An Adaptive and Dynamic Design Approach for Natural Conditioning of Offices in Hot Climates of India

MSSD Synthesis Final Presentation

August 2016

Radhna Saxena | Krupa Patel

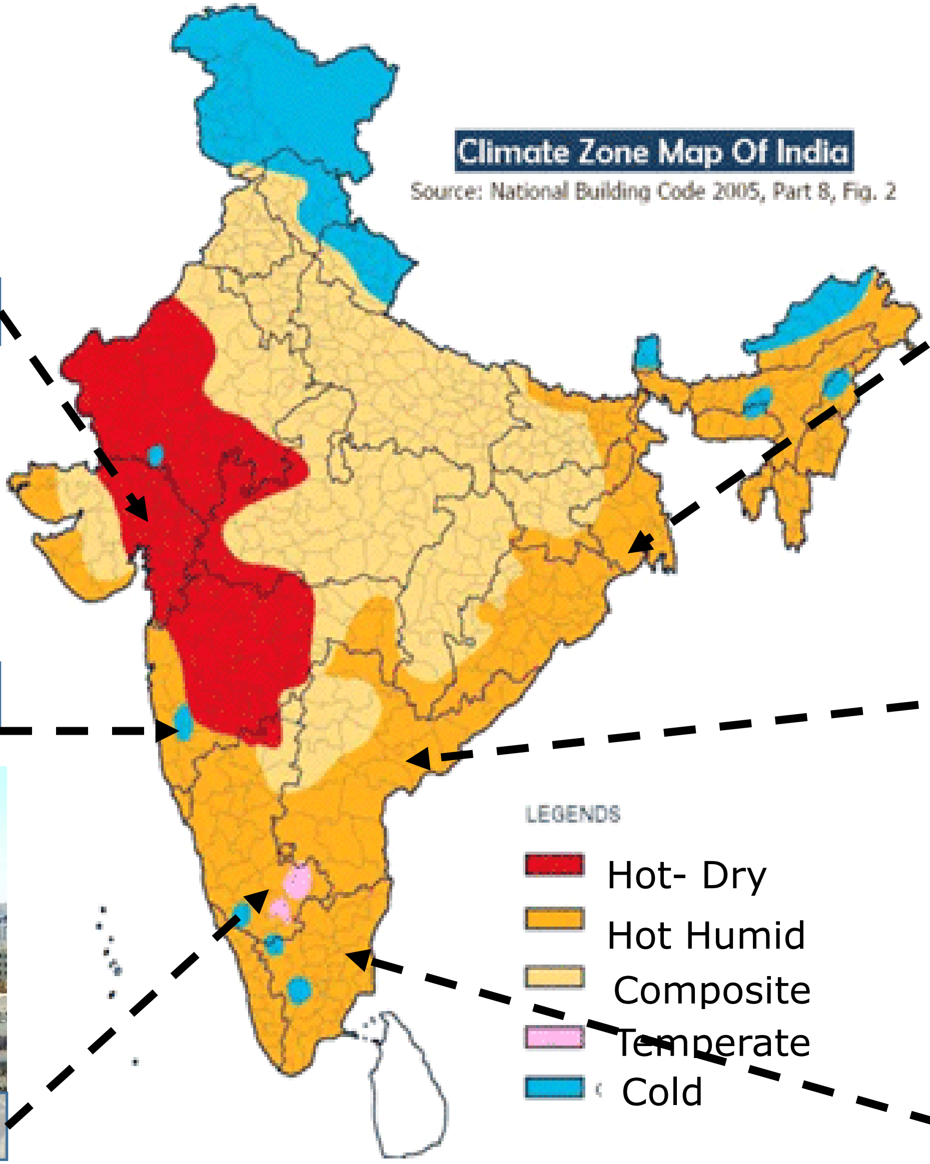
Advisors: Vivian Loftness | Erica Cochran | Dana Cupkova

Blind aping of 'GLASS BOX' architecture …IRRELEVANT of Climate

AHMEDABAD

MUMBAI

BANGALORE

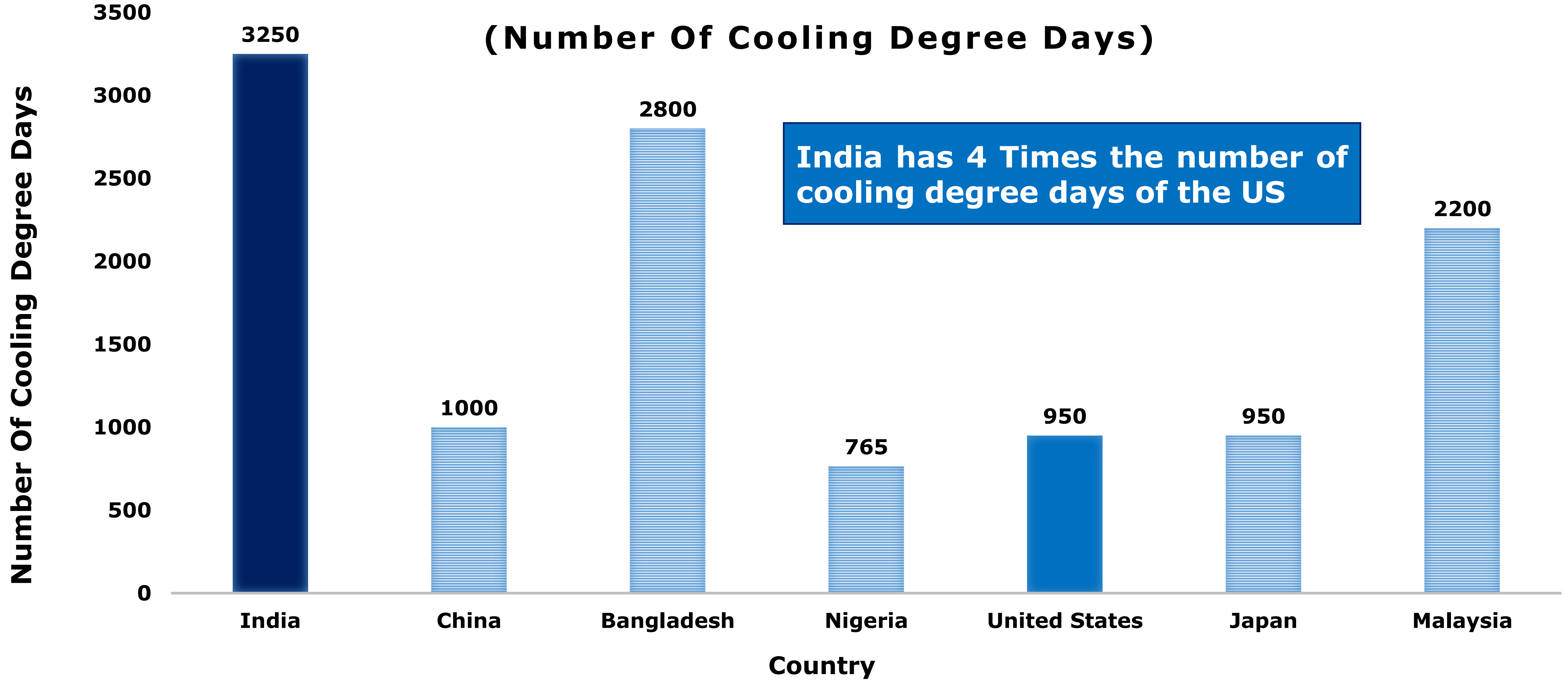


KOLKATA

HYDERABAD

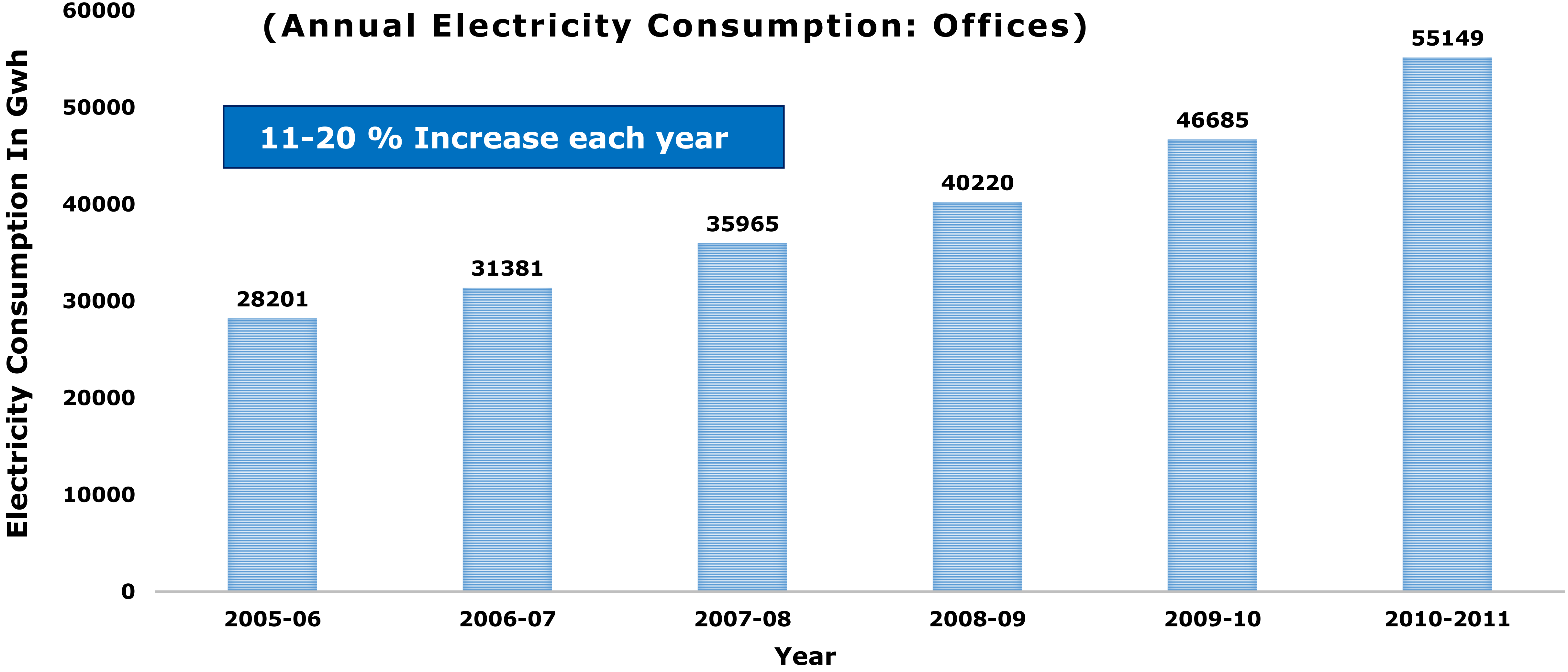
CHENNAI

Air Conditioning 'The Glass Box'



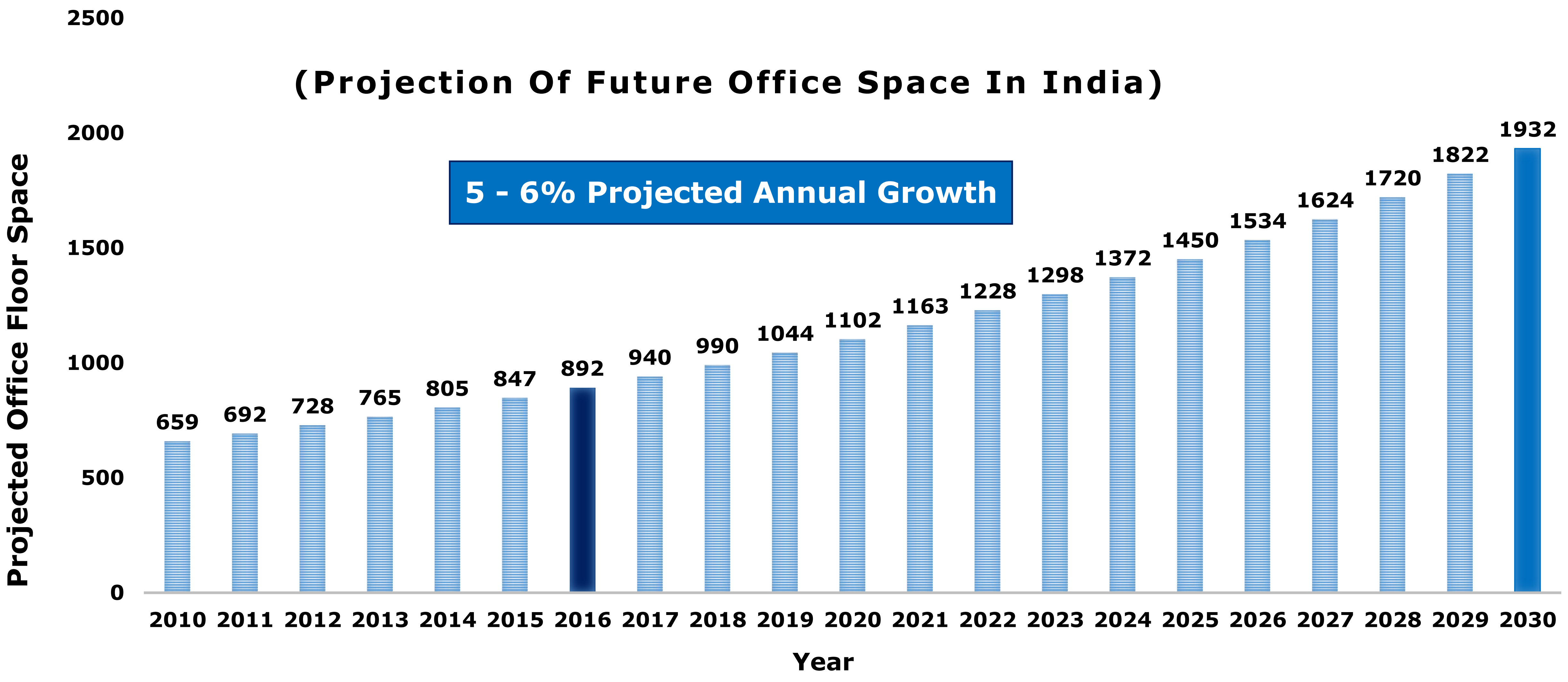
Source: Sivak, M. (2013, September). Will AC put a chill on the Global Energy Supply. American Scientist.

Constantly Increasing Electricity Consumption of Offices



Source: Energy Scenario in India. (2011). Central Electricity Authority.

Office Floor Space : Projected To Constantly Grow



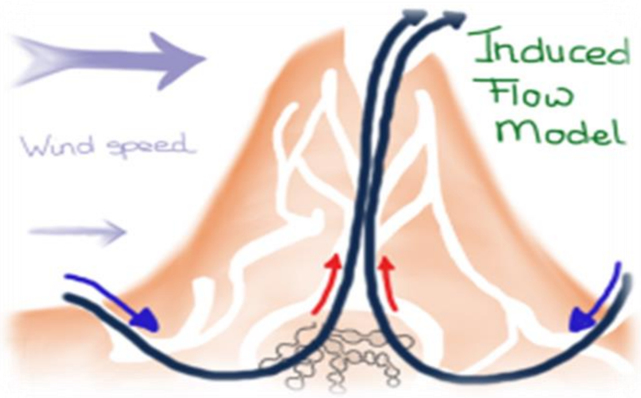
Source: (2015). Commercial Buildings Growth Forecast, ECBC.

What if an office building could, at any time, **be optimized for the environmental conditions** around it?

What if that meant more **comfortable** employees, **lower energy** use and significant **savings** in operating costs?

What if **the aesthetic and spatial quality** of these buildings could be **enhanced** by embracing passive conditioning strategies during the design process?

3-Tier Analysis Approach



Ingenious Natural Processes

Sustainable Vernacular Practices

Modern High Performance Strategies

Hypothesis:

In the increasingly warming climates of India, future office architecture must adopt **dynamic and adaptive design solutions** in order to design office buildings to be **resilient, energy efficient, beautiful, healthy and comfortable**, while enhancing the spatial quality and productivity of workspaces, without compromising any key performance criteria.

