing version of the AA platform is primarily targeted towards clients of small building projects; product manufacturers / suppliers could be easily brought into the loop by embedding the locations of local distributors of a particular type of product (high-insulation window systems, solar water heaters etc.).

The simplest and most direct dissemination strategy would be the targeted advertising towards specific user groups – for example, adverts for the AA platform could be embedded in the websites that offer stock design services (Fig. 17), so that there is a high ‘conversion rate’.
6.4. DISCUSSION

One of the strengths of this project is that it has a wide clientele – it attempts to bring specialized information that was previously in the domain of architects and building science professionals to a wider audience (the clients) – who have a large stake in the design and construction process of residential buildings, but so far did not have the resources in an easily accessible manner to make the necessary informed decisions. Also, the Indian scenario that has been discussed in thesis can be considered as a proof-of-concept or a replicable test-case; because the same process that went into its development – the climatic zone classification process, the development of design strategies for each climate, and the GIS & website development – could all be tailored and applied to apply to any large country that has varied climatic zones. China and the United States are the obvious other countries that have a pressing need to cut down on their share of carbon emissions.

There is immense potential in the use of more complex GIS data to create a comprehensive suite of applications for environmental design. For example, access to satellite data such as the heights of buildings could help plan appropriate public spaces in a city, while a system that assimilates local building codes could be a handy tool for designers and code inspectors alike.

At a broader level, this thesis simply attempts to build a bridge between traditional knowledge and new technology – because recent technological developments have provided us with new delivery systems to disseminate time-tested information – and synthesizes it into a product that can be a solution to a massive problem we face as a society today. Particularly for environment-related issues in which public participation is key, perhaps the focus should shift from the completely centralized top-down approach of today which at best brings about ‘coercive change’, and transition to a more decentralized bottom-up approach, which could bring about a more permanent behavioral change.
REFERENCES


