Thermal Comfort

Projects and Perspectives

CSE Conclave on Green Architecture | New Delhi

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DV Residence

Thermal Comfort Design Assistance

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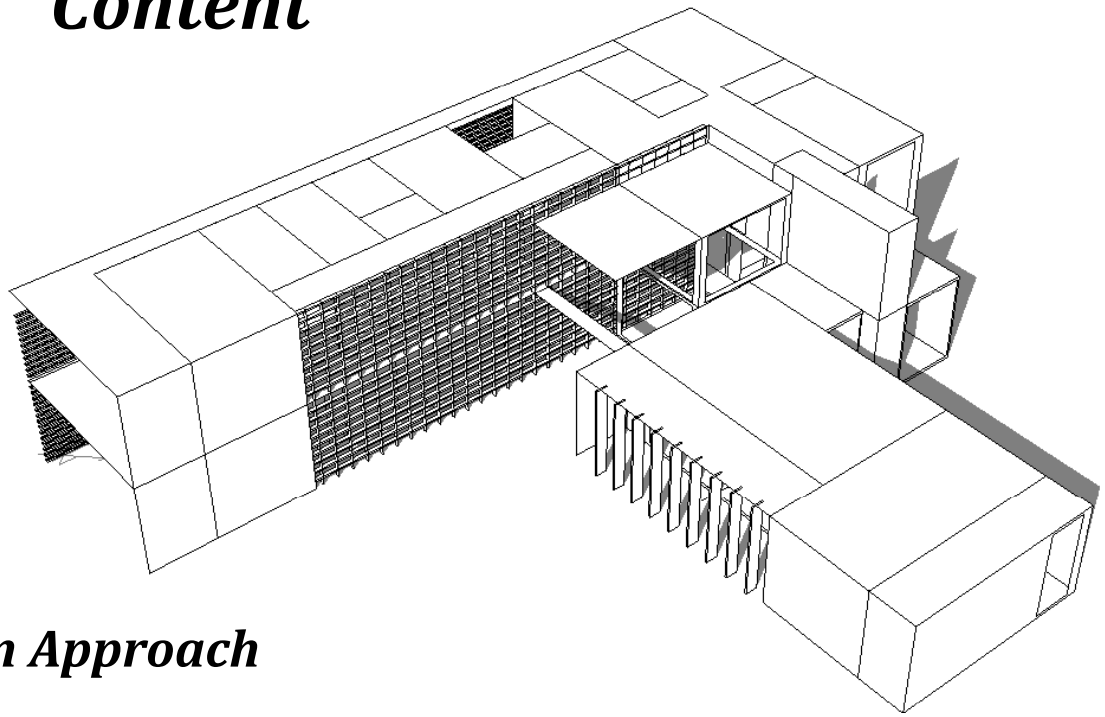

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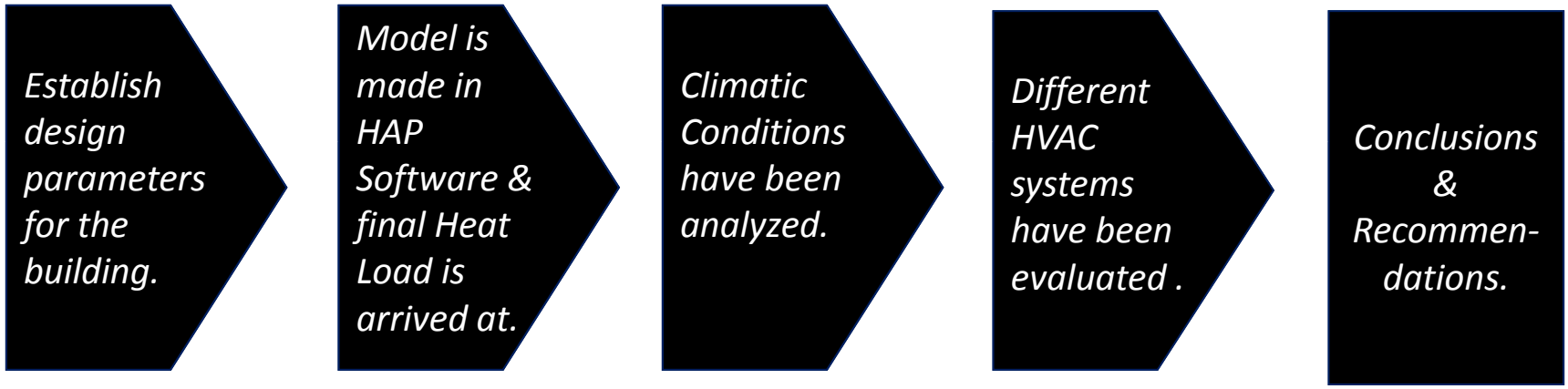
Introduction

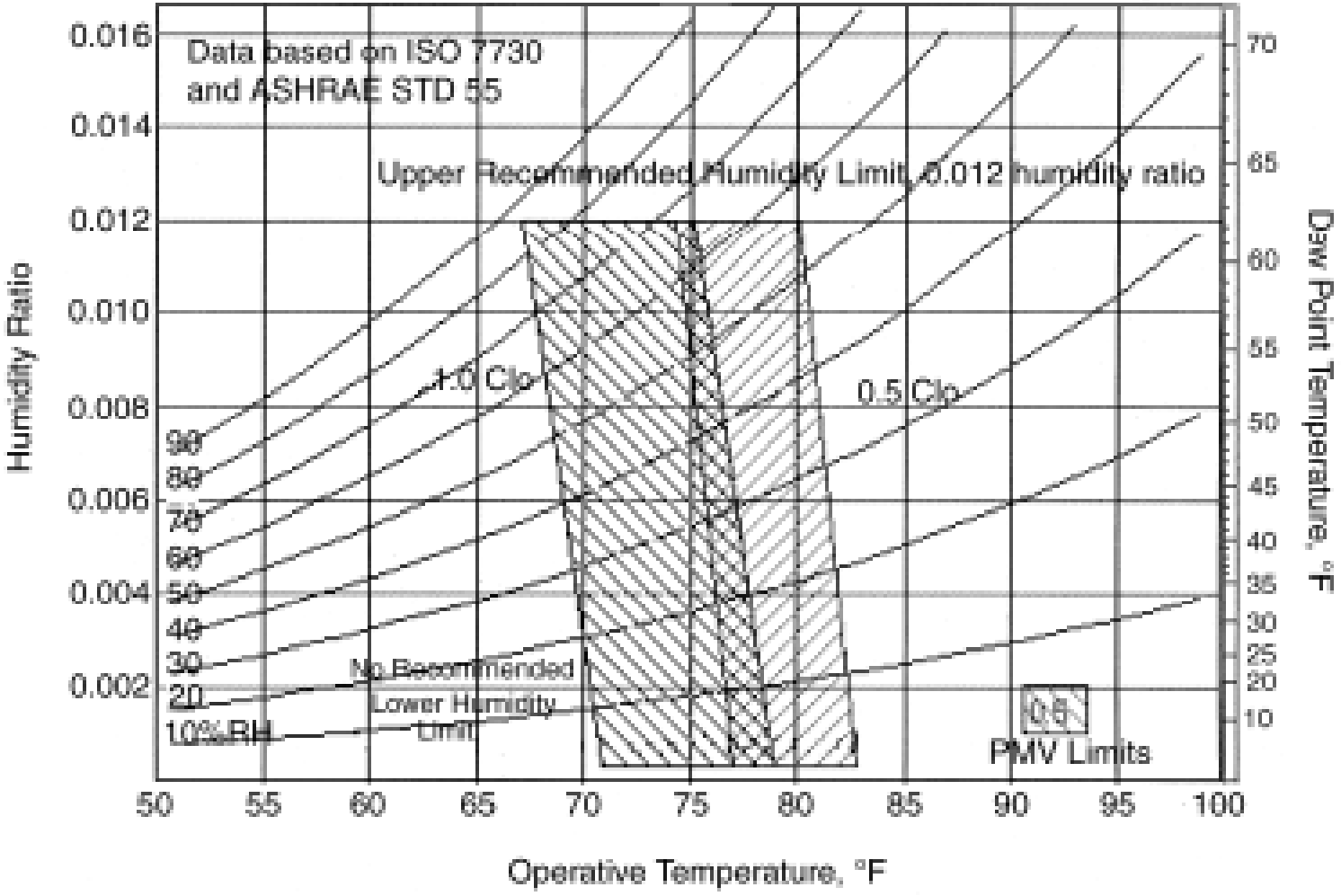
Objective of Study

To evaluate design options to achieve thermal comfort throughout the year with the lowest environmental impact and ensures energy efficiency.

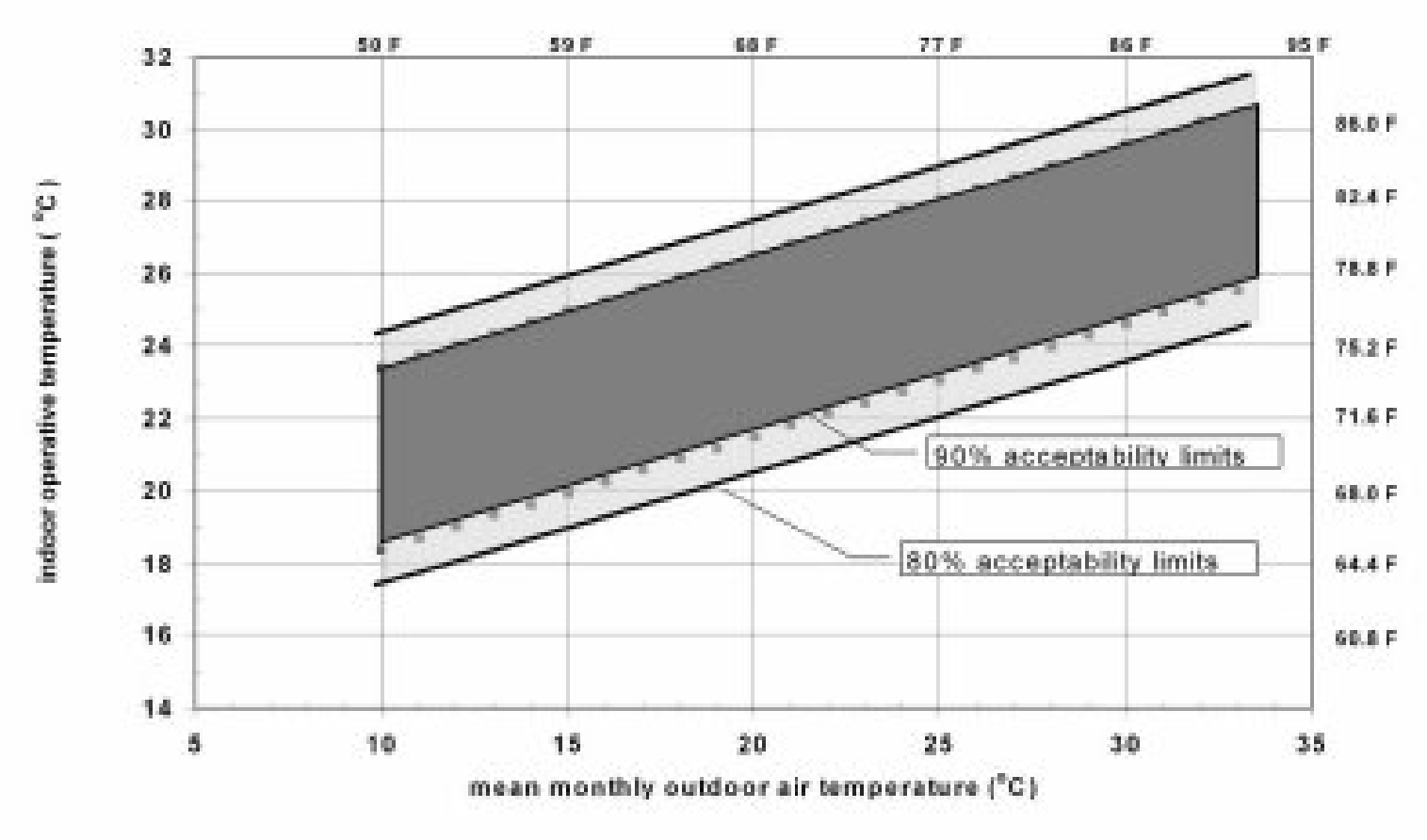
Analysis Methodology



What is Thermal Comfort ???



Understanding Comfort

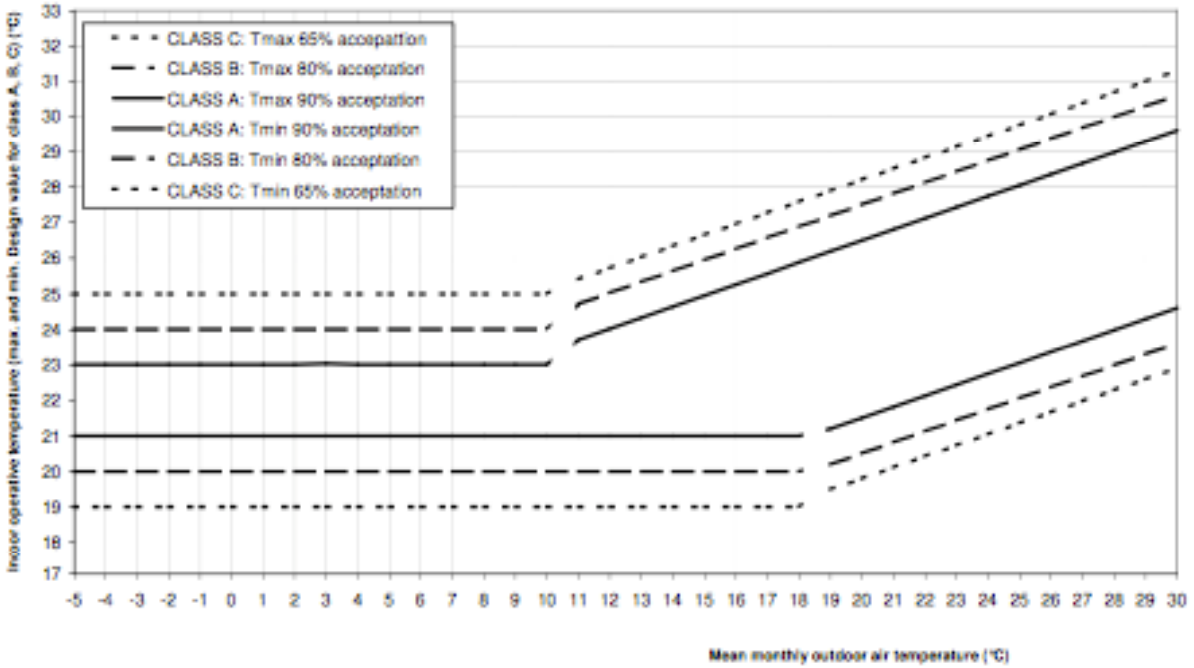


Mean monthly temperature for the peak month = 33 deg C.

Indoor operative temperature = 25–26 deg C

90% of the occupants that are in acceptability limit.

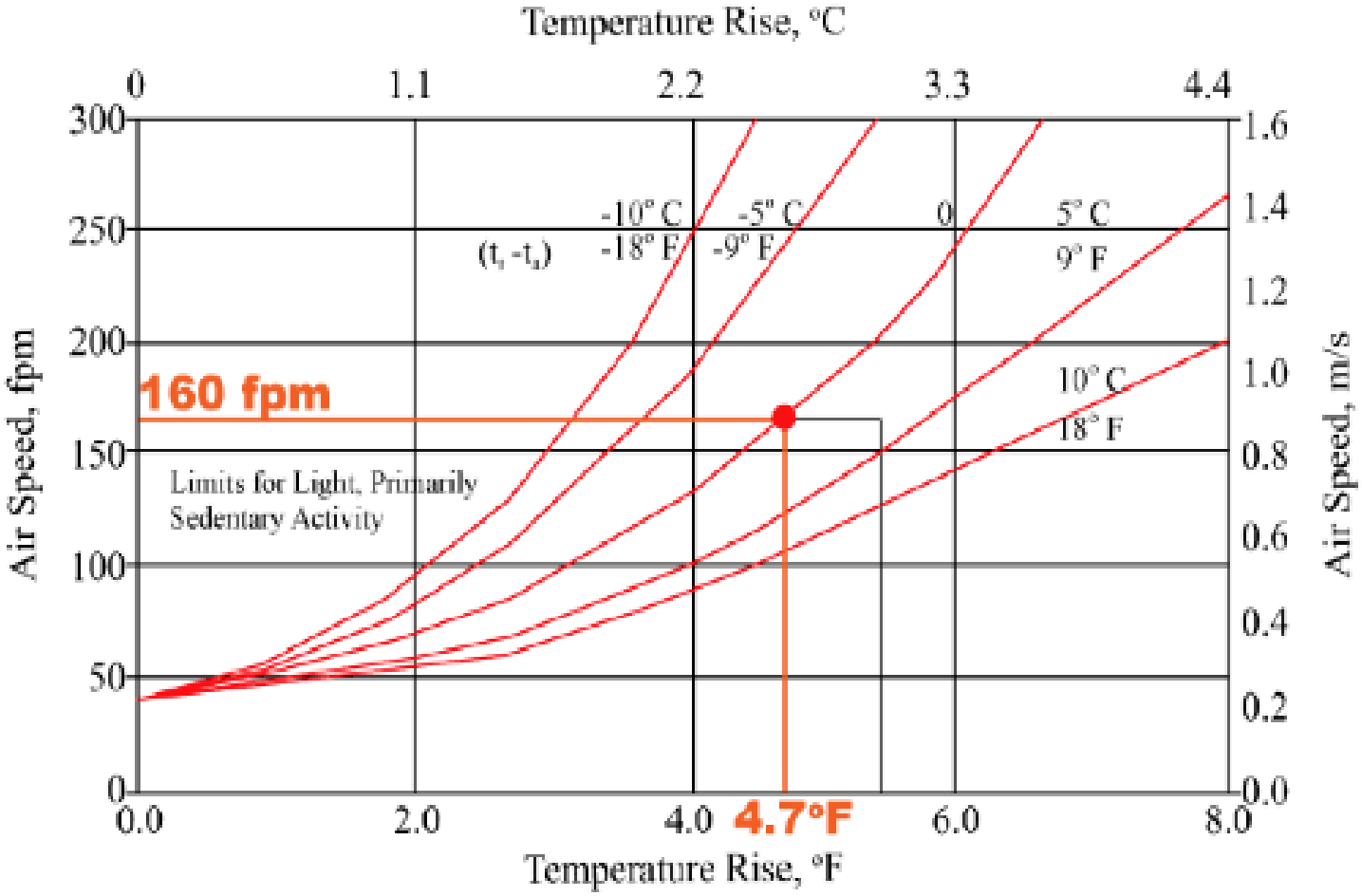
New Adaptive Comfort Model



Class A:	upper limit (warm season):	$T_{i\ max} = 17{,}8+2{,}5+(0{,}31\ T_o)$	(1a)
	lower limit (warm season):	$T_{i\ min} = 17{,}8\ -2{,}5+(0{,}31\ T_o)$	(1b)
Class B:	upper limit (warm season):	$T_{i\ max} = 17{,}8+3{,}5+(0{,}31\ T_o)$	(1c)
	lower limit (warm season):	$T_{i\ min} = 17{,}8-3{,}5+(0{,}31\ T_o)$	(1d)
Class C:	upper limit (warm season):	$T_{i\ max} = 17{,}8+4{,}2+(0{,}31\ T_o)$	(1e)
	lower limit (warm season):	$T_{i\ min} = 17{,}8-4{,}2+(0{,}31\ T_o)$	(1f)

where T_i = acceptable indoor temperature,
T_o = mean monthly outdoor temperature, °C

Impact of Air Flow



The combination of the air speed and the temperature defined by the lines is given in this figure results in the same heat loss from the skin.