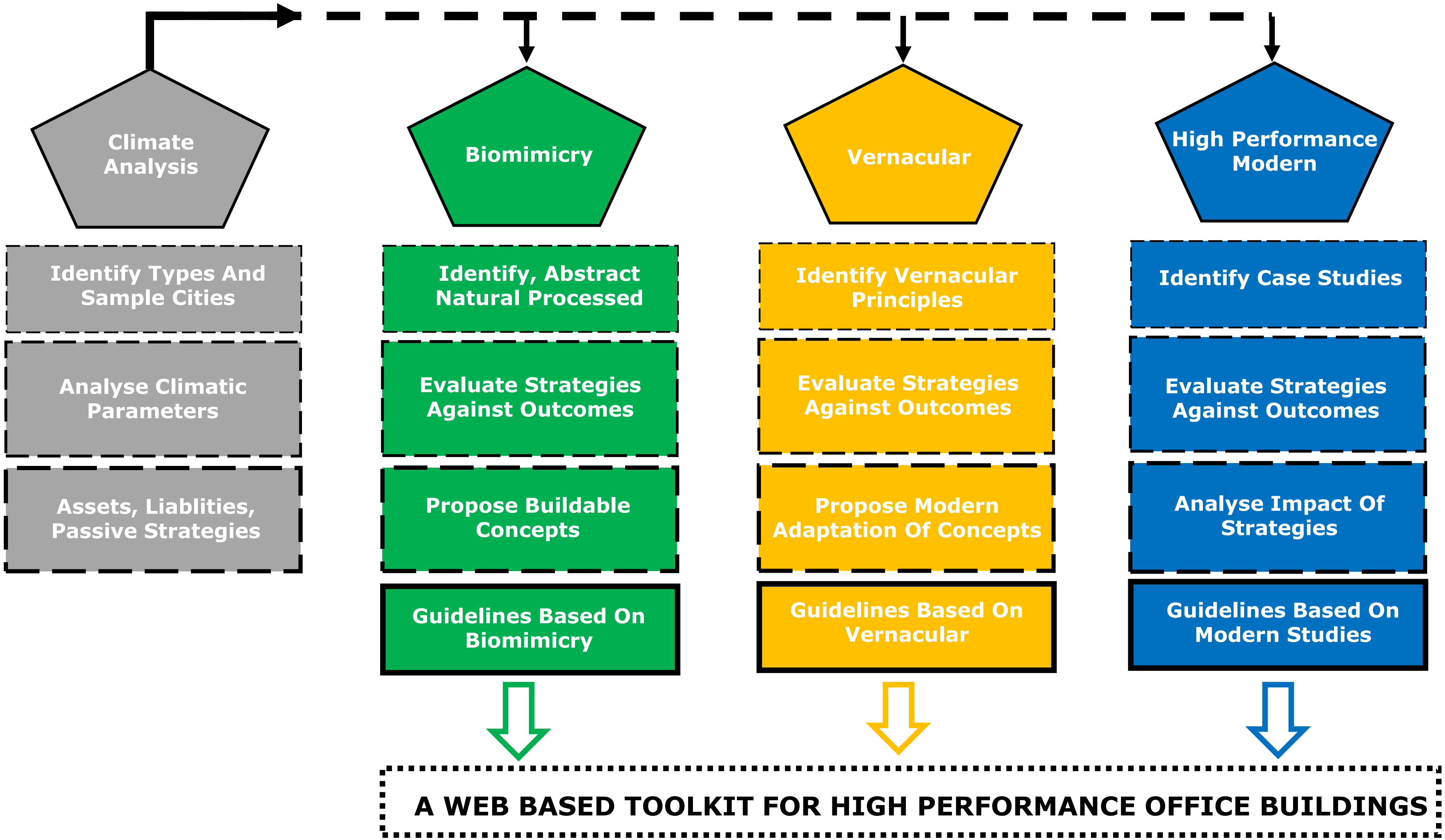
Sub – Hypotheses:

Biomimicry offers invaluable insights for form finding based on dynamic behaviour that can lead to adaptive façade solutions that ensure resiliency and sustainability.

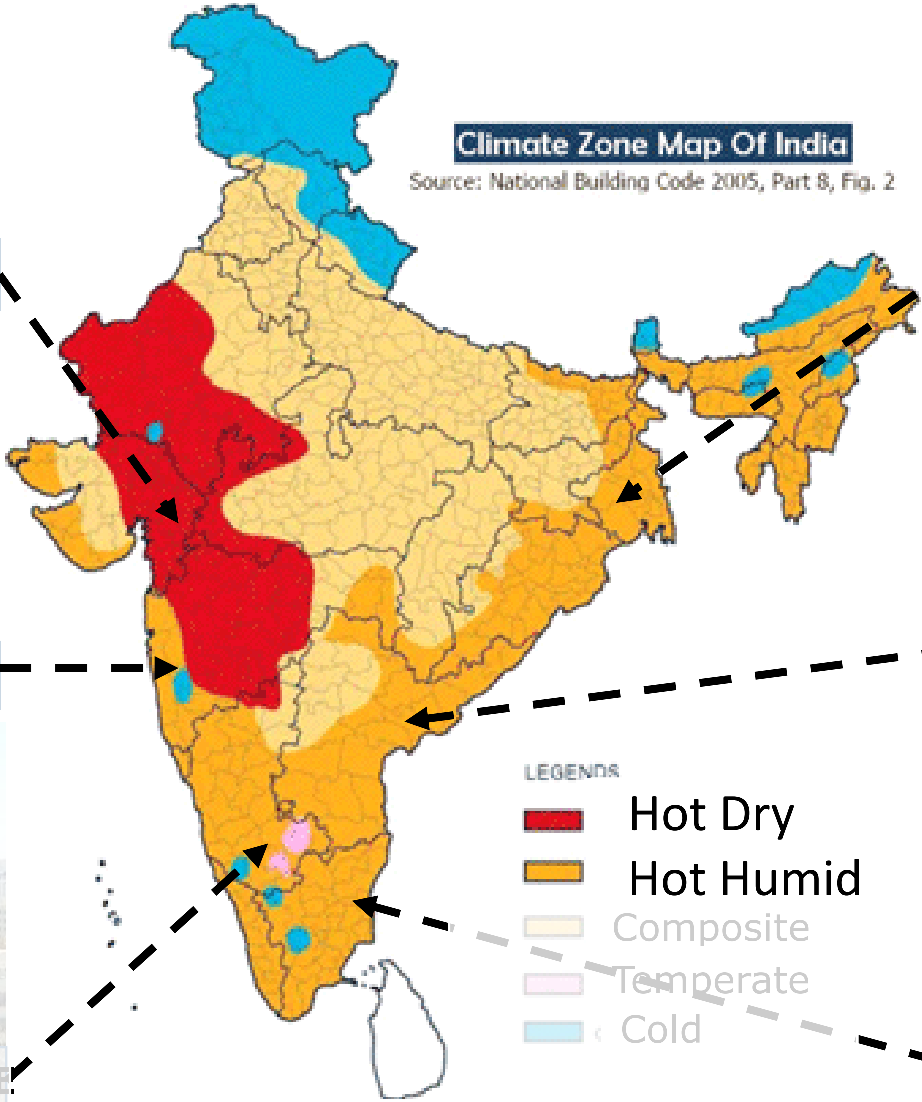
Vernacular solutions offer historical insights to adaptive comfort and can inform contemporary solutions tightly coupled to climate.

High performance climate responsive modern buildings offer technological insights for dynamic and adaptive solutions and can imbibe qualities of ingenious natural processes and sustainable vernacular techniques.

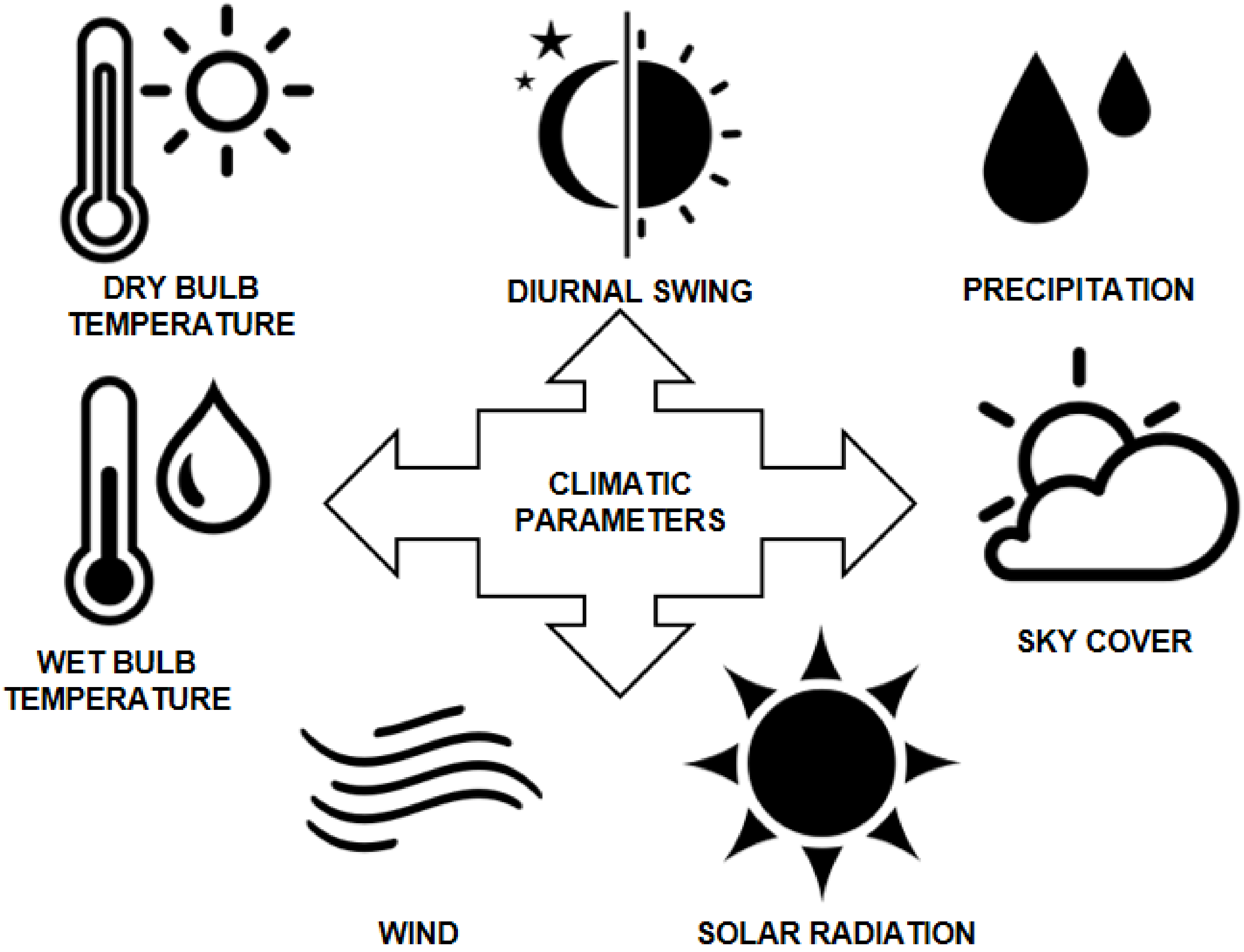
Methodology Of Research



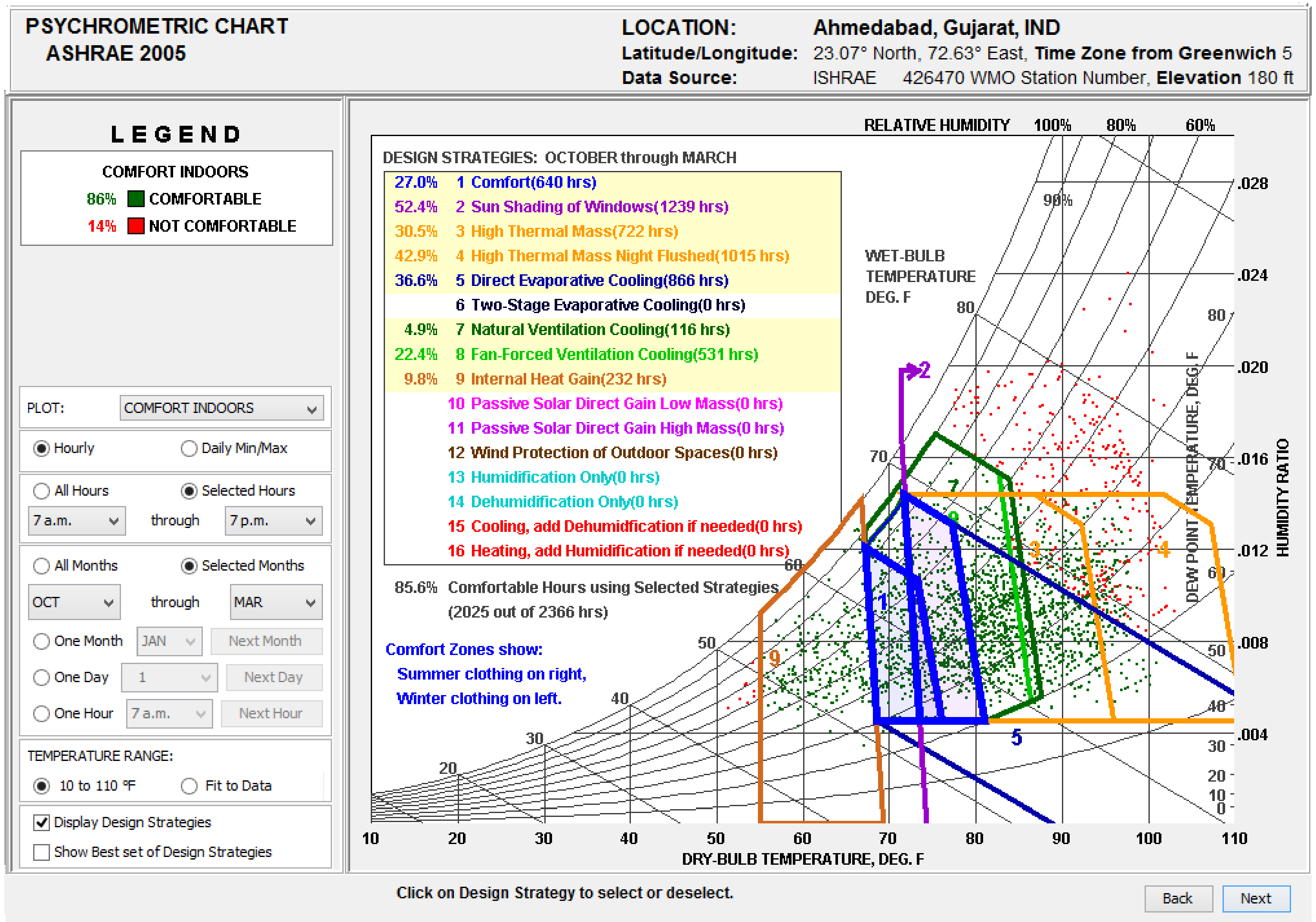
Selection of Sample Cities in Hot Climates



