PERFORMANCE COUNTS

Building Energy Simulation – Case study

Environmental Protection Administration, Taipei City, Taiwan

Rajan Rawal
rajanrawal@cept.ac.in

CEPT University

Understand
Design
Planning
Construction
Management
of

Human Habitat

Energy and Habitat

Fuel Type Including RE

Technology

Economics

Generation

Transmission

Distribution

Cities

Buildings

Industry

Design

Construction

Operation

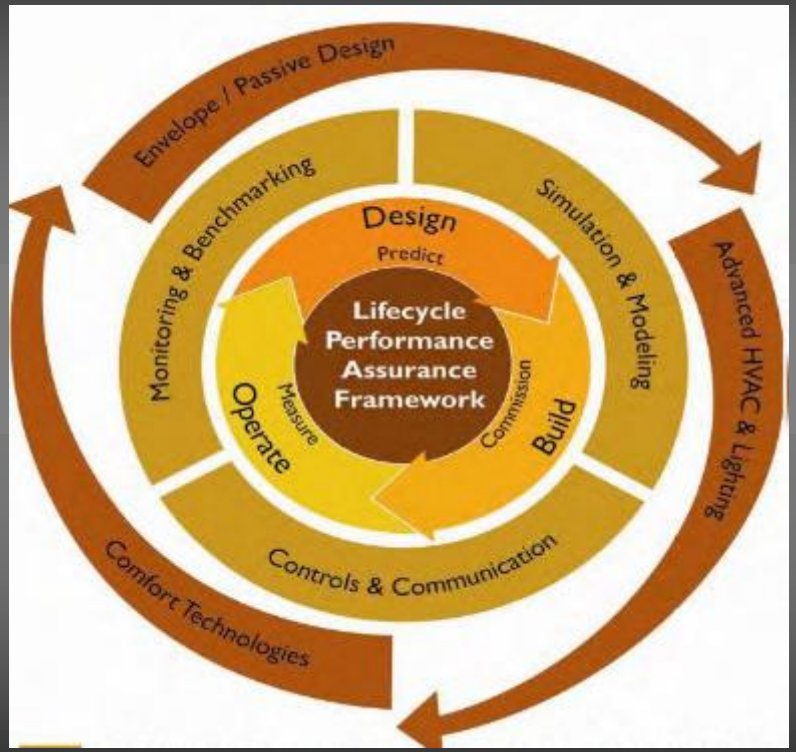
Maintenance

Onsite Renewable integration

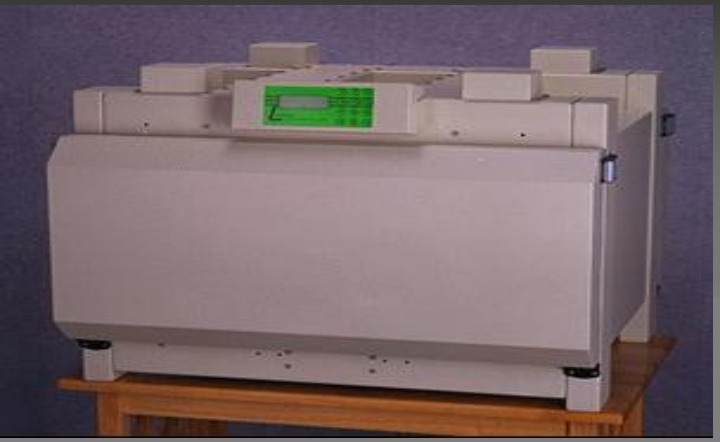
Supply Side

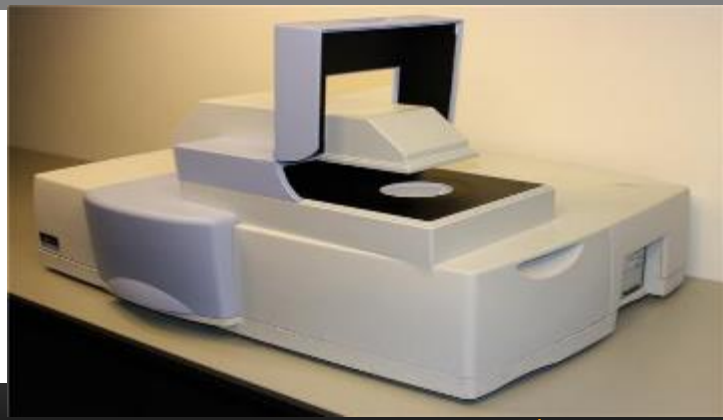
Demand Side

Nature of Work

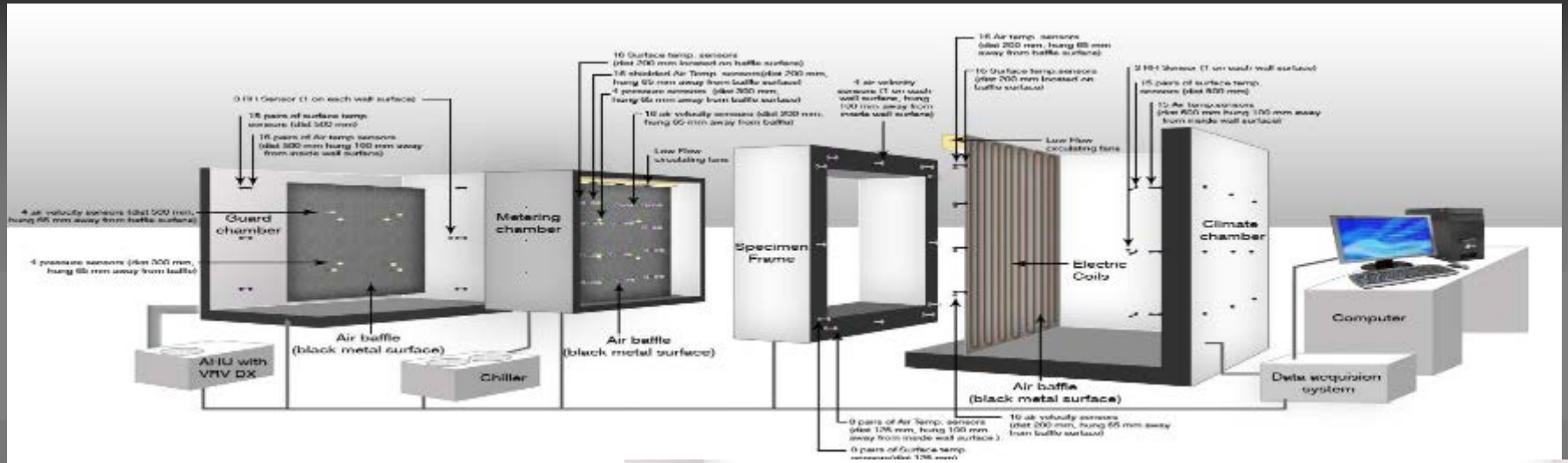


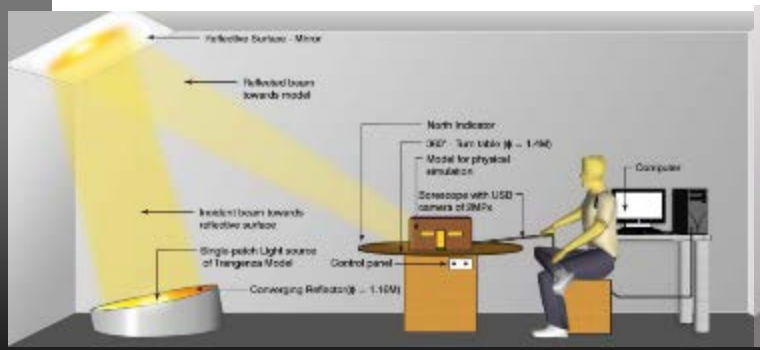
State of Art Testing Facility

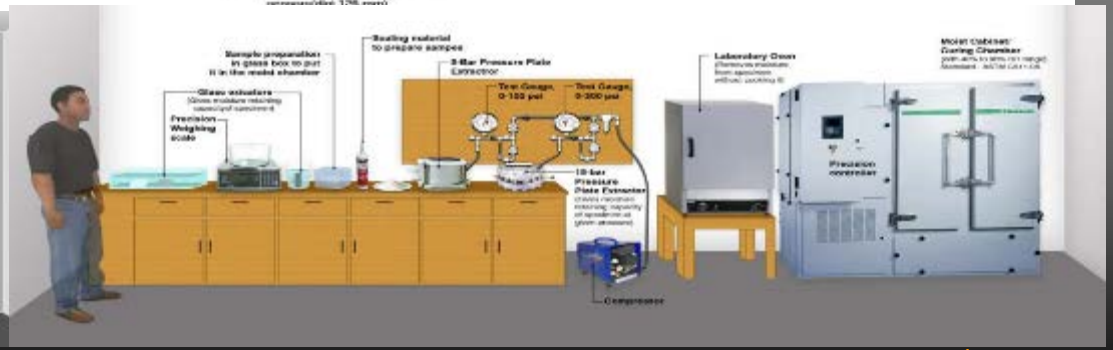




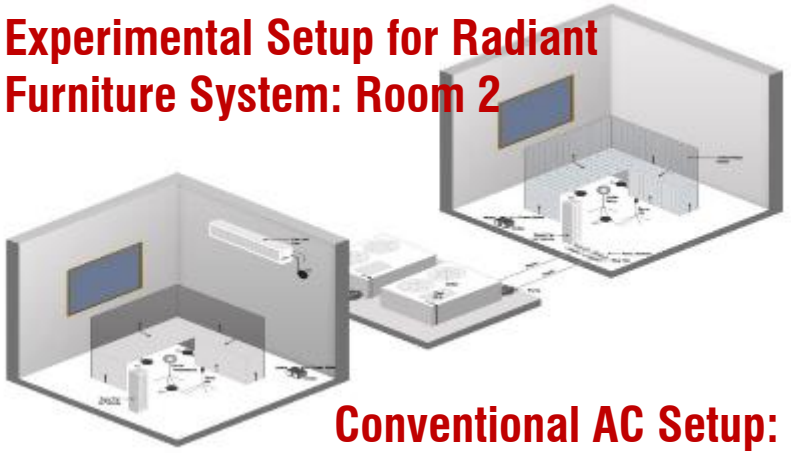
State of Art Testing Facility



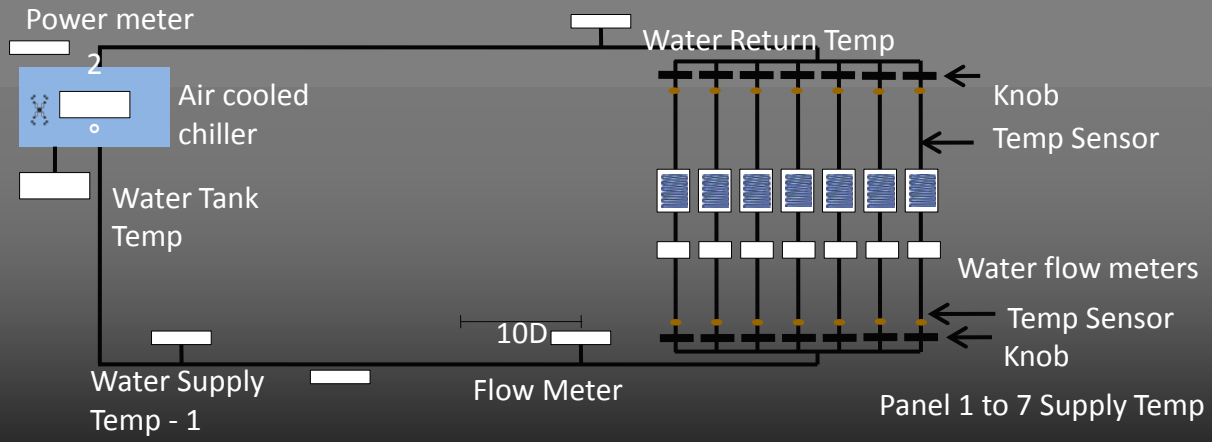




Experimental Setup for Radiant Furniture System: Room 2

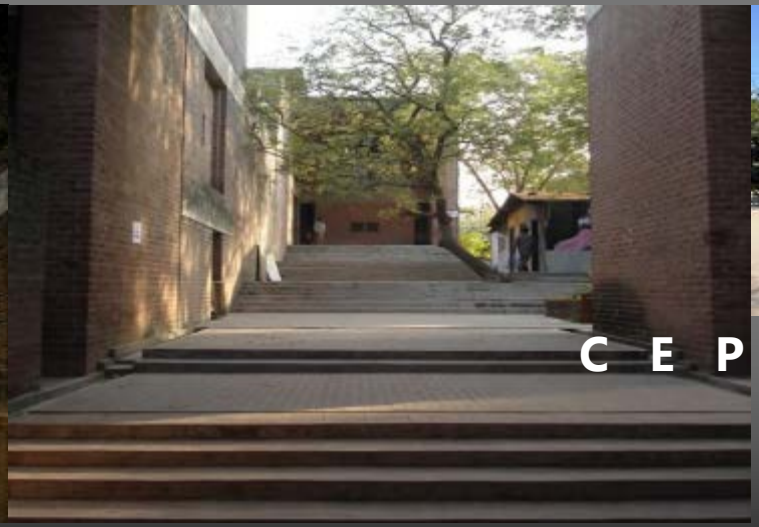


Conventional AC Setup: Room 1



CEPT University Campus Site

A H M E D A B A D



C E P T C A M P U S

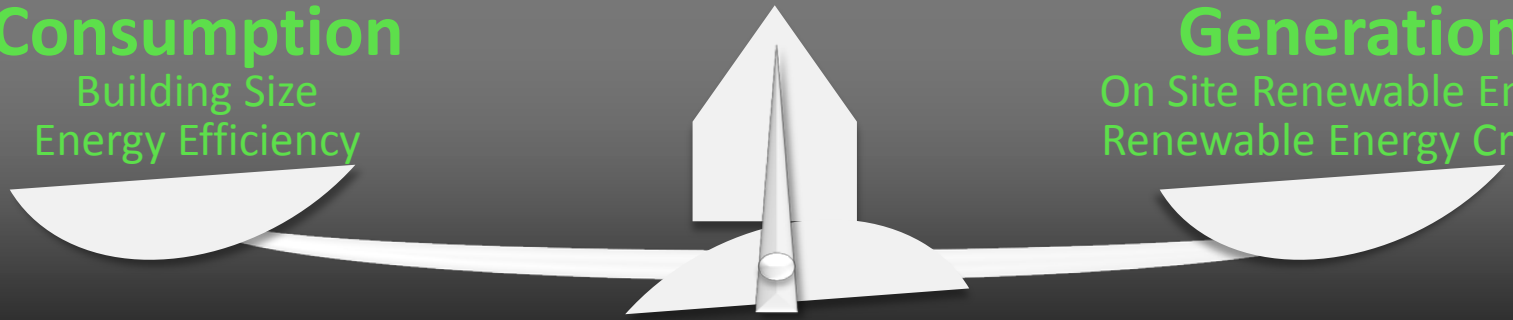
What is a Net Zero Energy Building?

"A building that produces and exports

***at least* as much renewable energy on site as it imports and uses** from emission-producing energy sources annually."

Source: U.S. Department of Energy

Consumption
Building Size
Energy Efficiency

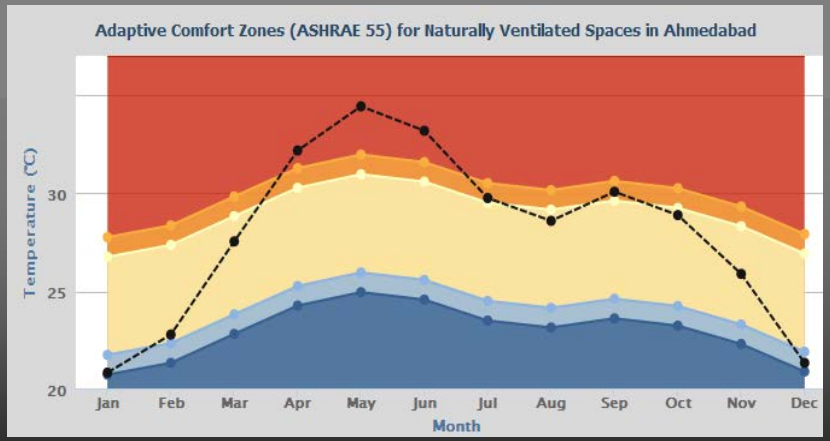


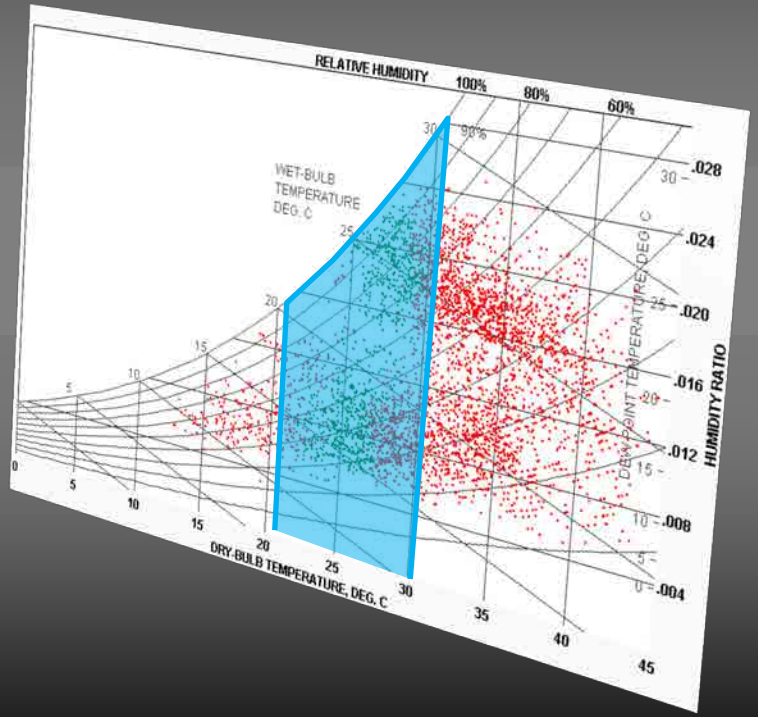
Generation
On Site Renewable Energy
Renewable Energy Credits