Elevated air speed may be used to offset the rise in temperature and the mean radiant temperature.

Design parameters & Cooling Loads

Design Parameters for Air Conditioned systems

Ambient Conditions

Outdoor	DB (ºC)	WB (ºC)	RH (%)
Summer	42.2	23.3	23
Monsoon	32.2	29.4	82
Winter	11.1	7.8	65

Indoor Design Conditions

Space	Temp (Deg. C)	RH (%)
Bedroom	24° C ± 1° C	< 60
Lobby Area	25° C ± 1° C	< 65
Kitchen and Utility	28° C ± 1° C	< 65
Drawing/Dining	24° C ± 1° C	< 60
Fitness	24° C ± 1° C	< 60
Corridors	28° C ± 1° C	< 65
Home Cinema	24° C ± 1° C	< 60

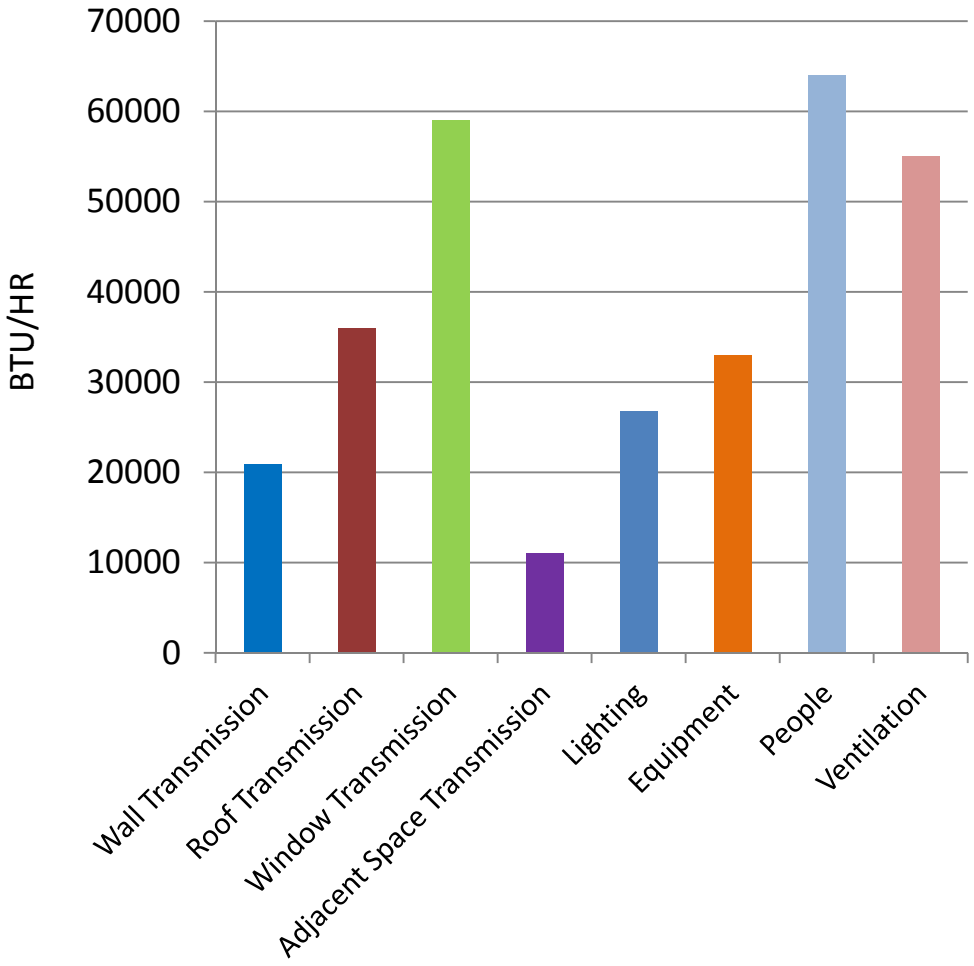
Indoor Design Parameters

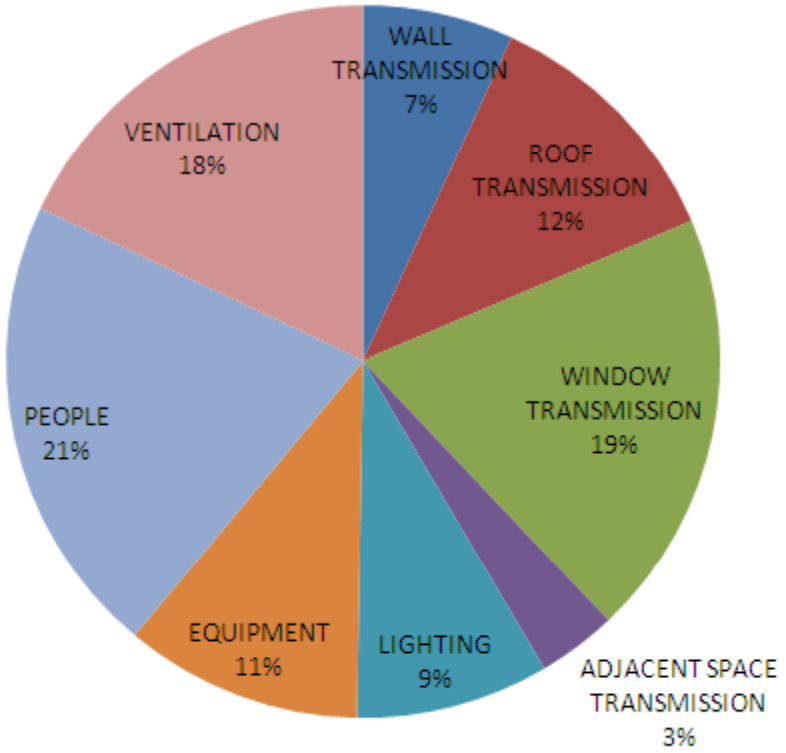
Space	Occupancy (Nos.)	Lighting Load (Watts / sq ft)	Equipment Load (Watts / sq ft)
Bedroom	2	1.5	1
Lobby Area	1	1	0.5
Kitchen and Utility	3	1.5	3
Drawing/Dining	25	1.5	1
Fitness	8	1	1.5
Corridors	---	1	0.5
Home Cinema	22	0.5	2

Building Envelope Parameters

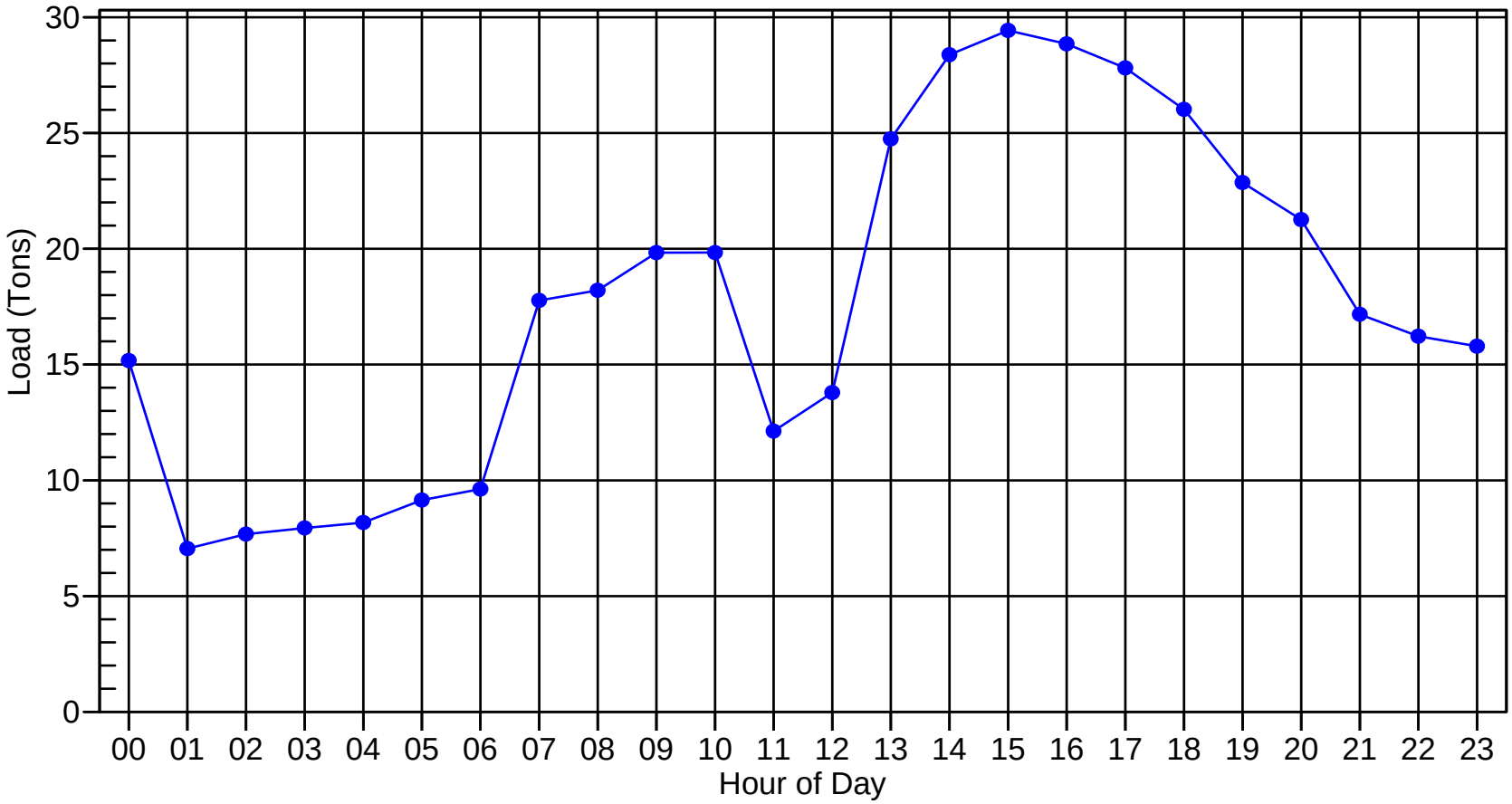
	Proposed	As per ECBC	Comments
U Value of Wall (Btu/Hr Sft F)	0.23	0.077	Proposed Case U value > ECBC value 2" Insulation should be considered for Energy efficient design
U Value of Roof (Btu/Hr Sft F)	0.1	0.045	Proposed Case U Value > ECBC value 3" insulation should be considered instead of 1" insulation with 1' soil.
U Value of Glass (Btu/Hr Sft F)	1.1	0.6	Proposed Case U value > ECBC value Double glazing could be considered.
SHGC (Solar Heat Gain Coefficient) (Solar factor)	0.65	0.25	Proposed Case SHGC Value > ECBC value The glass should be double glass wherever the shading is not used.

Energy End Use : Proposed Case



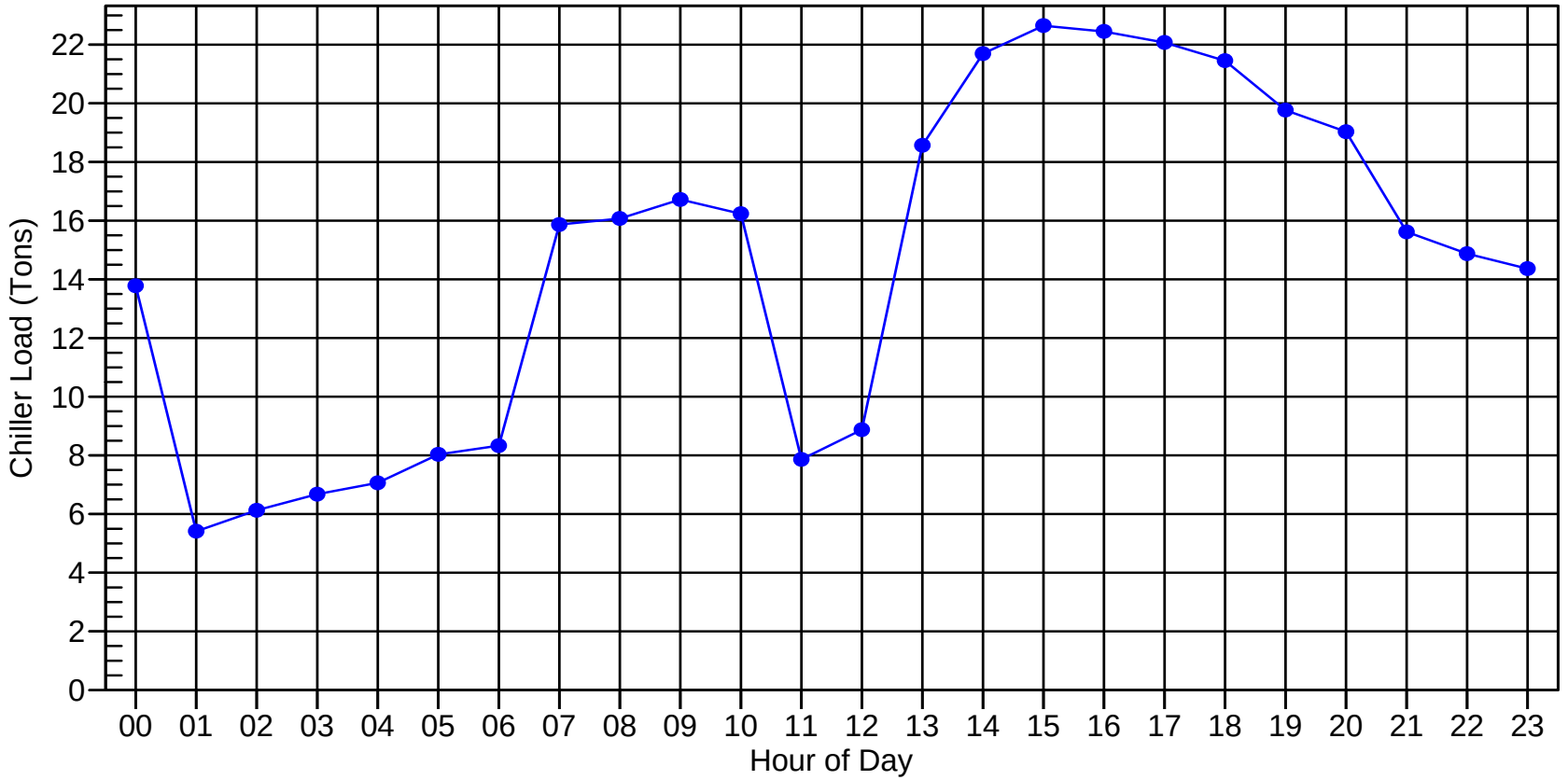


Cooling Peak Load as per Design Conditions



The peak load has decreased from 35 TR to 29 TR after the revised envelope materials.

Cooling Peak Load as per ECBC recommendations



Peak load reduces to **22.5 TR** from **29 TR,** resulting in reduction of capital and running cost for the system.

ECBC Recommendations:

Walls - 2 inch XPS Insulation

Roof - 3 inch XPS Insulation

Window - Double glazed windows with 0.25 SHGC.

Thermal Comfort Design

Thermal Comfort Design Approach

Step 1:

Different Climatic segments

Step 2:

Each Climatic segment has been studied for:

1. *Temperature (Dry bulb) (deg C)*
2. *Relative Humidity (RH) %*
3. *Solar Radiation / Sky Coverage*
4. *Wind Velocity (m/s)*
5. *Ground Temperature*

Step 3:

APPROPRIATE Strategies for each Climate Segment

ARCHITECTURE/ DESIGN	PASSIVE SYSTEM	ACTIVE SYSTEM

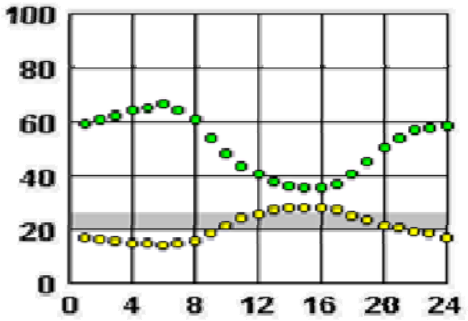
Step 4:

Recommendation of APPROPRIATE system design

Climate Segment 1

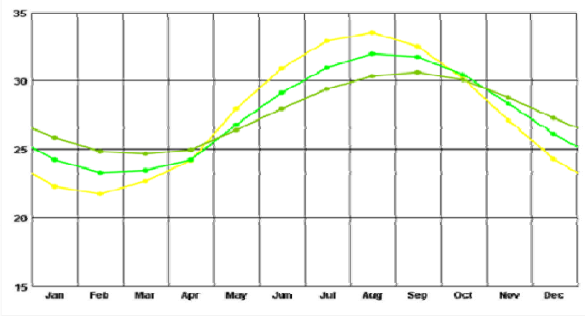
Weather Characteristics

DB Temp / RH



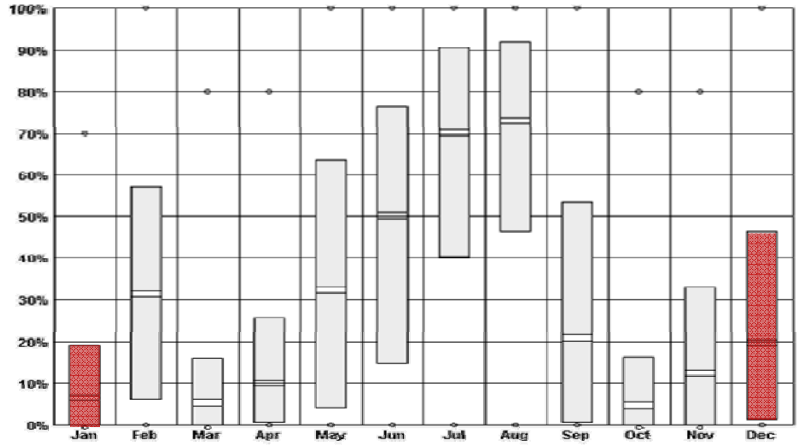
RH
DB Temp

Ground Temperature



0.5 m depth
2m depth
4 m depth

Sky Cover Range



DEC- JAN

Temperature is just below the comfort zone most of the time.
Day time, DB Temp. can go up to 28 deg C in the afternoon but will be comfortable due to low RH at this temperature.