CLIMATE ANALYSIS

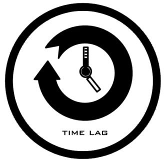


Hot And Dry Climate: Ahmedabad



Source: Climate Consultant

High Performance Shading



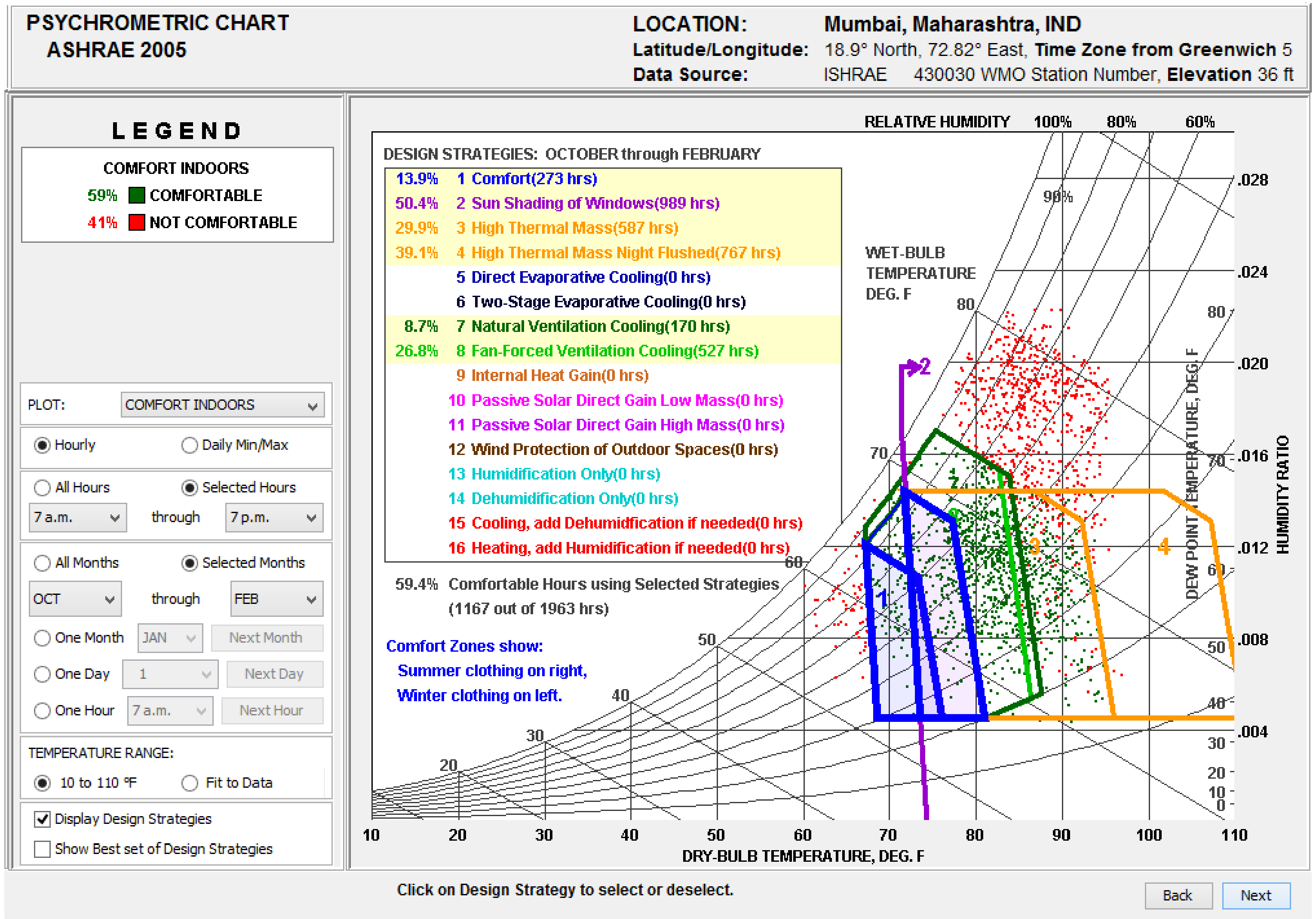
Time Lag

Evaporative Cooling

Natural Ventilation

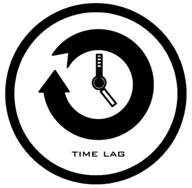
45% of the year can be made comfortable with these strategies without mechanical cooling

Hot And Humid Climate: Mumbai



Source: Climate Consultant

High Performance Shading

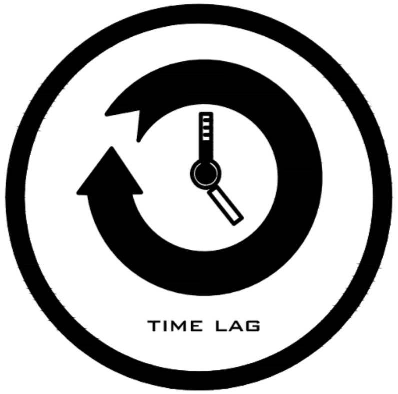


Time Lag

Natural Ventilation

27% of the year can be made comfortable with these strategies without mechanical cooling

Crucial Strategies Identified from the Psychrometric Chart

	High Performance Shading	Heat Gain Reduction	Natural Ventilation
		 	
Hot Dry	Increases comfort by 2742/**4745 hrs** annually **(57%)**	Increases comfort by 2687/**4745 hrs** annually **(56%)**	Increases comfort by 733/**4745 hrs** annually **(15%)**
Hot Humid	Increases comfort by 2563/**4745 hrs** annually **(54%)**	Increases comfort by 1412/**4745 hrs** annually **(29%)**	Increases comfort by 827/**4745 hrs** annually **(17%)**

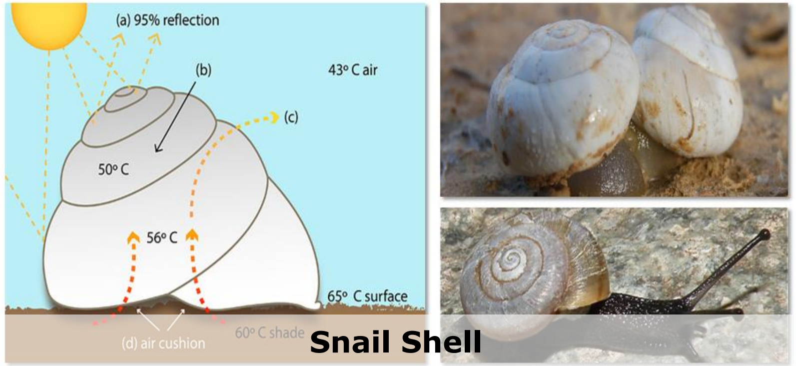
High Performance Shading

BIOMIMICRY

Integrated layered system of **self shading** spines

Desert Cacti

Highly reflective shell, **insulating** air cushion and a **cooler** interior core



Snail Shell

1 Incorporate **self shading** façade elements such as recessed windows, articulated cladding materials, roof overhangs or building offsets that mutually shade built spaces.

2 Integrate PV along with shading devices such as louvres or fins that move **in response to sun's movement** and power either the building or the dynamic shading itself.

3 Use only **light colored or reflective materials** that reflect the sunlight instead of absorbing it.

4 Design an adaptive hinge less shading system that takes advantage of the **inherent elastic material property.**

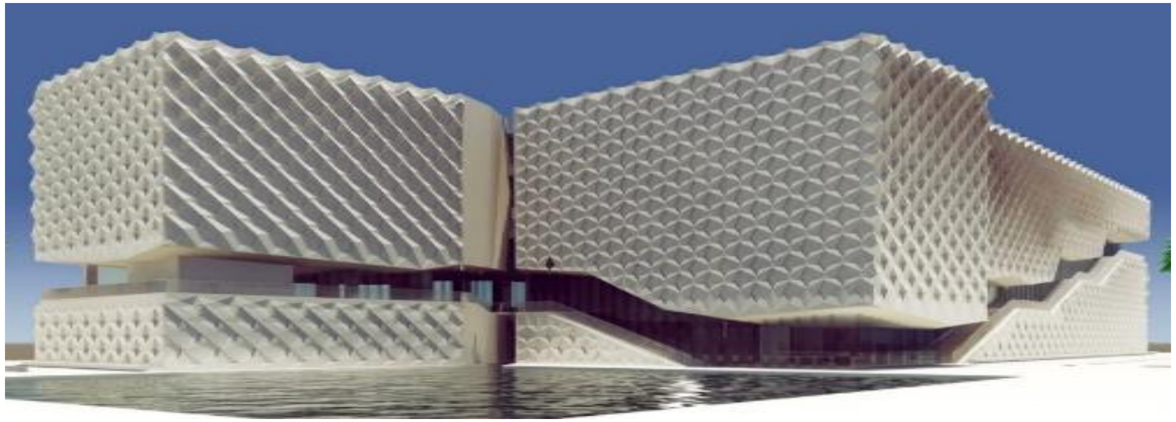
A diurnal motion in **response to sun** (Heliotropism)

Sunflower

An **elastic property** of regaining original form after deformation

Strelitzia Reginae

Biomimetic Case Study: Kuwait University Building, Kuwait



Custom designed shading

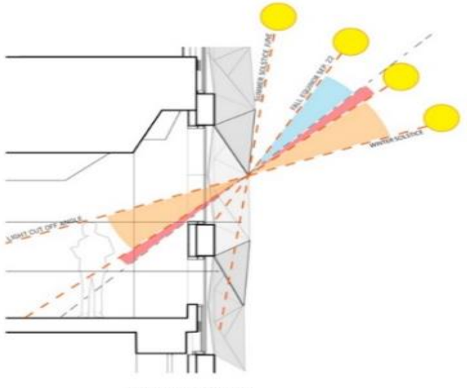
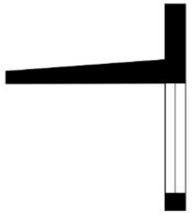
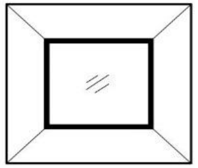


Diagram: sun and the shading device

By incorporating recessed windows designed for different orientations, The Kuwait University building achieves a 50% reduction in energy compared to a typical building of same size.



STATIC SHADING



RECESSED WINDOWS

- ✓ **Abundant Daylighting**
- ✓ **Excellent Outdoor views**
- **No natural ventilation**

A Self-shading façade:

The architects drew inspiration from a cacti's shading technique to calibrate the building's self-shading skin in response to its specific solar exposure.

Sculpted, pre-cast concrete panels shield the underlying windows from over 80% of the sun's heat energy. (Kuwait University College Building, 2014)

To maximize daylight penetration there is the addition of a ground glass diffusing fin at each window.

High Performance Shading

VERNACULAR

Mutually **shaded open space** ensuring cross ventilation

Courtyards

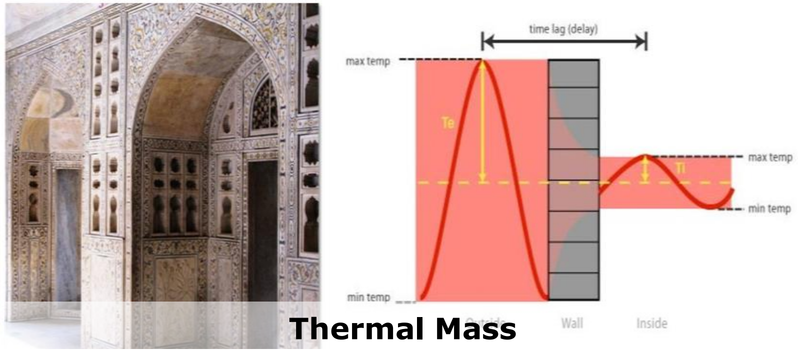
1 Incorporate either **central or external courtyards,** for shading the surrounding built spaces and delaying heat gain while ensuring daylight and cross ventilation.

2 Create **buffer spaces** by having balconies, terraces or semi open corridors that move the main façade away from direct solar gain.

Semi open circulation space protecting interior from **direct solar gain**

Buffer Spaces

Walls with **high mass delaying** the heat transfer

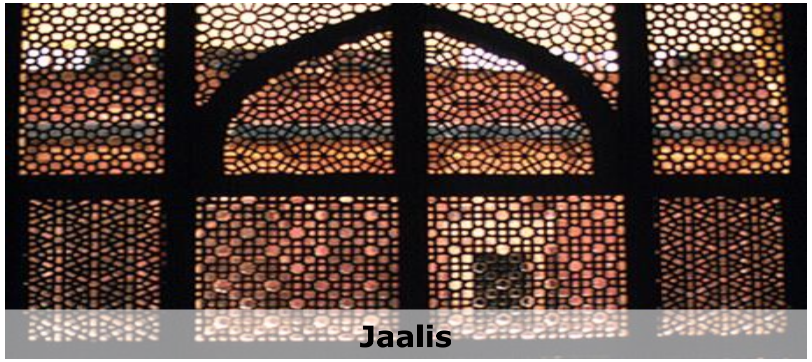


Thermal Mass

3 Incorporate **Jaali walls** that obstruct the sunlight and shade as well as cause a time lag with thermal mass.

4 Choose materials and wall assemblies with **high thermal mass** to absorb the heat and delay its transfer into the indoor workspaces.

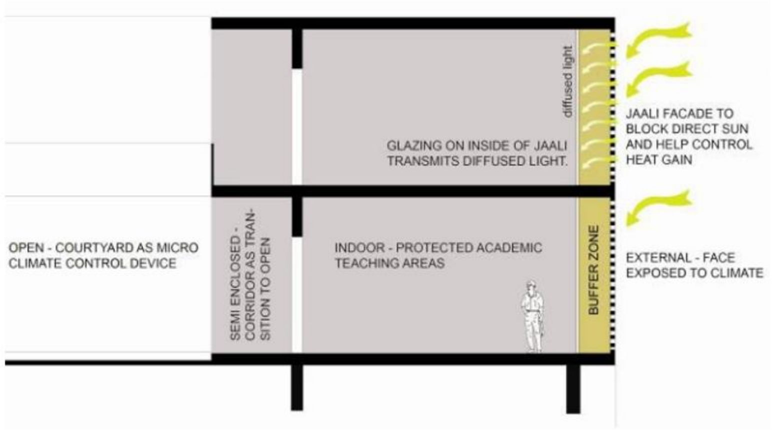
Perforated screens that modulate sun and wind based on unique physical pattern



Jaalis

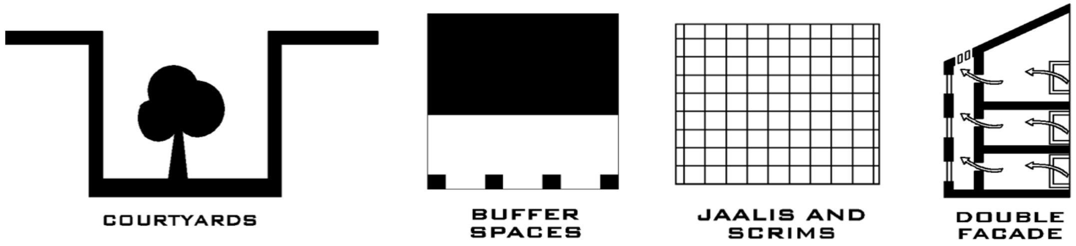
Vernacular Inspired Case Study: Pearl Academy Building, Jaipur

Semi open corridors, a courtyard and a sunken pool



Section showing buffer space

By incorporating, jaalis and evaporative cooling, The Pearl Academy building achieves a 54% lesser EUI when compared to a standard GRIHA Compliant Building.



- ✓ **Abundant Daylighting**
- ✓ **Excellent Outdoor views**
- ✓ **Natural Ventilation**

Jaali and a double façade:

The perforated outer skin sits 4 feet away from the building, reduces direct heat gain and allows diffused daylight.

Evaporative cooling:

Drip channels running along the inner face of the screen allow for passive downdraft evaporative cooling

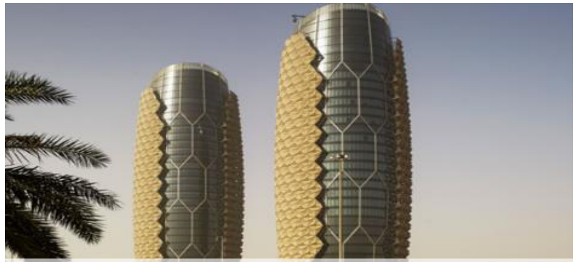
Earth cooling, thermal mass and ponds:

In the central courtyard, a scooped out under belly forms a natural thermal sink, cooled by water bodies through evaporative cooling.