Hot-Dry Climate

Only 23% of the daytime hours fall in the comfort range

Adaptive Thermal Comfort Standard





Additional Goals

- Respect the context
- Ensure cost effectiveness and maintainability
- Exemplify technology demonstration
- Showcase the building for education
- Use the building itself as a laboratory for research

Iterative Design Process

- **Predesign**
  - Climate Analysis
  - Technical Potential Analysis
- **Conceptual Design**
  - Passive Thermal Comfort
  - Building Massing
  - HVAC System Options
- **System Development**
  - Section, Windows, Shading, Daylighting
  - Active System Thermal Comfort
  - HVAC Capacity Optimization
  - Natural Ventilation Scheduling, CFD
- **Systems Optimization**

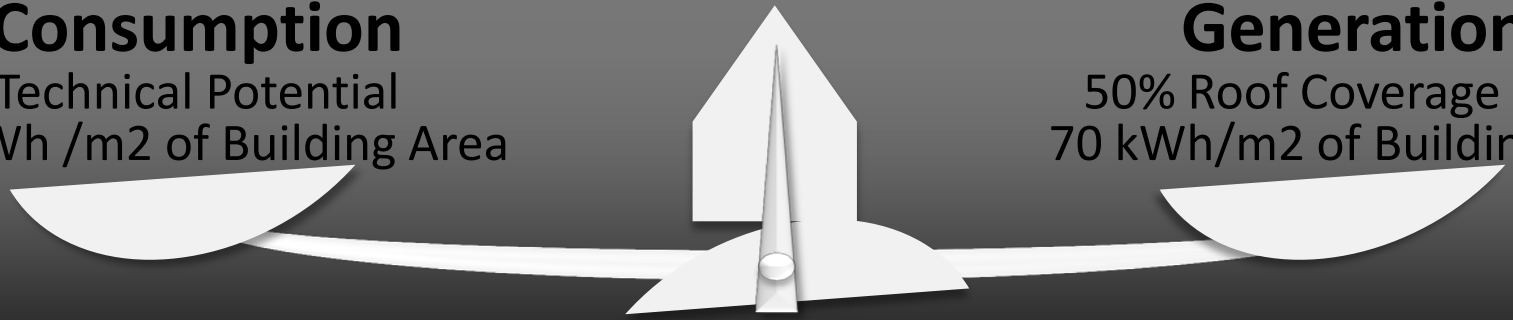
Three in-person charrettes in Ahmedabad

Over 50 virtual meetings and presentations

Predesign

The entire team with all consultants met over three days in Ahmedabad, to **establish technical potential, generate options, and agree on design directions.**

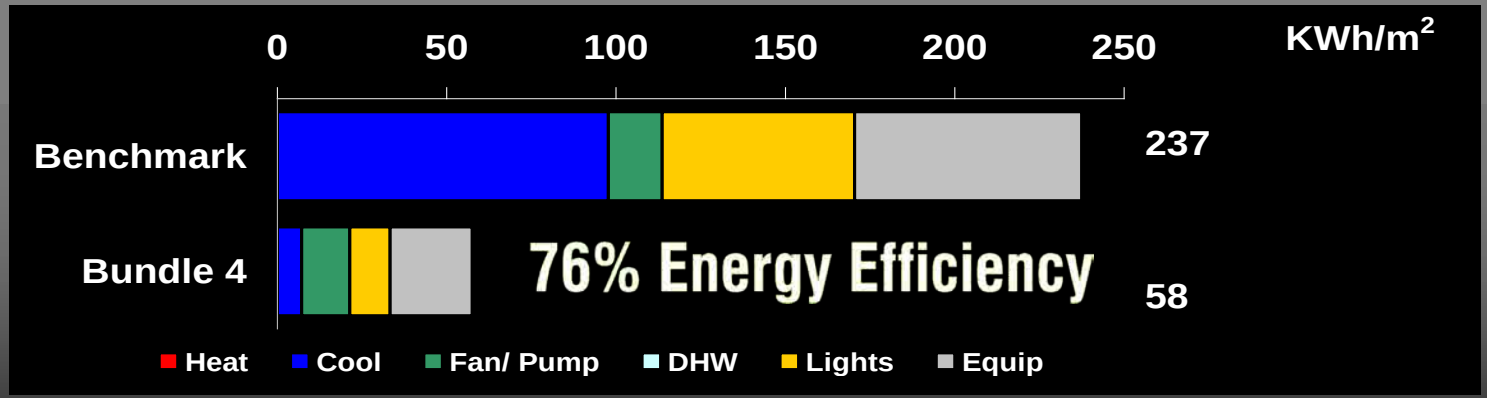
Consumption
Technical Potential
58 kWh /m2 of Building Area



Generation
50% Roof Coverage of PV
70 kWh/m2 of Building Area

Predesign

Pre-design energy simulations of a benchmark building, investigated about 80 energy conservation measures (ECMs) and also compiled bundles of strategies to test the energy efficiency potential of this building type **in the Ahmedabad climate**



Predesign Direction

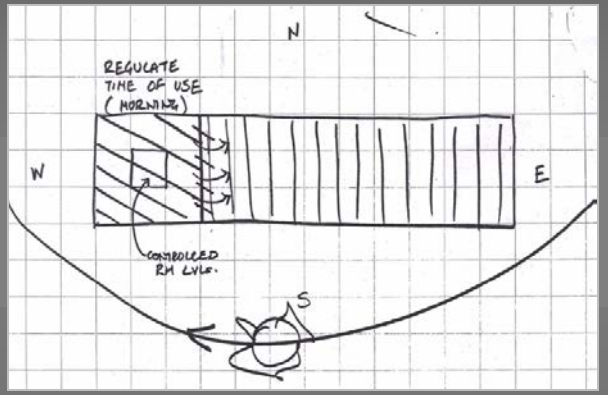
- Consumption limit of 60 kWh/m2
- 3-1 building aspect ratio along East-west axis.
- 20%WWR, with 0.3 SHGC, 1.7 unit –U-value .
- R-4.4 wall, R-7 roof assembly , cool roof
- Exterior window shading with 15° projection angle
- All spaces daylight with dimming control of lighting .
- Connected lighting power densities of 6.0W/m², occupancy sensor control.

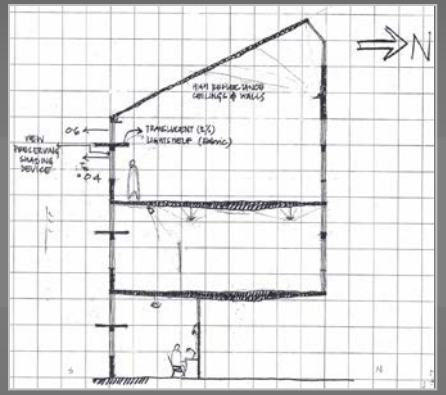
Predesign Direction

- Plug load reduction by 30% and occupancy sensor control of all office related plug loads .
- Direct evaporative system for indoor comfort as per Adaptive Thermal Comfort standard
- CO_2 controls of outside air in office /seminar areas
- 50 % roof coverage of PV panels for on-site generation, tilted at 23º facing south .

Building Massing Analysis

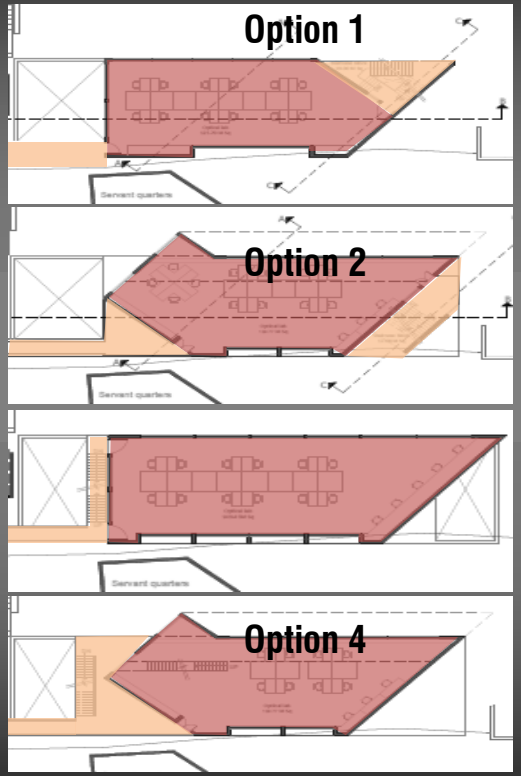
Basis of Design for Energy Performance

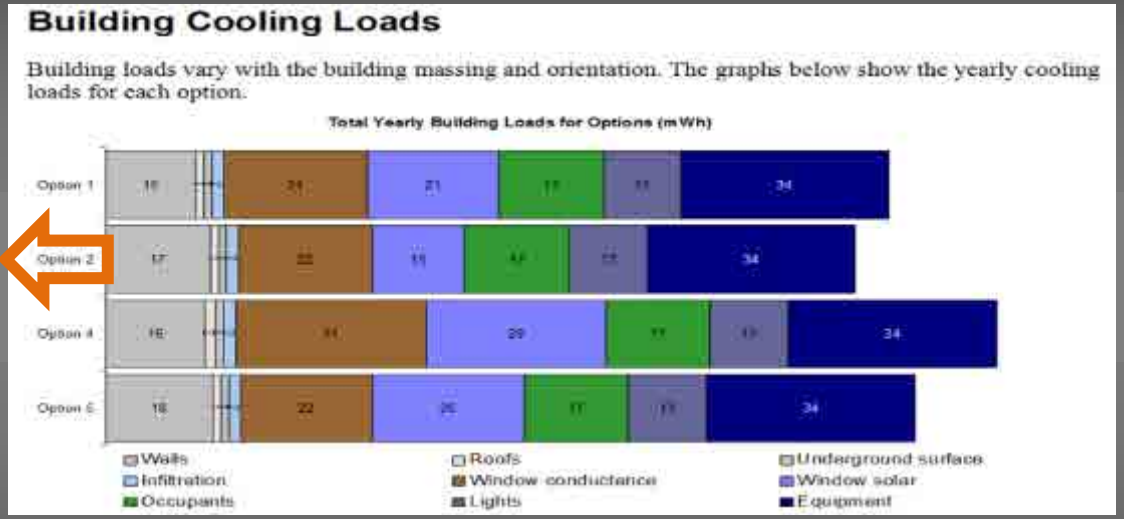




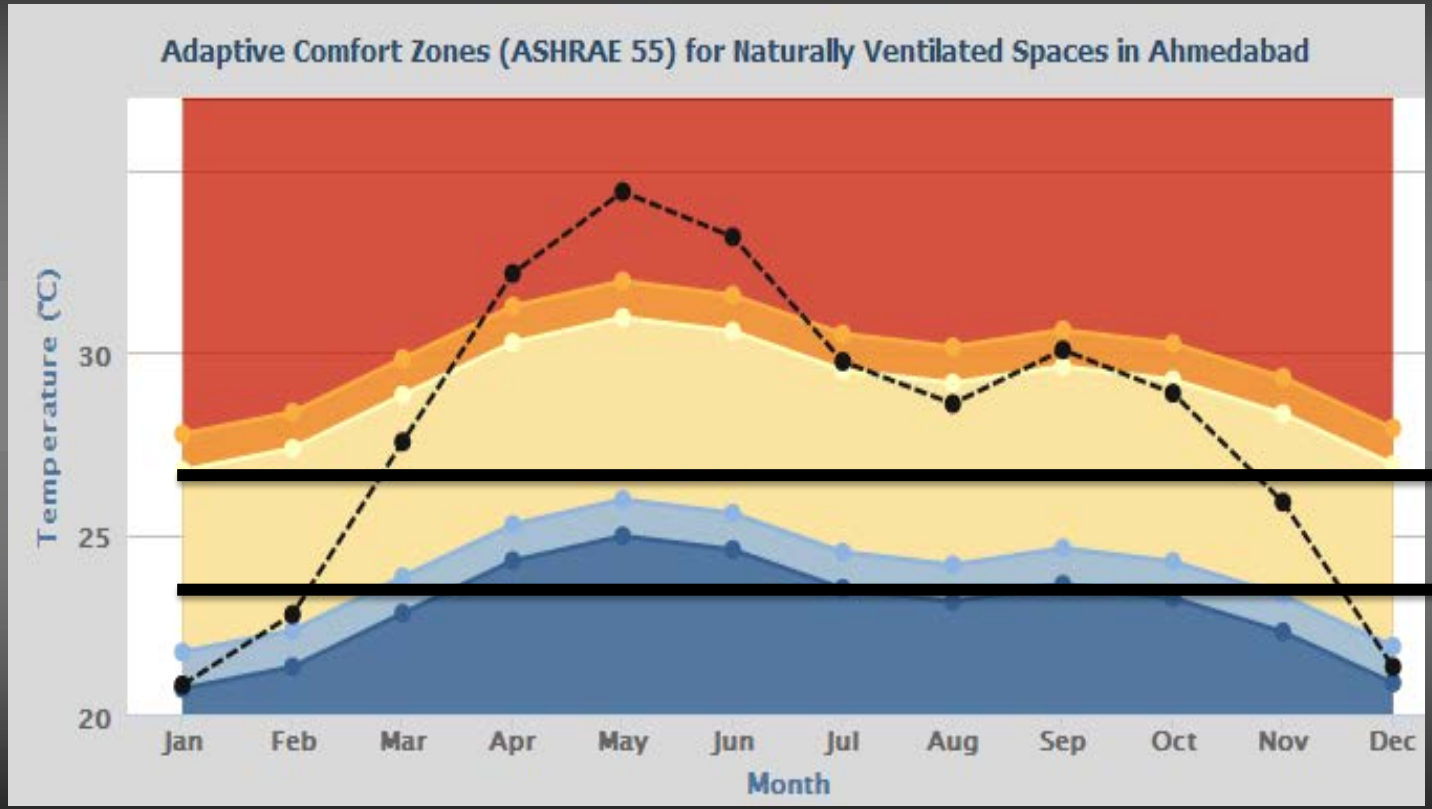
Use of Shading Devices & Light Shelf to get maximum advantage of daylight