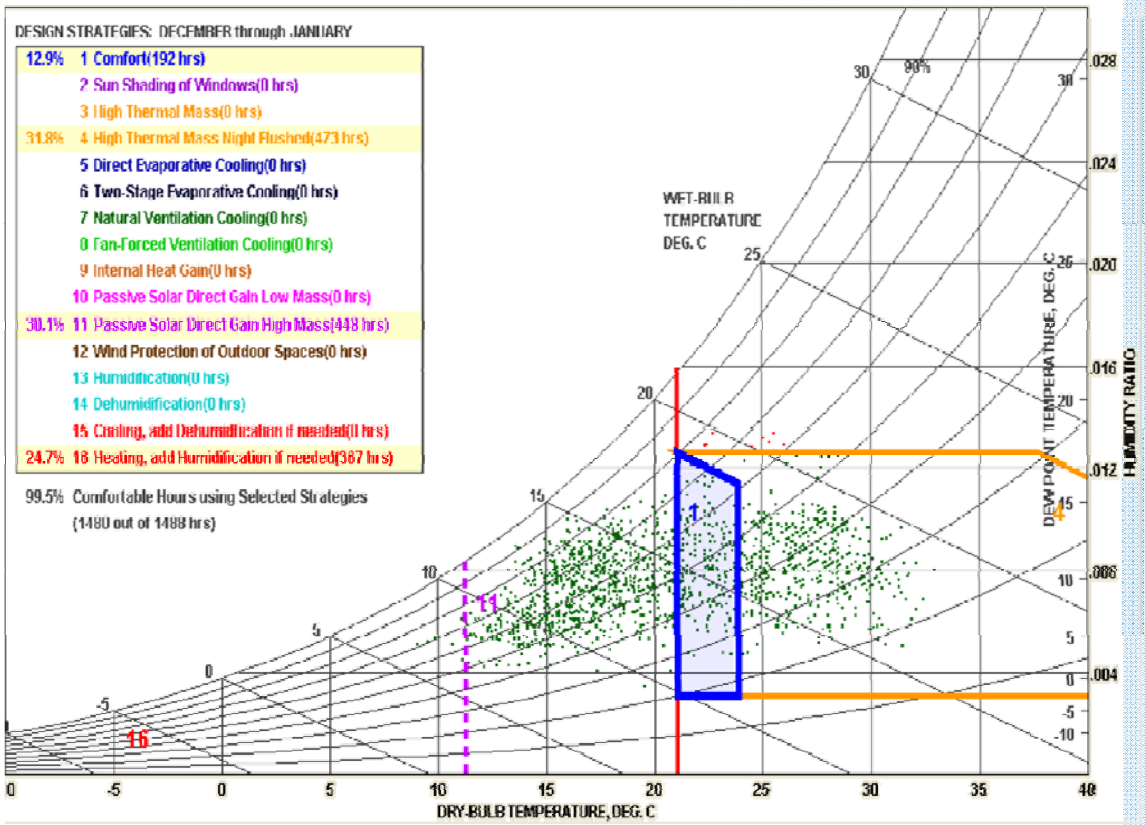
Sky cover
January : 20% - More solar radiation.
December : 46% - Less solar radiation.

Wind Velocity
Highest wind velocity : 7 meter/sec
The mean is around 2 meter/sec.

Ground Temperature
Max ground temp. = 26 deg C
Mean ground temp. = 27.5 deg C
When the outside temp. is as low as 15 deg C the ground temp. is at 26 deg C.
Difference in outdoor temp. and ground temp. is around 12-13 deg C.

Climate Segment 1

Thermal Comfort Strategies



DEC- JAN

Architectural elements

The Insulation on walls and roof is required to store the internal heat gain.

Passive System

Ground temperature is high as compared to the ambient conditions.

Earth Air Tunnels: Supply air temperature at 20-22 deg C.

Solar green house : Heat trapped and reflected in the space through the use of glasses.

Active Systems

Options to meeting heating requirements:

Geothermal Heat Pump

VRV Heat pump

Solar heat collected from the heat extractors used as the radiation is high in these months.

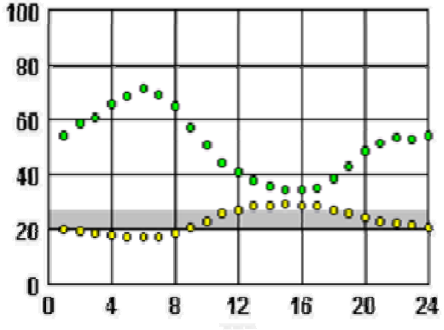
Radiant cooling Systems

Under floor air distribution system

Climate Segment 2

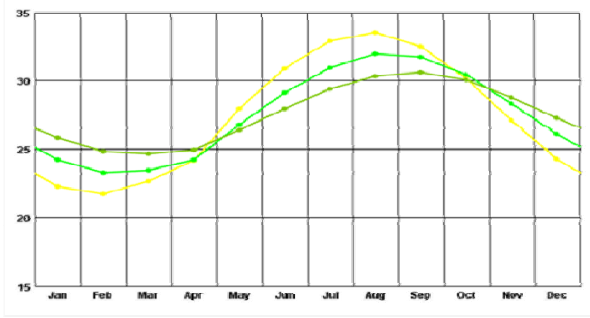
Weather Characteristics

DB Temp / RH



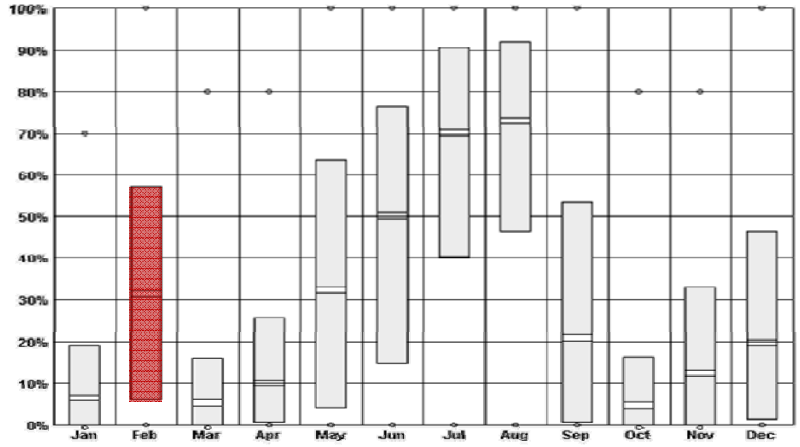
RH
DB Temp

Ground Temperature



0.5 m depth
2m depth
4 m depth

Sky Cover Range



FEBRUARY

Temperature is just below or in the comfort zone at night time and late evening.
Day time DB Temperature: 32 deg C in the afternoon but will be comfortable due to low RH at this Temperature.

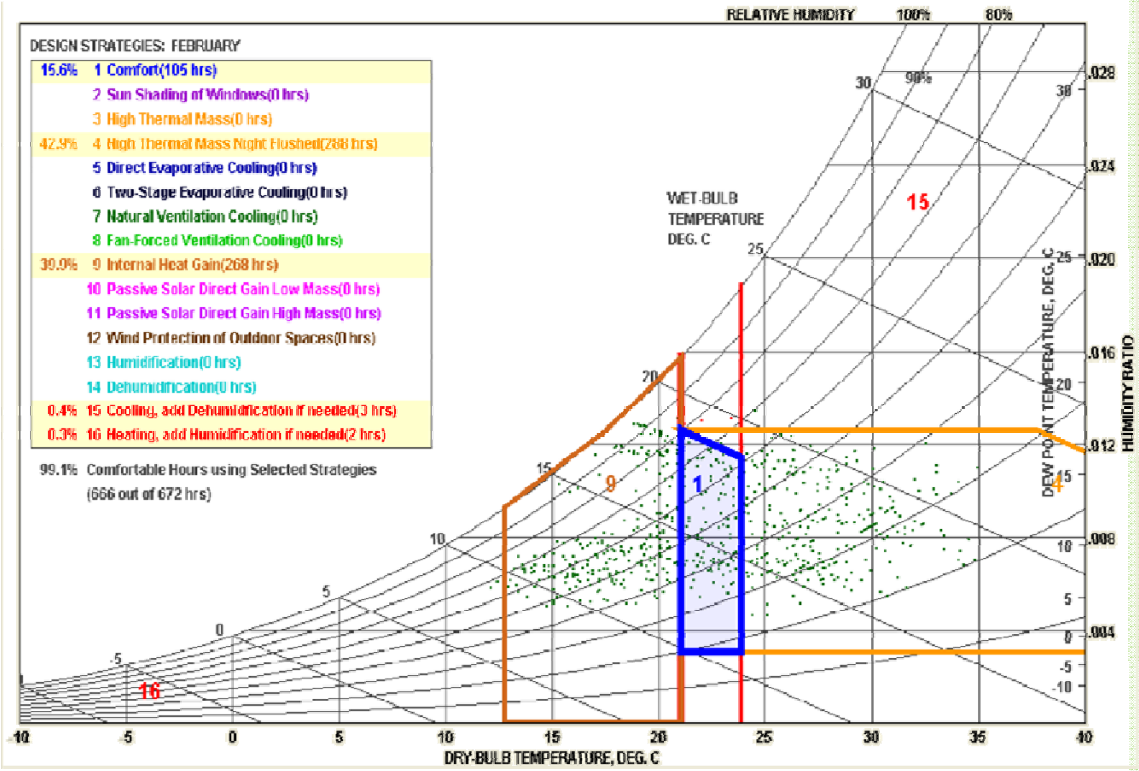
Sky cover
57% - Less solar radiation.

Wind Velocity
Highest wind velocity : 8 meter/sec (uncomfortable during day)
Mean is 2 meter/sec.

Ground Temperature
Max ground temp. = 25 deg C
Mean ground temp. = 27.5 deg C
Difference in outdoor temp. and ground temp. is around 7-8 deg C.

Climate Segment 2

Thermal Comfort Strategies



FEBRUARY

Architectural elements

Shading is not required.

Insulation is recommended on walls and roof to store the internal heat gain.

Passive System

The use of Earth Air Tunnels to supply air at temperature 20-22 deg C.

Daytime : Natural Ventilation through open able windows.

Active Systems

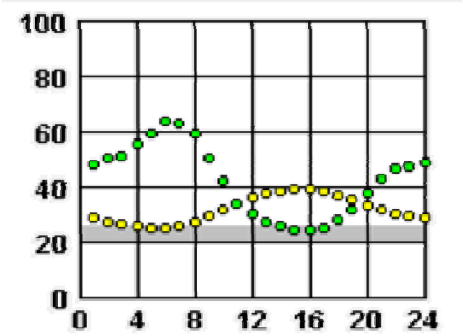
Heating is required for few days at night and cooling is required for few hours at daytime.

1. Geothermal Heat Pump Can be used.
2. VRV Heat pump can be used.
3. Solar heat collected from the heat extractors can be used as the radiation is high in these months.
4. Radiant cooling Systems
5. Under-floor air distribution system.

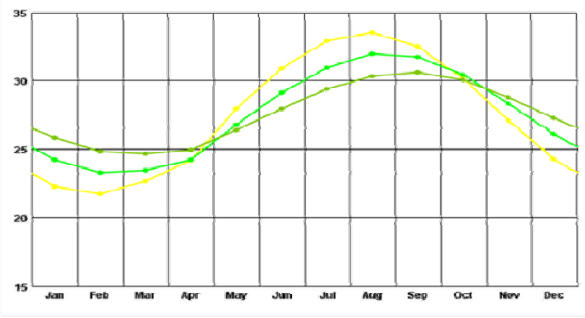
Climate Segment 3

Weather Characteristics

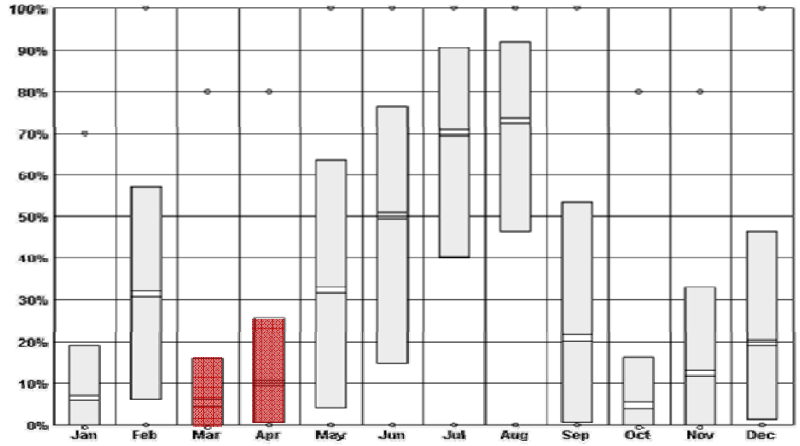
DB Temp / RH



Ground Temperature



Sky Cover Range



MAR - APR

Temperature is above comfort zone at day time.
Day time, DB Temp. can go up to 40 deg C which would be uncomfortable.

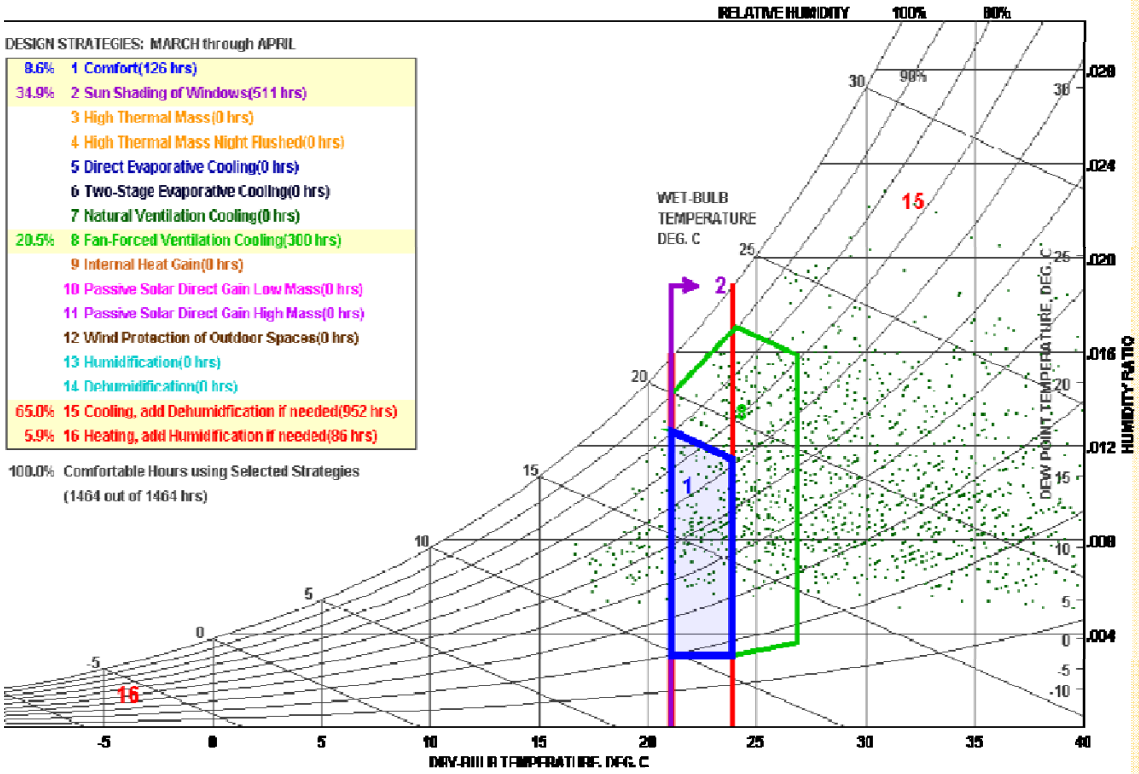
Sky cover
16-25% - Good Sunlight

Wind Velocity
Highest wind velocity : 8-10 m/s
Mean = 2-3 m/s

Ground Temperature
Max ground temp. = 25 deg C
Mean ground temp. = 27.5 deg C
When the outside temp. is as high as 40 deg C the ground temp. is at 25 deg C.
Difference in outdoor temp. and ground temp. is around 15 deg C.

Climate Segment 3

Thermal Comfort Strategies



MAR - APR

Architectural elements

Shading on windows and Insulation on roof

Passive System

Night flushing for the daytime cooling, Ceiling Fans

Active Systems

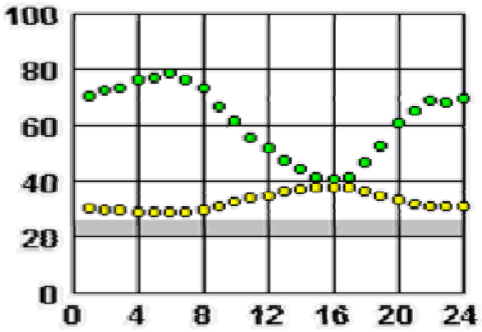
Cooling is required in the daytime and night time of April.

1. Geothermal Heat Pump Can be used.
2. Vapour absorption machine can be coupled with the solar hot water through the solar extractors can be used.
3. Water cooled VRV technology can be used.
4. Chilled water system by water cooled scroll chillers.
5. Chilled water system by air cooled scroll chillers.
6. Radiant cooling Systems
7. Under-floor air distribution system
8. Air cooling system by two stage air washers.

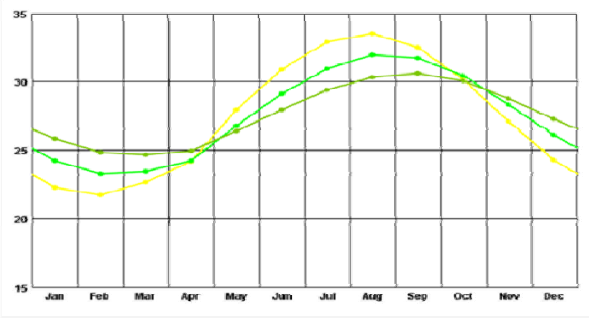
Climate Segment 4

Weather Characteristics

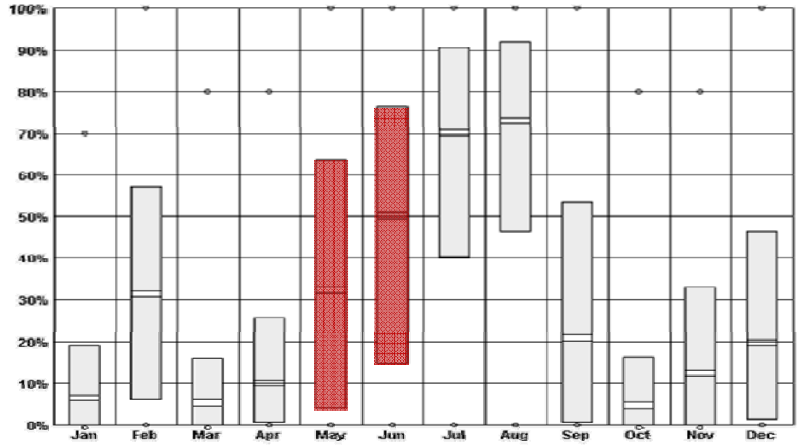
DB Temp / RH



Ground Temperature



Sky Cover Range



MAY - JUN

Temperature is above comfort zone for all 24 hours.
DB Temp. above 40 deg C, RH 40-42%
Uncomfortable due to high DB Temp.