High Performance Shading in Contemporary Buildings

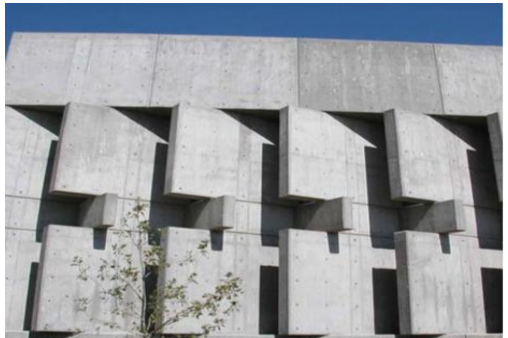
Hot Dry Climate


Burton Barr Library, Phoenix


Al Bahr, Abu Dhabi


IRRAD, New Delhi


DPR Office Building, Phoenix


UNM School of Law, New Mexico

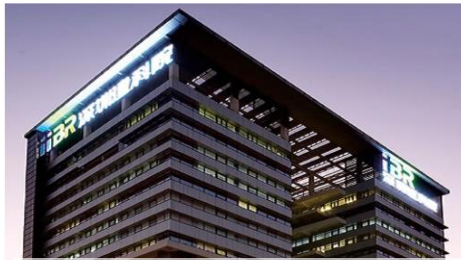

Cambridge Public Library, Boston

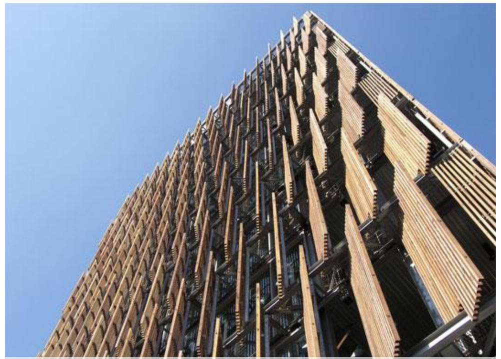
Hot Humid Climate


CJ Corp Headquarters, Seoul


BCA Building, Singapore

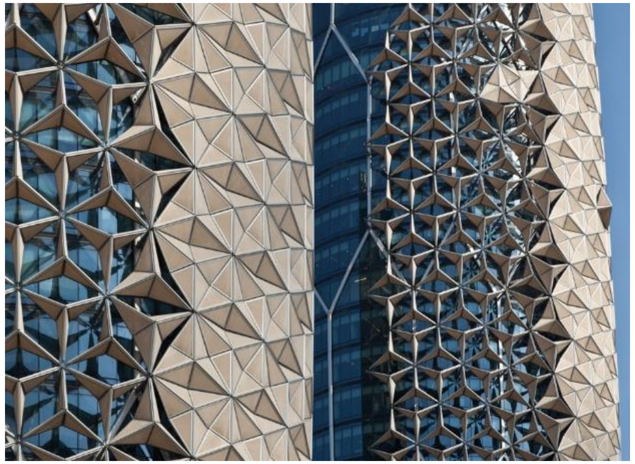

MESP, Rio De Janeiro


Shenzhen Inst, Shenzhen

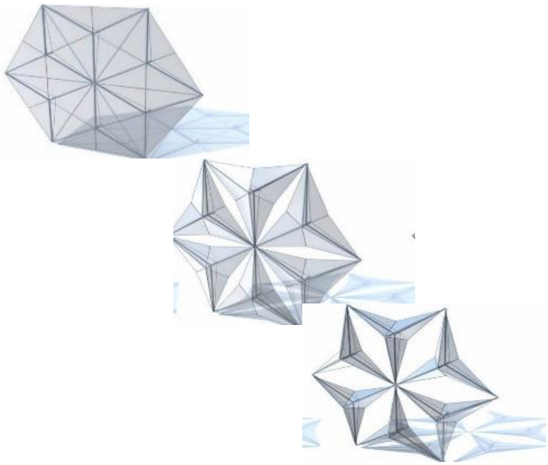

CH2 Building, Melbourne


1 Bligh Street, Sydney

Al Bahr Building, Abu Dhabi (Hot Dry Climate)



Dynamic PTFE Panels



Function diagram

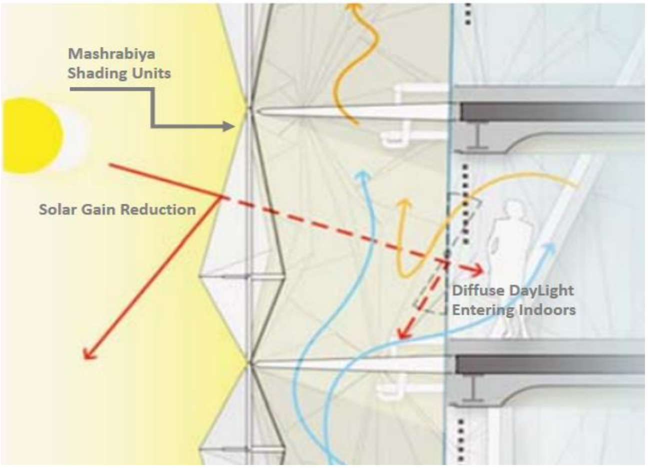
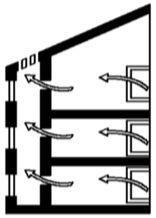
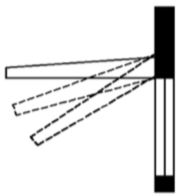


Diagram: Sun and shading device

By incorporating a dynamic shading system that reacts to the sun angle at a particular time of the day, the Al Bahr Building achieves a 25% reduction in building cooling loads and a 50% reduction in solar radiation gains.



DOUBLE FACADE



DYNAMIC CUSTOMIZED SHADING

✓ Abundant Daylighting

Compromised Outdoor views

No Natural Ventilation

East and west façade: PTFE Open-close panels:

2000 PTFE panels that fold and unfold with respect to sun's movement.

Conceptualised and emulated from the natural process of the Sunflower's Heliotropism and vernacular lattice screens.

The automation conditions for the folding action of the shading units which are as follows:

If solar rays land on the curtain-wall > than 83 degrees → Fully-folded

If solar rays land on the curtain-wall 80 - 83 degrees → Mix-folded

If solar rays land on the curtain-wall < 80 degrees → Un-folded

BCA Building, Singapore (Hot Humid Climate)

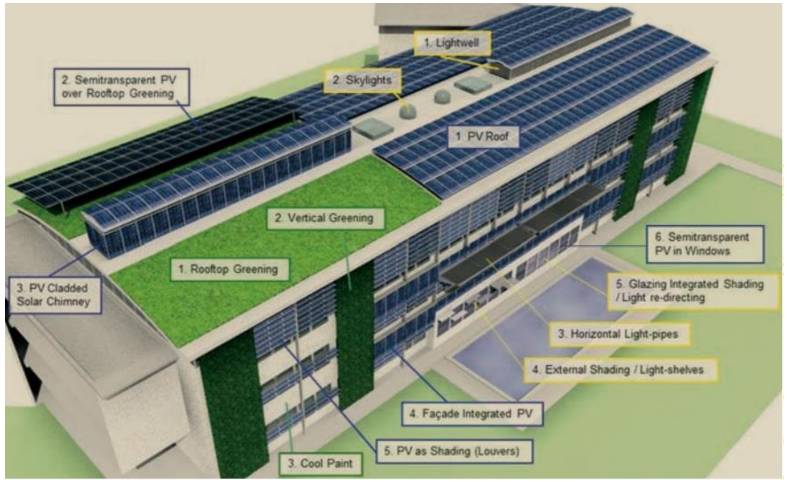
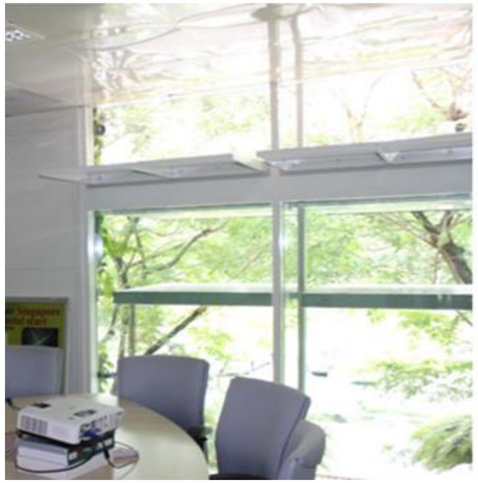


Diagram: Implemented green strategies



Daylighting

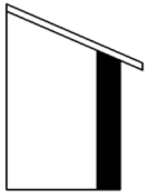
Solar chimneys

By incorporating automated horizontal louvres integrated with PV, the BCA Building achieves a 63.5% reduction in EUI compared to a typical building in Singapore.

HORIZONTAL LOUVRES

PV INTEGRATED SHADING

VEGETATION FOR SHADING



BLANK MASS WALL

- ✓ **Abundant Daylighting**
- ✓ **Excellent Outdoor Views**
- ✓ **Natural Ventilation**

South Façade: Horizontal PV Integrated louvres:

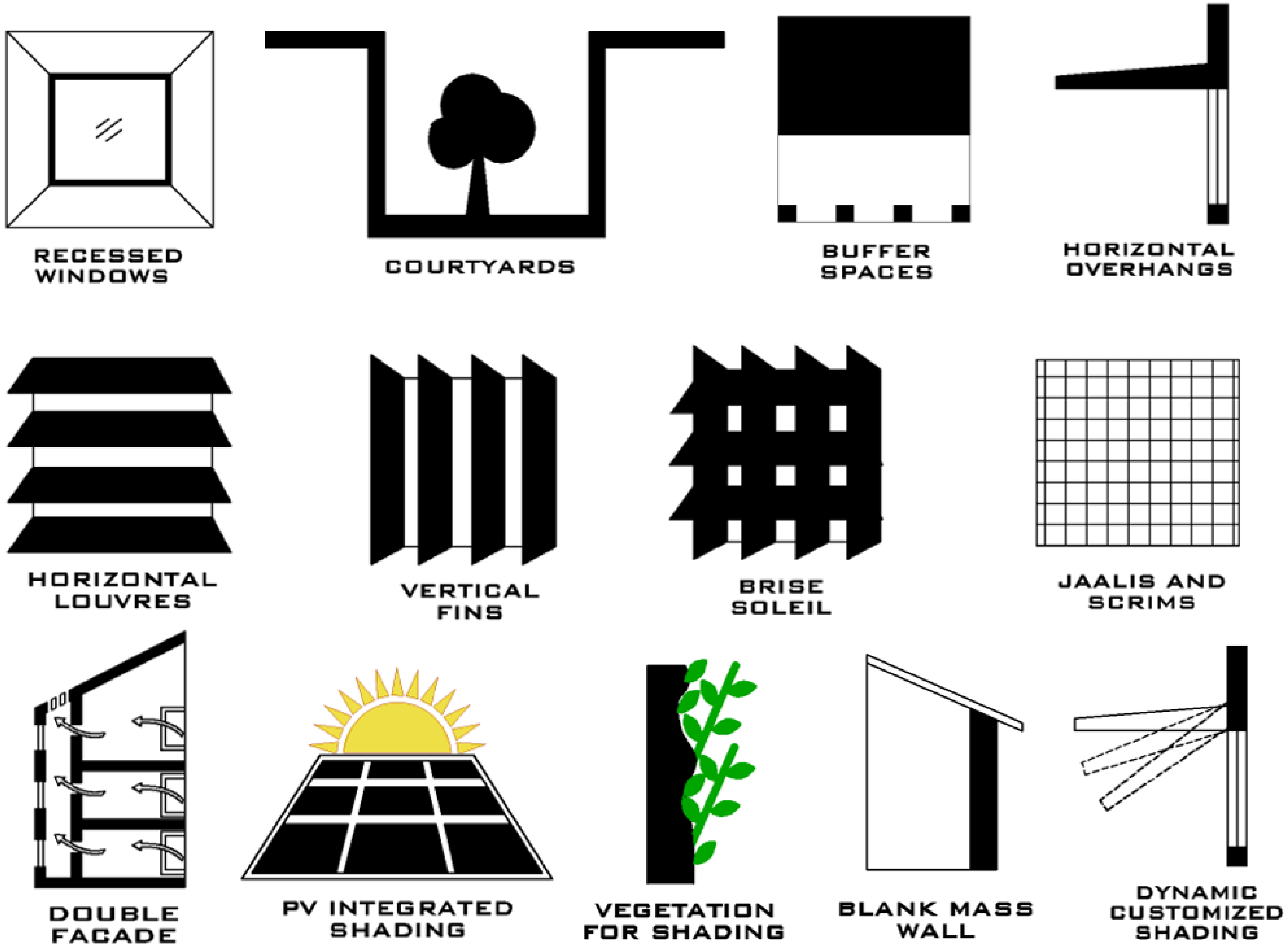
Horizontal louvres on South are PV Integrated to harness the available solar energy and power the shading elements, resulting in the building achieving a net zero energy status.

The louvres also have a reflecting film doubling them as light shelves that help penetrate light deeper into the building. (Wittcopf, 2015)

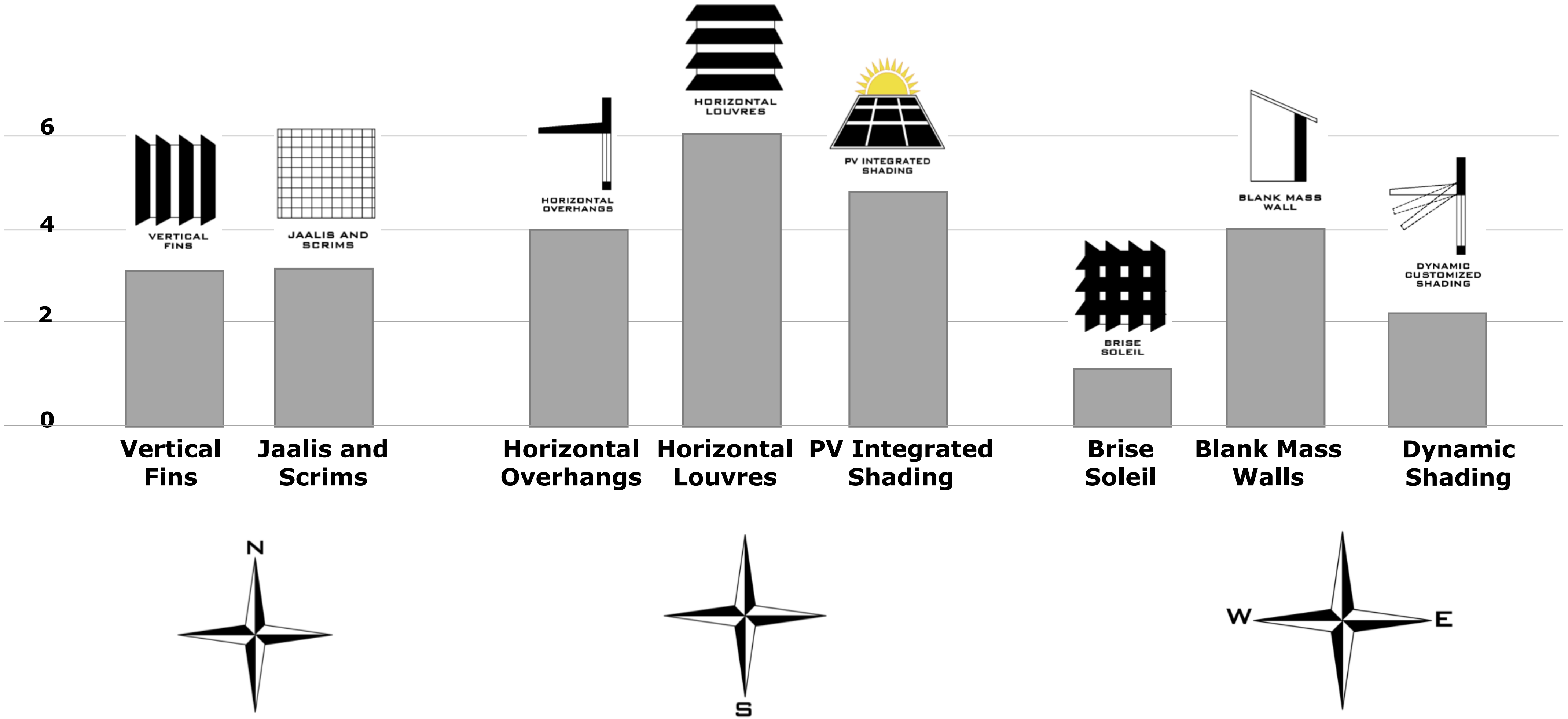
Vegetation:

Vertical green walls on the south facade as well as green spaces on the roof help in cooling the façade too.