Building Massing Analysis

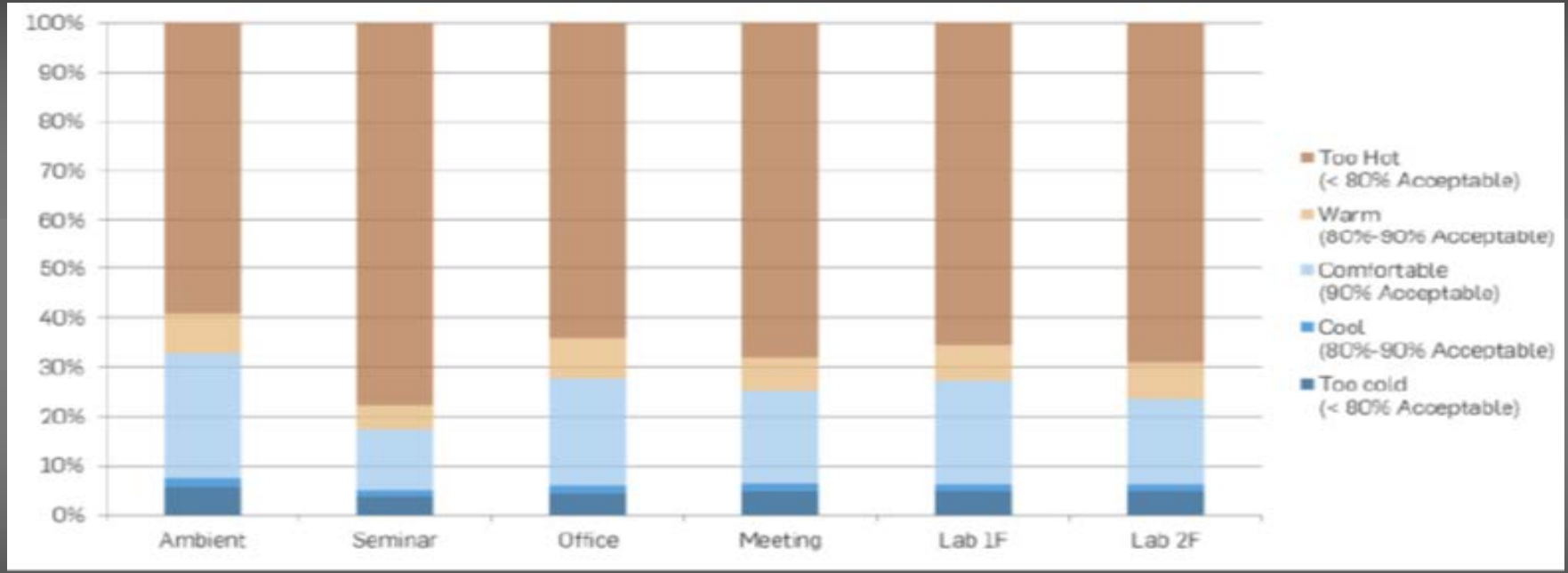




Passive Thermal Comfort

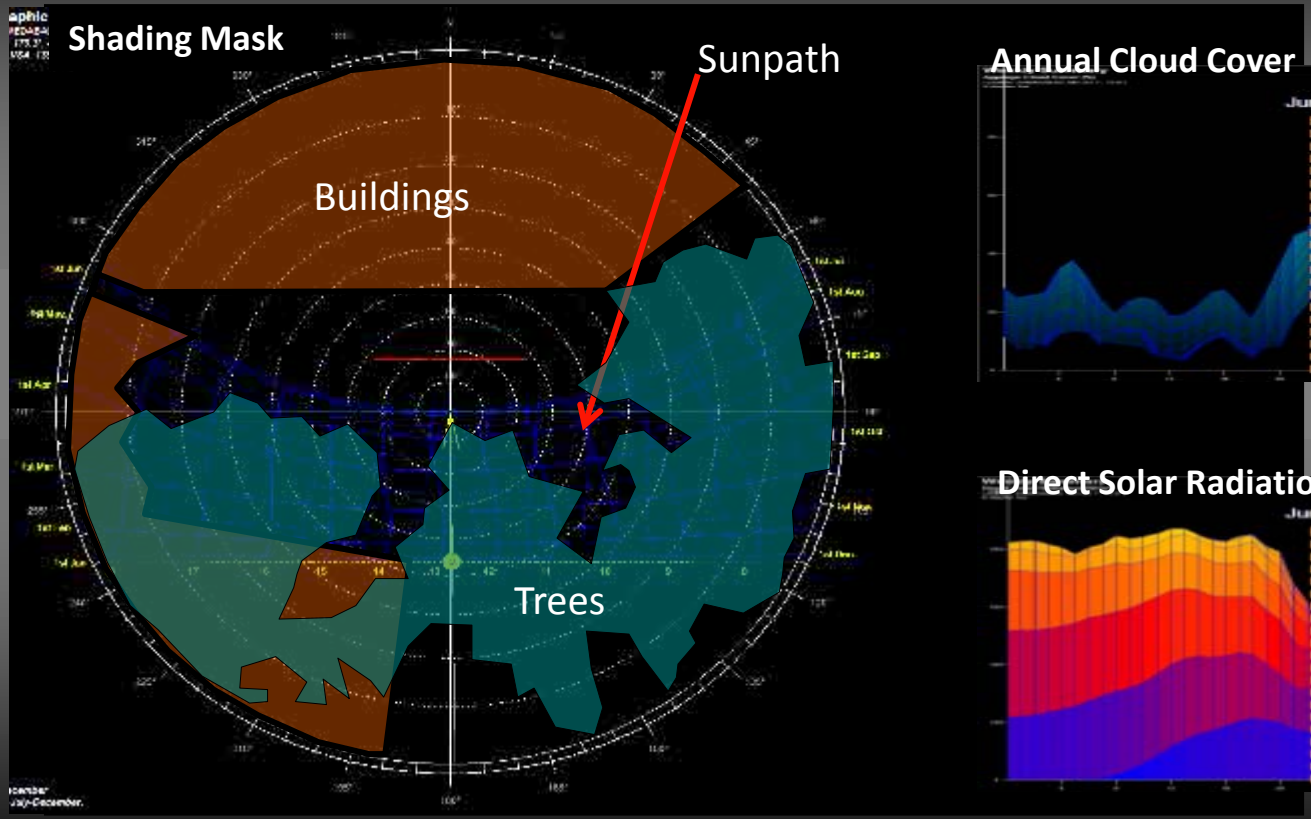


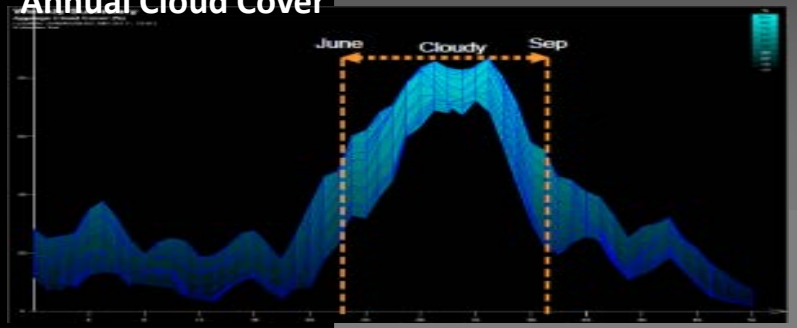
Passive Thermal Comfort

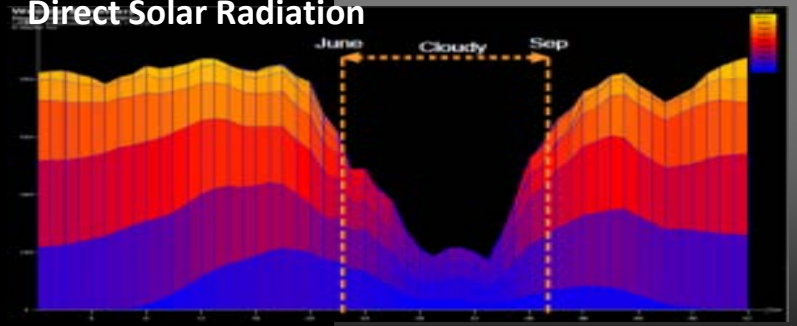


ASHRAE 55 Comfort Band Performance per space type using typical CEPT building standards

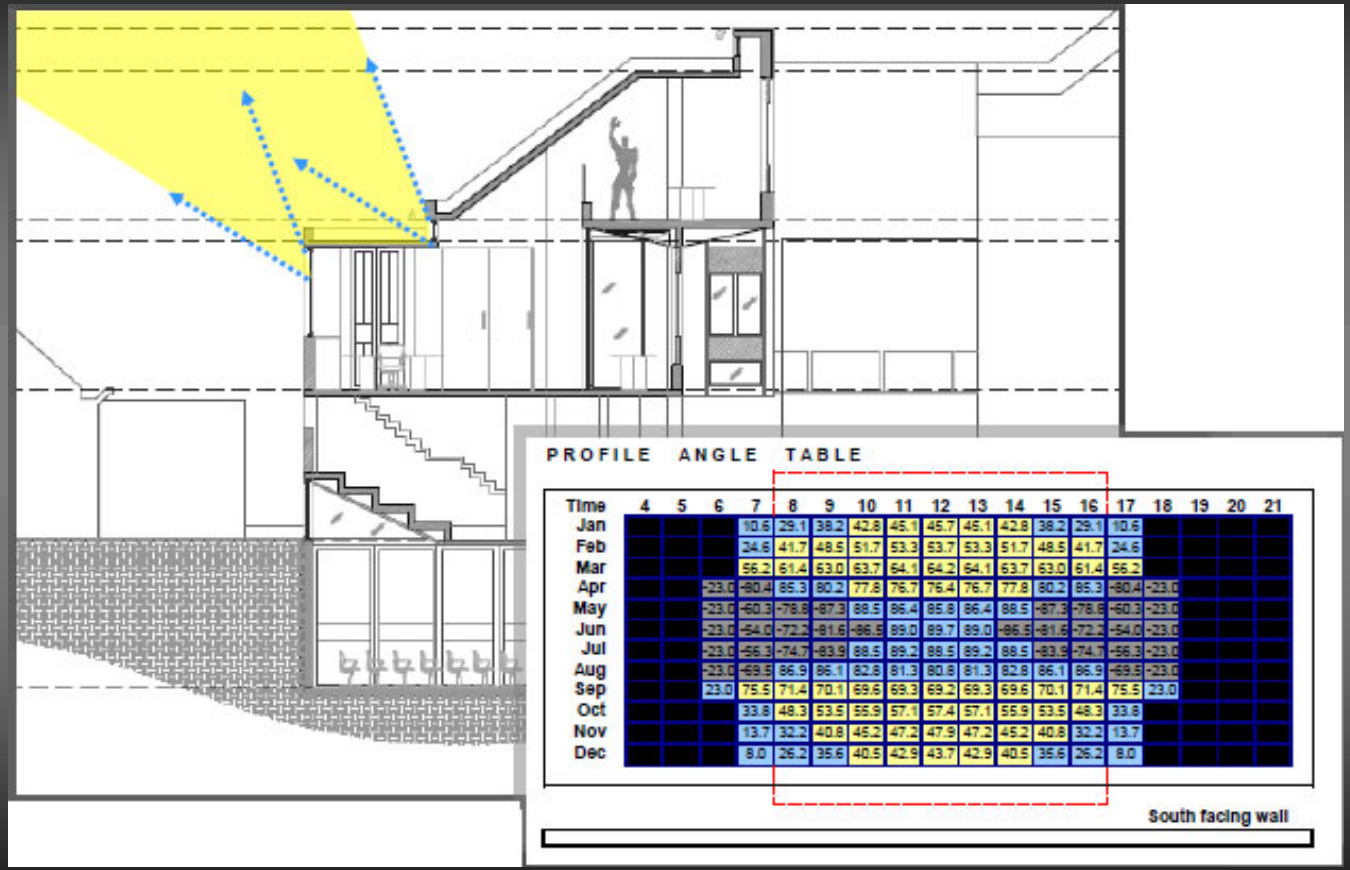
Daylighting







Direct sun access needed for daylighting 40° minimum, 80° maximum

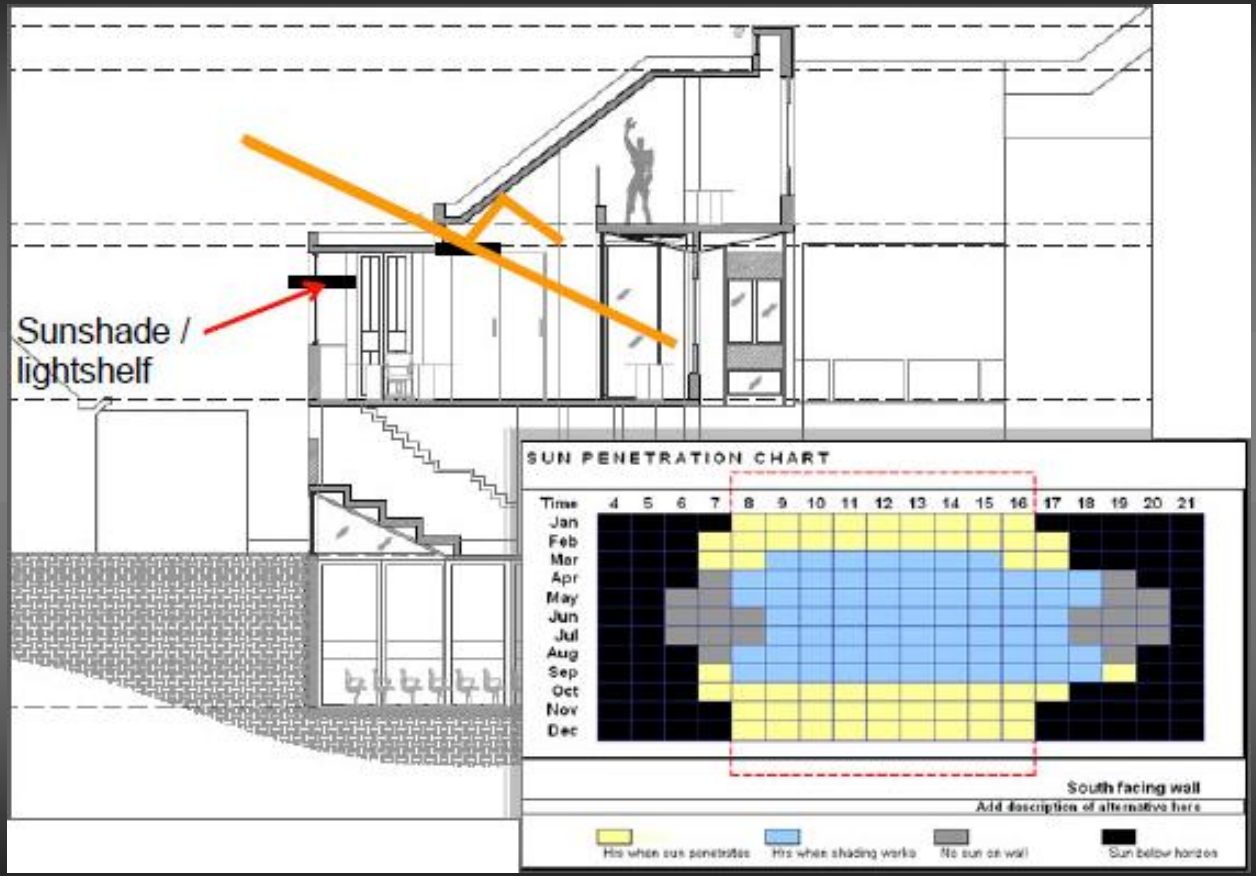


PROFILE ANGLE TABLE

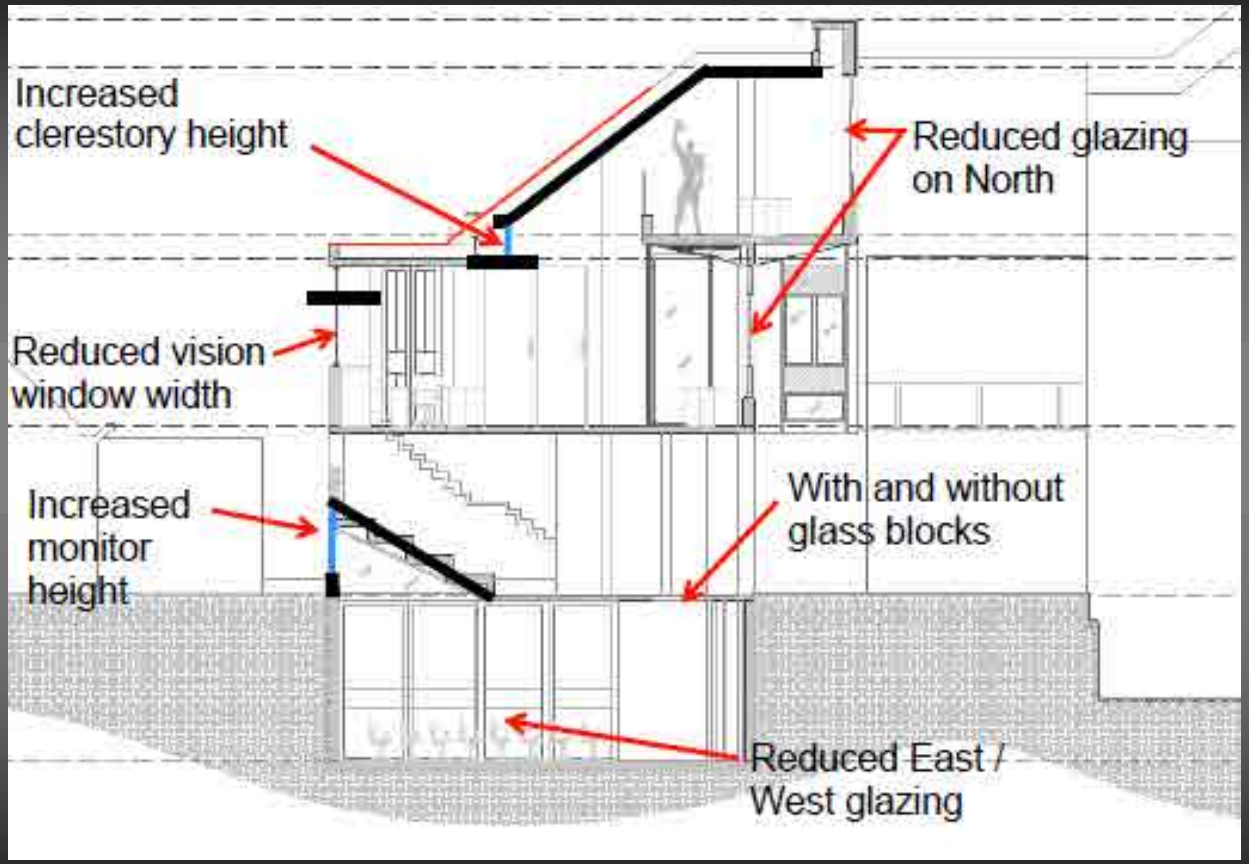
Time	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Jan				10.6	29.1	38.2	42.8	45.1	45.7	45.1	42.8	38.2	29.1	10.6				
Feb				24.6	41.7	48.5	51.7	53.3	53.7	53.3	51.7	48.5	41.7	24.6				
Mar				56.2	61.4	63.0	63.7	64.1	64.2	64.1	63.7	63.0	61.4	56.2				
Apr			-23.0	-80.4	85.3	80.2	77.8	76.7	76.4	76.7	77.8	80.2	85.3	-80.4	-23.0			
May			-23.0	-60.3	-78.6	-87.3	88.5	86.4	85.8	86.4	88.5	-87.3	-78.6	-60.3	-23.0			
Jun			-23.0	-54.0	-72.2	-81.6	-86.5	89.0	89.7	89.0	-86.5	-81.6	-72.2	-54.0	-23.0			
Jul			-23.0	-56.3	-74.7	-83.9	88.5	89.2	88.5	89.2	88.5	-83.9	-74.7	-56.3	-23.0			
Aug			-23.0	-69.5	86.9	86.1	82.8	81.3	80.8	81.3	82.8	86.1	86.9	-69.5	-23.0			
Sep			23.0	75.5	71.4	70.1	69.6	69.3	69.2	69.3	69.6	70.1	71.4	75.5	23.0			
Oct				33.8	48.3	53.5	55.9	57.1	57.4	57.1	55.9	53.5	48.3	33.8				
Nov				13.7	32.2	40.8	45.2	47.2	47.9	47.2	45.2	40.8	32.2	13.7				
Dec				8.0	26.2	35.6	40.5	42.9	43.7	42.9	40.5	35.6	26.2	8.0				

South facing wall

Daylighting Schemes Base case



Daylighting Schemes Options



Analysis Objectives

Optimize shading elements

- Basement south monitor
- 1st floor south window light shelf (translucent material)
- 1st floor clerestory light shelf (w/ triangular fins every 1800 mm)
- Minimize summer heat gain
- Minimize direct sun glare