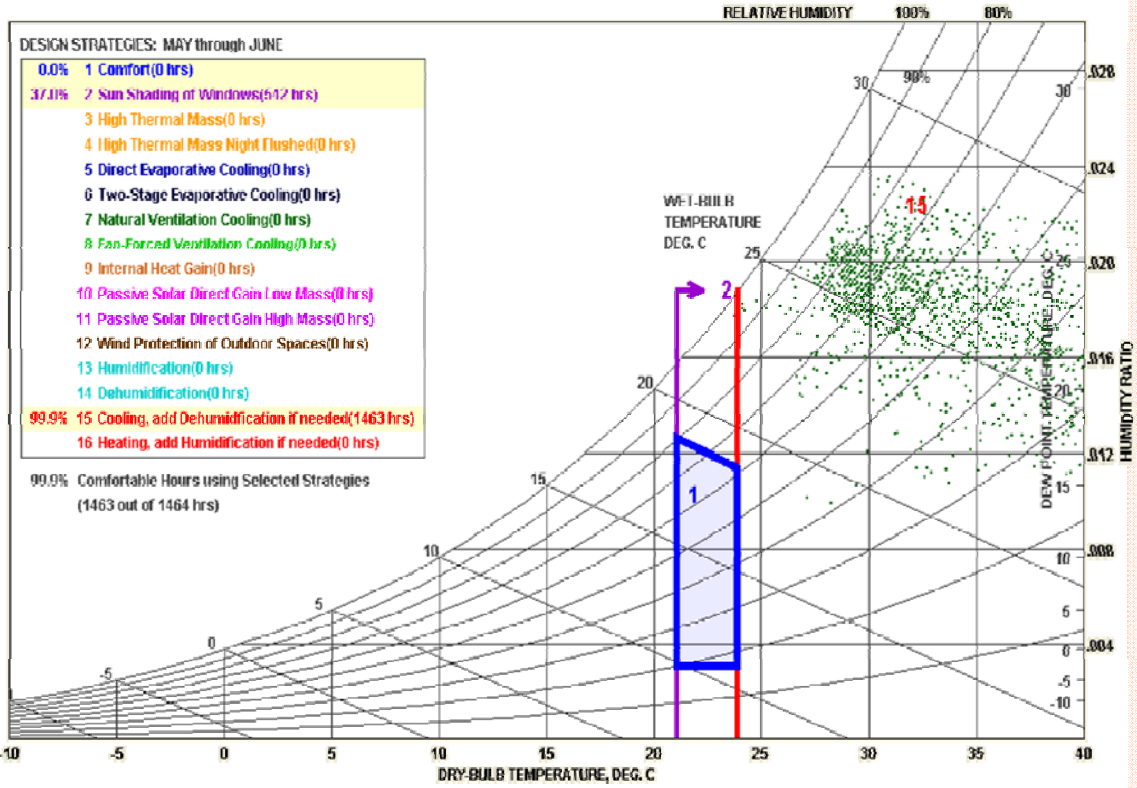
Sky cover
60-75% - Less intensity of sun.

Wind Velocity
Highest wind velocity : 8-9 m/s
Mean = 4 m/s
Uncomfortable in afternoon & evening.

Ground Temperature
Max ground temp. = 25-27 deg C
Mean ground temp. = 27.5 deg C
When the outside temp. is as high as 42 deg C the ground temp. is at 25 deg C.
Difference in outdoor temp. and ground temp. is around 15 deg C.

Climate Segment 4

Thermal Comfort Strategies



MAY - JUN

Architectural elements

Window Shading is recommended.

Insulation on wall and roof is required.

Passive System

The ambient temp is high 24 hours.

The ground temp is at around 25 degC.

Use of Earth Air Tunnels to lower the air temperature to 29-30 degC. This can be used for reducing the fresh air load for air-conditioning system.

Active Systems

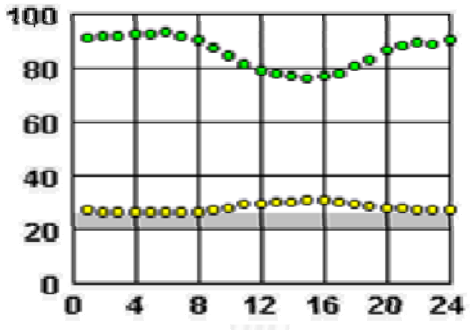
As days and nights are uncomfortable, there is the need of only cooling:

1. Geothermal Heat Pump
2. Vapour absorption machine coupled with the solar hot water through the solar extractors
3. Water cooled VRV technology
4. Chilled water system by water cooled scroll chillers/ air cooled scroll chillers
5. Radiant cooling Systems
6. Under-floor air distribution system
7. Air cooling by two stage washers.

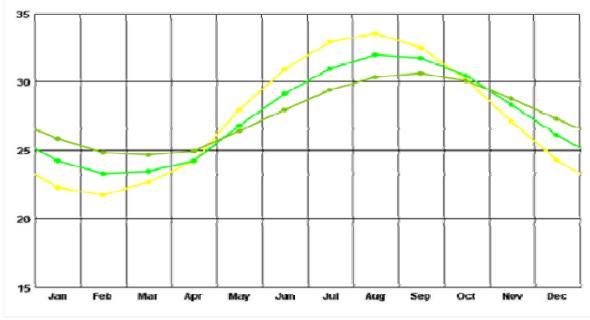
Climate Segment 5

Weather Characteristics

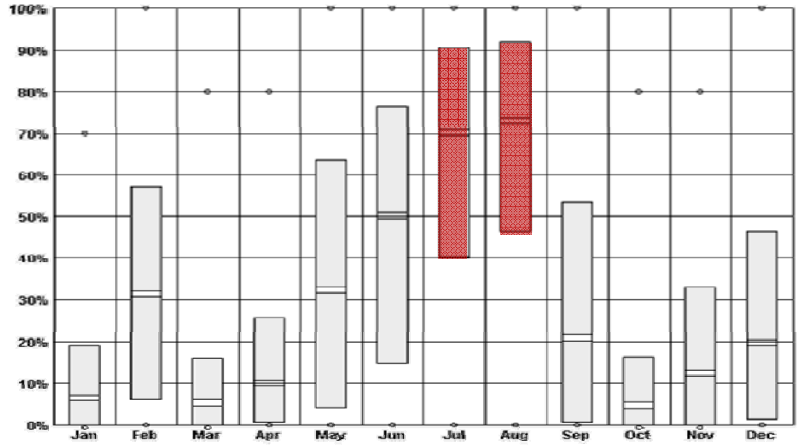
DB Temp / RH



Ground Temperature



Sky Cover Range



JULY - AUG

Temperature is above comfort zone for all 24 hours.
DB Temp. 24-35 deg C, RH 90%
Uncomfortable due to high humidity.

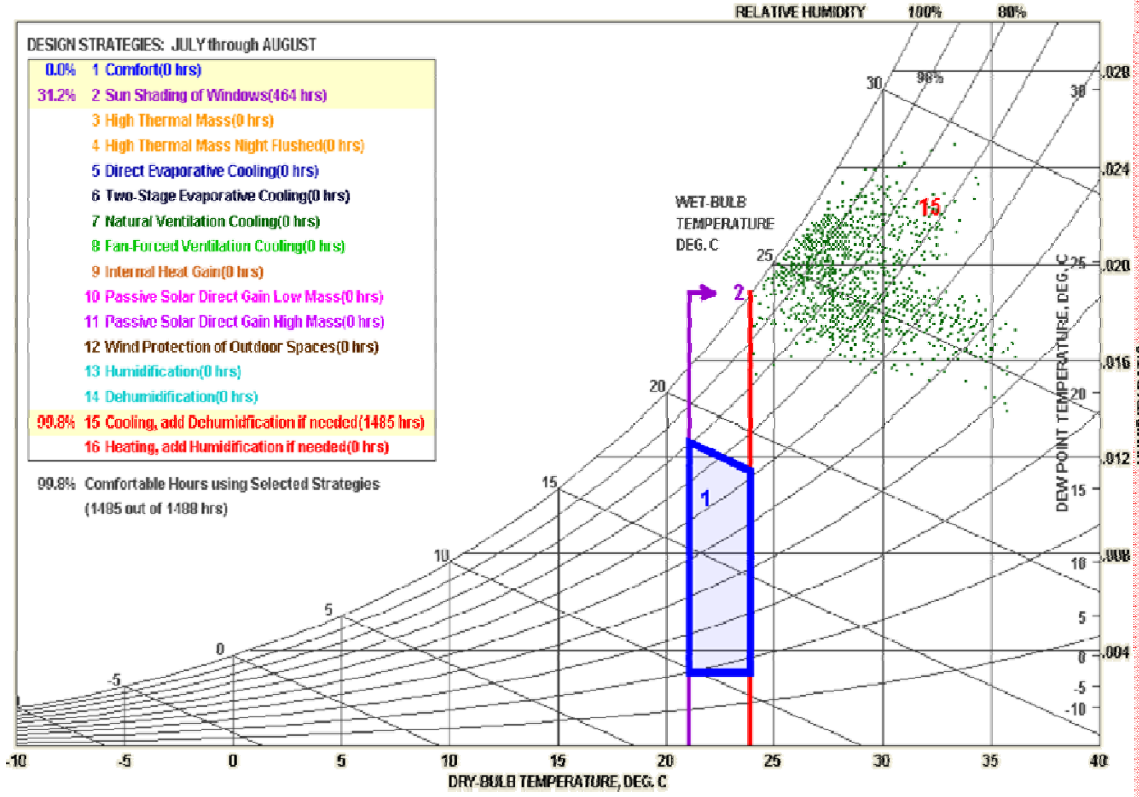
Sky cover
90% - Sunlight intensity is low

Wind Velocity
Highest wind velocity : 6-8 m/s
Mean = 3 m/s
Uncomfortable due to high humidity → Increase air velocity.

Ground Temperature
Max ground temp. = 28-31 deg C
Mean ground temp. = 27.5 deg C .
Difference in outdoor temp. and ground temp. is around 4-7 deg C.

Climate Segment 5

Thermal Comfort Strategies



JULY - AUG

Architectural elements

Window Shading is recommended.
Insulation on roof is required.

Passive System

The ambient temp is high 24 hours.
The ground temp is at around 28 degC.
Use of Earth Air Tunnels to lower the air temperature to 31-33 degC. This can be used for reducing the fresh air load for air-conditioning system.

Active Systems

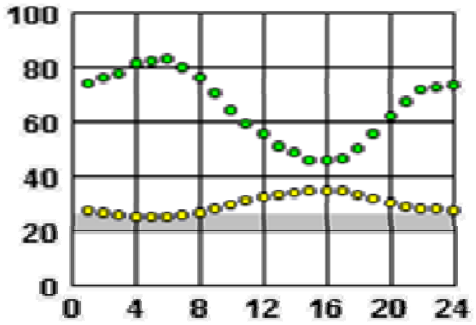
As days and nights are uncomfortable, there is the need of only cooling:

1. Geothermal Heat Pump
2. Vapour absorption machine coupled with the solar hot water through the solar extractors
3. Water cooled VRV technology
4. Chilled water system by water cooled scroll chillers/ air cooled scroll chillers
5. Radiant cooling Systems
6. Under-floor air distribution system

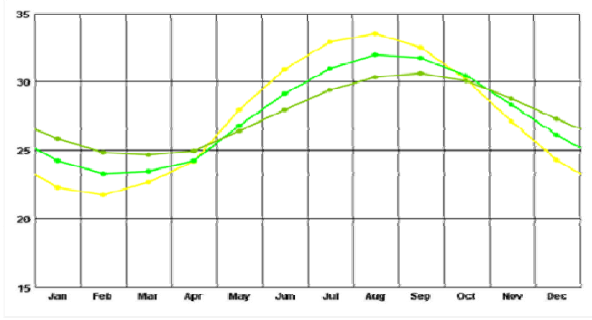
Climate Segment 6

Weather Characteristics

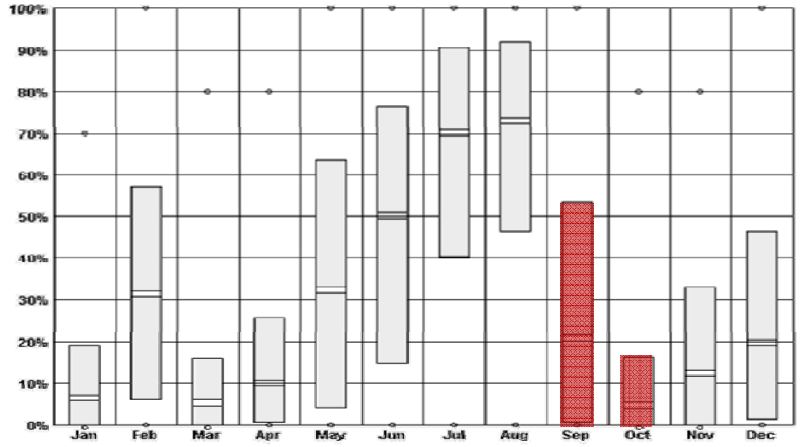
DB Temp / RH



Ground Temperature



Sky Cover Range



SEPT - OCT

Temperature is below comfort zone for 24 hours.
DB temp. will be between 24 -38 deg C with the RH increasing to 90% at night time and 35% at day time. At night in late October its comfortable but days are hot.

Sky cover

September : 50% - Less Solar radiation
October : 20% Clear Skies

Wind Velocity

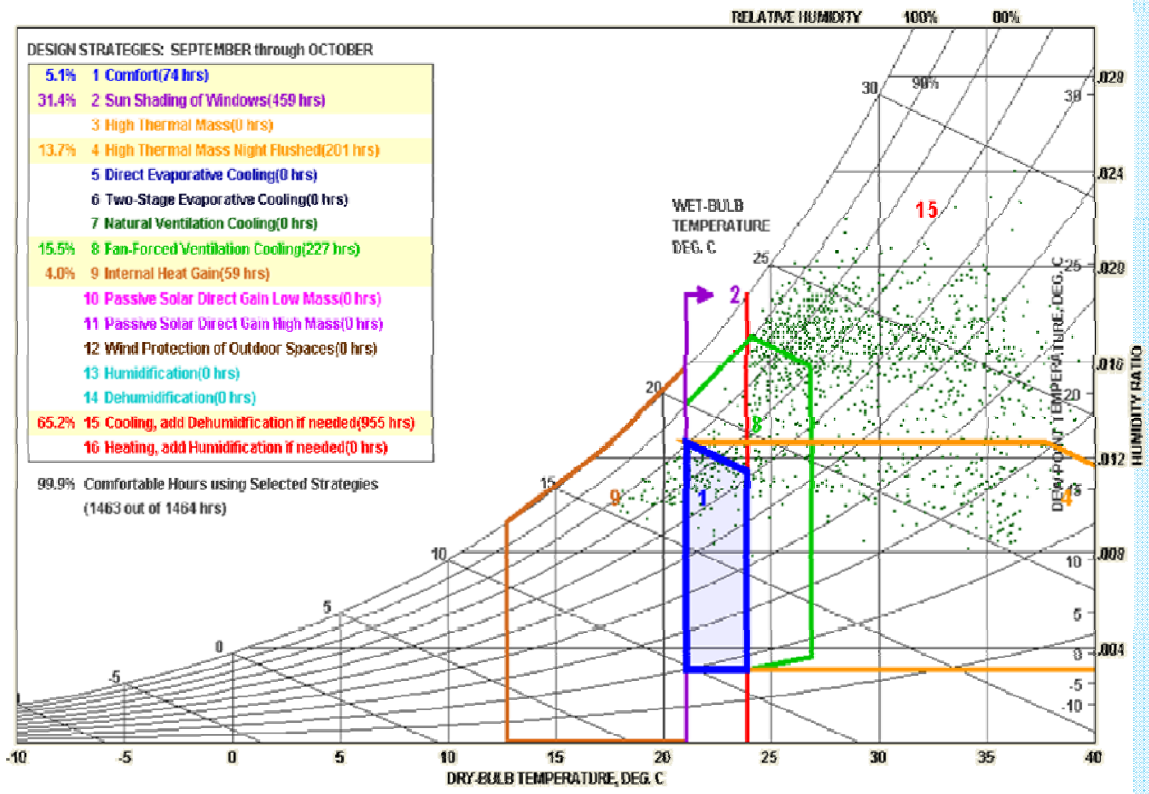
Highest wind velocity : 6-18 m/s
Mean = 1.5- 3m/s
Comfortable

Ground Temperature

Max ground temp. = 29-31 deg C
Mean ground temp. = 27.5 deg C
Difference in outdoor temp. and ground temp. is around 7-9 deg C.

Climate Segment 5

Thermal Comfort Strategies



SEPT - OCT

Architectural elements

Window Shading is recommended.

Insulation on walls and roof is required.

Passive System

Night flushing can be helpful in creating the thermal mass for the daytime cooling for most of the days in October.

Air-conditioning is required in September.

Active Systems

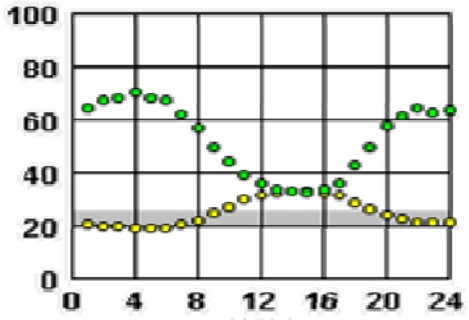
September is uncomfortable. Few days of October are also uncomfortable. Cooling is required in the daytime and night time of September.

1. Geothermal Heat Pump
2. Vapour absorption machine coupled with the solar hot water through the solar extractors
3. Water cooled VRV technology
4. Chilled water system by water cooled scroll chillers/ air cooled scroll chillers
5. Radiant cooling Systems
6. Under-floor air distribution system

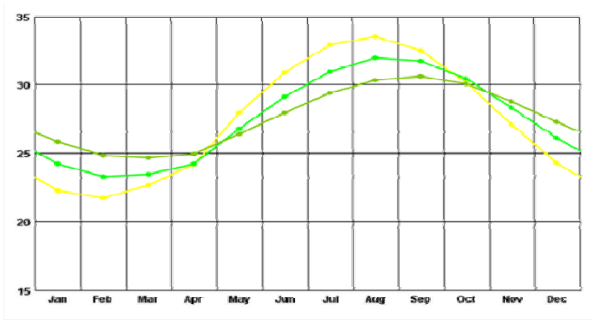
Climate Segment 7

Weather Characteristics

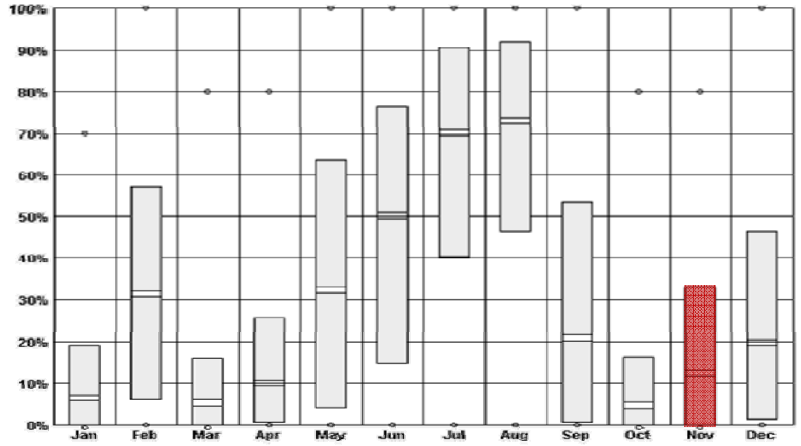
DB Temp / RH



Ground Temperature



Sky Cover Range



NOV

Temperature is below comfort zone at night time.
Day time, DB Temp in afternoon 36 deg C
Comfortable due to radiant effect of thermal mass.