Key Strategies Identified
High Performance Shading

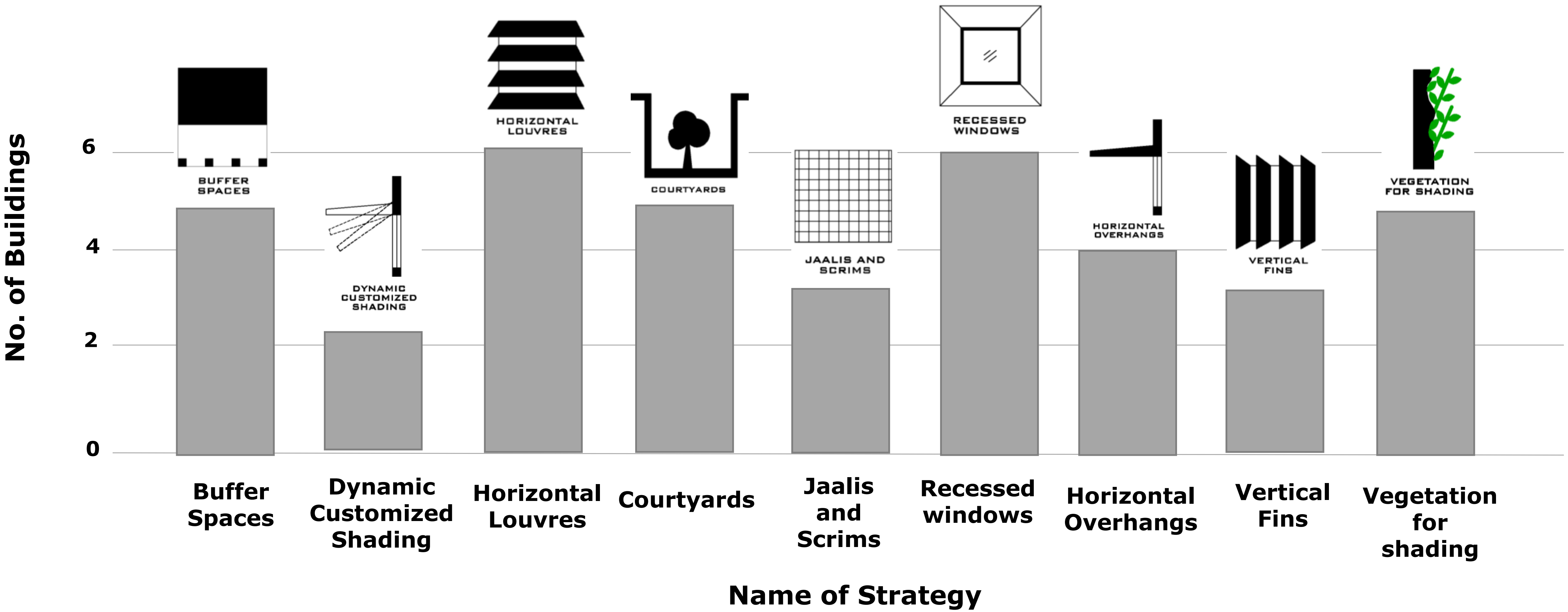


High Performance Shading: Orientation Based



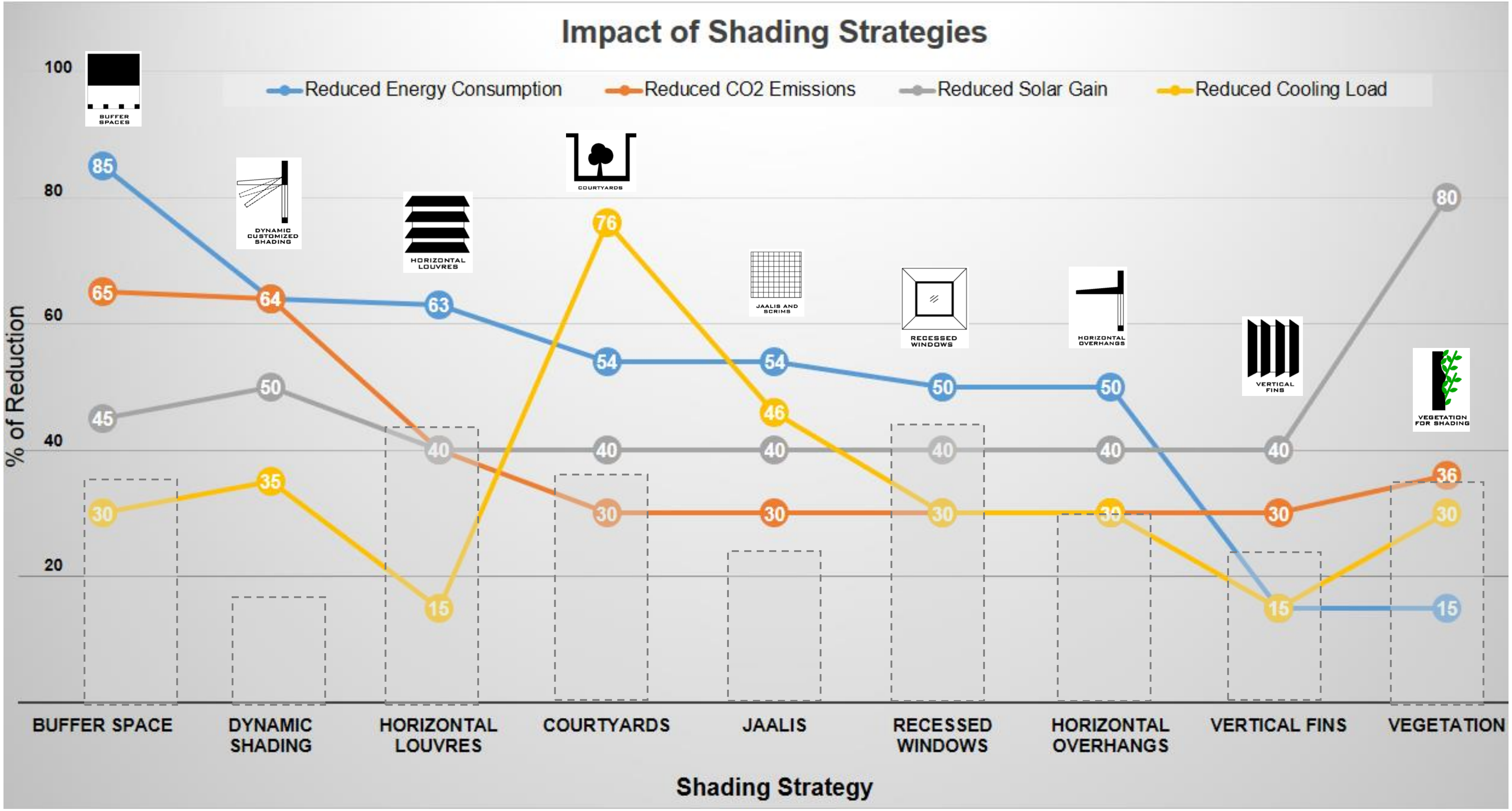
***Shading Strategies Based on Case Study Research of 16 Buildings**

Most Popular Shading Strategies



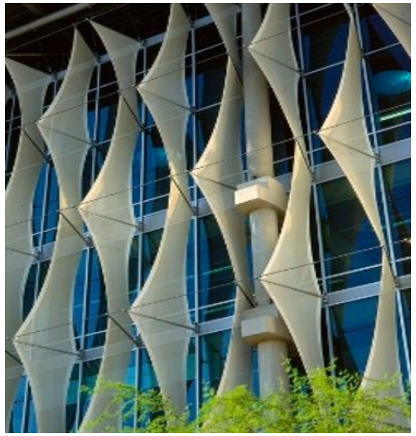
***Shading Strategies Based on Case Study Research of 16 Buildings**

Impact vs Popularity of Shading Strategies



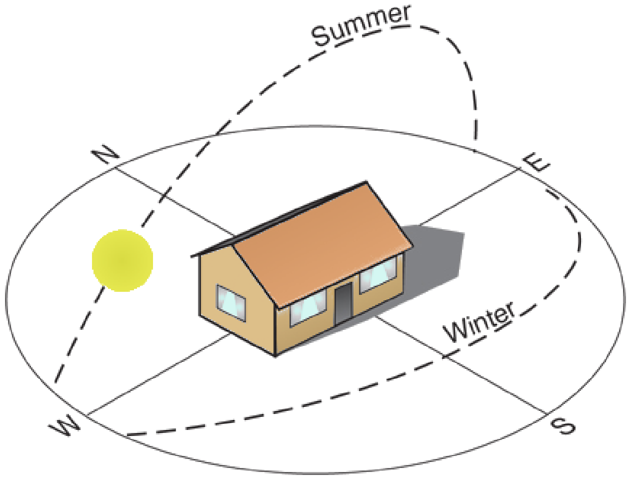
Guidelines Based On Modern Case Studies

To shade **North facades**, incorporate **Vertical shading elements** such as fins or fabric shades.

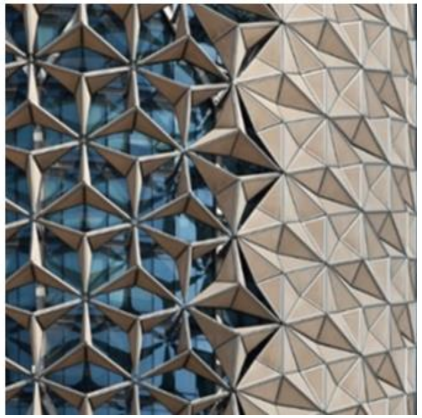
To shade **South facades**, incorporate **horizontal elements** such as louvres or movable overhangs


Orient the building with **longer North and South facades** and reduce the west and east exposure as much as possible.



To shade the **West and East facades**, have a **blank wall** with little to no glazing.


Incorporate horizontal and vertical elements such as **egg-crates with dynamic louvres** or jaalis.

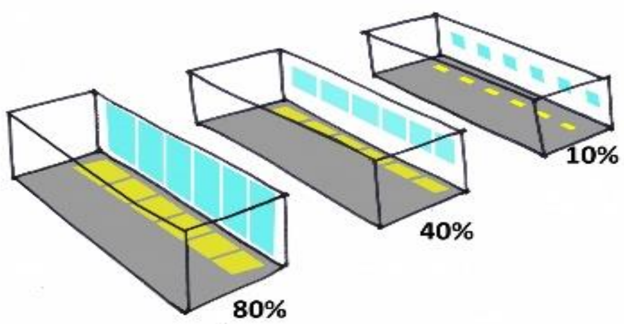



Guidelines Based On Modern Case Studies

Incorporate **courtyards**, for shading the built spaces while ensuring daylight and cross ventilation.

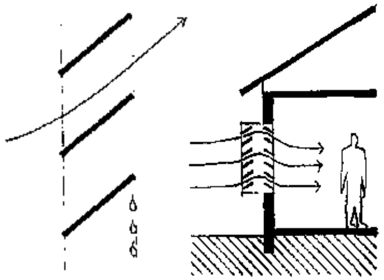
Integrate **Vegetation** as an element for shading using green walls, or vertical gardens to block solar radiation from entering the building.

Maintain a **window to wall ratio** of 20 - 30% on the north, 30 to 50% on the south and a 0 to 20% on the west and east facades to minimize heat gain while maximizing daylight.

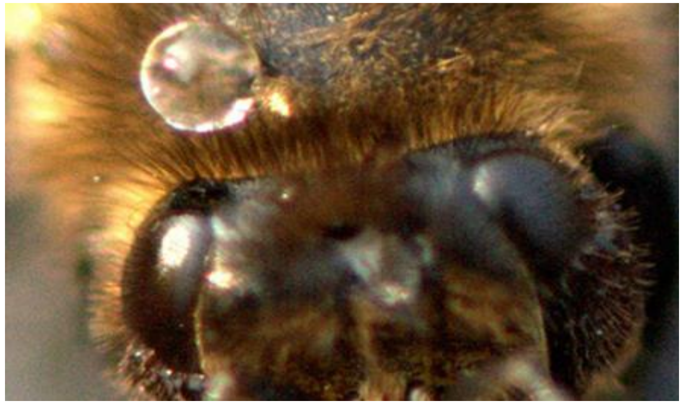


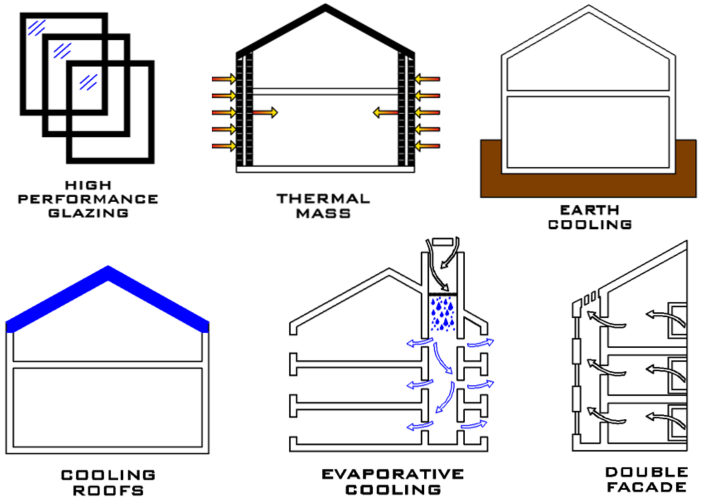
Incorporate **daylight enhancing elements** that also allow air flow for ventilation such as light redirection fins, light shelves or light tubes.

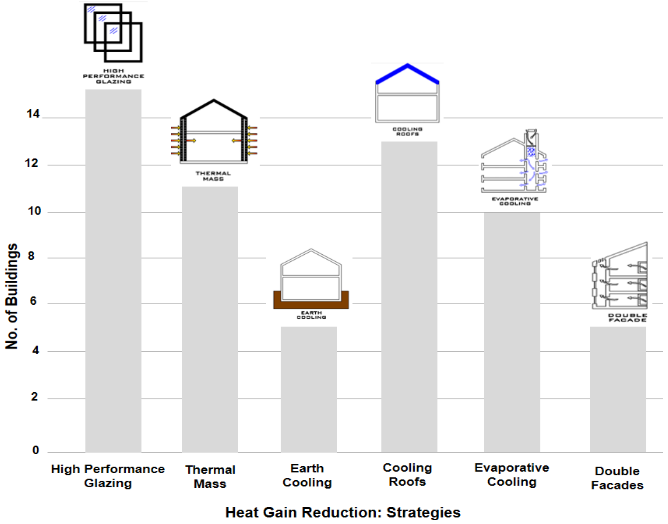
For hot-humid climates, ensure that the shading devices such as louvres **allow for ventilation** as well as keep the driving rain out of the indoors.