Use optimized shading elements for luminance analysis

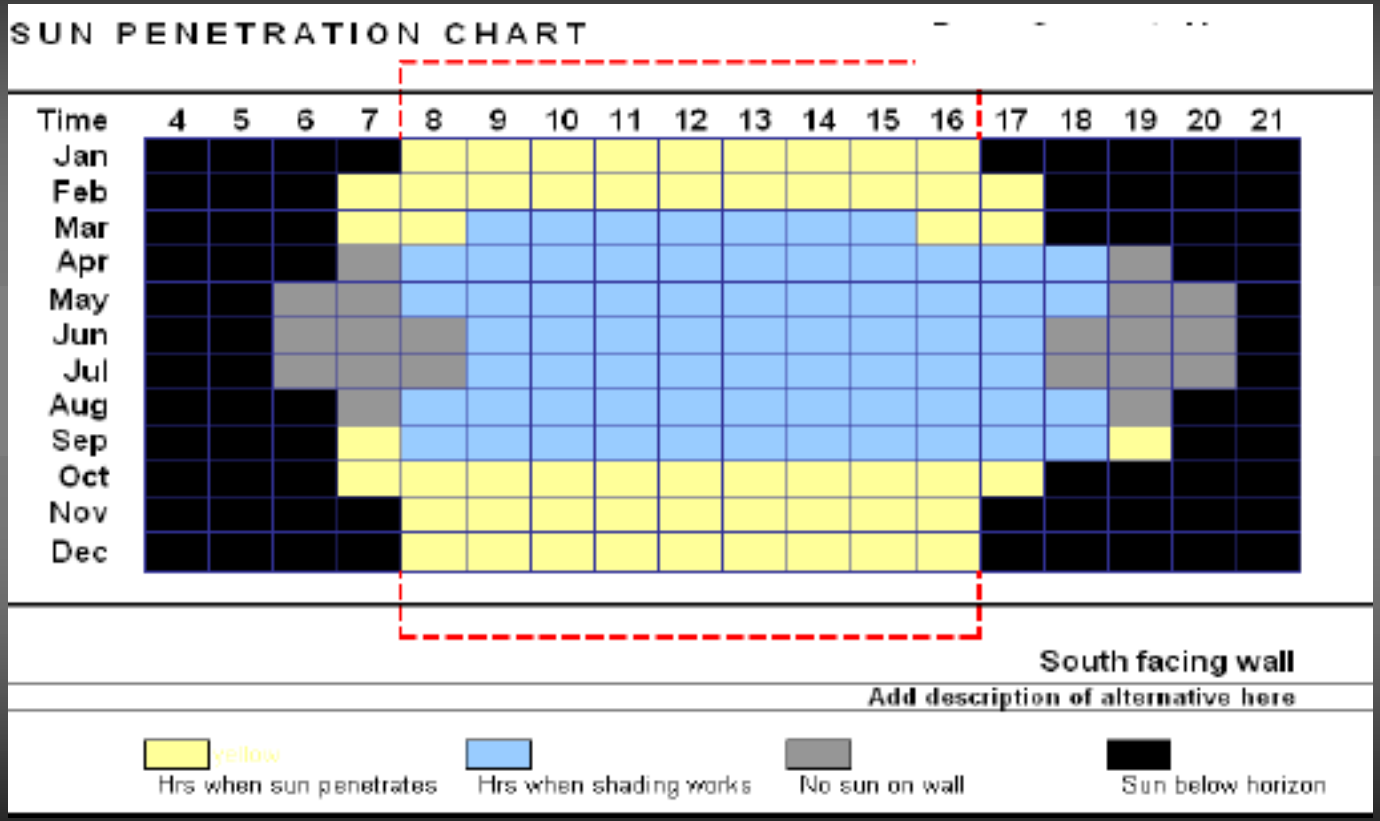
- Cloudy sky condition
- Daylight autonomy

Analysis Objectives

Optimize daylight apertures

- Basement south monitor (increase ht by 6”)
- Basement glass blocks (add) – with curb all around
- Basement East & west reduce VLT by 50%
- Reduce north glass VLT by 50%
- 1st floor clerestory
- 1st floor south vision window – reduce width

Sun Control Analysis Sample Chart

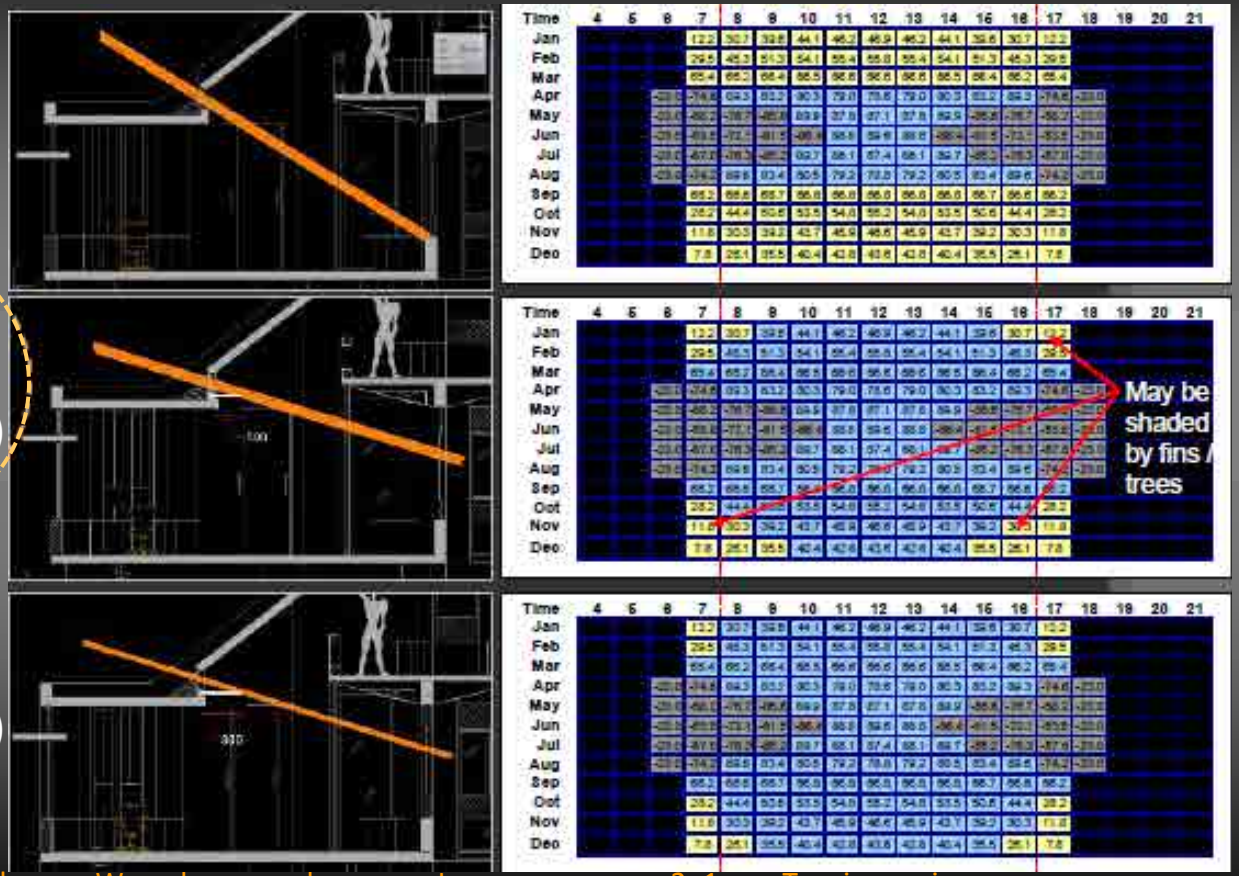


Sun Control Analysis South Facing Clerestory

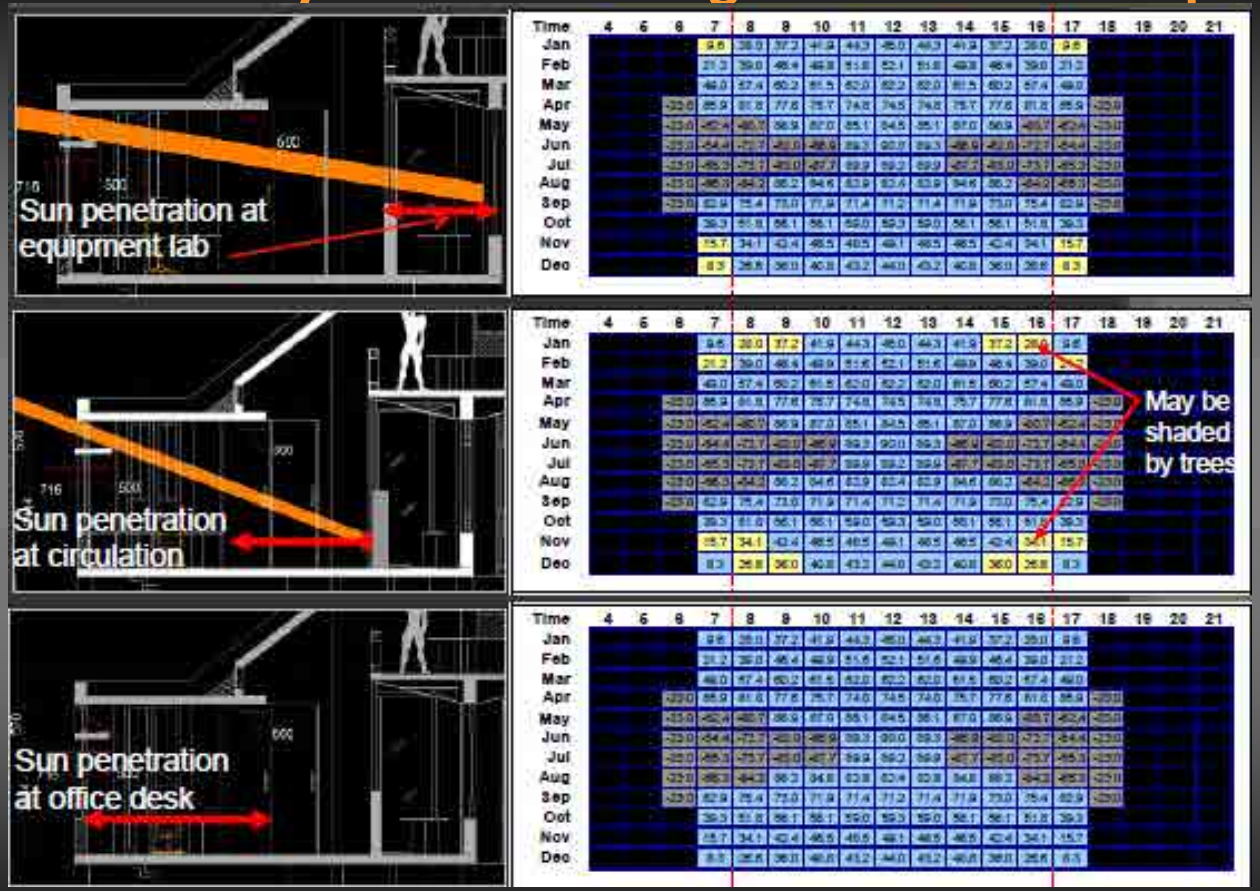
Base Case
No light shelf
(70 deg cut-off)

Option 1
500 light shelf
(39 deg cut-off)

Option 2
800 light shelf
(30 deg cut-off)



Sun Control Analysis South Facing Transom- with option 1



Sun Control Analysis – Basement Monitor

Base Case
No light shelf
(80 deg cut-off)

Time	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Jan				12.2	30.7	39.6	44.1	48.2	48.9	48.2	44.1	39.6	30.7	12.2				
Feb				29.5	46.3	51.3	54.1	55.4	55.8	55.4	54.1	51.3	46.3	29.5				
Mar				55.4	66.2	66.4	66.5	66.6	66.6	66.6	66.5	66.4	66.2	55.4				
Apr			[illegible]	[illegible]	86.3	83.2	80.3	79.0	78.6	79.0	80.3	83.2	86.3	[illegible]	[illegible]			
May			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	87.3	87.1	87.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Jun			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Jul			[illegible]	[illegible]	[illegible]	[illegible]	86.7	86.1	87.4	86.1	86.7	[illegible]	[illegible]	[illegible]	[illegible]			
Aug			[illegible]	[illegible]	86.6	83.4	80.5	79.2	78.8	79.2	80.5	83.4	86.6	[illegible]	[illegible]			
Sep				66.2	66.6	66.7	66.8	66.8	66.8	66.8	66.8	66.7	66.6	66.2				
Oct				28.2	44.4	50.6	53.5	54.8	55.2	54.8	53.5	50.6	44.4	28.2				
Nov				11.8	30.3	39.2	43.7	45.9	46.6	45.9	43.7	39.2	30.3	11.8				
Dec				7.8	26.1	35.5	40.4	42.8	43.6	42.8	40.4	35.5	26.1	7.8				

Option 1
500 light shelf
(61 deg cut-off)

Time	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Jan				12.2	30.7	39.6	44.1	48.2	48.9	48.2	44.1	39.6	30.7	12.2				
Feb				29.5	46.3	51.3	54.1	55.4	55.8	55.4	54.1	51.3	46.3	29.5				
Mar				55.4	66.2	66.4	66.5	66.6	66.6	66.6	66.5	66.4	66.2	55.4				
Apr			[illegible]	[illegible]	86.3	83.2	80.3	79.0	78.6	79.0	80.3	83.2	86.3	[illegible]	[illegible]			
May			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	87.3	87.1	87.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Jun			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Jul			[illegible]	[illegible]	[illegible]	[illegible]	86.7	86.1	87.4	86.1	86.7	[illegible]	[illegible]	[illegible]	[illegible]			
Aug			[illegible]	[illegible]	86.6	83.4	80.5	79.2	78.8	79.2	80.5	83.4	86.6	[illegible]	[illegible]			
Sep				66.2	66.6	66.7	66.8	66.8	66.8	66.8	66.8	66.7	66.6	66.2				
Oct				28.2	44.4	50.6	53.5	54.8	55.2	54.8	53.5	50.6	44.4	28.2				
Nov				11.8	30.3	39.2	43.7	45.9	46.6	45.9	43.7	39.2	30.3	11.8				
Dec				7.8	26.1	35.5	40.4	42.8	43.6	42.8	40.4	35.5	26.1	7.8				

Option 2
800 light shelf
(51 deg cut-off)

Time	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Jan				12.2	30.7	39.6	44.1	48.2	48.9	48.2	44.1	39.6	30.7	12.2				
Feb				29.5	46.3	51.3	54.1	55.4	55.8	55.4	54.1	51.3	46.3	29.5				
Mar				55.4	66.2	66.4	66.5	66.6	66.6	66.6	66.5	66.4	66.2	55.4				
Apr			[illegible]	[illegible]	86.3	83.2	80.3	79.0	78.6	79.0	80.3	83.2	86.3	[illegible]	[illegible]			
May			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	87.3	87.1	87.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Jun			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Jul			[illegible]	[illegible]	[illegible]	[illegible]	86.7	86.1	87.4	86.1	86.7	[illegible]	[illegible]	[illegible]	[illegible]			
Aug			[illegible]	[illegible]	86.6	83.4	80.5	79.2	78.8	79.2	80.5	83.4	86.6	[illegible]	[illegible]			
Sep				66.2	66.6	66.7	66.8	66.8	66.8	66.8	66.8	66.7	66.6	66.2				
Oct				28.2	44.4	50.6	53.5	54.8	55.2	54.8	53.5	50.6	44.4	28.2				
Nov				11.8	30.3	39.2	43.7	45.9	46.6	45.9	43.7	39.2	30.3	11.8				
Dec				7.8	26.1	35.5	40.4	42.8	43.6	42.8	40.4	35.5	26.1	7.8				

Design Guidelines & Implications

South Clerestory

- Provision of 500 mm wide translucent light shelf
- Low sun angles during winter morning and evening may get shaded by structural fins and adjacent trees
- Trim exterior trees (min 40 deg angle and max 80 deg angle) to get direct sun for daylighting

Design Guidelines & Implications

South Transom

- Provide 500 mm wide translucent light shelf
- An hour of sun penetration occurs during winter morning and evening at equipment lab
- Two hours of sun penetration occur during winter morning and evening at circulation
- No sun penetration at office desk
- Low sun angles during winter morning and evening may get shaded by adjacent trees

Daylighting Analysis Daylight Model Parameters

Model Parameters:

Sky conditions : Clear / Cloudy

Simulation Day / Time : September 21, 1:00 PM

Simulation tools : Radiance ™

DAYSIM ™

Location : Ahmedabad, India

Latitude : 23 N

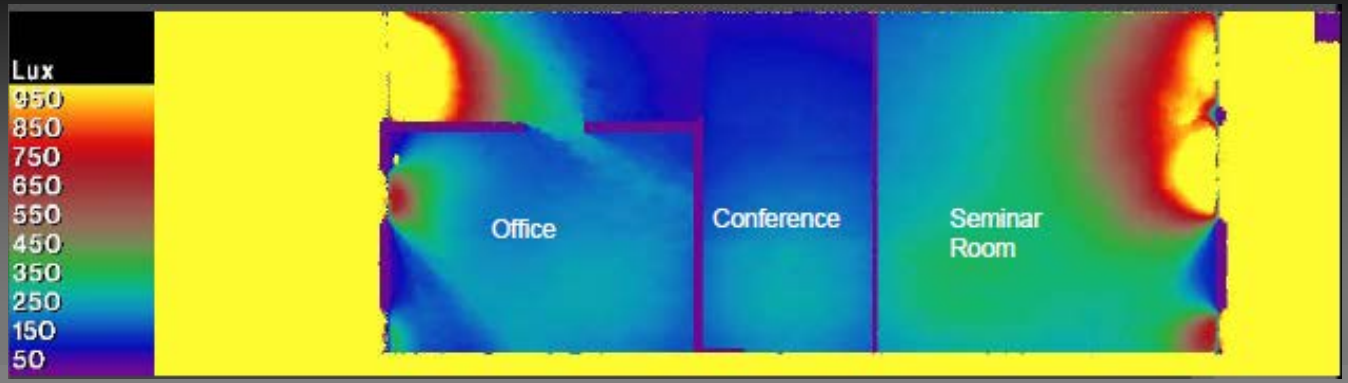
Luminance of floor plan under clear sky Basement level