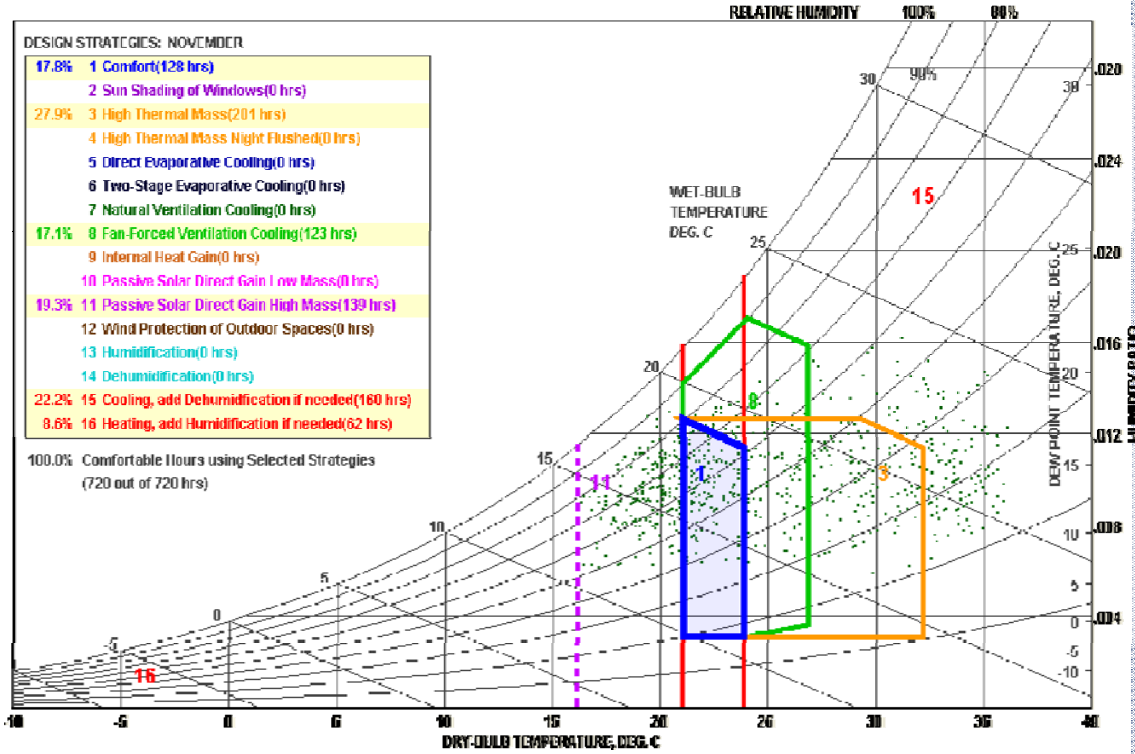
Sky cover
32% - Good Sunlight

Wind Velocity
Highest wind velocity : 7 m/s
Mean = 1.5 m/s
Daytime : Comfortable

Ground Temperature
Max ground temp. = 27 deg C
Mean ground temp. = 27.5 deg C
When the outside temp. is as high as 35 deg C the ground temp. is at 27 deg C.
Difference in outdoor temp. and ground temp. is around 9 deg C.

Climate Segment 7

Thermal Comfort Strategies



NOV

Architectural elements

The indoor temperature will be below the comfort zone. Insulation on walls and roof is required to store the internal heat gain.

Passive System

Use of Earth Air Tunnels to supply air at around 20-22 deg C which can provide a comfort condition inside the space at night.

Daytime : Natural ventilation through open able windows.

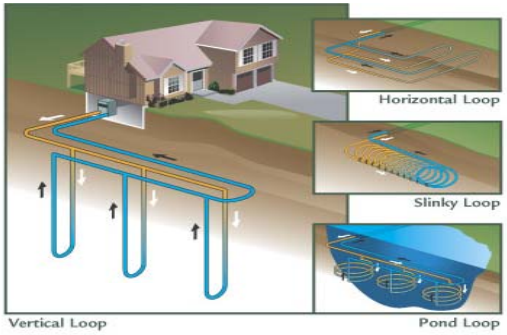
Active Systems

Heating is required for few days at night and cooling is required for few hours at daytime.

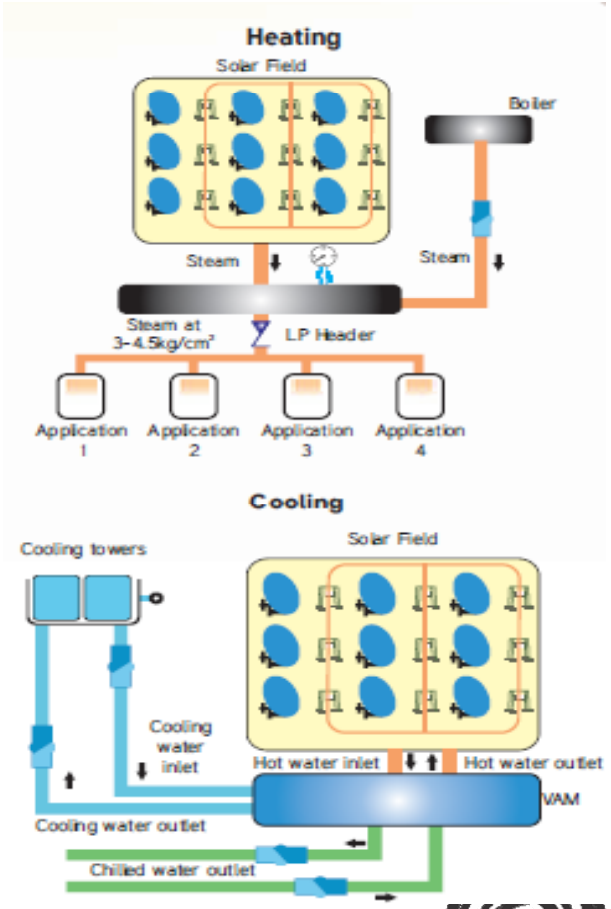
1. Geothermal Heat Pump
2. VRV Heat pump
3. Solar heat collected from the heat extractors can be used as the radiation is high in these months.
4. Radiant cooling Systems
5. Underfloor air distribution system.

Feasibility of Active Systems

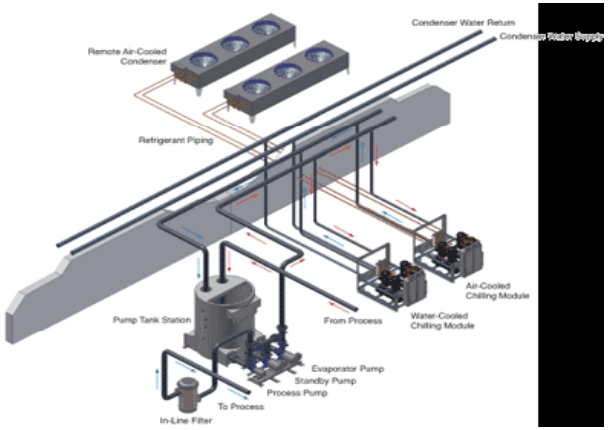
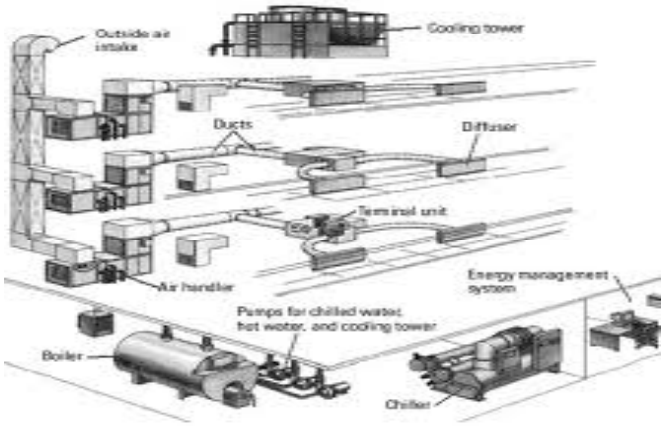
Feasibility of Active Systems

System	Pros	Cons	Recommendation	Schematic Design
Ground source Heat Pumps	Improves Energy Efficiency. Less Outdoor Equipments. Quite Operations. Can be used for heating and cooling.	Require surface area of ground heat exchanger. Higher initial cost. Less space required over ground	**Recommended** Less load and space to dig boreholes. Soil is Sandy clay in which the system can be used.	
Earth Air tunnel System	Improves Energy Efficiency. Less Outdoor Equipments. Quite Operations. Green Technology	Require large ground area. Higher initial cost. High maintenance required. System efficiency only good in few months. Has to be connected with the chilled water system.	**Not Recommended** Use of the tunnel directly is only for winters and it needs to be designed with the chilled water system to reduce the air temperature. If used only for the fresh air then its not worth because the fresh air is not much and the capital cost is high.	

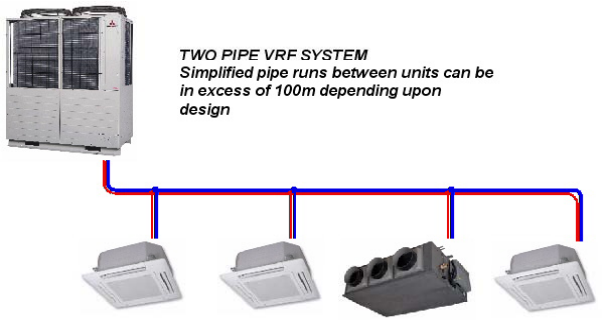
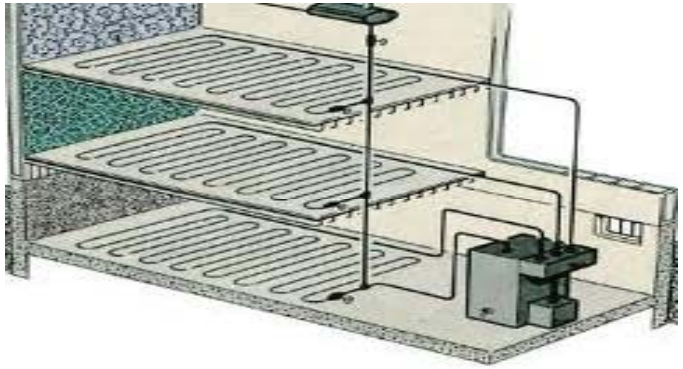
Feasibility of Active Systems

System	Pros	Cons	Recommendation	Schematic Design
Solar Cooling with hot water for VAM	Improves Energy Efficiency. Green technology. Can be used for heating and cooling. Low running cost.	Dependent on the sunlight. Does not work if the sky is cloudy. Alternative chillier plug in in absence of sunlight or at night. High Capital cost Payback time is long	**Recommended** In parallel with the standby chiller because of the high efficiency technology and availability of space to put solar extractors.	

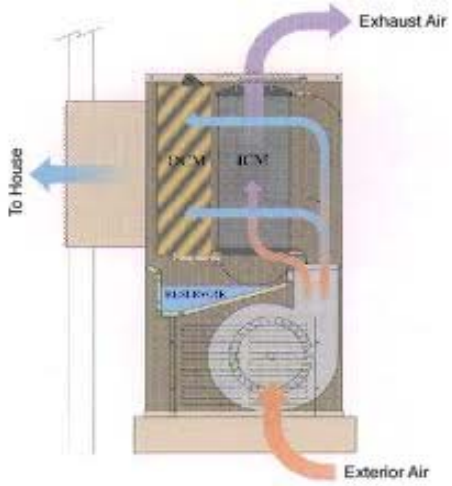
Feasibility of Active Systems

System	Pros	Cons	Recommendation	Schematic Design
Central cooling system (Air cooled Scroll Chillers)	Less space . Less Capital Cost. No use of Water. Easy maintenance.	High running cost.	**Not recommended** as the efficiency of the system is low.	
Central cooling system (Water cooled Scroll Chillers)	Low Capital cost Low running cost as compared to air cooled scroll chillers.	Use of water More space required over ground. Maintenance cost.	**Not recommended** as the efficiency of the system is not very good at full load as well as part loads and the space requirement is more.	

Feasibility of Active Systems

System	Pros	Cons	Recommendation	Schematic Design
Water cooled Variable Refrigerant Volume system	High efficiency at part loads. Easy installation Low capital cost. Less space required. Can be used for heating and cooling.	Specialised maintenance required.	**Recommended** Part load efficiency is very good. Because this is a residence the system will mostly run at part loads.	
Radiant cooling	High efficiency system Quite Operations.	High maintenance required. Have to be connected with the DX system for fresh air supply. Very complicated controls	**Not recommended** due to very complicated controls.	

Feasibility of Active Systems

System	Pros	Cons	Recommendation	Schematic Design
Under-floor Air Distribution System	Efficient System Low air velocity.	Plenum required under the floor. High Maintenance.	**Not recommended** as the space requirement for the air circulation inside the space is more. A plenum is required and lots of ducting is required.	
Two Stage Air cooling System	High Efficiency system. Less capital cost. Very Effective in dry climate conditions.	Only comfortable for 3-4 months in a year. Large water requirement. Less level of comfort. Large amount of ducting required.	**Recommended** to be used for 3-4 months when there is low humidity.	

Final System Selection and Operations

Comparative of Recommended Systems

	Ground Source heat pumps	Water cooled VRV	Solar Cooling	Two Stage Air Washers
System Require-ment	30 TR Heat pump	36 HP Water cooled Variable Refrigerant Volume system	Vapor Absorption Machine of 30 TR with solar collectors and diesel backup	20,000 CFM two stage Air washer.
Life of the system	15	12	15	12
CAPEX (RS) Approx	40,00,000	33,00,000	32,00,000 for VAM , Cooling towers, Ahu's. + 35,00,000 for 20 TR Solar extractor	3,00,000 for the air washers and ducting
Electrical Load At full load (Approx.)	25 KW	28 KW	18 KW Including VAM , solar extractors , Cooling tower, Ahu's.	11 KW
Energy consumption for 100% load. (annual units)	121500 (considered to be working 18 hrz a day & 270 days in a year)	136080 (considered to be working 18 hrz a day & 270 days in a year)	87500 (considered to be working 18 hrz a day & 270 days in a year)	17820 (considered to be working 18 hrz a day & 90 days in a year)
Running Cost (Rs) annually	7,29,000	8,16,000	5,25,000	1,07,000
Water Consum-ption	---	280 LPH	280 LPH	380 LPH

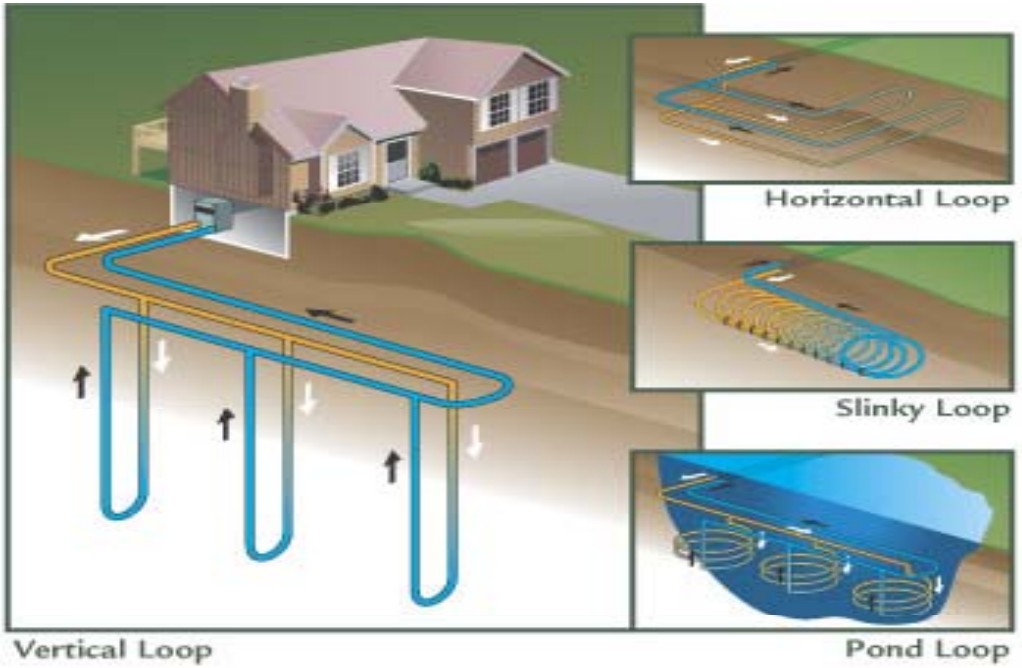
Comparative of Recommended Systems

	Ground Source heat pumps	Water cooled VRV	Solar Cooling	Two Stage Air Washers
Space requirements	**4 m x 4 m** plant size requirement on the ground or on the terrace. **20 bore-wells** of 90 meter deep on the ground level.	Can be installed on ground or terrace. **4 m x 2 m** space for the outdoor units **1.5 mx 1 m** for cooling tower at terrace.	Solar extractor will require the area of approx **600 sq mt** on terrace or ground or both combined. VAM will require **5 m x 4 m** area on ground level.	Two stage air washers will require the area of **3m x 4m** on terrace or on ground.