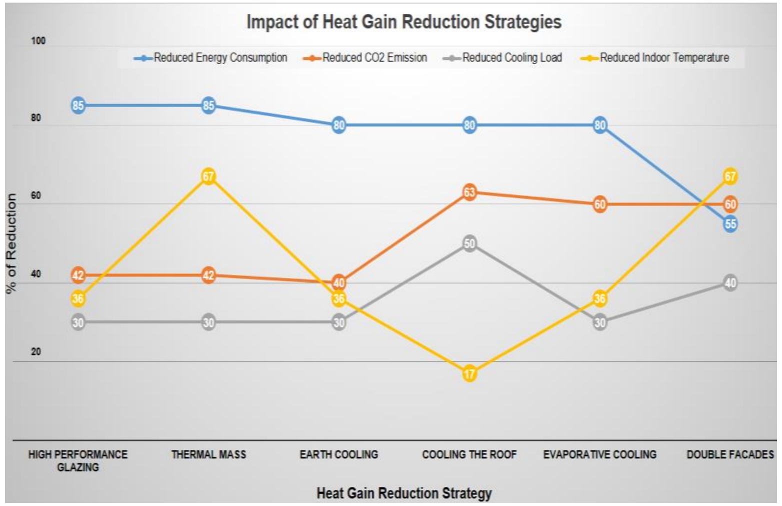


Heat Gain Reduction

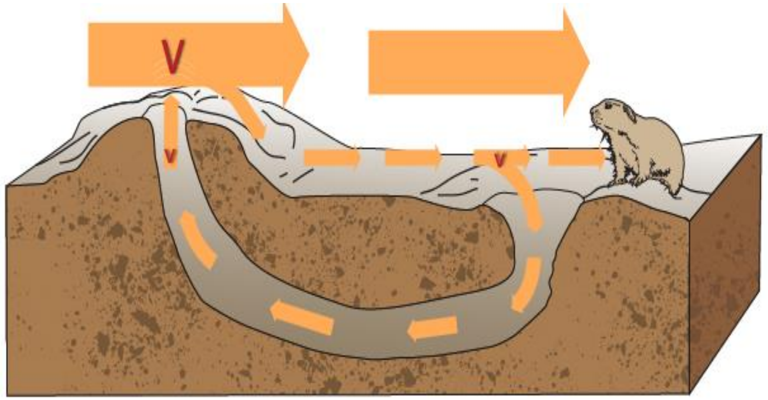


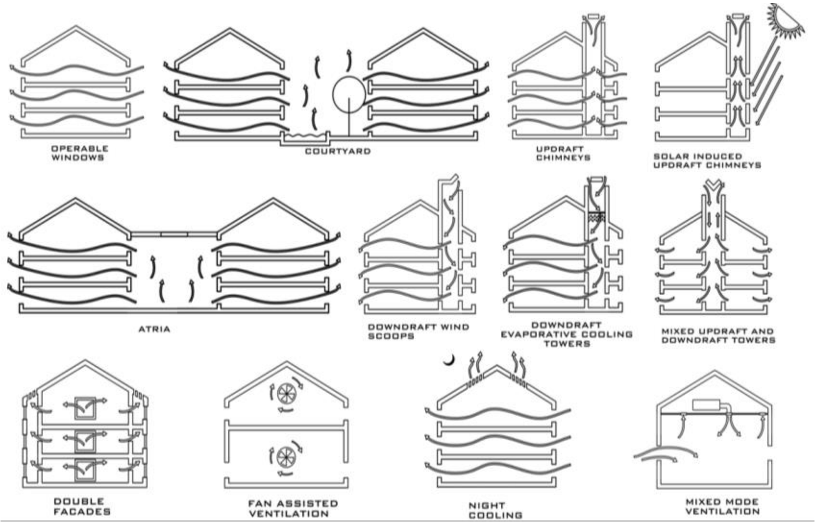


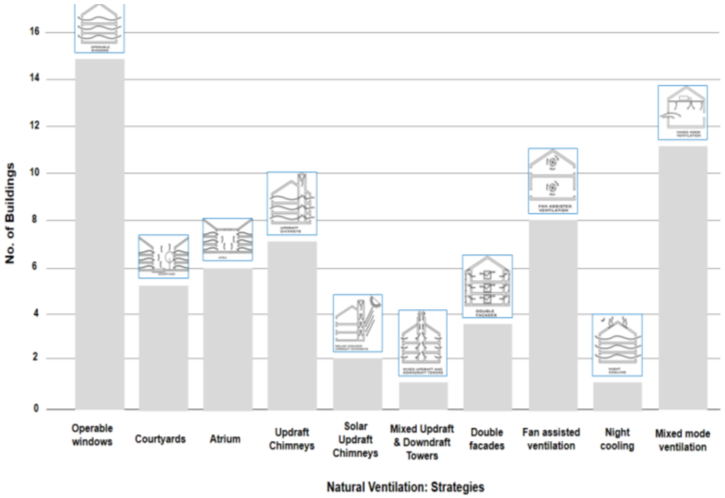


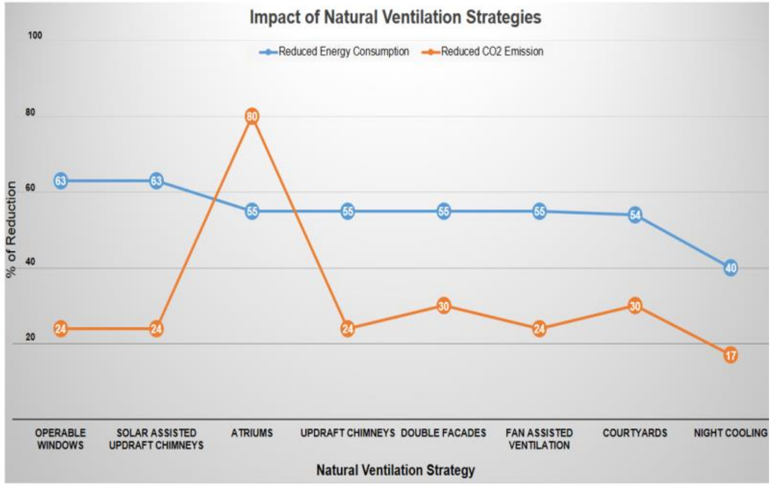


Natural Ventilation









Current Design Guidelines for Ahmedabad: Climate Consultant 6

DESIGN GUIDELINES (for the Full Year)
ASHRAE 2005
User Modified Design Strategies, Default Criteria

LOCATION: Ahmedabad, Gujarat, IND
Latitude/Longitude: 23.07° North, 72.63° East, **Time Zone from Greenwich** 5
Data Source: ISHRAE 426470 WMO Station Number, **Elevation** 180 ft

Assuming only the Design Strategies that were selected on the Psychrometric Chart, 49.6% of the hours will be Comfortable.
This list of Non-Residential Design guidelines applies specifically to this particular climate, starting with the most important first.
Click on a Guideline to link to the 2030 Palette for related passive design ideas (see Help).

45	Flat roofs work well in hot dry climates (especially if light colored) 2030
42	On hot days ceiling fans or indoor air motion can make it seem cooler by 5 degrees F (2.8C) or more, thus less air conditioning is needed
66	Climate responsive buildings in hot windy dry climates used enclosed well shaded courtyards, with a small fountain to provide wind-protected microclimates
37	Window overhangs (designed for this latitude) or operable sunshades (awnings that extend in summer) can reduce or eliminate air conditioning 2030
32	Minimize or eliminate west facing glazing to reduce summer and fall afternoon heat gain 2030
35	Good natural ventilation can reduce or eliminate air conditioning in warm weather, if windows are well shaded and oriented to prevailing breezes 2030
58	This is one of the more comfortable climates, so shade to prevent overheating, open to breezes in summer, and use passive solar gain in winter 2030
43	Use light colored building materials and cool roofs (with high emissivity) to minimize conducted heat gain 2030
62	Climate responsive buildings in temperate climates used light weight construction with slab on grade and operable walls and shaded outdoor spaces
39	A whole-house fan or natural ventilation can store nighttime 'coolth' in high mass interior surfaces (night flushing), to reduce or eliminate air conditioning 2030
20	Provide double pane high performance glazing (Low-E) on west, north, and east, but clear on south for maximum passive solar gain 2030
47	Use open plan interiors to promote natural cross ventilation, or use louvered doors, or instead use jump ducts if privacy is required 2030
41	The best high mass walls use exterior insulation (like EIFS foam) and expose the mass on the interior or add plaster or direct contact drywall
36	To facilitate cross ventilation, locate door and window openings on opposite sides of building with larger openings facing up-wind if possible 2030
19	For passive solar heating face most of the glass area south to maximize winter sun exposure, and design overhangs to fully shade in summer 2030
51	Slab on grade should provide enough thermal mass for storing night 'coolth', but if air conditioning is still needed add more interior mass 2030
56	Screened occupancy areas and patios can provide passive comfort cooling by ventilation in warm weather and can prevent insect problems
17	Use plant materials (bushes, trees, ivy-covered walls) especially on the west to minimize heat gain (if summer rains support native plant growth) 2030
33	Long narrow building floorplan can help maximize cross ventilation in temperate and hot humid climates 2030
49	To produce stack ventilation, even when wind speeds are low, maximize vertical height between air inlet and outlet (open stairwells, two story spaces, roof monit... 2030

- One of the guidelines states that this ***'is one of the more comfortable climates'*** which is ambiguous as it is not a comfortable climate always.
- The use of ***passive solar gain in winters*** is not required in Ahmedabad, since the temperatures in winter do not fall below 15°C (50°F).
- Incorporating ***clear glass on the South for maximum passive solar gains***, is highly inappropriate for Ahmedabad.
- In a hot climate, all orientations need to have high performing windows which are at least double paned and there is no need to maximise passive solar gain.

Current Design Guidelines for Mumbai: Climate Consultant 6

DESIGN GUIDELINES (for the Full Year) ASHRAE 2005
User Modified Design Strategies, User Modified Criteria

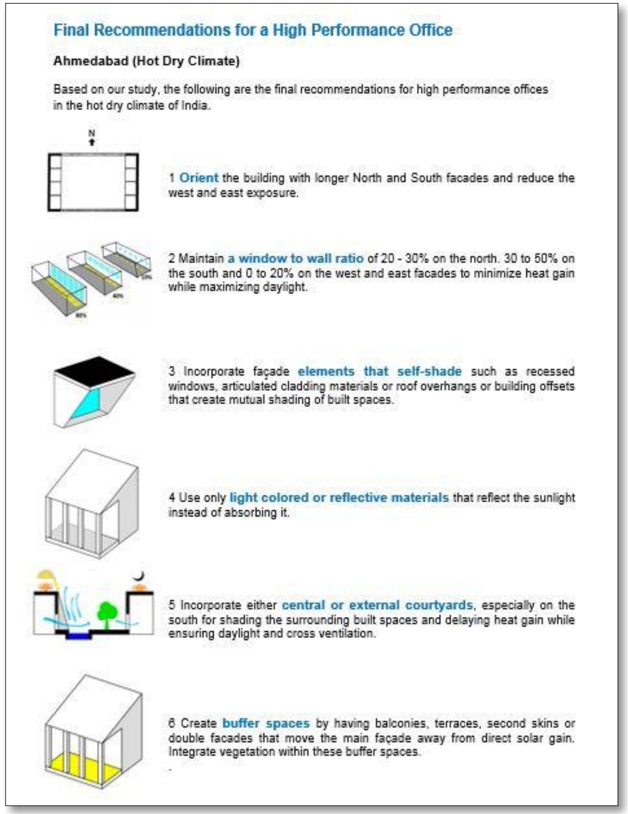
LOCATION: Mumbai, Maharashtra, IND
Latitude/Longitude: 18.9° North, 72.82° East, Time Zone from Greenwich 5
Data Source: ISHRAE 430030 WMO Station Number, Elevation 36 ft

Assuming only the Design Strategies that were selected on the Psychrometric Chart, 34.5% of the hours will be Comfortable. This list of Non-Residential Design guidelines applies specifically to this particular climate, starting with the most important first. Click on a Guideline to link to the 2030 Palette for related passive design ideas (see Help).

42	On hot days ceiling fans or indoor air motion can make it seem cooler by 5 degrees F (2.8C) or more, thus less air conditioning is needed
45	Flat roofs work well in hot dry climates (especially if light colored) 2030
37	Window overhangs (designed for this latitude) or operable sunshades (awnings that extend in summer) can reduce or eliminate air conditioning 2030
35	Good natural ventilation can reduce or eliminate air conditioning in warm weather, if windows are well shaded and oriented to prevailing breezes 2030
32	Minimize or eliminate west facing glazing to reduce summer and fall afternoon heat gain 2030
66	Climate responsive buildings in hot windy dry climates used enclosed well shaded courtyards, with a small fountain to provide wind-protected microclimates
39	A whole-house fan or natural ventilation can store nighttime 'coolth' in high mass interior surfaces (night flushing), to reduce or eliminate air conditioning 2030
43	Use light colored building materials and cool roofs (with high emissivity) to minimize conducted heat gain 2030
17	Use plant materials (bushes, trees, ivy-covered walls) especially on the west to minimize heat gain (if summer rains support native plant growth) 2030
56	Screened occupancy areas and patios can provide passive comfort cooling by ventilation in warm weather and can prevent insect problems
62	Climate responsive buildings in temperate climates used light weight construction with slab on grade and operable walls and shaded outdoor spaces
36	To facilitate cross ventilation, locate door and window openings on opposite sides of building with larger openings facing up-wind if possible 2030
20	Provide double pane high performance glazing (Low-E) on west, north, and east, but clear on south for maximum passive solar gain 2030
58	This is one of the more comfortable climates, so shade to prevent overheating, open to breezes in summer, and use passive solar gain in winter 2030
47	Use open plan interiors to promote natural cross ventilation, or use louvered doors, or instead use jump ducts if privacy is required 2030
33	Long narrow building floorplan can help maximize cross ventilation in temperate and hot humid climates 2030
41	The best high mass walls use exterior insulation (like EIFS foam) and expose the mass on the interior or add plaster or direct contact drywall
49	To produce stack ventilation, even when wind speeds are low, maximize vertical height between air inlet and outlet (open stairwells, two story spaces, roof monit... 2030
53	Shaded outdoor buffer zones (porch, patio, lanai) oriented to the prevailing breezes can extend occupancy spaces in warm or humid weather 2030
19	For passive solar heating face most of the glass area south to maximize winter sun exposure, and design overhangs to fully shade in summer 2030

- One of the guidelines states that ***'well enclosed shaded courtyards with a small fountain'*** would be ideal in this climate. However, considering that the city is extremely humid with RH reaching 85%, fountains or evaporative cooling is not feasible.
- ***Night flushing*** with high mass is stated as one of the recommendations, however since this climate does not have a sufficient day-night swing, this may not be one of the best strategies for Mumbai.
- Incorporating ***clear glass on the South*** for maximum passive solar gains, is highly inappropriate for Mumbai.

Final Design Recommendations for Ahmedabad



Final Recommendations for a High Performance Office

Ahmedabad (Hot Dry Climate)

Based on our study, the following are the final recommendations for high performance offices in the hot dry climate of India.

1 **Orient** the building with longer North and South facades and reduce the west and east exposure.