With Glass Blocks

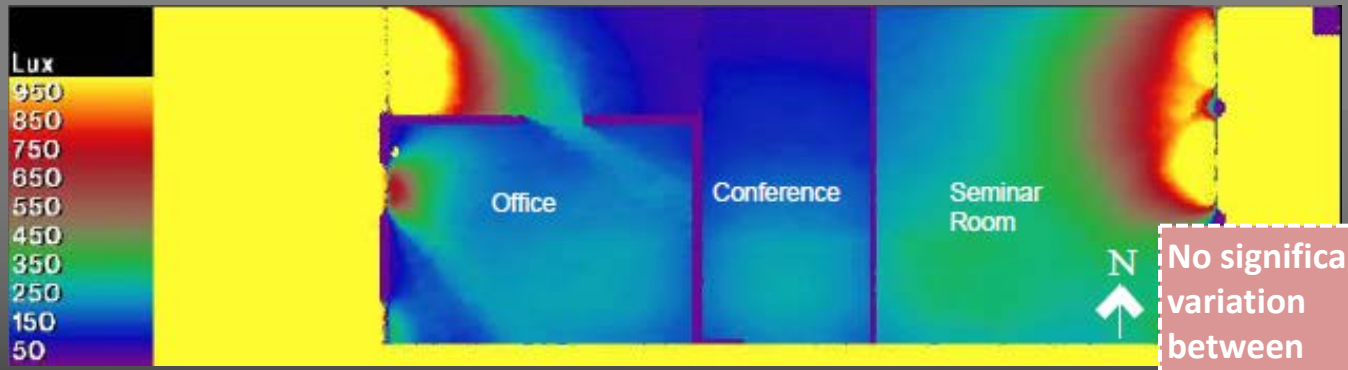
Without Glass Blocks

No significant variation between options,

Illuminance of floor plan under clear sky



With Glass Blocks



Without Glass Blocks

No significant variation between options,

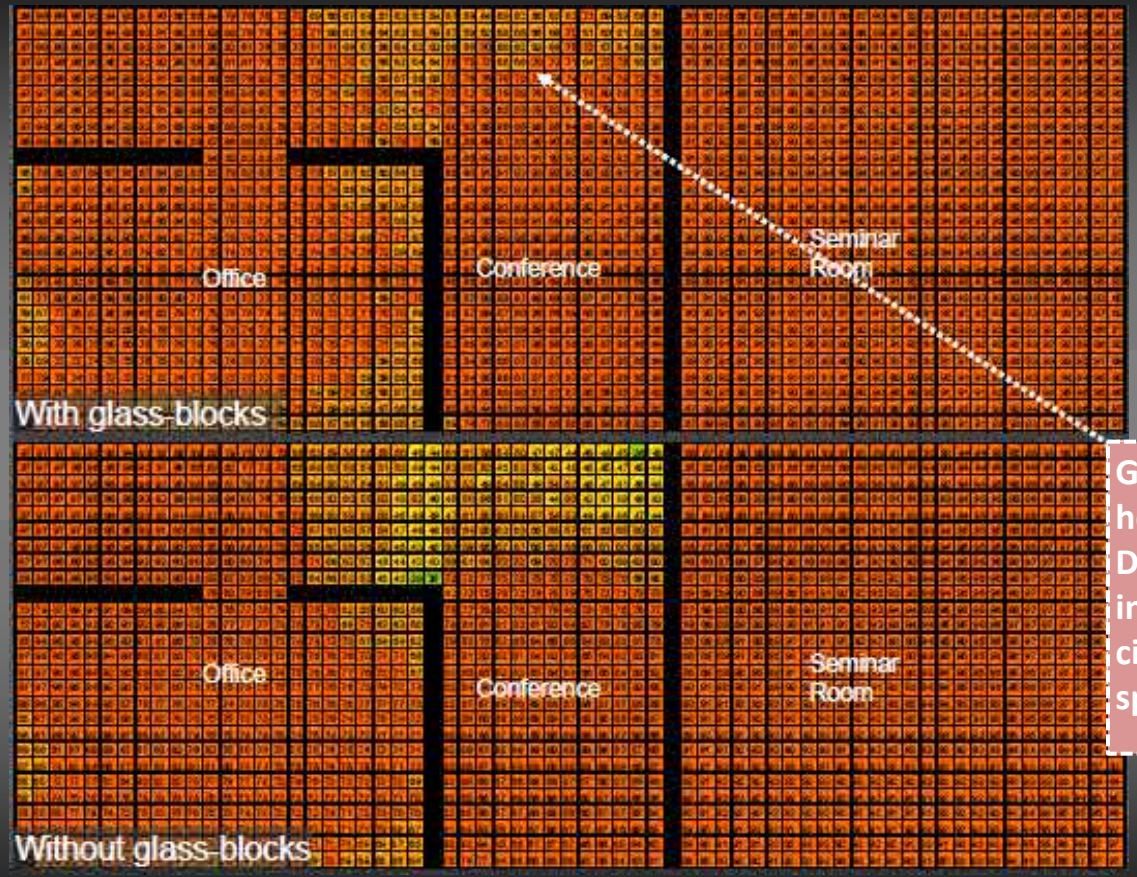
Luminance views under clear sky Basement level

With translucent glass-blocks

With out glass-blocks

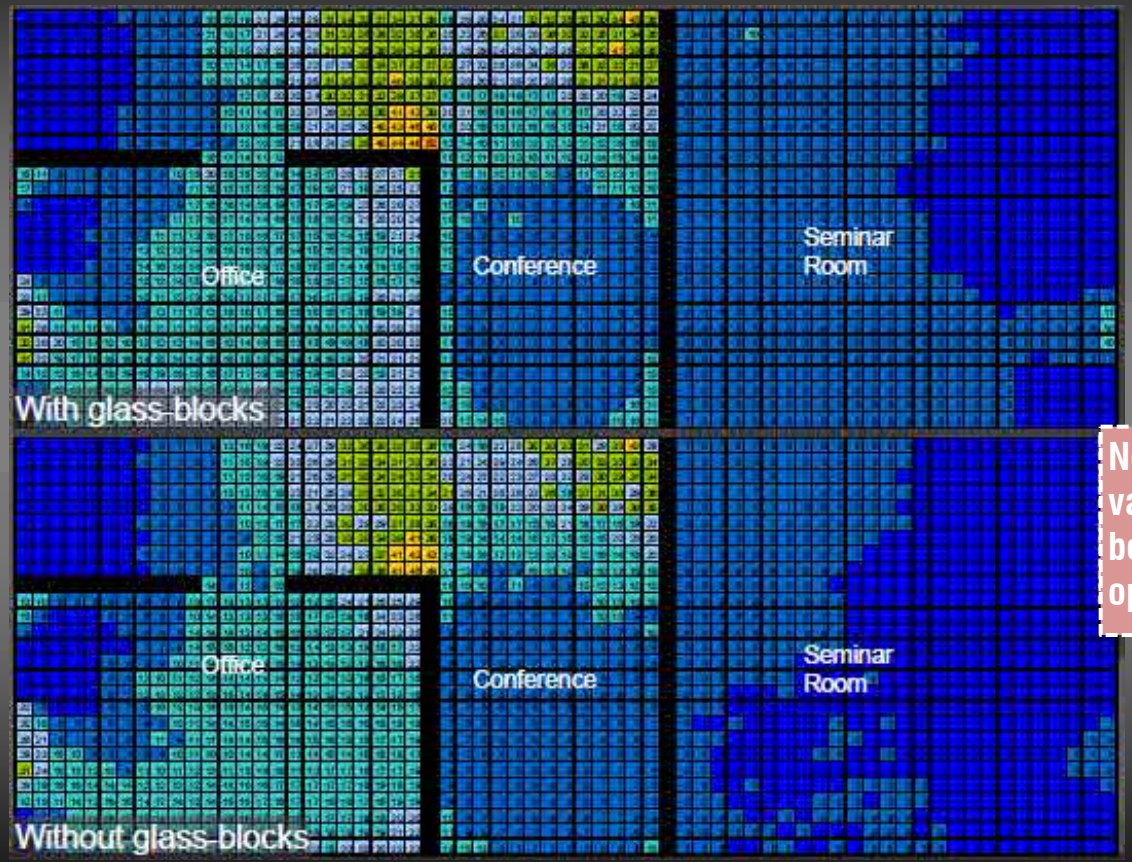
No significant variation between options

Continuous Daylight Autonomy (300 lux) on Work Plane Basement level



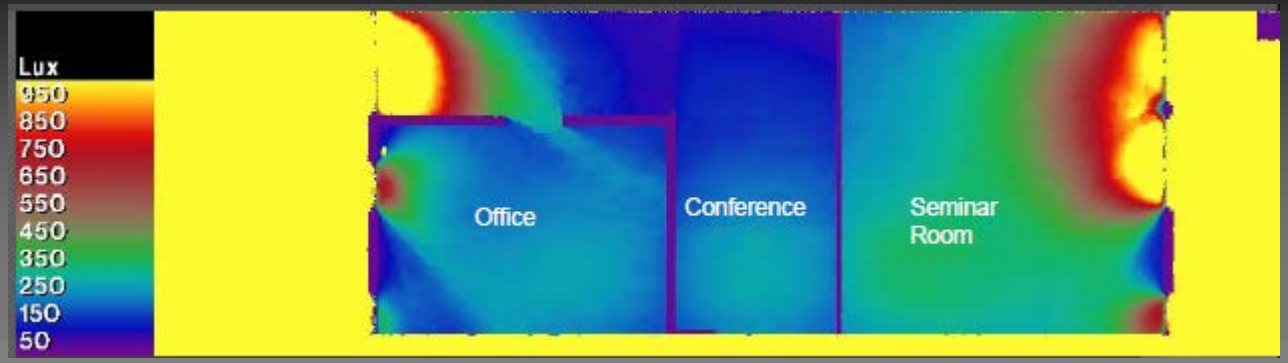
Glass-blocks help increase DA up to 15% in the circulation space

Useful Daylight Index (<100) on Work Plane Basement level



No significant variation between options,

Illuminance of floor plan under clear sky Basement level



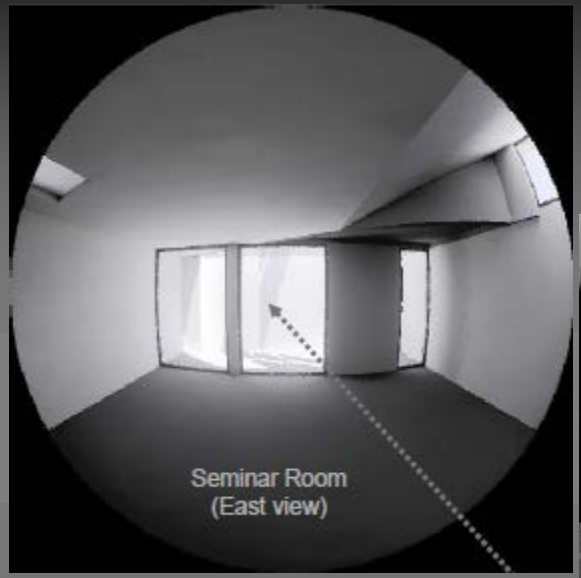
With 67% VT on East & West

With 33% VT on East & West

Reduced VT helps reduce high contrast/glare near windows

N

Luminance views under clear sky Basement level

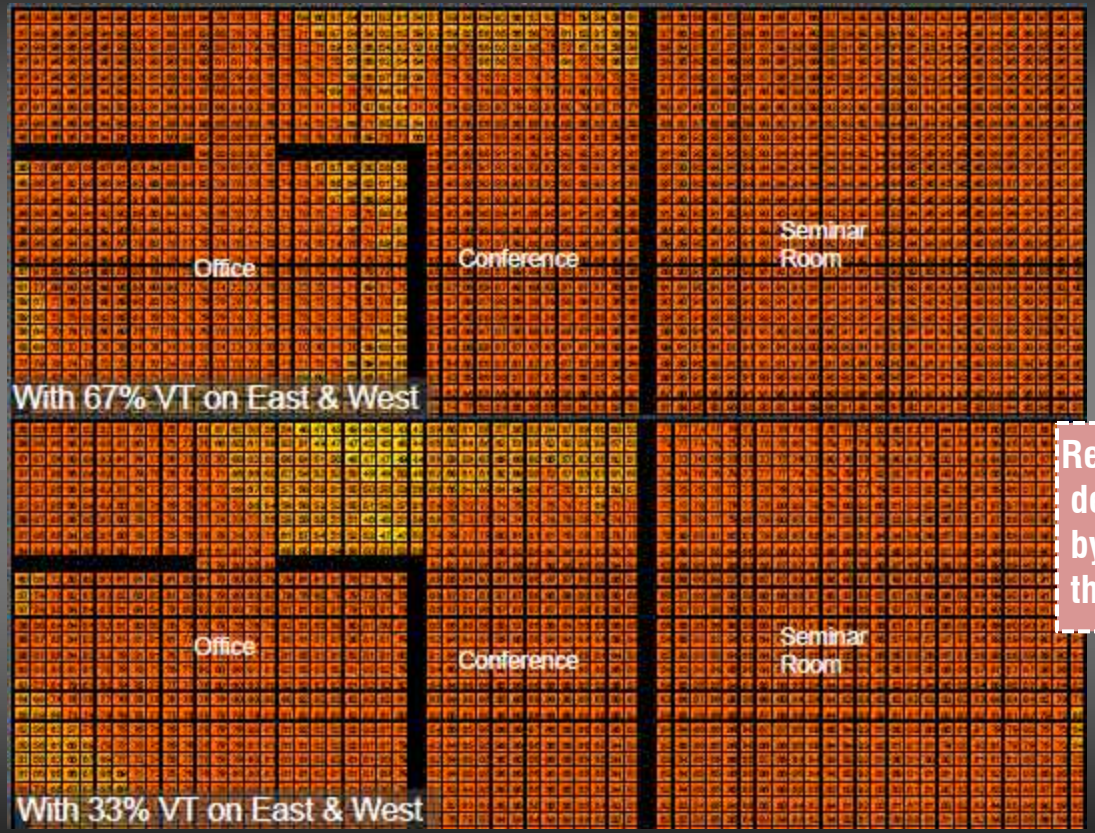


With 67 % VT on East & West

Split windows into vision (67% VT) and transom (33%) VT to reduce glare

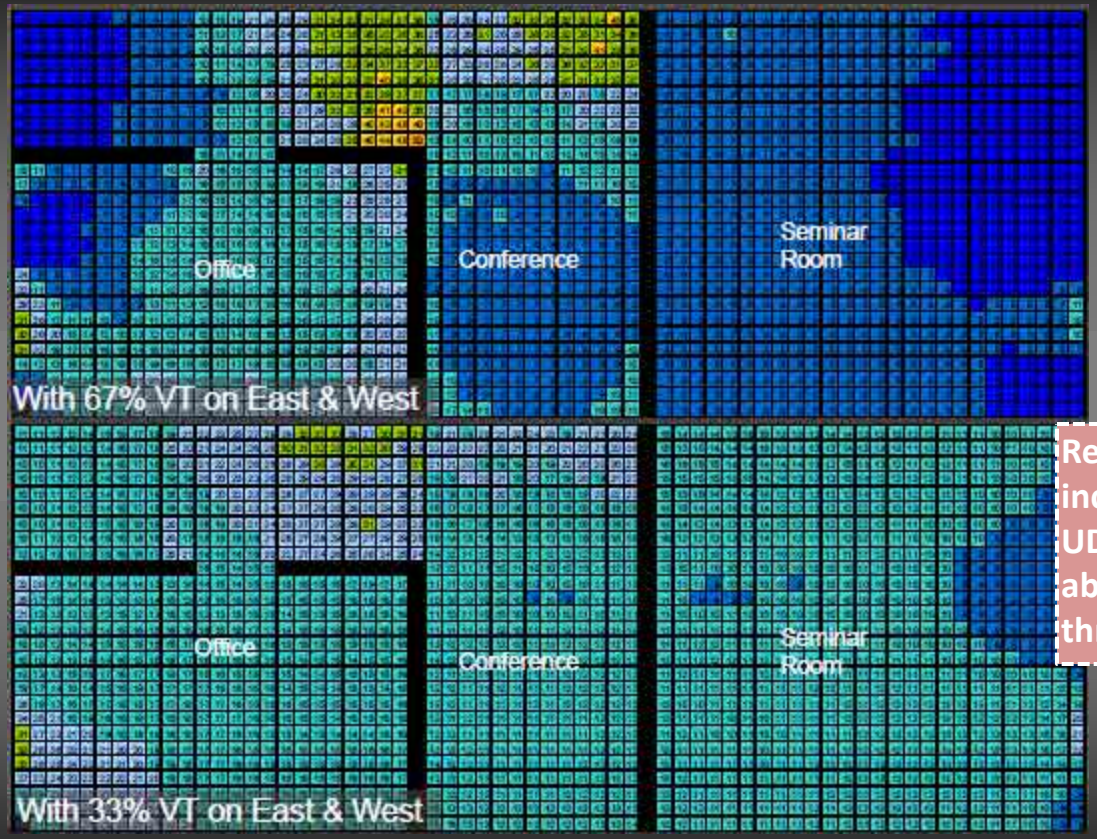
With 33% VT on East & West

Continuous Daylight Autonomy (300 lux) on Work Plane Basement level



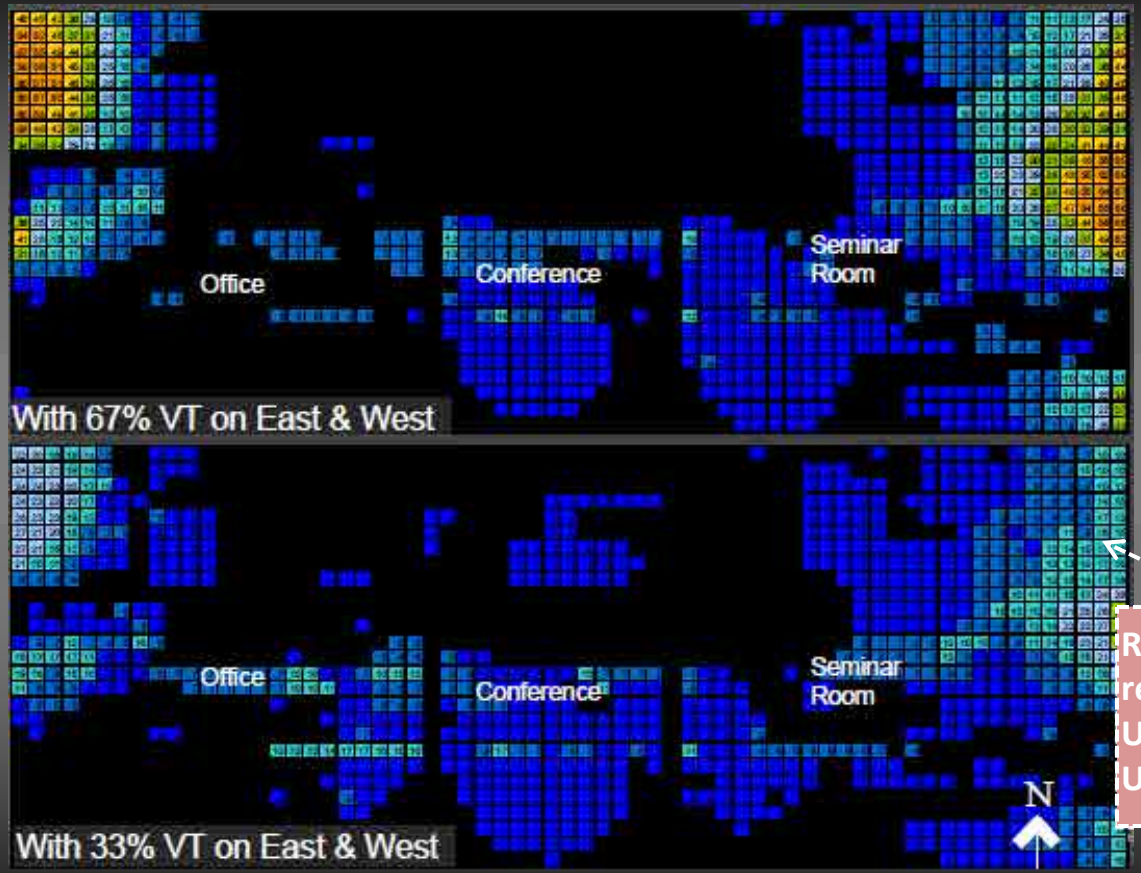
Reduced VT decreases DA by about 10% throughout