Final System Recommendation

Ground source heat pump system

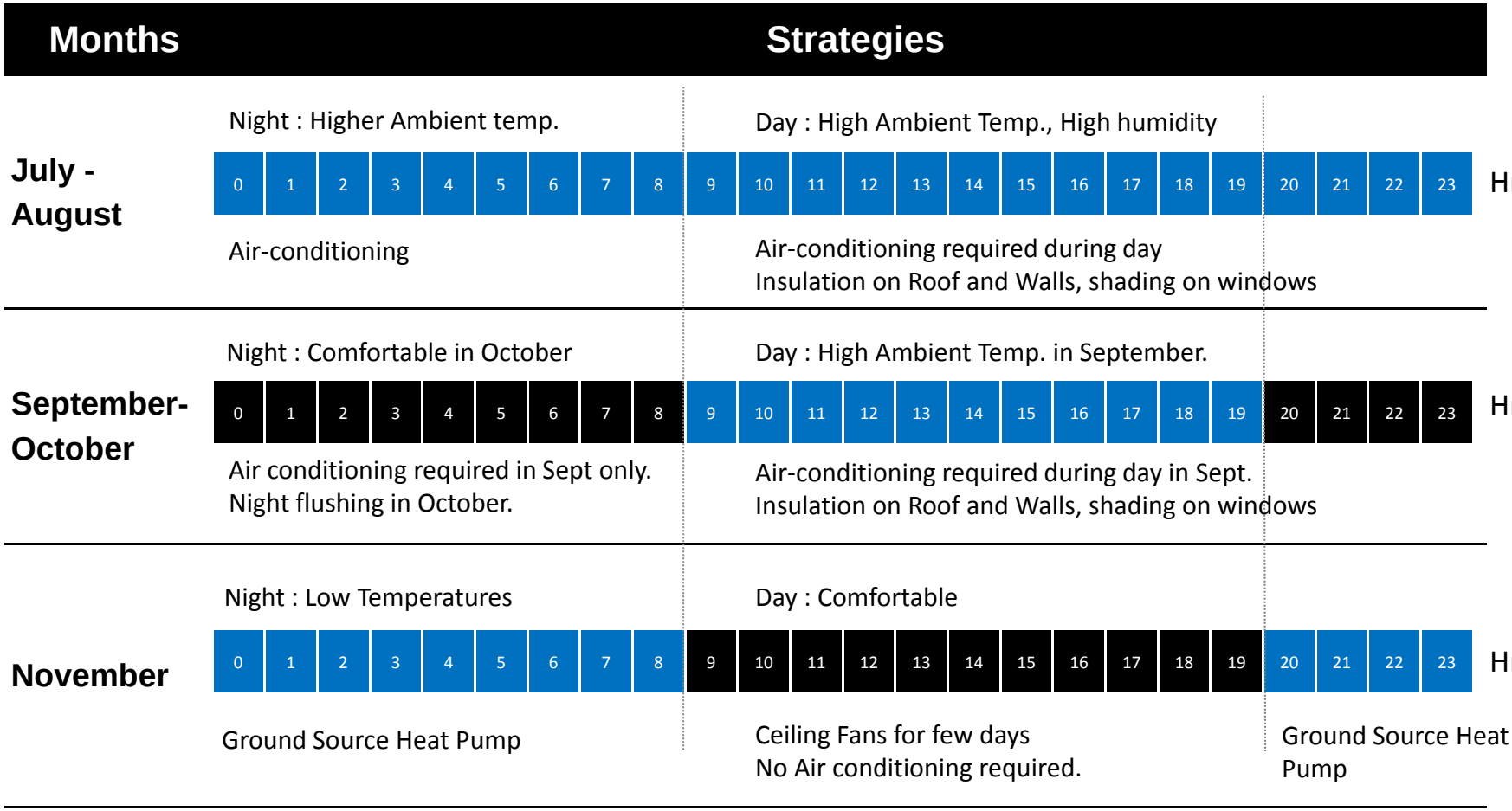
1. It is not a very complicated system as the controls are simpler.
2. Low maintenance
3. Capital cost and running cost are moderate
4. Less Space requirement above the ground.
5. No cooling towers required
6. No water softening plant required as its a closed condenser loop
7. Green system with the use of geothermal energy
8. Chilled water system so the airflow will be more as compared to refrigerant based system



Passive and Active System Operations

Months	Strategies
December – January	Night : Low Temperature 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 Hr Ground Source Heat Pump Insulation on Roof and Wall Day : Comfortable No Air-conditioning Required Insulation to store Internal heat gain. Ground Source Heat Pump
February	Night : Low Temperature for few nights 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 Hr Ground Source Heat Pump Day : Comfortable No Air-conditioning, Ceiling Fans Ground Source Heat Pump
March- April	Night : Comfortable (March) 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 Hr Night Flushing to bring down day temperatures Day : Requires active system for thermal comfort. Ceiling Fans during the day. Air conditioning in April. Shading on windows and roof insulation. Night Flushing
May- June	Night : Temperature rises at night. 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 Air-conditioning Day : High ambient temperature Solar radiation intensity is high. Air-conditioning required during day Insulation on Roof and Walls, shading on windows

Passive and Active System Operations



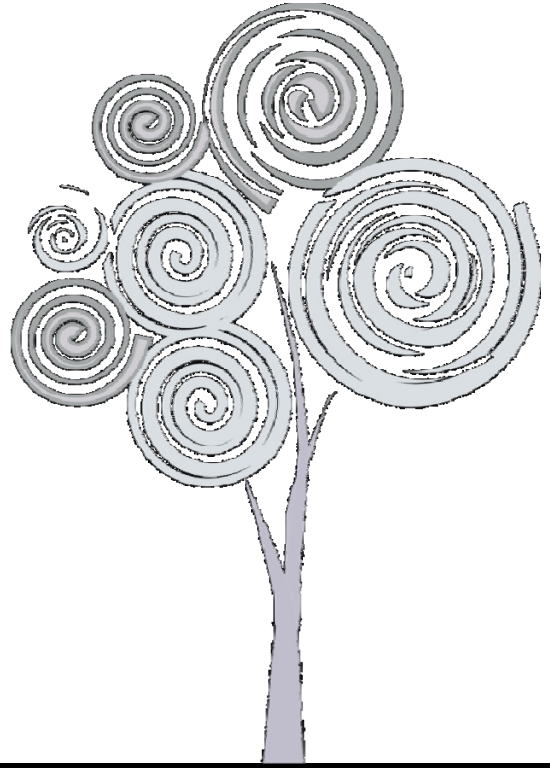
Passive System Only, Active System not required.

Active System Required to achieve Thermal Comfort

Thermal Comfort Analysis

Public School

Ahmadabad



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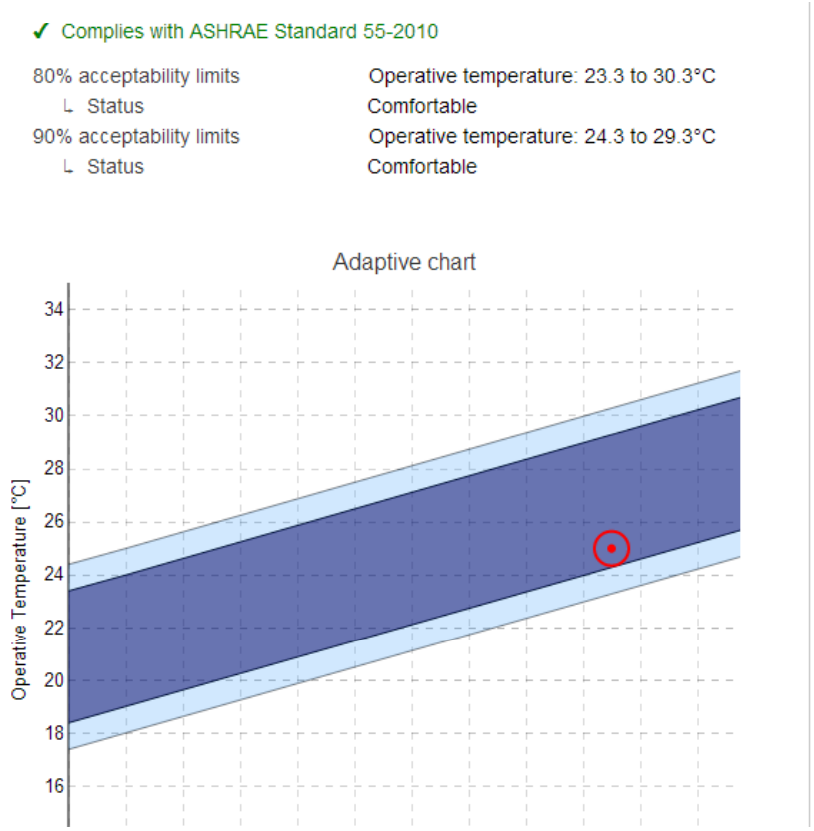
ASHRAE 55-2010: Adaptive Thermal Comfort Analysis

To verify the Thermal Comfort Analysis in Admin Block, School Building and Hostel Building



Indoor Thermal Comfort Operative Temperature : equal to OR less than 29 Deg C

Façade Optimization: Parametric Run

	Wall	Roof	Window	
Window Optimization			U value (w/m2)	SHGC
Case-1	9 Inch Brick	6 Inch RCC	6	0.86
Case-2	9 Inch Brick	6 Inch RCC	3.23	0.76
Case-3	9 Inch Brick	6 Inch RCC	1.3	0.3
Wall Optimization				
Case-1	200 AAC Block	6 Inch RCC	6	0.86
Case-2	100mm AAC+50 mm Air gap+100 mm AAC	6 Inch RCC	3.23	0.76
Case-3	200 mm AAC+50 mm Air gap+ 100mm AAC	6 Inch RCC	1.3	0.3
Roof Optimization				
Case-1	Best Case from Wall Optimiztion	Eco Roof/Green Roof	Best Case from Window Optimization	

Thermal Comfort Analysis: Window optimization

	Comfort hours achieved with Window Optimization @ 6 Air Change per Hour (ACH)			
Simulation Cases	**Simulation details**	**Percentage of hours observed below 29 Deg C for occupied hours**		
		Admin Building	**School Building**	**Hostel Building**
Case-1	**Wall: 9 Inch Brick Roof: 6Inch RCC Glazing: Single Clear Glass**	**41.80%**	**57.90%**	**43.32%**
Case-2	**Wall: 9 Inch Brick Roof: 6Inch RCC Glazing: Double Clear Glass**	**43.40%**	**60.10%**	**44.32%**
Case-3	**Wall: 9 Inch Brick Roof: 6Inch RCC Glazing: Double Low e Glass**	**47.20%**	**62.90%**	**45.82%**

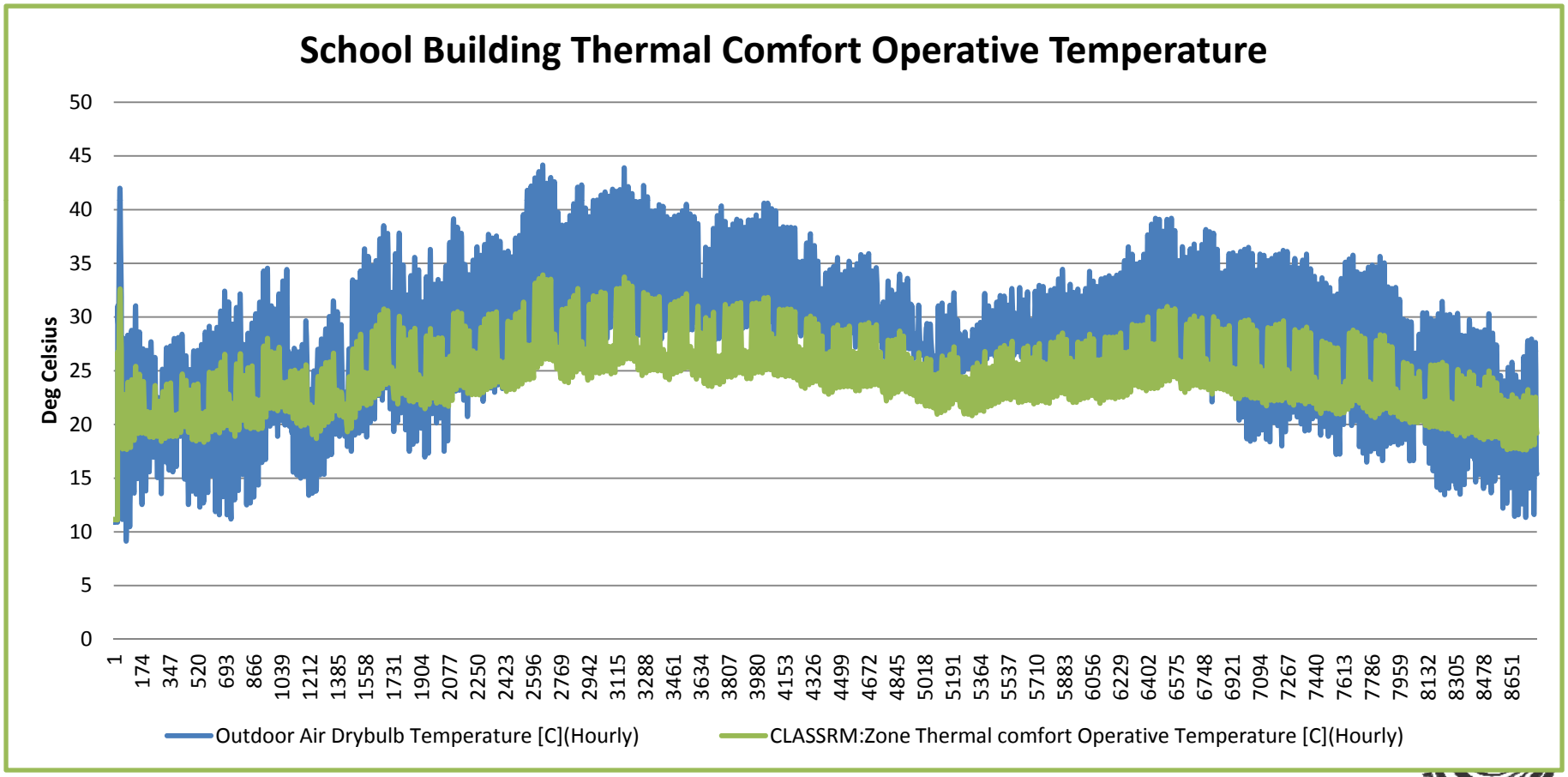
Thermal Comfort Analysis: Wall optimization

	Comfort hours achieved with Wall Optimization @ 6 Air Change per Hour (ACH)			
Simulation Cases	**Simulation details**	**Percentage of hours observed below 29 Deg C for occupied hours**		
		Admin Building	**School Building**	**Hostel Building**
Case-1	**Wall: 200mm AAC Roof: 6 Inch RCC Glazing: Double Low-e Glass**	**48.30%**	**66.70%**	**46.30%**
Case-2	**Wall: 100mm AAC+50mm+100mm AAC Roof: 6 Inch RCC Glazing: Double Low-e Glass**	**57.70%**	**76.40%**	**57.20%**
Case-3	**Wall: 200mm AAC+50mm+200mm AAC Roof: 6 Inch RCC Glazing: Double Low-e Glass**	**68.20%**	**82.70%**	**68.32%**

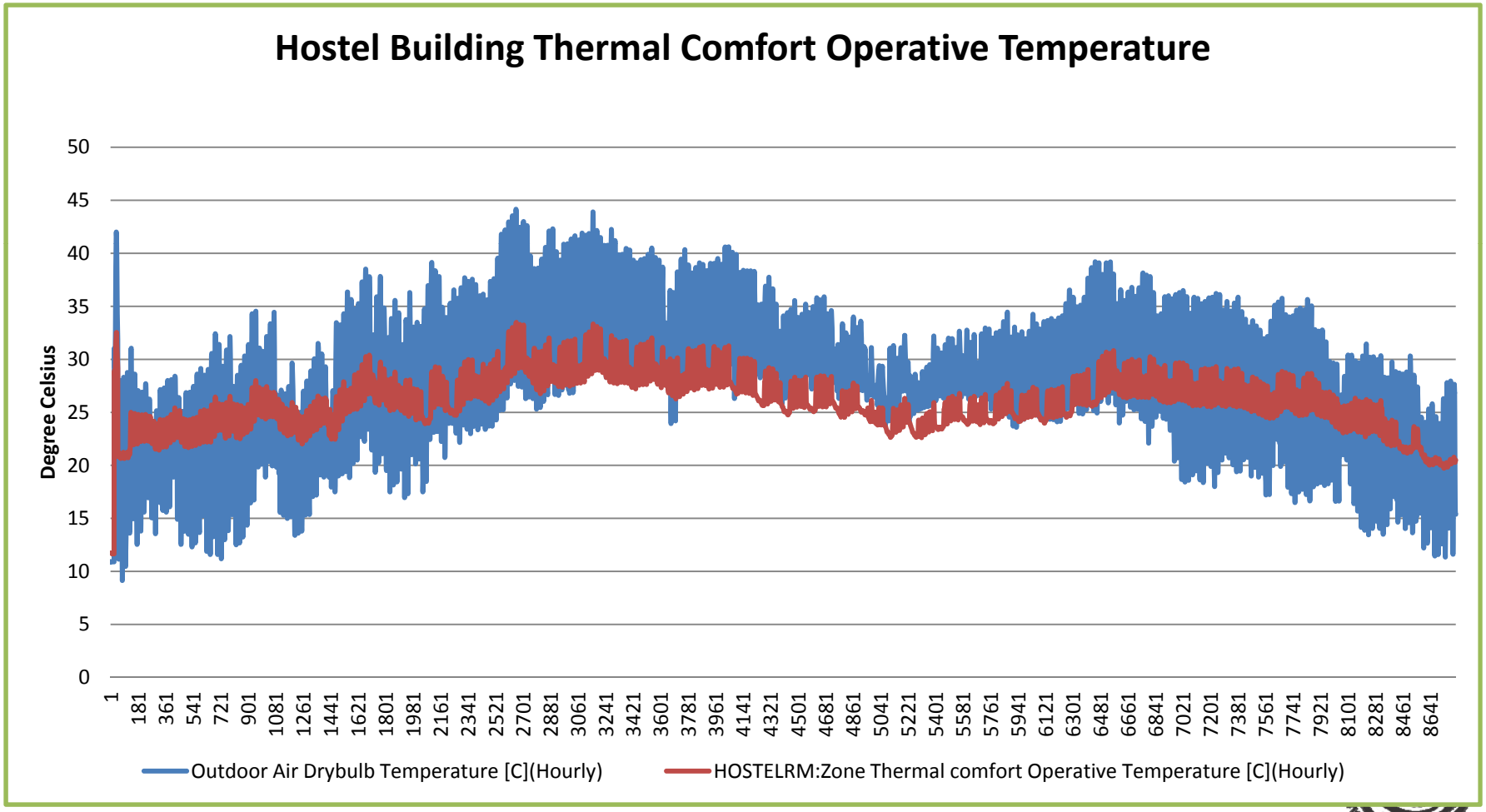
Thermal Comfort Analysis: Roof optimization

	Comfort hours achieved with Roof Optimization @ 6 Air Change per Hour (ACH)			
Simulation Cases	**Simulation details**	**Percentage of hours observed below 29 Deg C for occupied hours**		
		Admin Building	**School Building**	**Hostel Building**
Case-1	**Wall: 200mm AAC+50mm+200mm AAC Roof: Green Roof Glazing: Double Low-e Glass**	**79.60%**	**90.20%**	**79.30%**
Case-1	**Wall: 200mm AAC+50mm+200mm AAC Roof: Green Roof Glazing: Single clear Glass**	**61.90%**	**80.00%**	**65.00%**

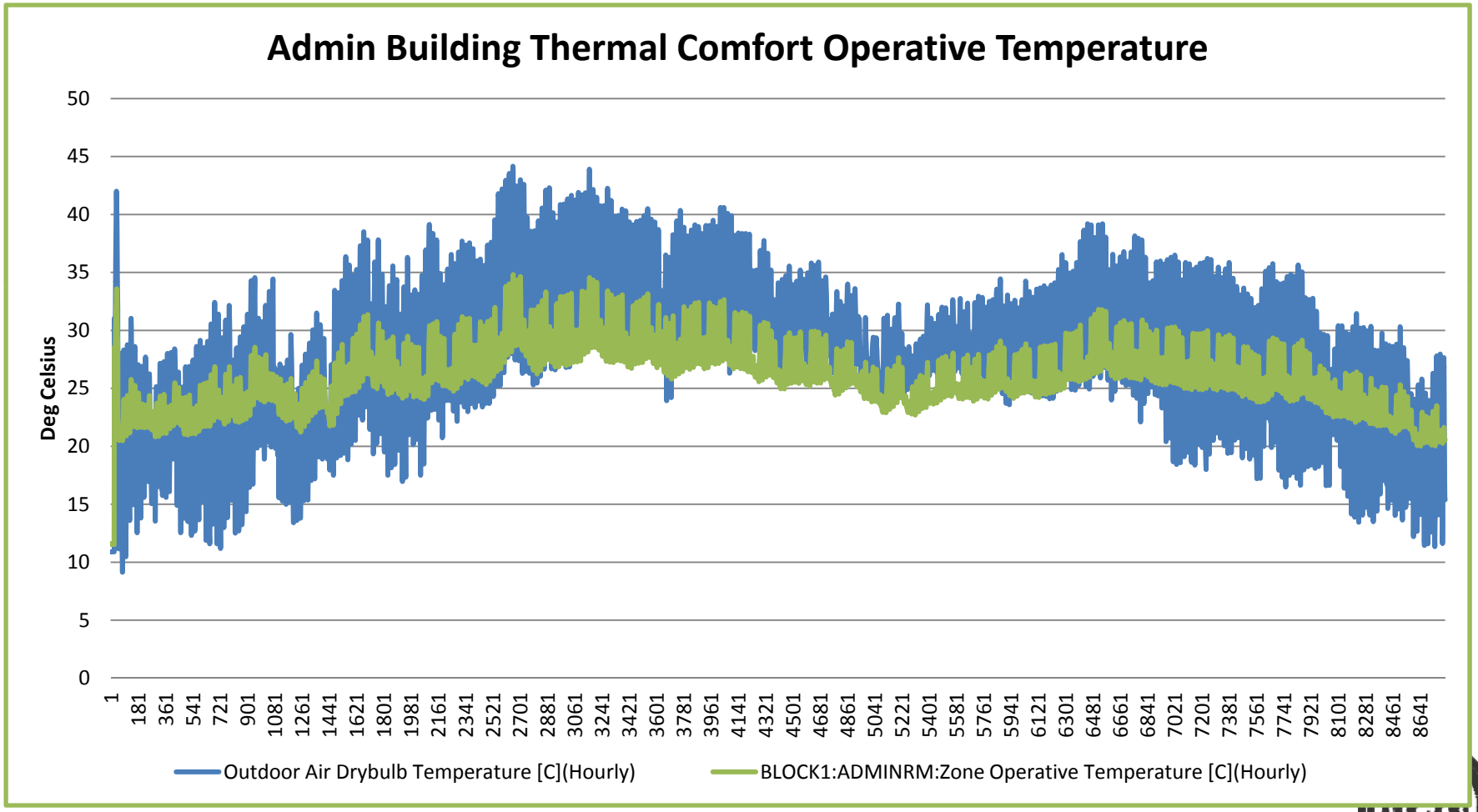
Class Room Thermal Comfort Operative Temperature



Hostel Thermal Comfort Operative Temperature



Admin Building Thermal Comfort Operative Temperature



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Envelope Recommendations

Observation

All the Analysis has been done based on Typical School operating Schedule

Natural ventilation with Operable windows has been simulated for 8760 hrs

Based on the hourly profile it has been observed that comfort conditions are maintained in most of the months except April, May, June and August.