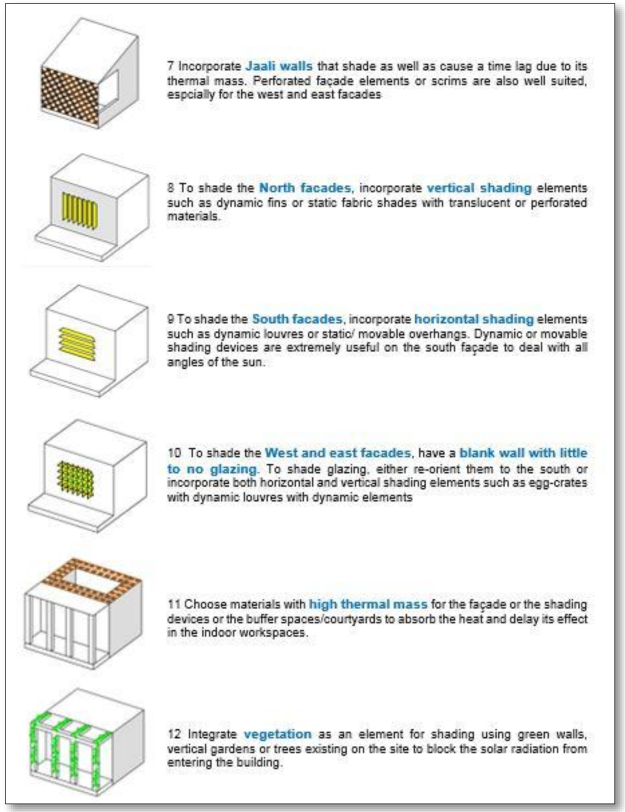
2 Maintain **a window to wall ratio** of 20 - 30% on the north. 30 to 50% on the south and 0 to 20% on the west and east facades to minimize heat gain while maximizing daylight.

3 Incorporate façade **elements that self-shade** such as recessed windows, articulated cladding materials or roof overhangs or building offsets that create mutual shading of built spaces.

4 Use only **light colored or reflective materials** that reflect the sunlight instead of absorbing it.

5 Incorporate either **central or external courtyards**, especially on the south for shading the surrounding built spaces and delaying heat gain while ensuring daylight and cross ventilation.

6 Create **buffer spaces** by having balconies, terraces, second skins or double facades that move the main façade away from direct solar gain. Integrate vegetation within these buffer spaces.



7 Incorporate **Jaali walls** that shade as well as cause a time lag due to its thermal mass. Perforated façade elements or scrims are also well suited, espcially for the west and east facades

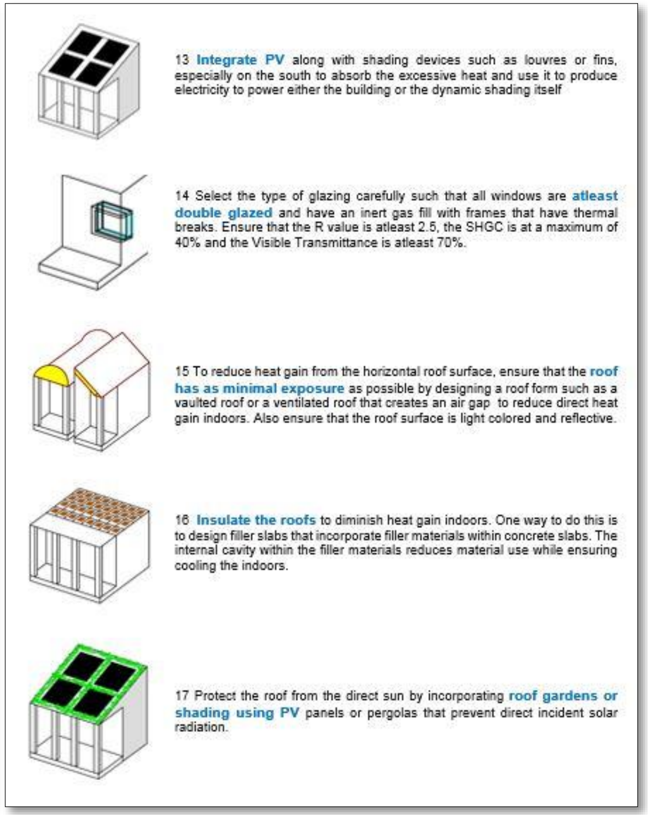
8 To shade the **North facades**, incorporate **vertical shading** elements such as dynamic fins or static fabric shades with translucent or perforated materials.

9 To shade the **South facades**, incorporate **horizontal shading** elements such as dynamic louvres or static/ movable overhangs. Dynamic or movable shading devices are extremely useful on the south façade to deal with all angles of the sun.

10 To shade the **West and east facades**, have a **blank wall with little to no glazing**. To shade glazing, either re-orient them to the south or incorporate both horizontal and vertical shading elements such as egg-crates with dynamic louvres with dynamic elements

11 Choose materials with **high thermal mass** for the façade or the shading devices or the buffer spaces/courtyards to absorb the heat and delay its effect in the indoor workspaces.

12 Integrate **vegetation** as an element for shading using green walls, vertical gardens or trees existing on the site to block the solar radiation from entering the building.



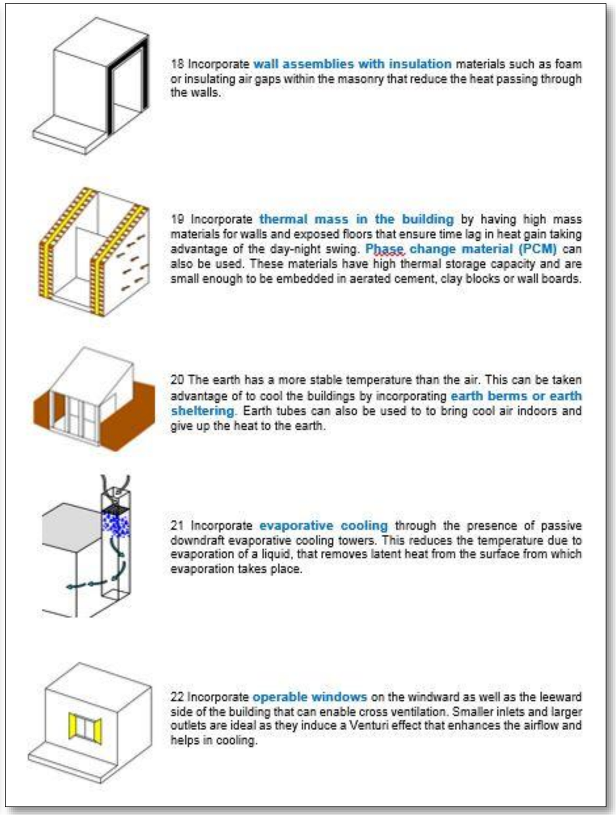
13 **Integrate PV** along with shading devices such as louvres or fins, especially on the south to absorb the excessive heat and use it to produce electricity to power either the building or the dynamic shading itself

14 Select the type of glazing carefully such that all windows are **atleast double glazed** and have an inert gas fill with frames that have thermal breaks. Ensure that the R value is atleast 2.5, the SHGC is at a maximum of 40% and the Visible Transmittance is atleast 70%.

15 To reduce heat gain from the horizontal roof surface, ensure that the **roof has as minimal exposure** as possible by designing a roof form such as a vaulted roof or a ventilated roof that creates an air gap to reduce direct heat gain indoors. Also ensure that the roof surface is light colored and reflective.

16 **Insulate the roofs** to diminish heat gain indoors. One way to do this is to design filler slabs that incorporate filler materials within concrete slabs. The internal cavity within the filler materials reduces material use while ensuring cooling the indoors.

17 Protect the roof from the direct sun by incorporating **roof gardens or shading using PV** panels or pergolas that prevent direct incident solar radiation.



18 Incorporate **wall assemblies with insulation** materials such as foam or insulating air gaps within the masonry that reduce the heat passing through the walls.

19 Incorporate **thermal mass in the building** by having high mass materials for walls and exposed floors that ensure time lag in heat gain taking advantage of the day-night swing. **Phase change material (PCM)** can also be used. These materials have high thermal storage capacity and are small enough to be embedded in aerated cement, clay blocks or wall boards.

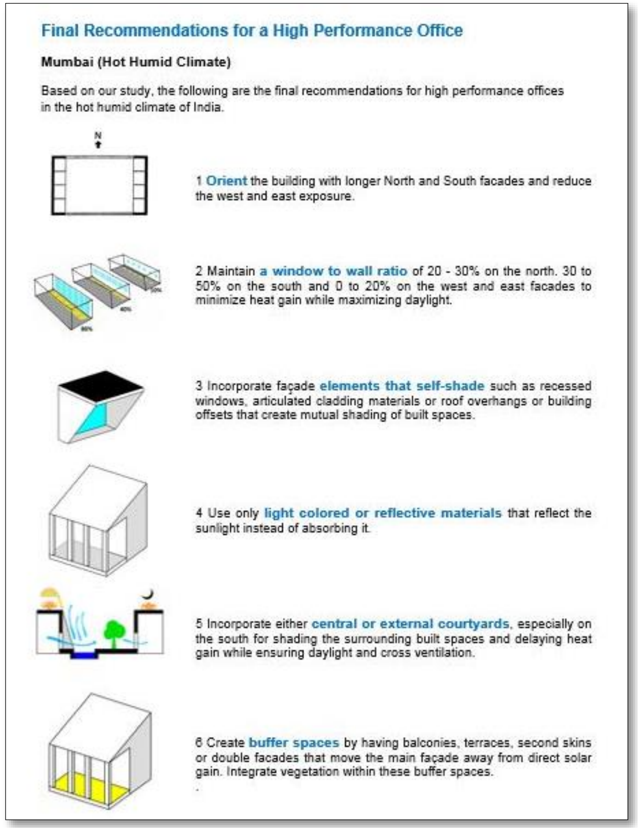
20 The earth has a more stable temperature than the air. This can be taken advantage of to cool the buildings by incorporating **earth berms or earth sheltering**. Earth tubes can also be used to to bring cool air indoors and give up the heat to the earth.

21 Incorporate **evaporative cooling** through the presence of passive downdraft evaporative cooling towers. This reduces the temperature due to evaporation of a liquid, that removes latent heat from the surface from which evaporation takes place.

22 Incorporate **operable windows** on the windward as well as the leeward side of the building that can enable cross ventilation. Smaller inlets and larger outlets are ideal as they induce a Venturi effect that enhances the airflow and helps in cooling.

Recommendations for Climate Consultant Design Guidelines Page

Final Design Recommendations for Mumbai



Final Recommendations for a High Performance Office

Mumbai (Hot Humid Climate)

Based on our study, the following are the final recommendations for high performance offices in the hot humid climate of India.

1 **Orient** the building with longer North and South facades and reduce the west and east exposure.

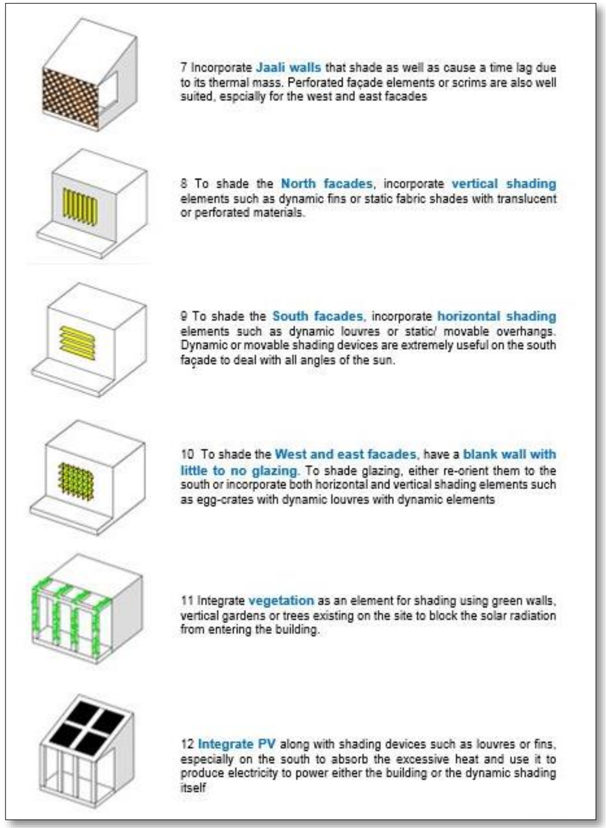
2 Maintain **a window to wall ratio** of 20 - 30% on the north. 30 to 50% on the south and 0 to 20% on the west and east facades to minimize heat gain while maximizing daylight.

3 Incorporate façade **elements that self-shade** such as recessed windows, articulated cladding materials or roof overhangs or building offsets that create mutual shading of built spaces.

4 Use only **light colored or reflective materials** that reflect the sunlight instead of absorbing it.

5 Incorporate either **central or external courtyards**, especially on the south for shading the surrounding built spaces and delaying heat gain while ensuring daylight and cross ventilation.

6 Create **buffer spaces** by having balconies, terraces, second skins or double facades that move the main façade away from direct solar gain. Integrate vegetation within these buffer spaces.



7 Incorporate **Jaali walls** that shade as well as cause a time lag due to its thermal mass. Perforated façade elements or scrims are also well suited, espcially for the west and east facades

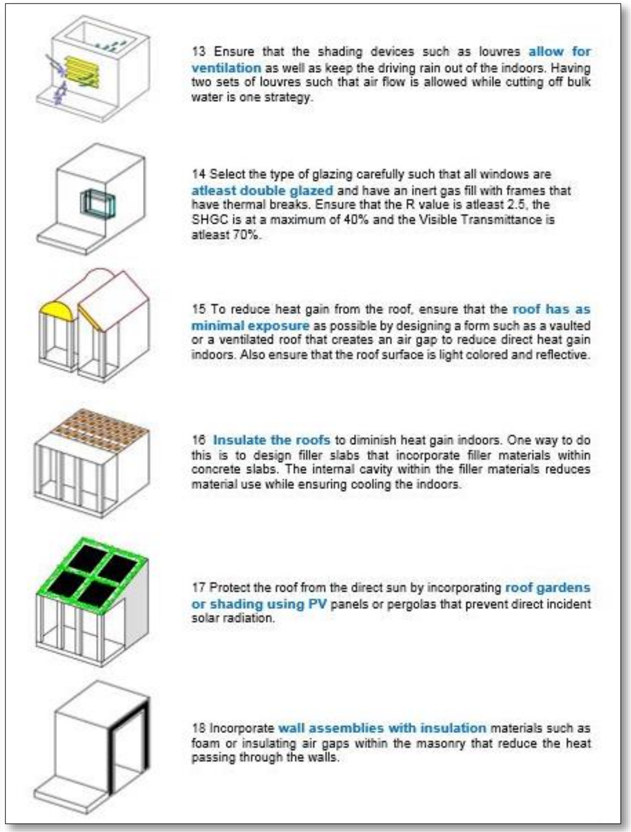
8 To shade the **North facades**, incorporate **vertical shading** elements such as dynamic fins or static fabric shades with translucent or perforated materials.

9 To shade the **South facades**, incorporate **horizontal shading** elements such as dynamic louvres or static/ movable overhangs. Dynamic or movable shading devices are extremely useful on the south façade to deal with all angles of the sun.

10 To shade the **West and east facades**, have a **blank wall with little to no glazing**. To shade glazing, either re-orient them to the south or incorporate both horizontal and vertical shading elements such as egg-crates with dynamic louvres with dynamic elements

11 Integrate **vegetation** as an element for shading using green walls, vertical gardens or trees existing on the site to block the solar radiation from entering the building.

12 **Integrate PV** along with shading devices such as louvres or fins, especially on the south to absorb the excessive heat and use it to produce electricity to power either the building or the dynamic shading itself



13 Ensure that the shading devices such as louvres **allow for ventilation** as well as keep the driving rain out of the indoors. Having two sets of louvres such that air flow is allowed while cutting off bulk water is one strategy.