Useful Daylight Index (<100) on Work Plane Basement level

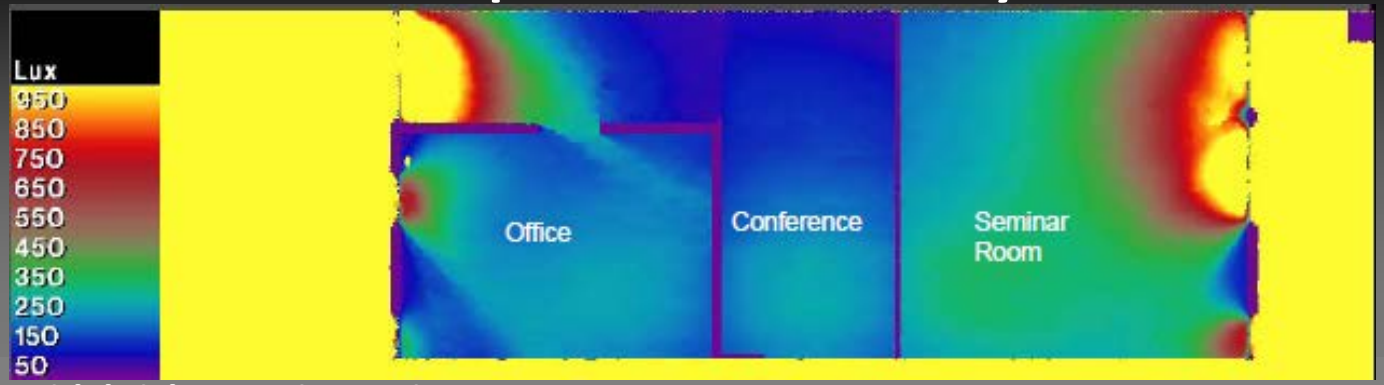


Reduced VT increases UDI(<100) by about 6% throughout

Useful Daylight Index (>2000) on Work Plane Basement level



Illuminance of floor plan under clear sky Basement level



With bright exterior paving

Without dark paving

Exterior paving has significant impact on light level

Daylighting Options - I Floor

Reduced vision windows on South

- Base case: 2 nos 2.8m wide
- Alternate: 2 nos 1.4m wide

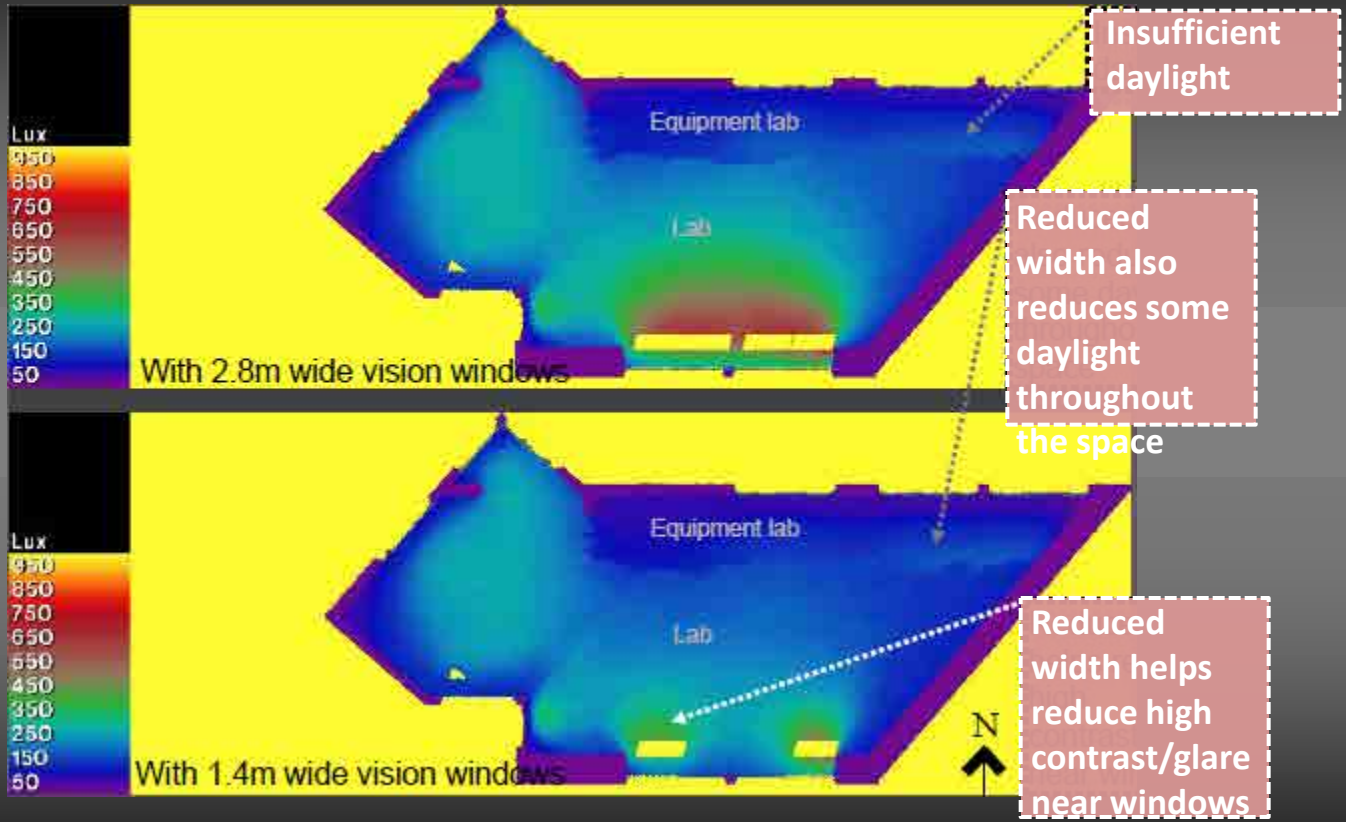
Reduced ClerestoryBase case:

- 450mm ht
- Alternate: 300mm ht

Change glass partition to opaque wall

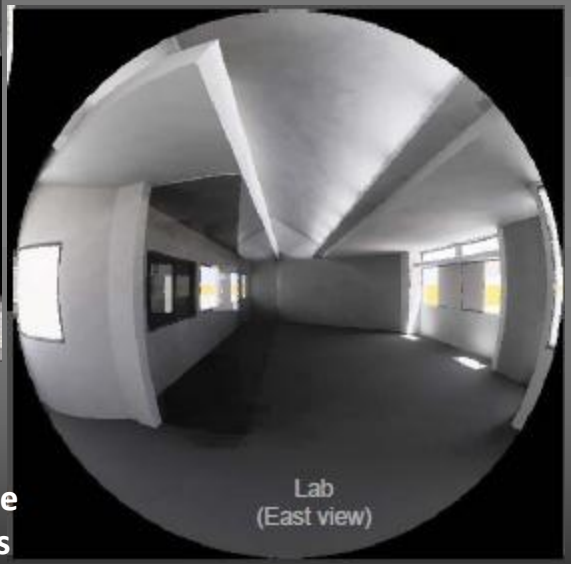
- Base case: Glass partition wall
- Alternate: Opaque partition wall

Illuminance of floor plan under clear sky I Floor



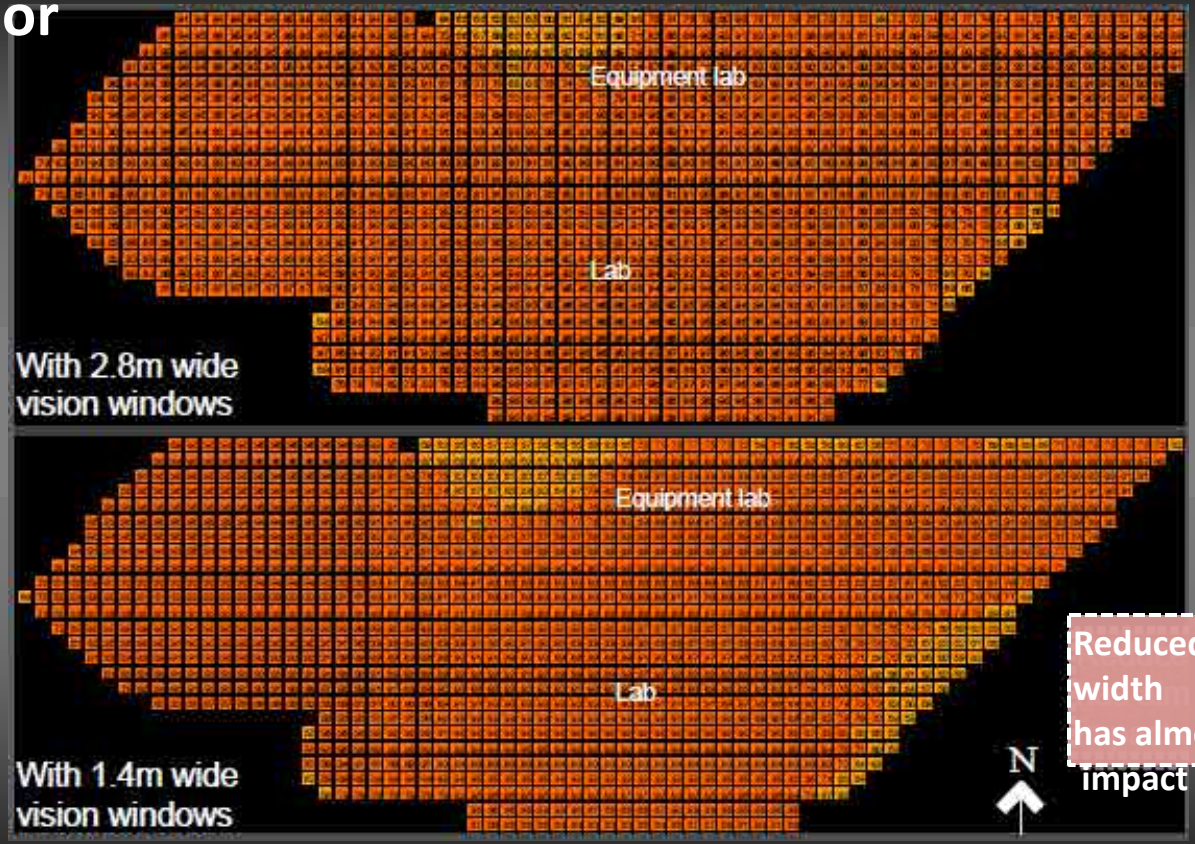
Luminance views under clear sky I Floor

With 2.8m wide vision windows



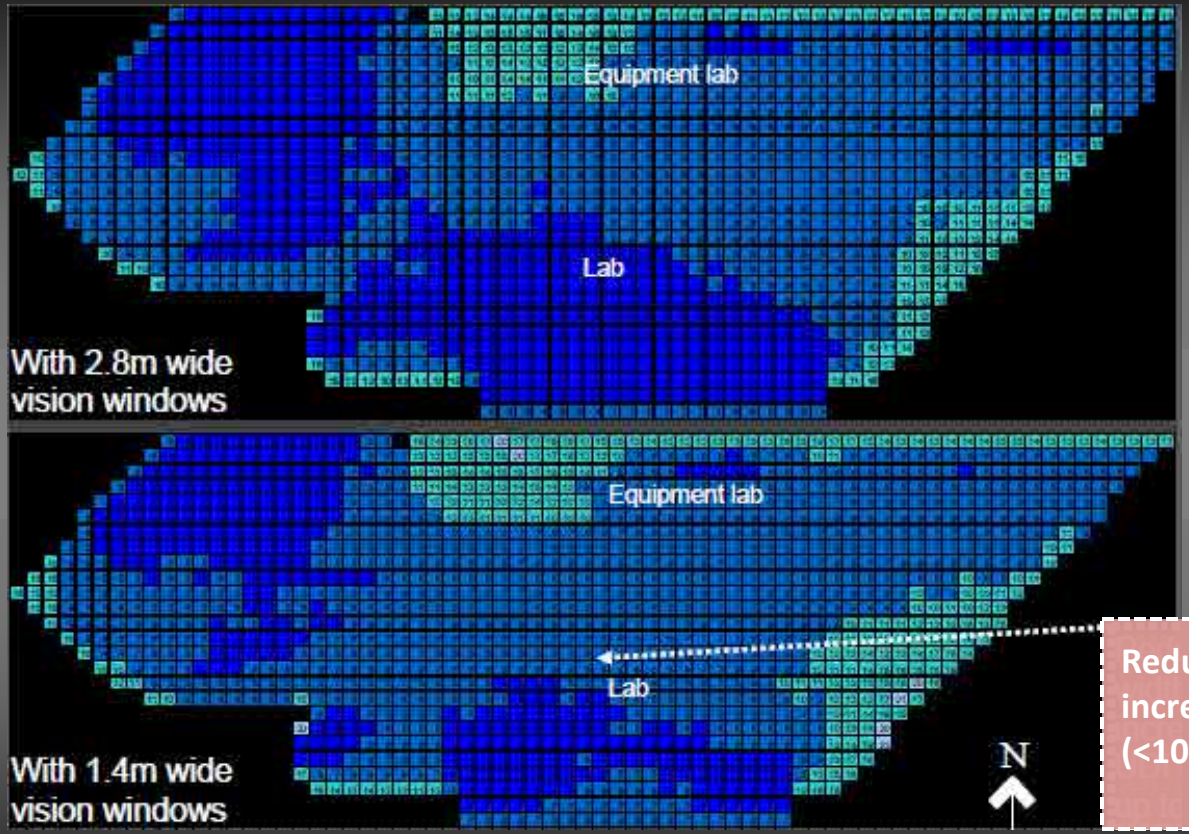
With 1.4m wide vision windows

Continuous Daylight Autonomy (300 lux) on Work Plane I Floor



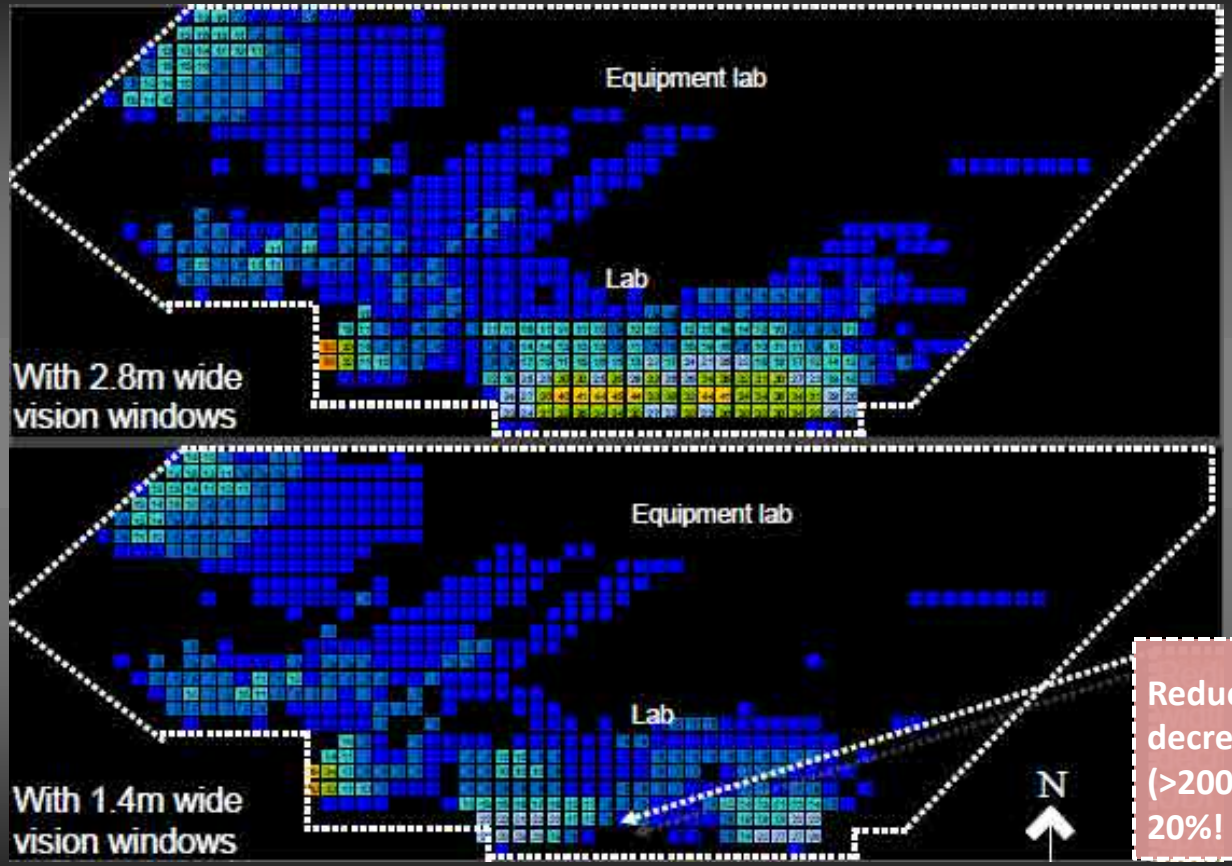
Reduced width has almost no impact on DA