Recommendations

Wall: 200mm AAC+50mm+200mm
Window: Double Glazing or Single Glazing?? (Need feedback from client and designer)
Roof: Green Roof

The window opening may impact the heat gain and it should be closed or opened based on actual weather conditions. Additionally, Minimum Air Changes are required in the range of 3-6 ACH to maintain good Indoor Air Quality

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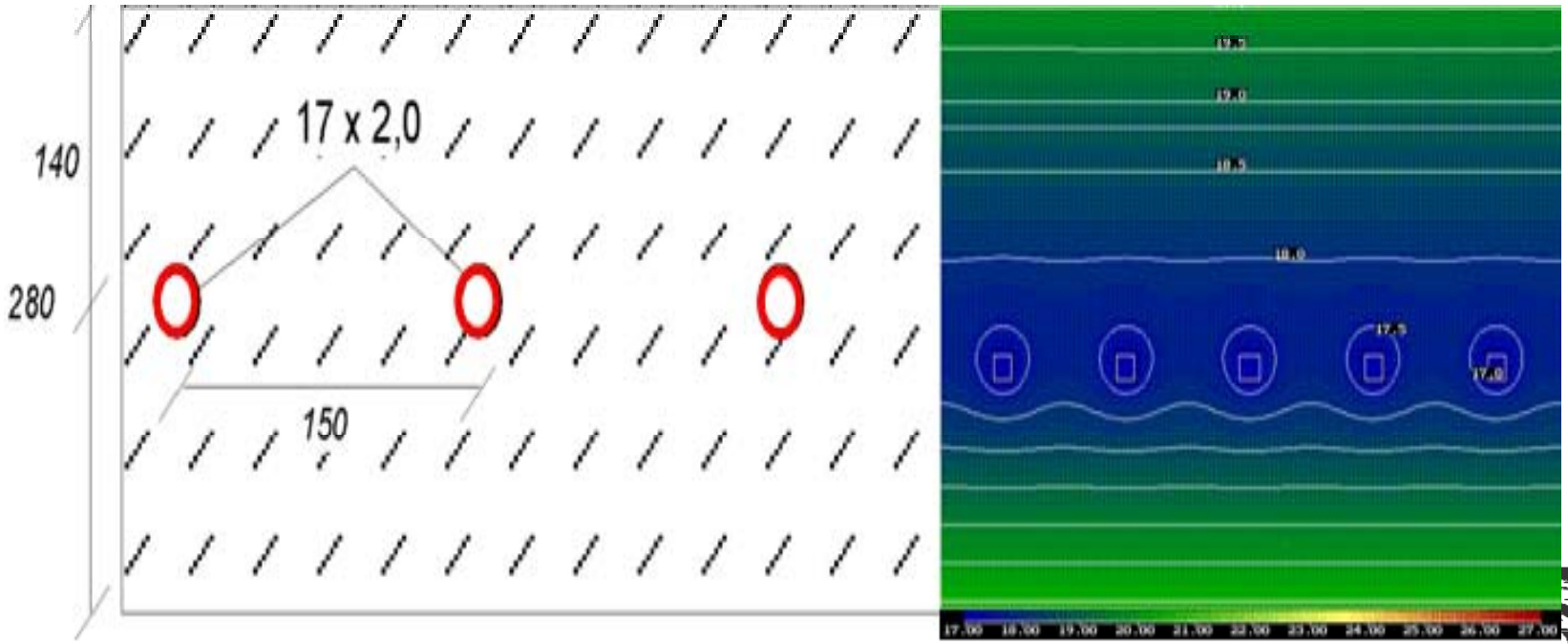
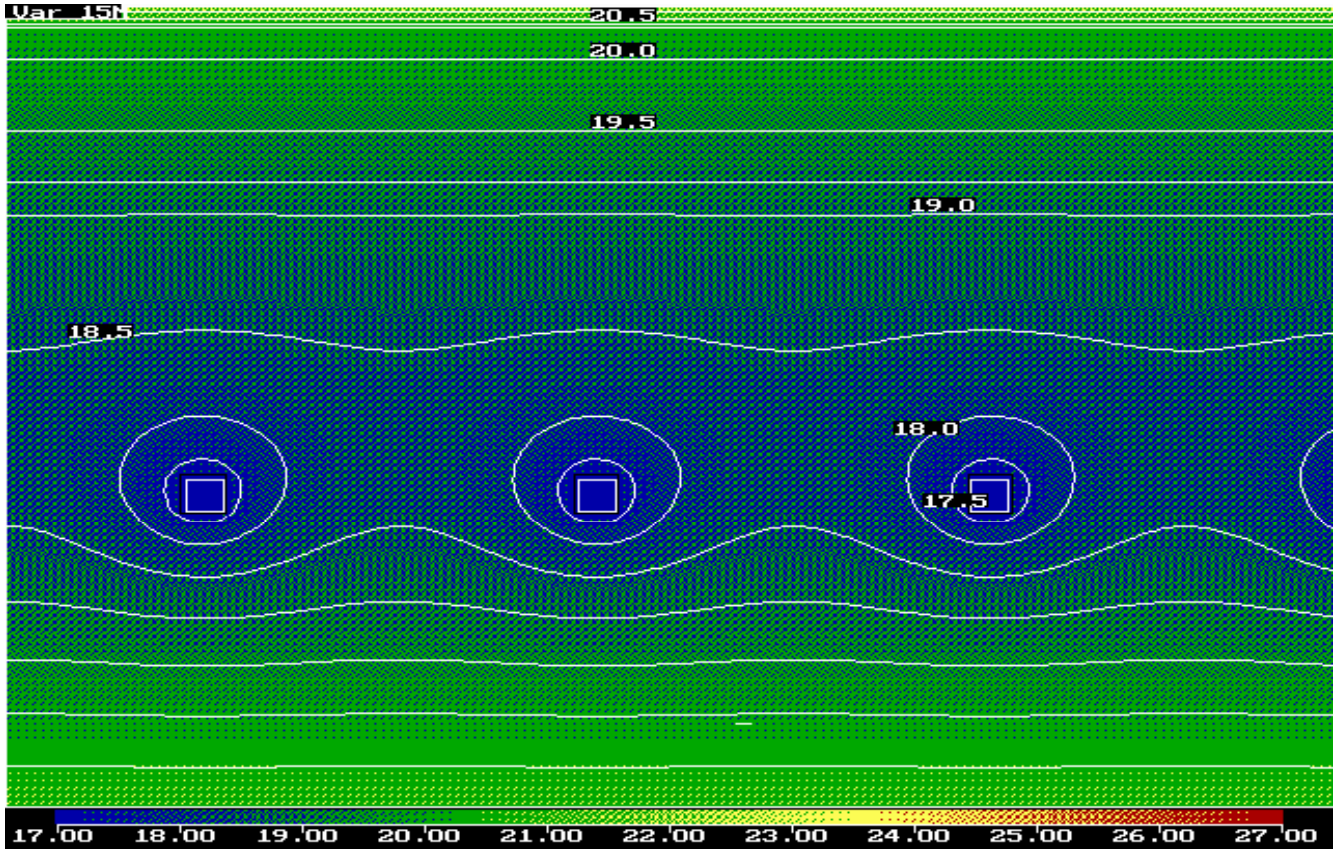
Modes of heat transfer

Pipes embedded in concrete slab

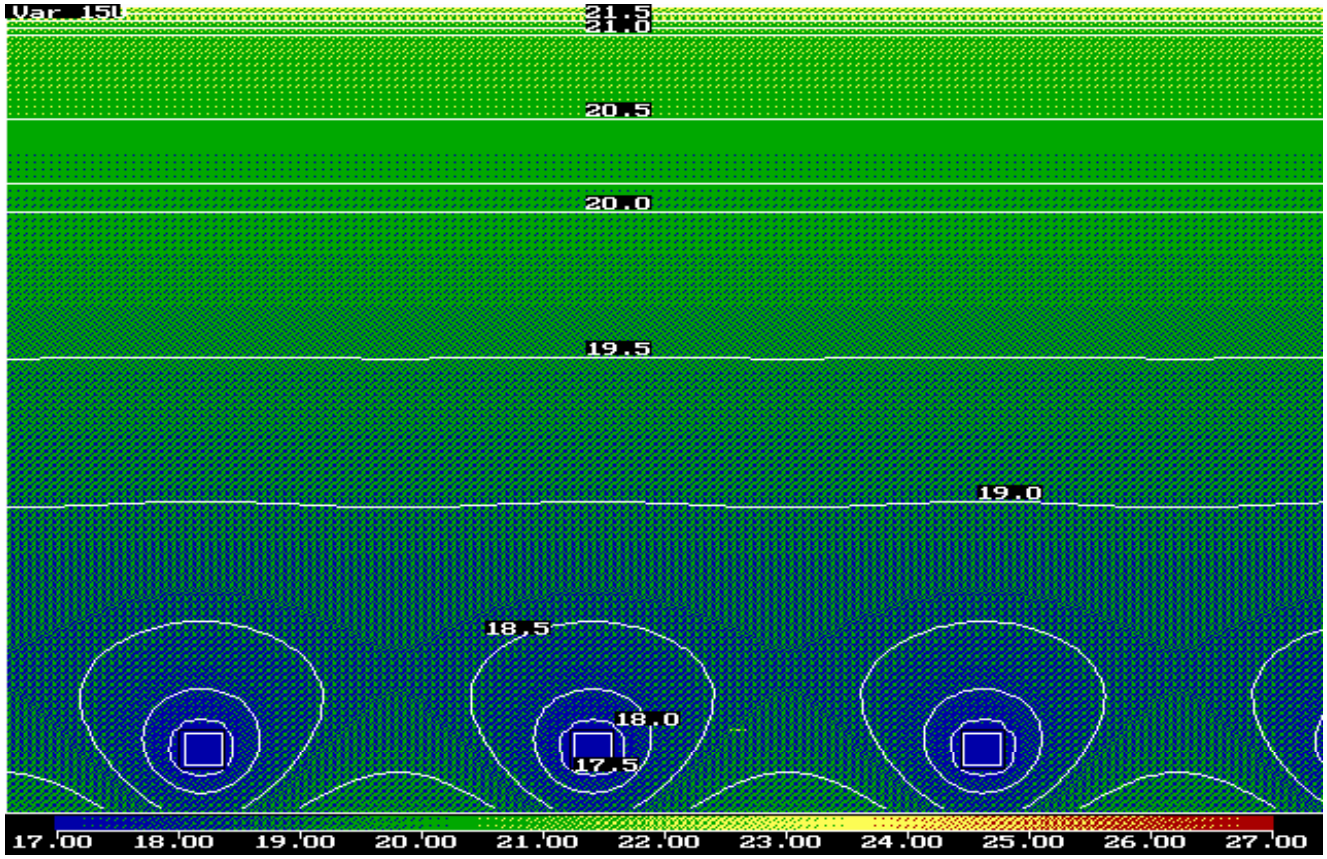


Subsurface heating and cooling



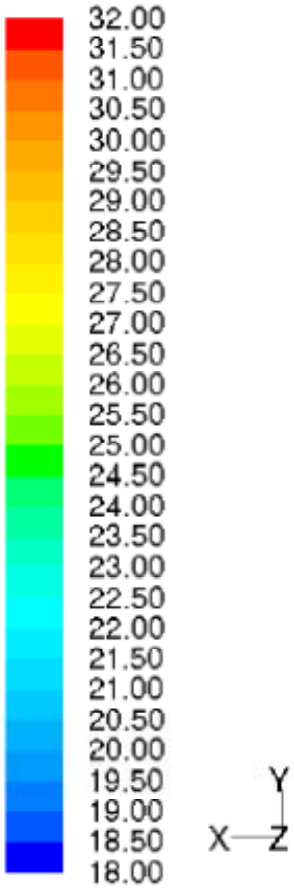
CONCRETE CORE TEMPERATURE CONTROL - PIPE POSITION „MIDDLE“

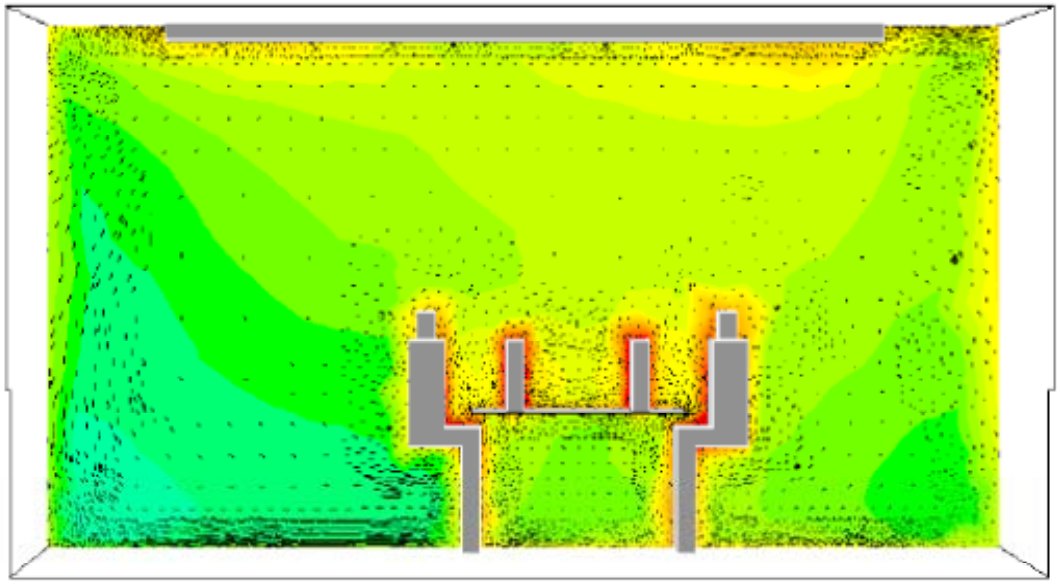
Subsurface heating and cooling



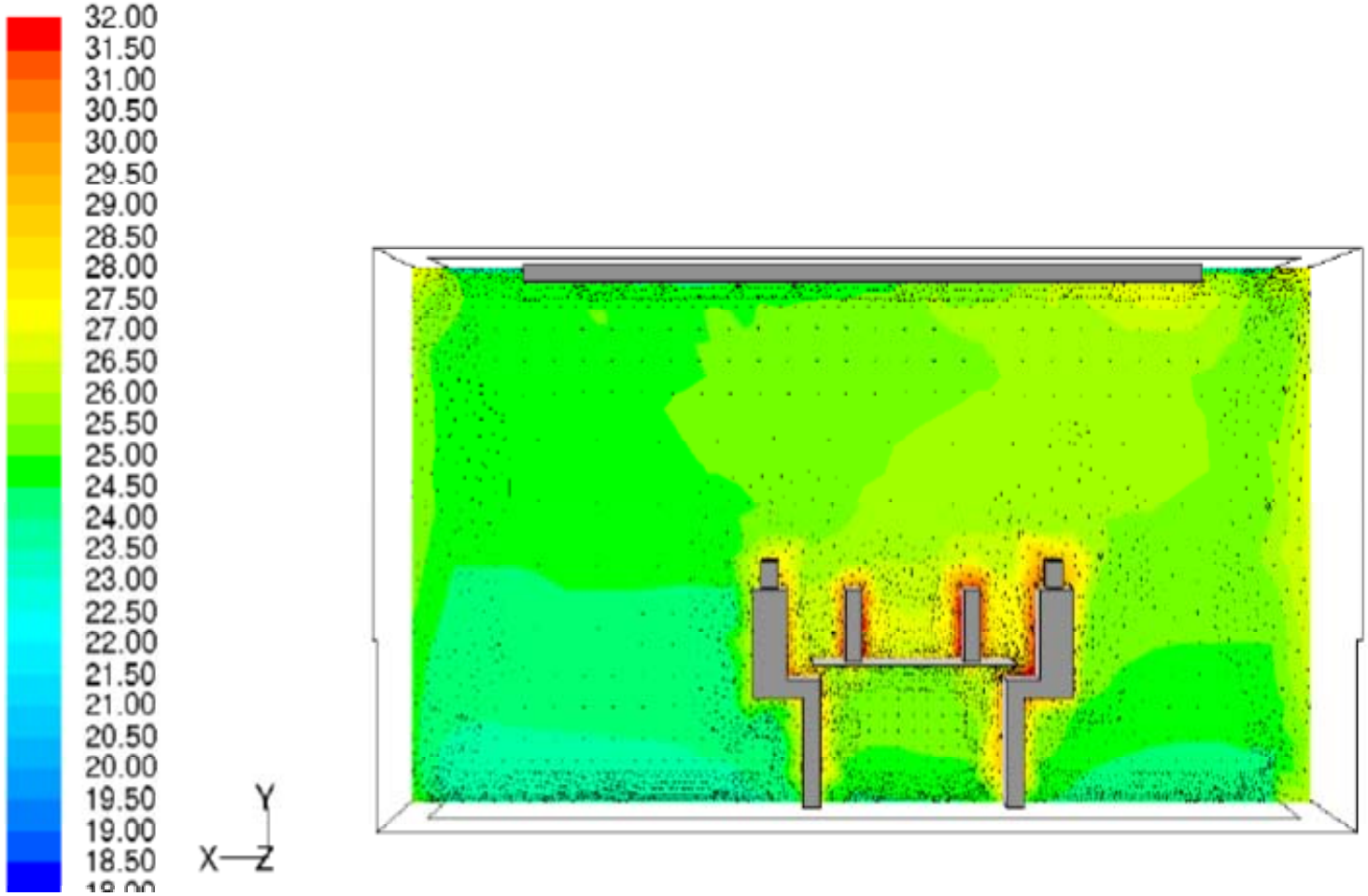
CONCRETE CORE TEMPERATURE CONTROL - PIPE POSITION „BELOW"