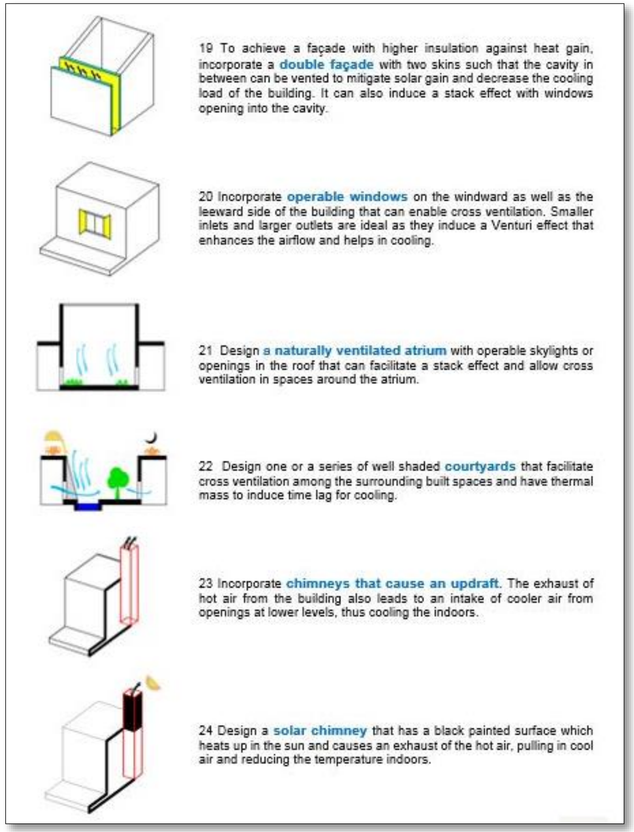
14 Select the type of glazing carefully such that all windows are **atleast double glazed** and have an inert gas fill with frames that have thermal breaks. Ensure that the R value is atleast 2.5, the SHGC is at a maximum of 40% and the Visible Transmittance is atleast 70%.

15 To reduce heat gain from the roof, ensure that the **roof has as minimal exposure** as possible by designing a form such as a vaulted or a ventilated roof that creates an air gap to reduce direct heat gain indoors. Also ensure that the roof surface is light colored and reflective.

16 **Insulate the roofs** to diminish heat gain indoors. One way to do this is to design filler slabs that incorporate filler materials within concrete slabs. The internal cavity within the filler materials reduces material use while ensuring cooling the indoors.

17 Protect the roof from the direct sun by incorporating **roof gardens or shading using PV** panels or pergolas that prevent direct incident solar radiation.

18 Incorporate **wall assemblies with insulation** materials such as foam or insulating air gaps within the masonry that reduce the heat passing through the walls.



19 To achieve a façade with higher insulation against heat gain, incorporate a **double façade** with two skins such that the cavity in between can be vented to mitigate solar gain and decrease the cooling load of the building. It can also induce a stack effect with windows opening into the cavity.

20 Incorporate **operable windows** on the windward as well as the leeward side of the building that can enable cross ventilation. Smaller inlets and larger outlets are ideal as they induce a Venturi effect that enhances the airflow and helps in cooling.

21 Design **a naturally ventilated atrium** with operable skylights or openings in the roof that can facilitate a stack effect and allow cross ventilation in spaces around the atrium.

22 Design one or a series of well shaded **courtyards** that facilitate cross ventilation among the surrounding built spaces and have thermal mass to induce time lag for cooling.

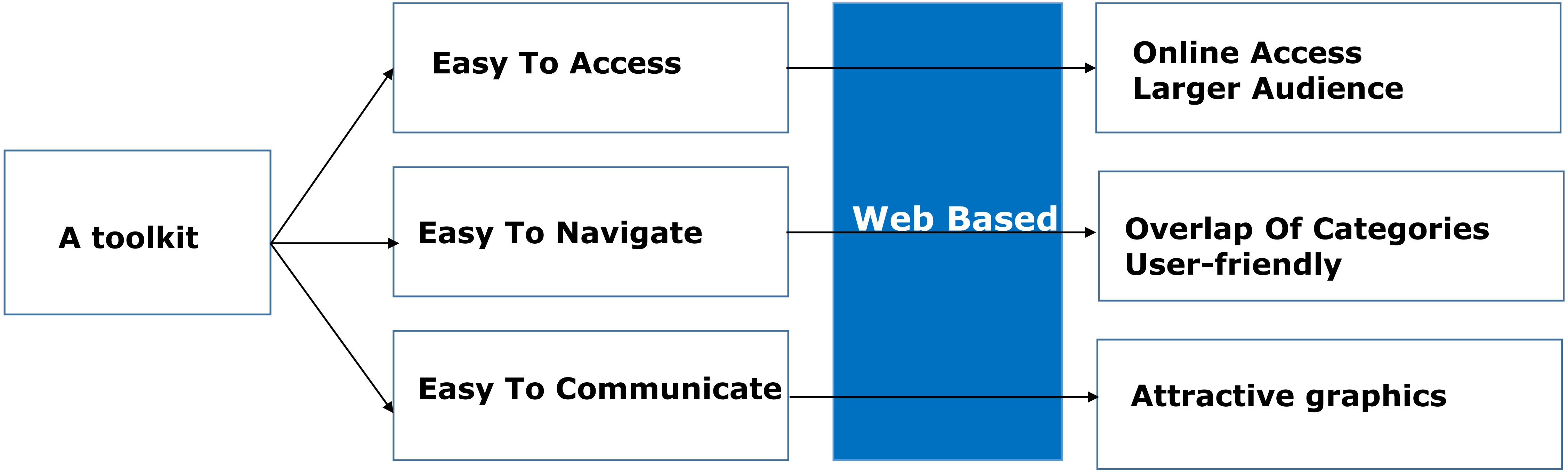
23 Incorporate **chimneys that cause an updraft**. The exhaust of hot air from the building also leads to an intake of cooler air from openings at lower levels, thus cooling the indoors.

24 Design a **solar chimney** that has a black painted surface which heats up in the sun and causes an exhaust of the hot air, pulling in cool air and reducing the temperature indoors.

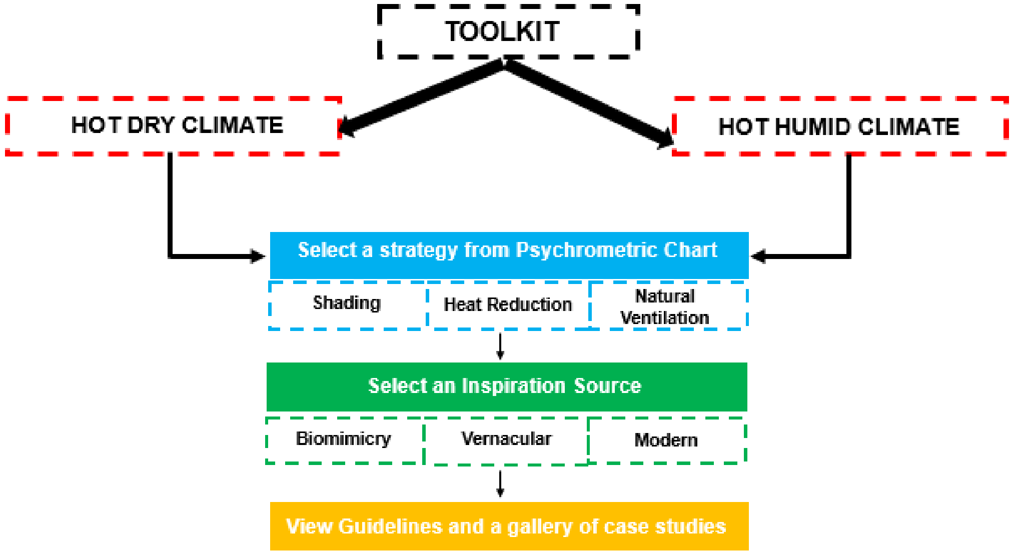
Recommendations for Climate Consultant Design Guidelines Page

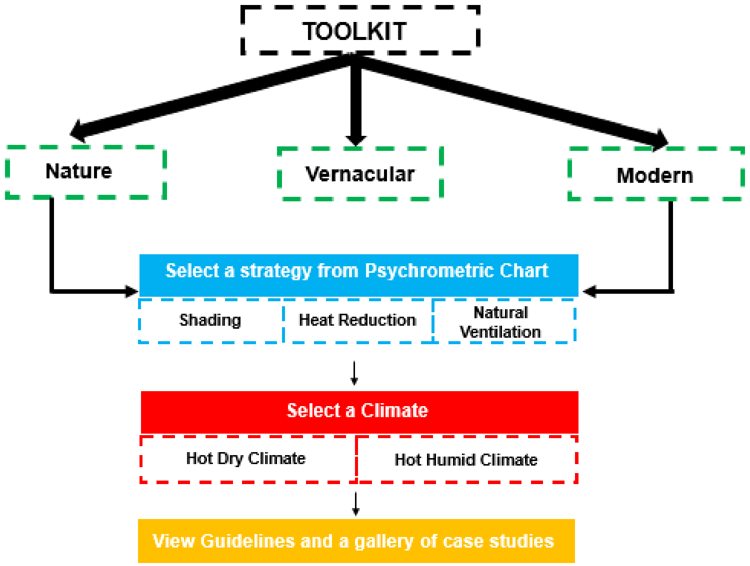
1st Aug 2016

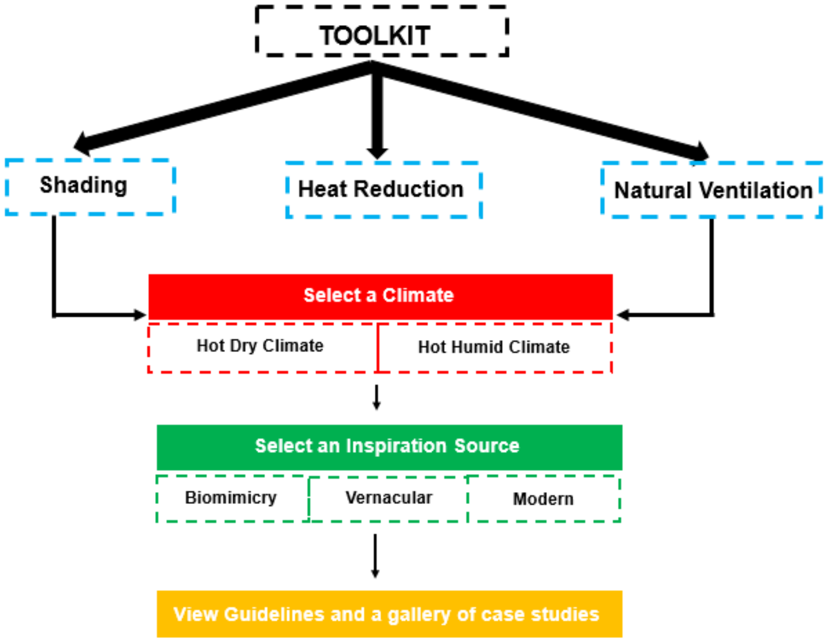
A Toolkit to Encourage High performance Offices in India

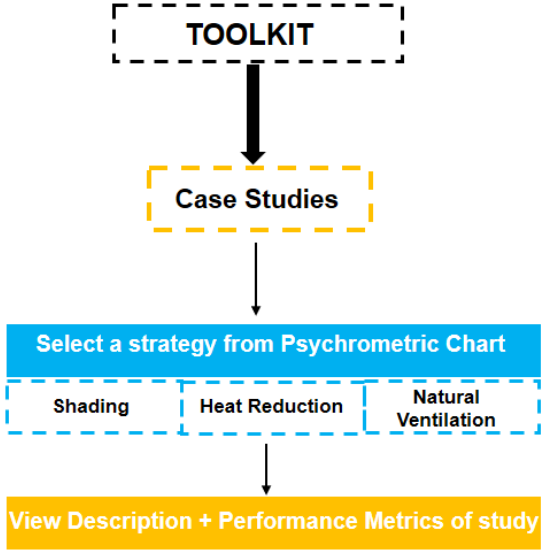


Navigation Flows for the Web Based Toolkit



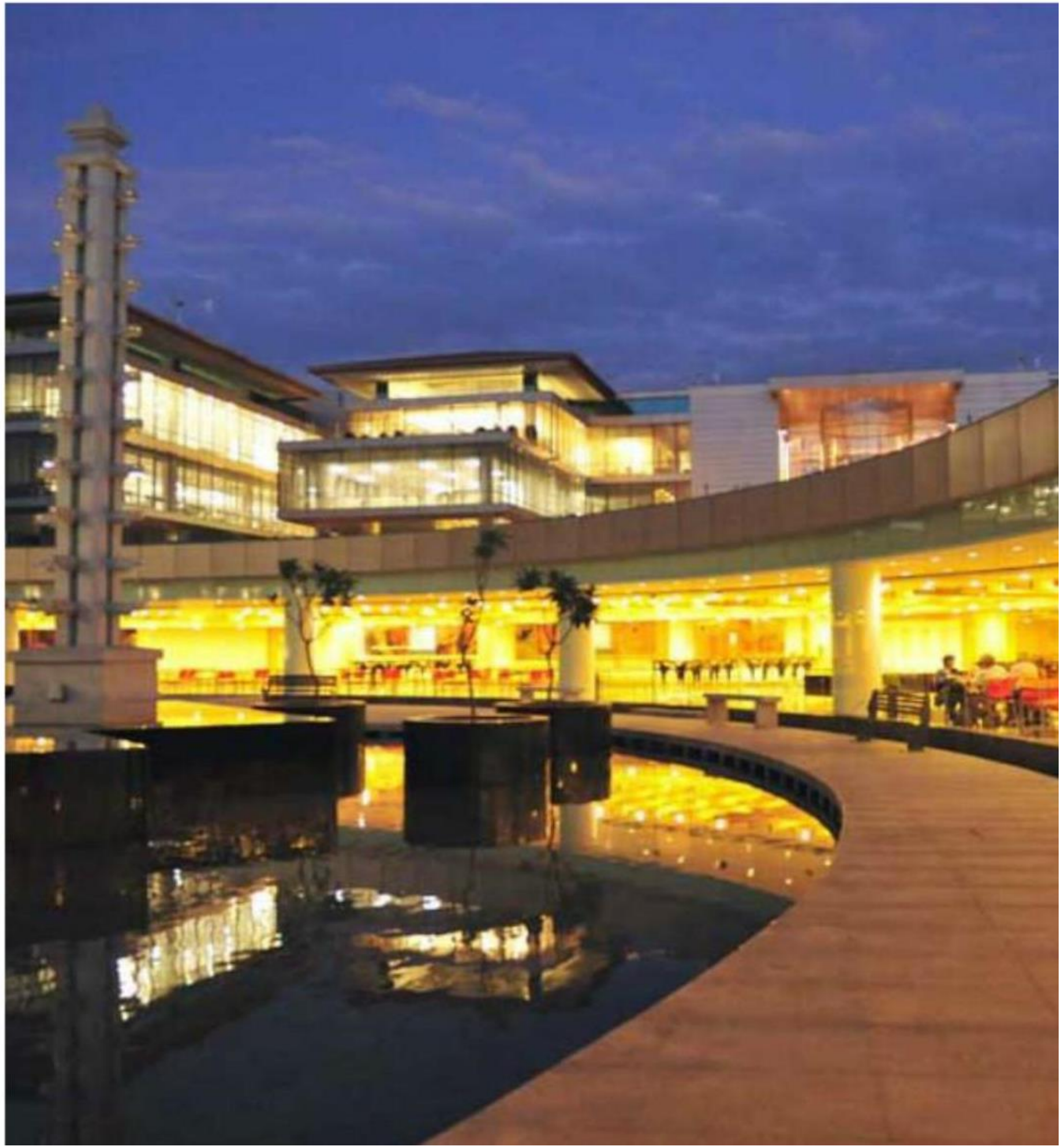






Future Work

- Energy Simulation of selected strategies
- Extending guidelines to more climate zones
- Adding more case studies to database
- Updating the toolkit for more cities in India
- Making the toolkit accessible to as many designers and building owners as possible



An Adaptive and Dynamic Design Approach for Natural Conditioning of Offices in Hot Climates of India

THANK YOU

Any questions?

Radhna Saxena | Krupa Patel

Advisors: Vivian Loftness | Erica Cochran | Dana Cupkova

Image Courtesy: mysore.nic.in, integritusprime.com, e-architect.co