Useful Daylight Index (<100) on Work Plane I Floor



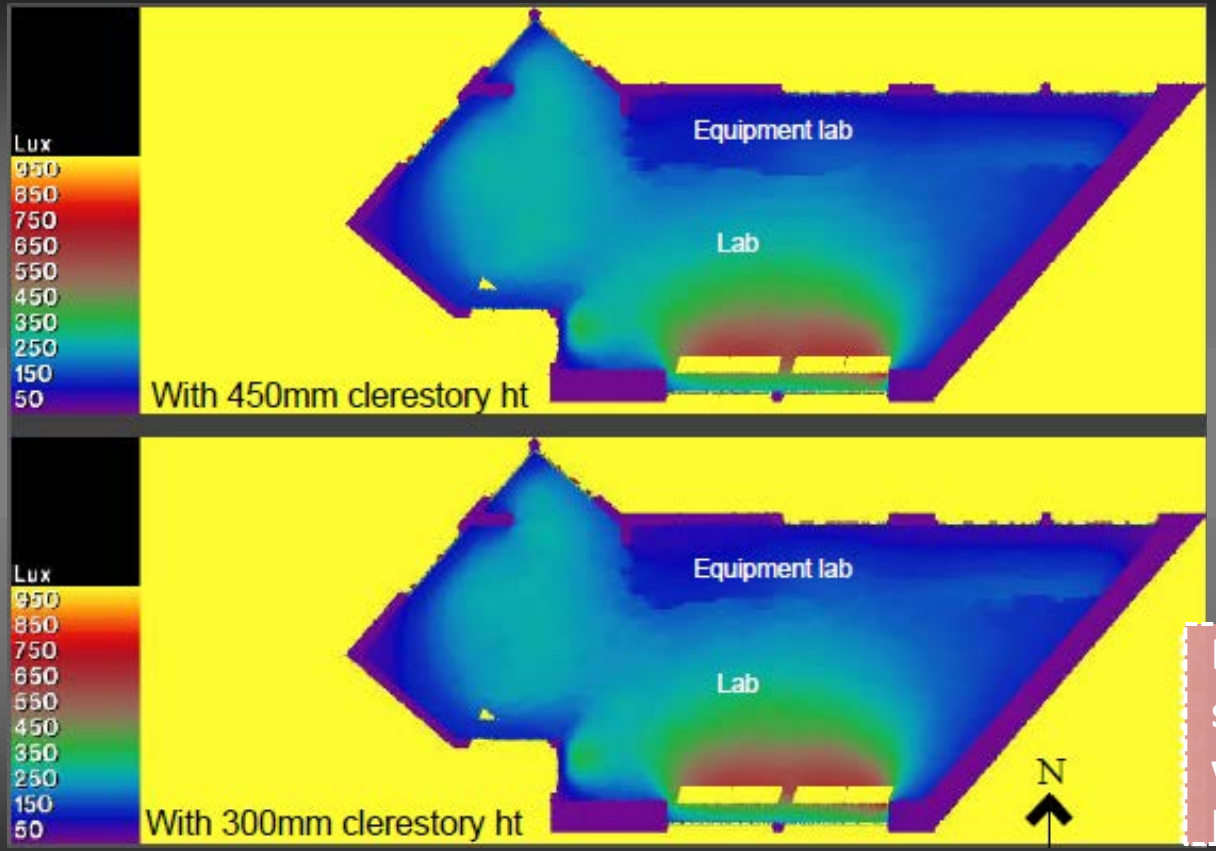
Reduced width increases UDI (<100) up to 2%

Useful Daylight Index (>2000) on Work Plane I Floor



Reduced width decreases UDI (>2000) up to 20%!

Illuminance of floor plan under clear sky I Floor



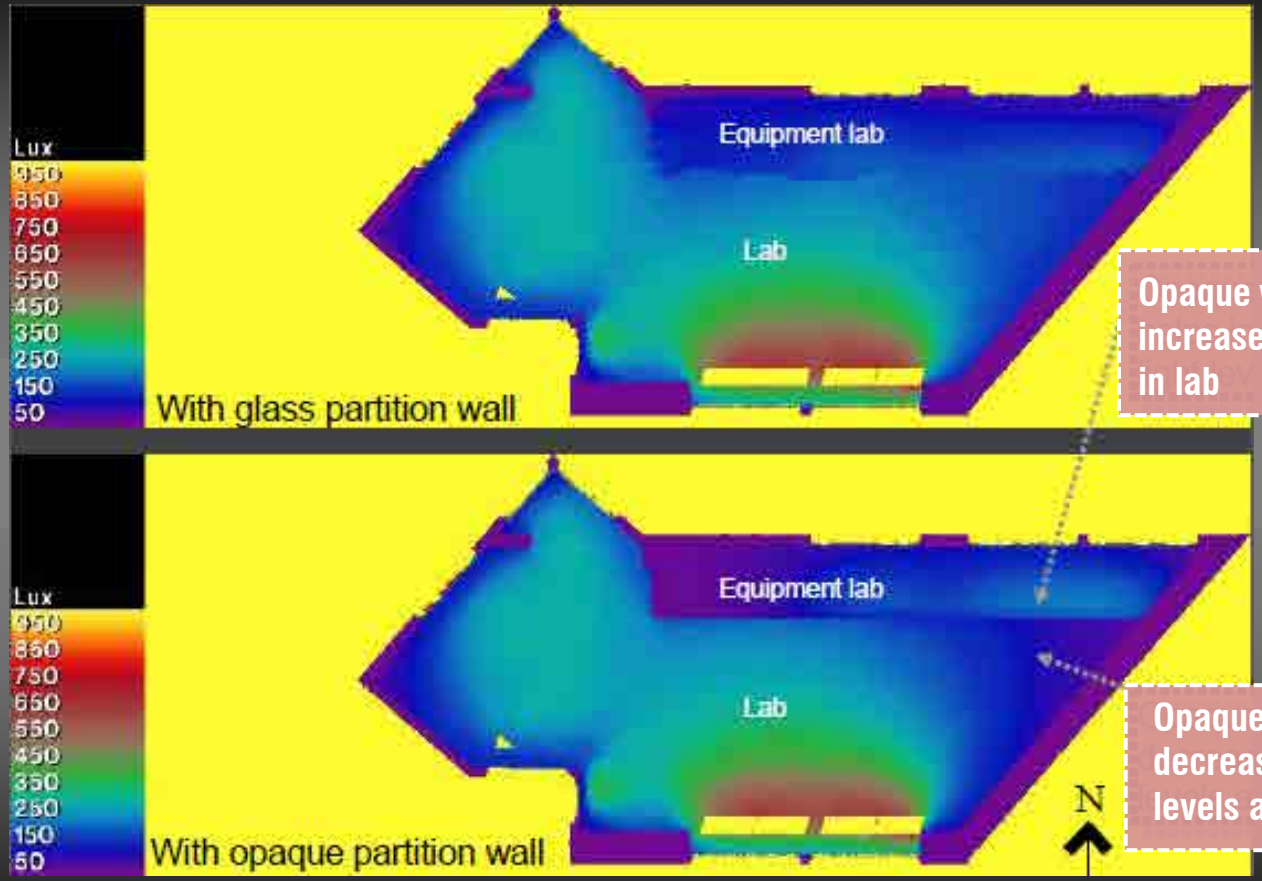
No significant variation between options

Luminance views under clear sky - I Floor

With 450mm clerestory ht

With 300mm clerestory ht

Illuminance of floor plan under clear sky I Floor



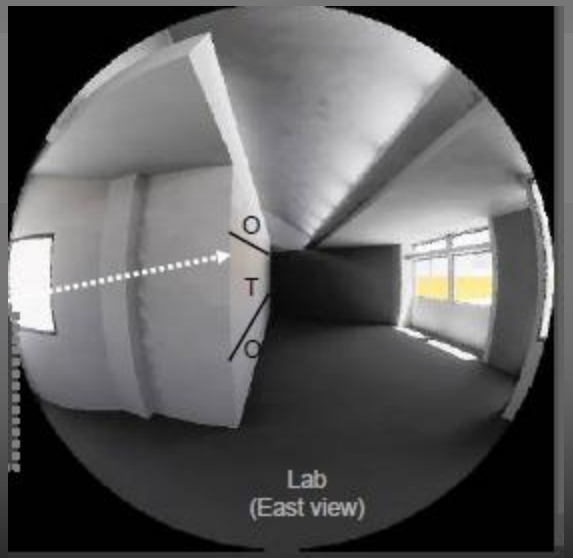
Opaque wall helps increase light levels in lab

Opaque wall decreases light levels at corner

Luminance views under clear sky I Floor

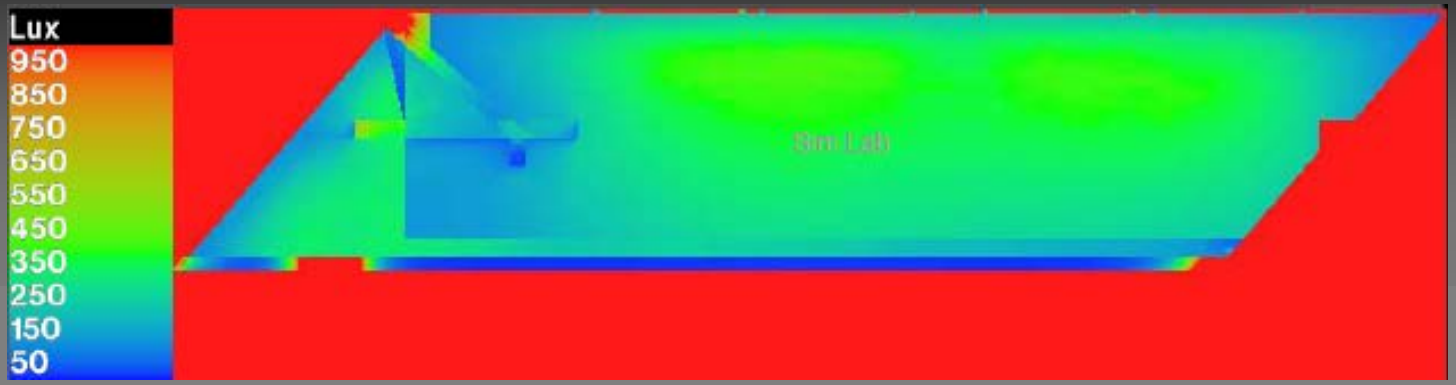
With glass partition wall

Split the partition wall as:
Top: Opaque
Middle: Transparent
Bottom: Opaque

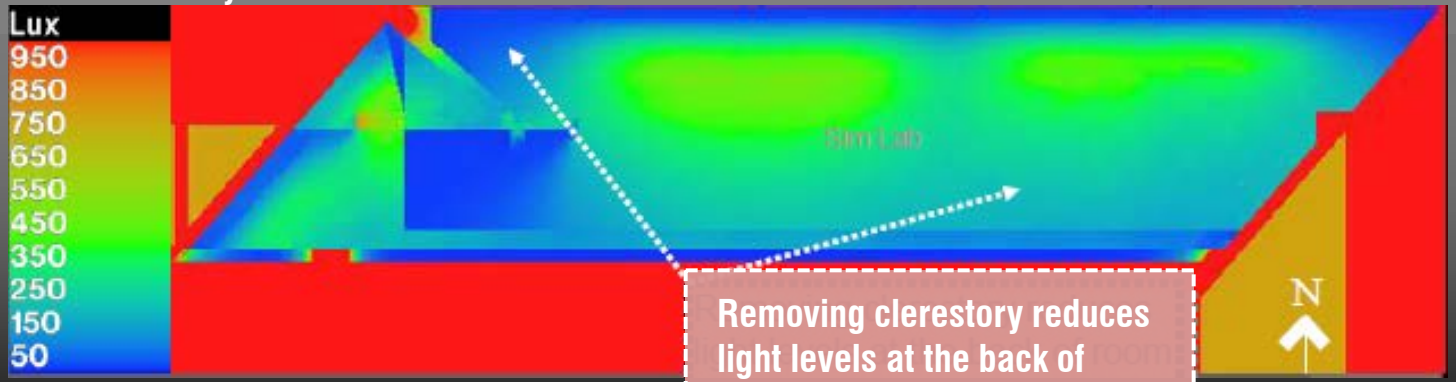


With opaque partition wall

Illuminance of floor plan under clear sky II Floor



With clerestory

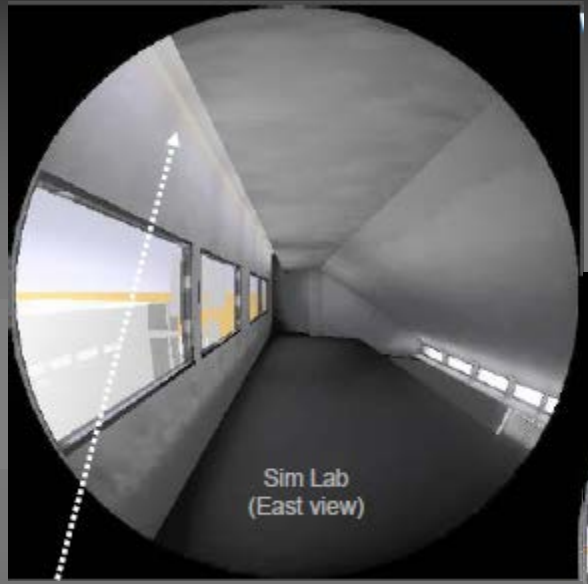


Removing clerestory reduces light levels at the back of room and corners

Without clerestory

Luminance views under clear sky II Floor

With clerestory

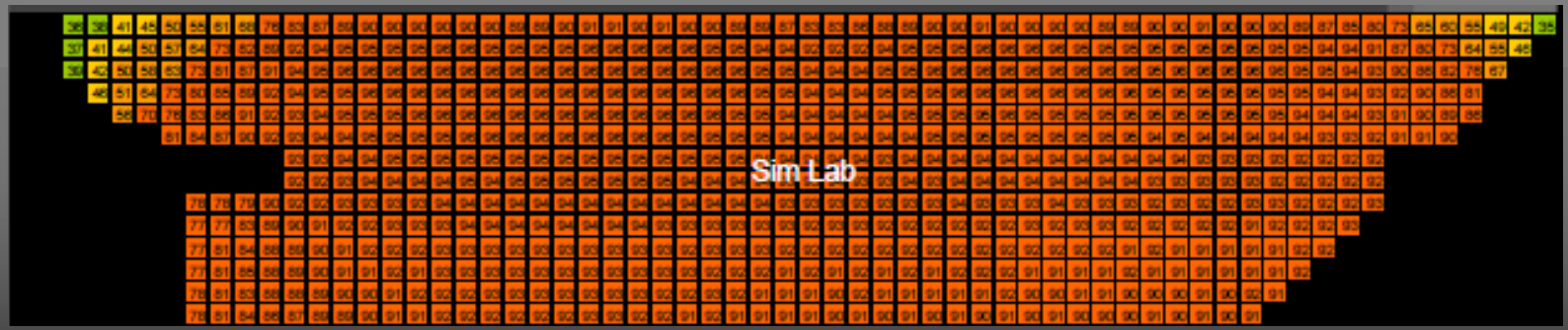


Clerestory helps wash the wall

Without clerestory

Continuous Daylight Autonomy (300 lux) on Work Plane II Floor

With clerestory



Without clerestory

No significant variation between options, except at corners

N

Useful Daylight Index (<100) on Work Plane II Floor

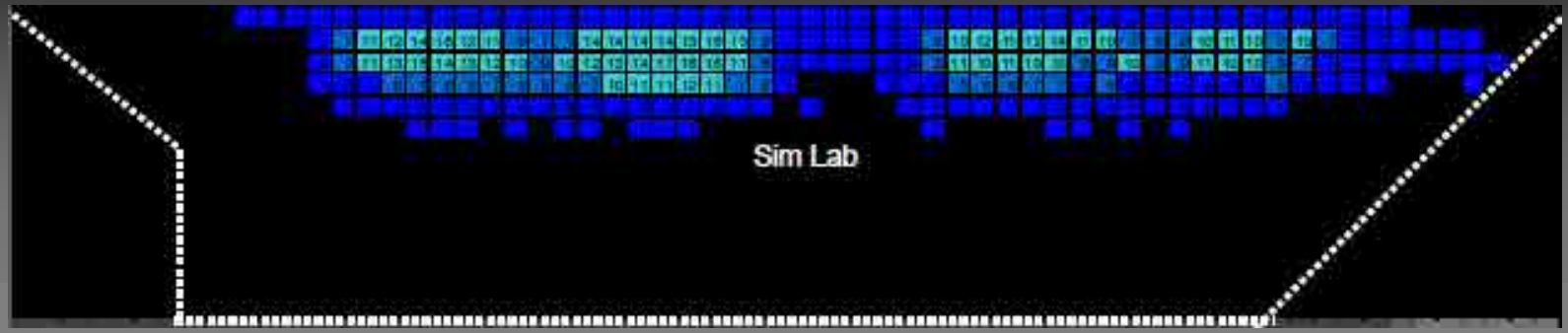
With clerestory

Without clerestory

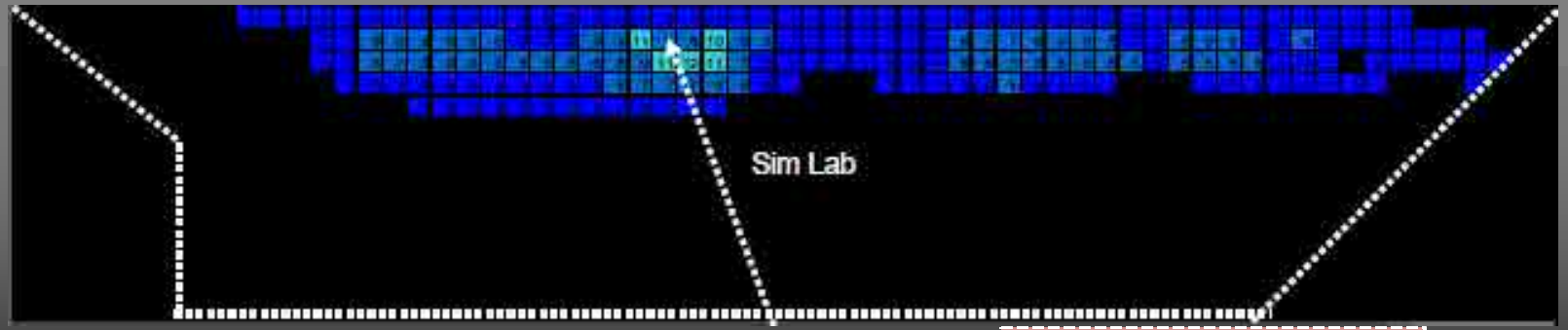
No significant variation between options, except at corners