Flow simulation conventional airconditioning





Flow simulation for Radiant system



The simulation shows a better and stable comfort conditions through radiant cooling system

Major pros and cons of radiant concrete core cooling

S.No	Pros	Cons
1.	The principle of concrete core design is based on the thermal mass of the building. It reduces the temperature of the building which in returns absorbs the heat from the occupants.	Potential for condensate formation on the cold radiant surface (resulting in water damage, mold etc), radiant cooling systems is the major disadvantage.
2.	The noise and drafts of air movement are removed. There are no diffusers in the way of décor and cleaning.	Very complicated controls are required for the radiant system design.
3.	When combined with a ventilation air system, thermal mass can significantly reduce the need of air side systems reducing the fan power in HVAC system drastically	This type of system needs to run at least 16-18 hours to keep the thermal mass. As it takes few hrz to change the temperature of the slabs.
4	Chilled water supply from the chiller is typically at 16 deg C compared to 7 deg C for conventional HVAC. This also leads to additional savings. Contribute to improved ROI with a triple bottom line in terms of social, economical and environmental benefits.	Condensation caused by Humidity is a limiting factor for the cooling capacity of a radiant cooling system.
5	The CAPEX of this system is the same as a	Its less feasible in spaces where temperature below

HVAC life cycle cost for a Radiant System design

System type	VRF System	Conventional Chilled Water System	High efficiency Chilled Water System	Air cooled chilled water system	Radiant Cooling System
Power requirement (KW)	875	654	582	780	505
Energy Consumption (Kwh/yr)	12,90,867	11,11,358	9,15,629	12,01,910	7,09,274
Capital cost (Rs)	5,10,63,000	4,13,33,000	4,91,51,000	4,13,33,000	4,95,54,000
Capital cost (Rs/sqft)	329	267	317	267	320

Results of the HVAC Analysis

System type	VRF System	Conventional Chilled Water System	High efficiency Chilled Water System	Air cooled chilled water system	Radiant Cooling System
Energy Cost (Rs/Yr)	77,45,202	66,68,147	54,93,772	72,11,461	42,55,646
Energy Cost (Rs/ft2/Yr)	50	43	35	47	28
Maintenance Cost (Rs/ft2/year)	8	10	10	9	10
Running Cost(Energy + maintenance)/ft2/year	58	53	45	56	38
Equipment Life (yrs)	15	18	18	18	18
Total life cycle cost	80	68	63	71	56

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Partnership to Advance Clean Energy-Deployment (PACE-D) Technical Assistance Contract

Low Energy Comfort Systems

Presentation Overview

Low Energy Comfort and HVAC Systems Defined

Examples of Low Energy Comfort and HVAC Systems

Challenges Associated with implementing Low Energy Comfort and HVAC Systems

Low Energy Comfort and HVAC Systems

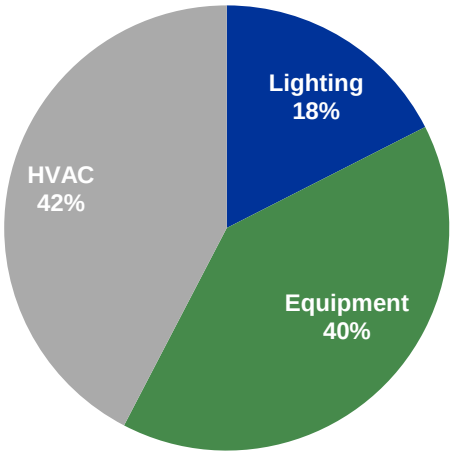
Use significantly less energy compared to conventional systems.

Require flexibility in comfort criteria.

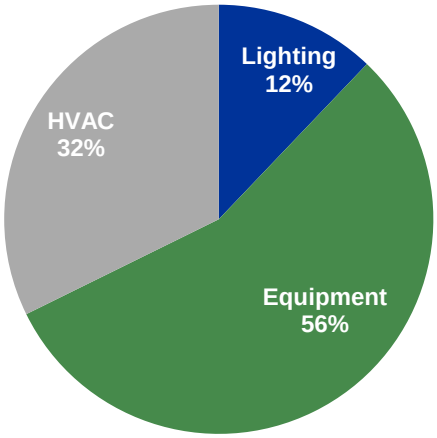
May or may not be capital intensive.

Require design and installation expertise.

Energy End Use Break Up - Typical IT Building



Energy End Use Break Up - Low Energy Design IT Building



Low Energy HVAC system examples

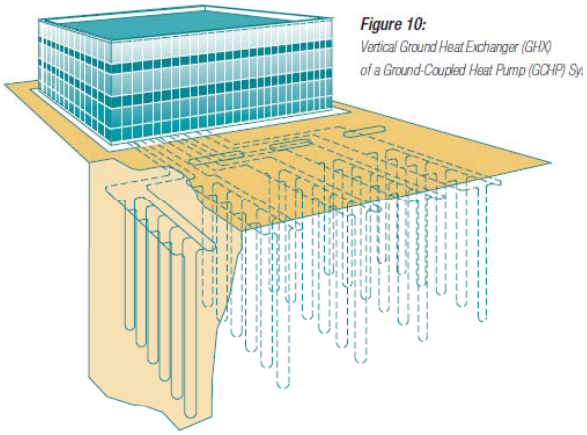
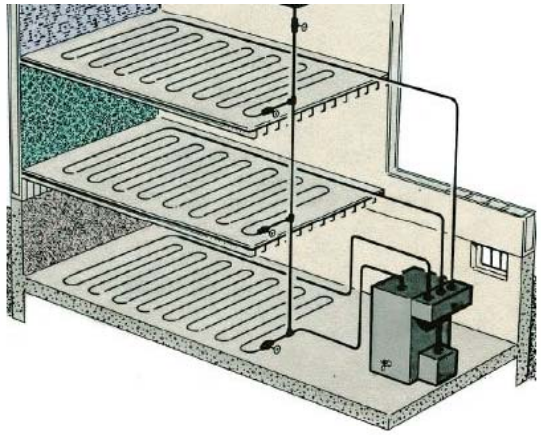
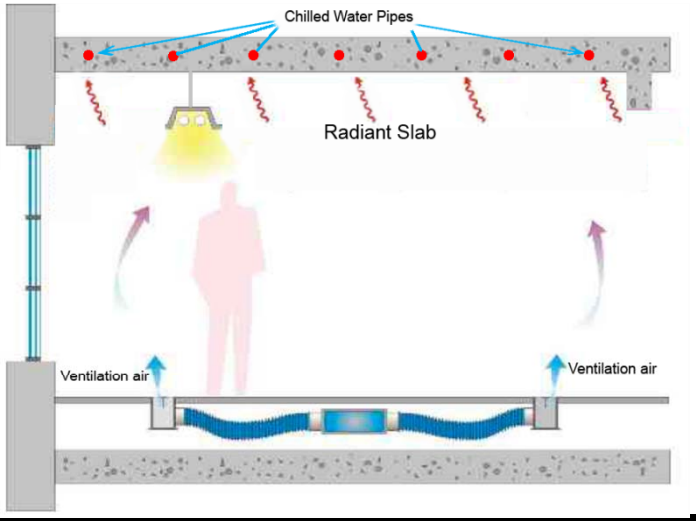
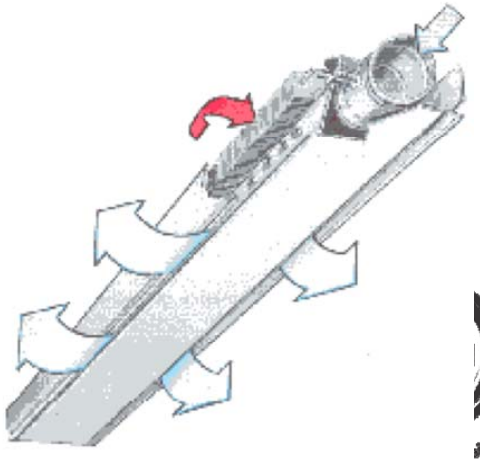


Figure 10:
Vertical Ground Heat Exchanger (GHX) of a Ground-Coupled Heat Pump (GCHP) Sy

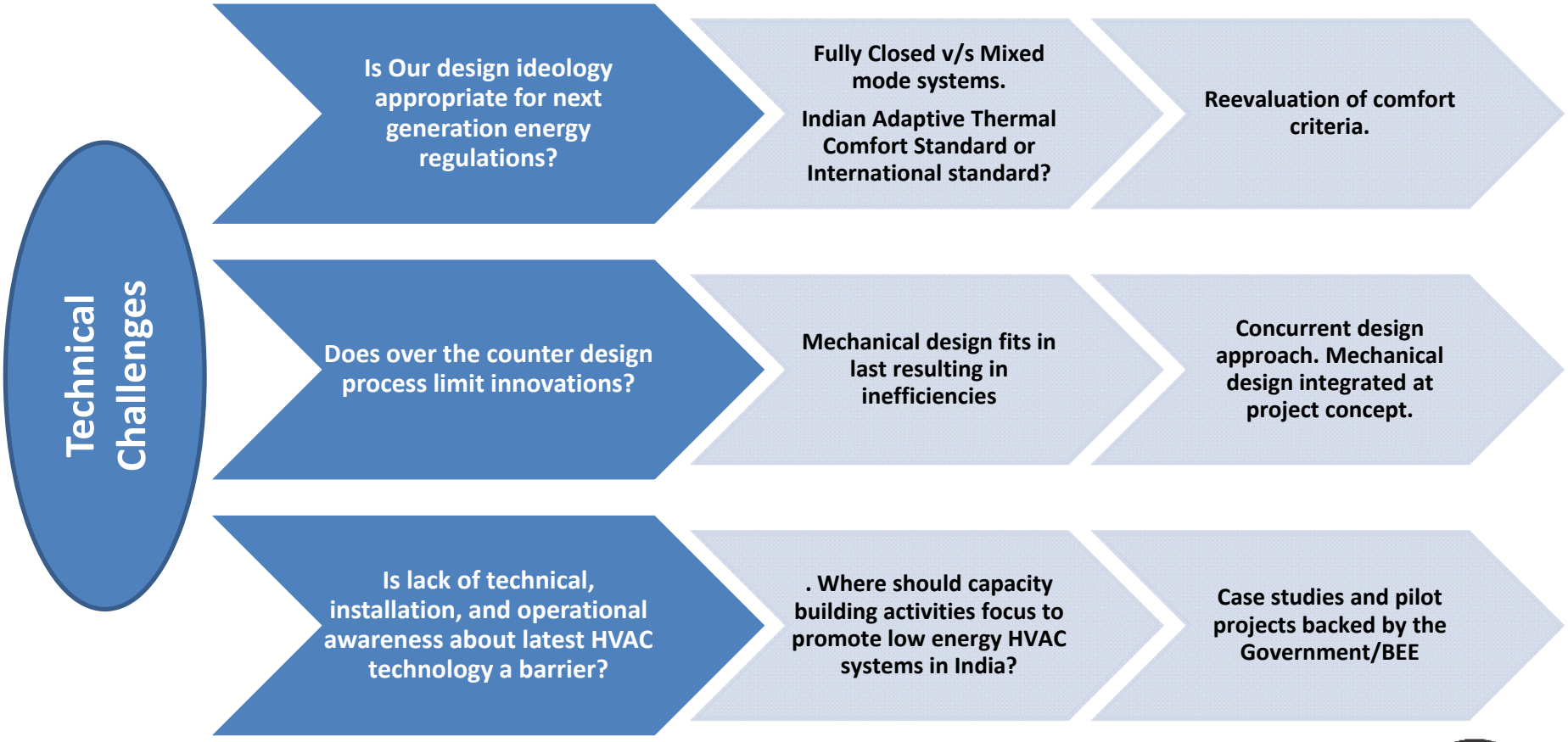


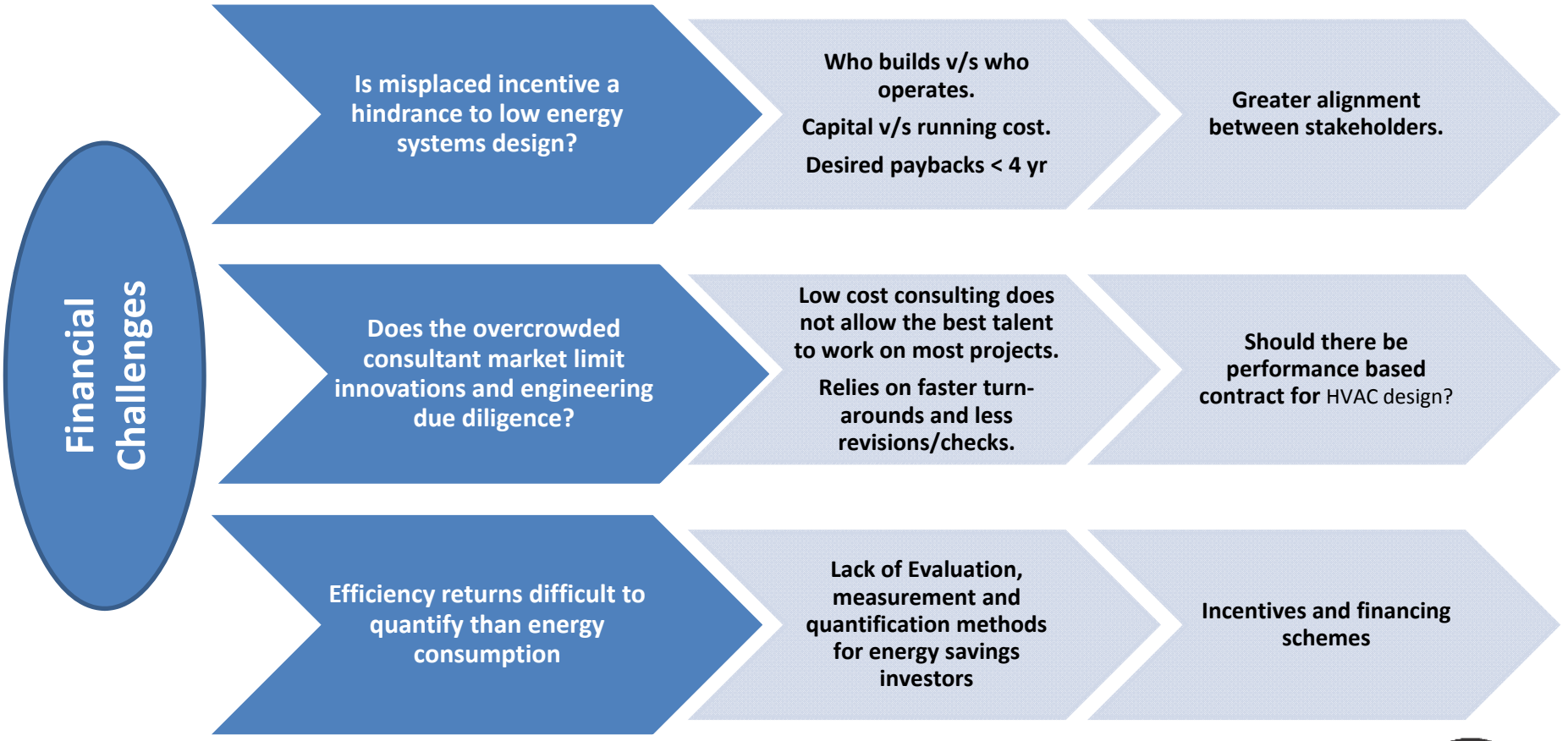


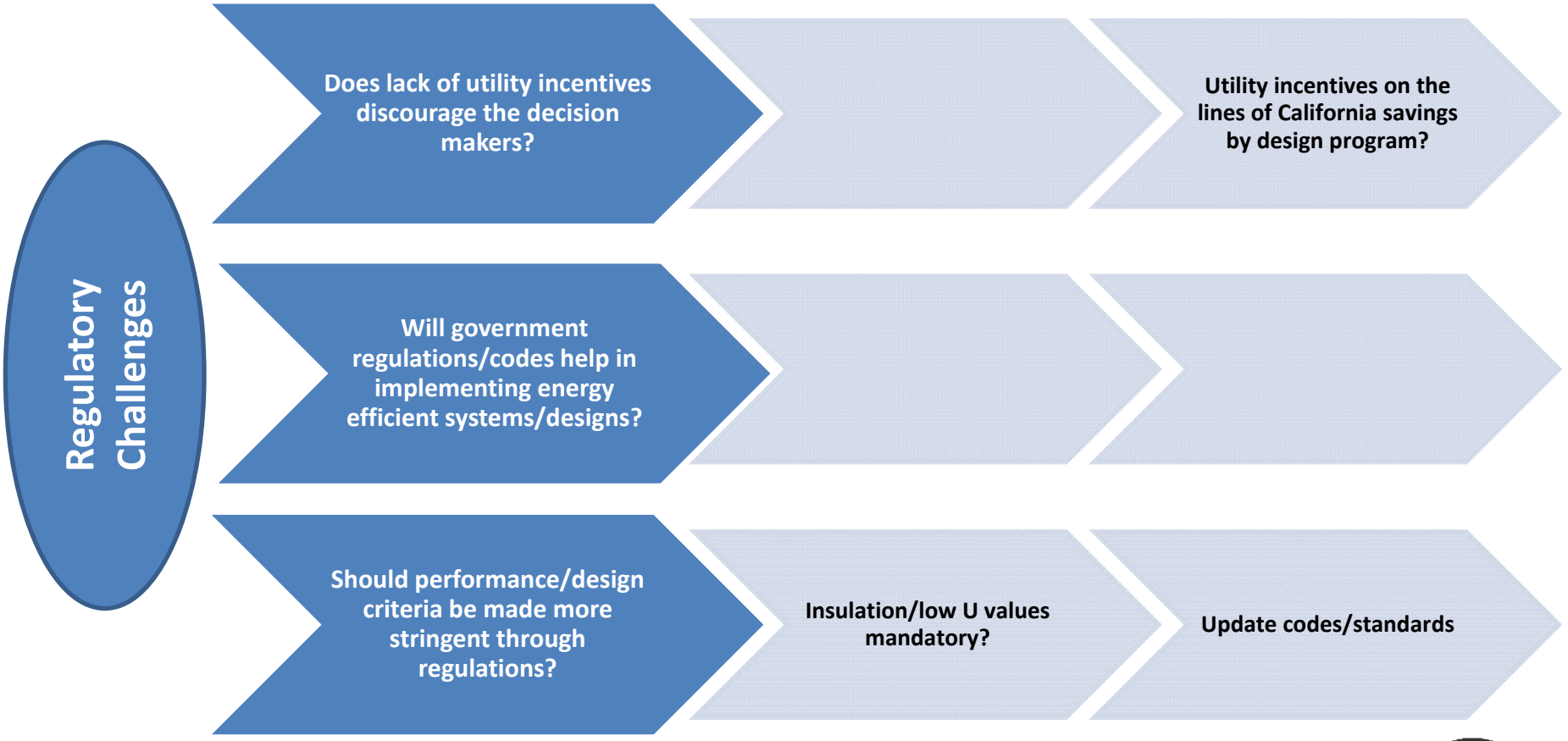


Challenges Associated with Implementing Low Energy and Comfort Systems in India:

- Technical Challenges
- Financial Challenges
- Regulatory Challenges







What has been the experience with new and low energy systems?

- Ground sources heat pumps
- Radiant cooling & heating systems
- Solar cooling
- Exhaust fired Vapour compression systems
- Integrated economizers
- Three and two stage evaporative cooling
- Water-side economizers
- Free cooling and Night Purge