N

Useful Daylight Index (>2000) on Work Plane II Floor



With clerestory



Without clerestory

Removing clerestory slightly reduces excess daylight hours up to 6%

N

Conclusions : Basement

- Colour of exterior paving on South has significant impact on interior light levels

Glass blocks

- Help increase Daylight Autonomy (300 lux) up to 15%
- Help wash the side walls
- If the glass-blocks need to be removed, it helps, if they are removed from the East / West rooms and kept in the conference room

Conclusions : Basement

50% reduction in VT at East / West facing windows Help decrease high contrast / glare near windows

- Help decrease UDI (>2000) up to 30% near windows!
- Although decrease DA up to 10% and UDI (<100) up to 6% throughout the space
- Spilt the windows into vision and transom: Vision- with 33% VT Transom- with 67% VT

Conclusions - I Floor

Reduced vision windows on South

Has no significant impact on DA

Helps reduce excess daylight near windows

Reduced Clerestory

Has no significant impact on daylight levels

Clerestory can be reduced to 300 mm ht

Changing glass partition to opaque wall

Split Glass partition wall as clear and opaque bands:

Top: Opaque Middle: Transparent Bottom: Opaque

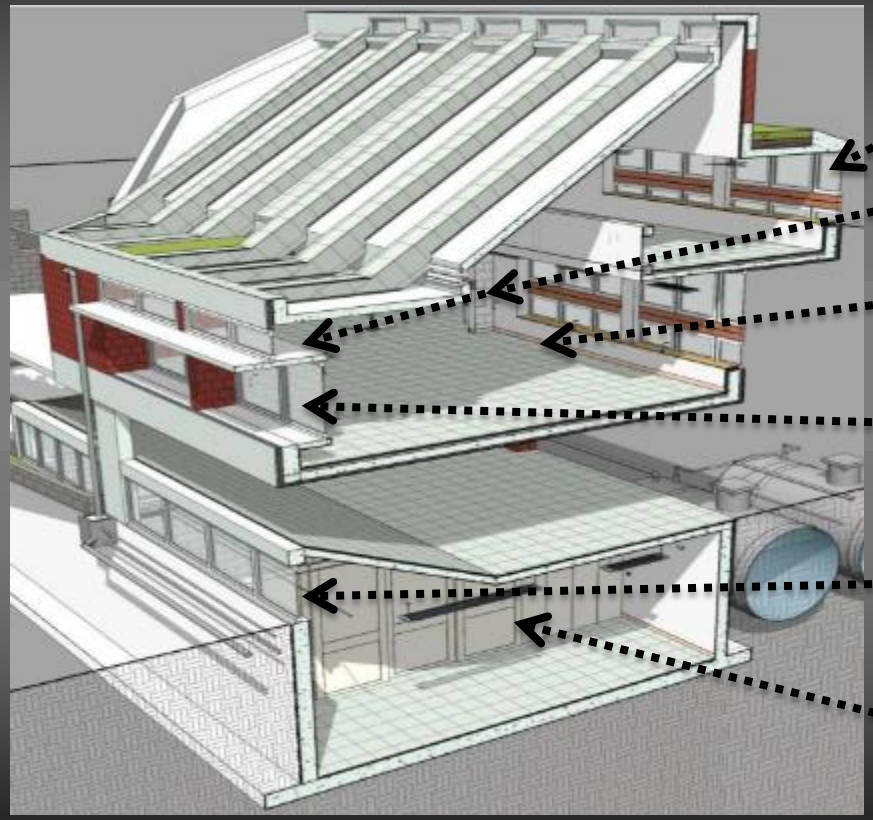
Increase North windows VT on I floor to 67%

Conclusions – II Floor

Removing clerestory

- No significant impact on light levels, although slightly reduces light levels at back and corners
- Clerestory helps wash the North wall

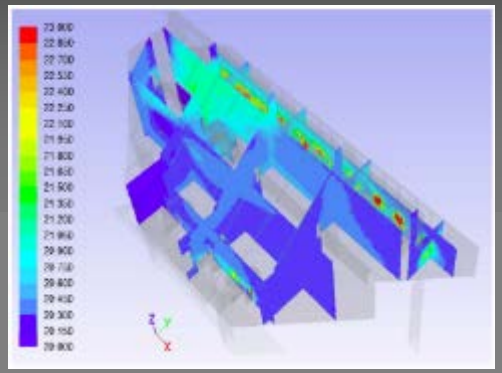
Daylighting Analysis Areas



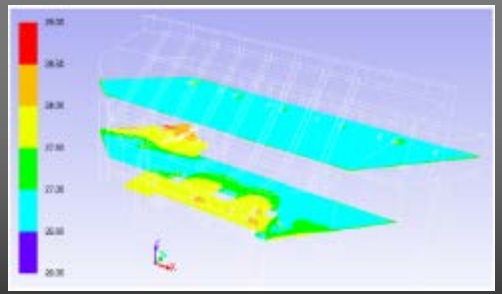
- Sizing of North Windows
- Sizing of Lightshelves
- Interior wall finishes
- Sizing of South Vision Windows
- Sizing Basement Light Monitor
- Sizing of Basement Courtyard Windows

Passive Cooling Potential

Assess Thermal Comfort and Natural Ventilation with CFD Model



Jan Morning



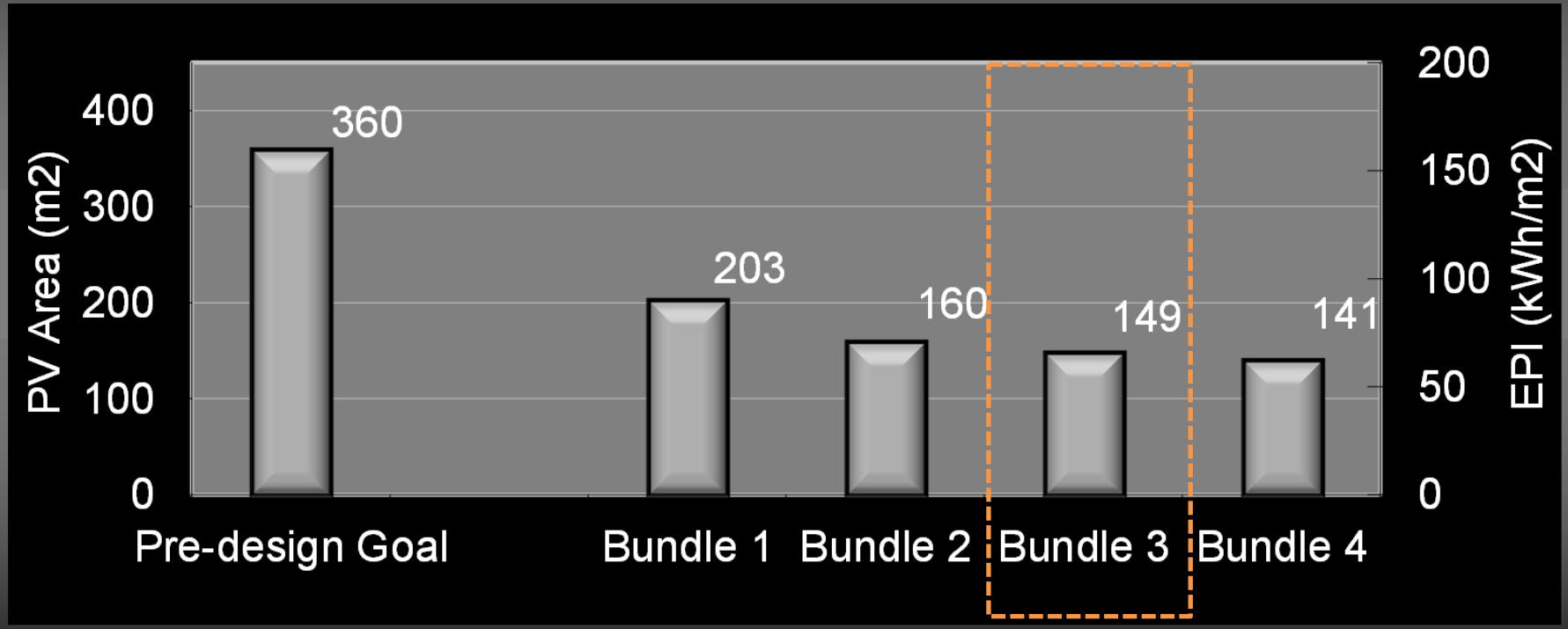
Feb Evening

Month	Morning	Afternoon	Evening
Jan	Windows Closed	Windows Open	Windows Open
Feb	Windows Closed	Windows Open	Windows Open
Mar	Windows Open	No	No
Apr	No	No	No
May	No	No	No
Jun	No	No	No
Jul	No	No	No
Aug	No	No	No
Oct	Windows Open	No	No
Nov	Windows Open	No	Windows Open
Dec	Windows Closed	Windows Open	Windows Open

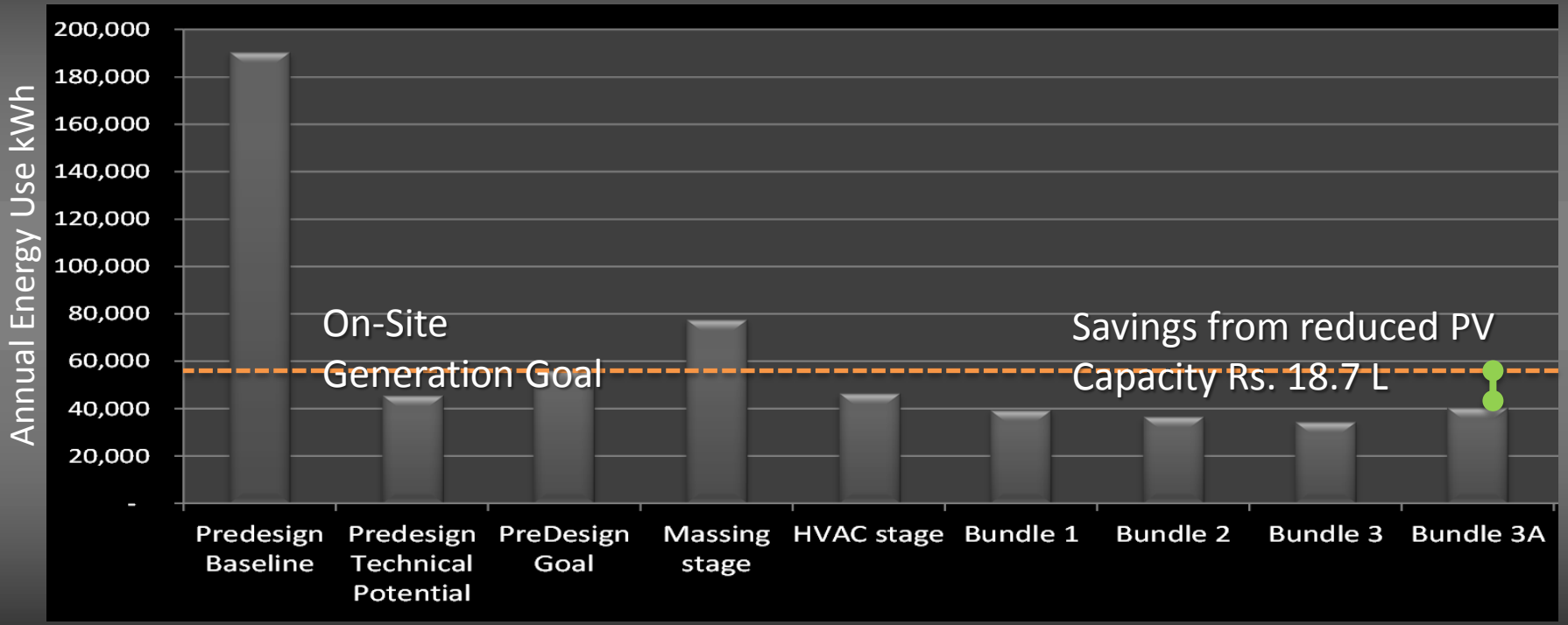
Systems Optimization Bundles

No.	Strategy Description	Cooling Ton	kWh/m2	PV kW	Energy Rs	Construct Cost	Payback Years	Bundle 1	Bundle 2	Bundle 3	Bundle 4
1	**Envelope Insulation Strategies**										
	Wall except basement										
EWC00	CEPT BAU wall assembly U-factor at 1.67	0.0	0.0	0.0	₹ 0	₹ 0	n/a				
EWC02	Wall assembly U-factor at 1.1 (except basemt.)	0.4	0.3	0.1	₹ 502	₹ 0	imm				
EWC03	Wall assembly U-factor at 0.78 w/ hollow bricks (except basemt.)	0.6	0.5	0.1	₹ 795	₹ 0	imm				
EWC04	Wall assembly U-factor at 0.6 (except basemt.)	0.5	0.6	0.1	₹ 985	₹ 152,846	155				
EWC01	ECBC wall assembly U-factor at 0.44 (except basemt.)	0.4	0.7	0.2	₹ 1,161	₹ 291,332	251				
EWC05	Wall assembly U-factor at 0.37 (except basemt.)	0.4	0.7	0.2	₹ 1,239	₹ 192,732	156				
EWC06	Wall assembly U-factor at 0.28 (except basemt.)	0.3	0.7	0.2	₹ 1,329	₹ 353,555	266				
EWC07	Wall assembly U-factor at 0.23 (except basemt.)	0.3	0.8	0.2	₹ 1,385	₹ 271,868	196				
	Wall basement										
EWC09	Wall assembly U-factor at 1.1 (basement only)	0.1	0.0	0.0	₹ 24	₹ 0	imm				
EWC10	Wall assembly U-factor at 0.75 (basement only)	0.1	0.1	0.0	₹ 32	₹ 0	imm				
EWC11	Wall assembly U-factor at 0.6 (basement only)	0.2	0.1	0.0	₹ 33	₹ 46,197	1,400				
EWC08	ECBC wall assembly U-factor at 0.44 (basement only)	0.2	0.1	0.0	₹ 34	₹ 88,055	2,590				
EWC12	Wall assembly U-factor at 0.37 (basement only)	0.2	0.1	0.0	₹ 33	₹ 58,253	1,765				
EWC13	Wall assembly U-factor at 0.28 (basement only)	0.2	0.1	0.0	₹ 33	₹ 106,861	3,238				
EWC14	Wall assembly U-factor at 0.23 (basement only)	0.2	0.1	0.0	₹ 30	₹ 82,171	2,739				
	Roof except basement										
ERC00	CEPT BAU roof assembly U-factor at 3.89	0.0	0.0	0.0	₹ 0	₹ 0	n/a				
ERC02	Roof assembly U-factor at 3 (except basemt.)	0.3	0.4	0.1	₹ 662	₹ 0	imm				
ERC03	Roof assembly U-factor at 1.5 (except basemt.)	0.7	0.8	0.2	₹ 1,478	₹ 80,140	54				
ERC04	Roof assembly U-factor at 0.8 (except basemt.)	0.8	1.3	0.3	₹ 2,346	₹ 108,132	46				
ERC01	ECBC roof assembly U-factor at 0.41	0.9	1.6	0.4	₹ 3,000	₹ 74,722	25				
ERC05	Roof assembly U-factor at 0.26 (except basemt.)	0.9	1.8	0.5	₹ 3,297	₹ 192,562	58				
ERC06	Roof assembly U-factor at 0.19 (except basemt.)	0.9	1.9	0.5	₹ 3,529	₹ 220,554	62				
ERC07	Roof assembly U-factor at 0.14 (except basemt.)	0.9	2.0	0.5	₹ 3,615	₹ 248,772	69				
	Roof basement										
ERC09	Roof assembly U-factor at 3 (Basement only)	0.2	0.2	0.0	₹ 188	₹ 0	imm				
ERC10	Roof assembly U-factor at 1.5 (Basement only)	0.3	0.1	0.0	₹ 48	₹ 52,636	1,097				
ERC11	Roof assembly U-factor at 0.8 (Basement only)	0.5	0.3	0.1	₹ 357	₹ 71,021	199				
ERC08	ECBC roof assembly U-factor at 0.41 (Basement only)	0.6	0.4	0.1	₹ 487	₹ 49,077	101				
ERC12	Roof assembly U-factor at 0.26 (Basement only)	0.6	0.5	0.1	₹ 624	₹ 126,474	203				
ERC13	Roof assembly U-factor at 0.19 (Basement only)	0.7	0.5	0.1	₹ 699	₹ 144,859	207				
ERC14	Roof assembly U-factor at 0.14 (Basement only)	0.7	0.6	0.1	₹ 755	₹ 163,393	216				
	Cool Roof except basement										
ERC18	Cool Roof w/ CEPT BAU roof assembly U-factor at 3.89 (except basemt)	0.5	0.8	0.2	₹ 1,343	₹ 0	imm				
ERC20	Cool roof w/ roof assembly U-factor at 3 (except basemt.)	0.8	1.2	0.3	₹ 1,983	₹ 0	imm				
ERC21	Cool roof w/ roof assembly U-factor at 1.5 (except basemt.)	1.3	2.0	0.5	₹ 3,300	₹ 80,140	24				
ERC22	Cool roof w/ roof assembly U-factor at 0.8 (except basemt.)	1.2	2.4	0.6	₹ 3,951	₹ 108,132	27				
ERC19	Cool roof w/ roof assembly U-factor at 0.41 (except basemt.)	1.2	2.8	0.7	₹ 4,689	₹ 74,722	16				
ERC23	Cool roof w/ roof assembly U-factor at 0.26 (except basemt.)	1.3	3.0	0.7	₹ 5,039	₹ 192,562	38				
ERC24	Cool roof w/ roof assembly U-factor at 0.19 (except basemt.)	1.3	3.1	0.8	₹ 5,212	₹ 220,554	42				
2	**Window Glazing Strategies**										
W5201	CEPT BAU glazing system	0.0	0.0	0.0	₹ 0	₹ 0	n/a				

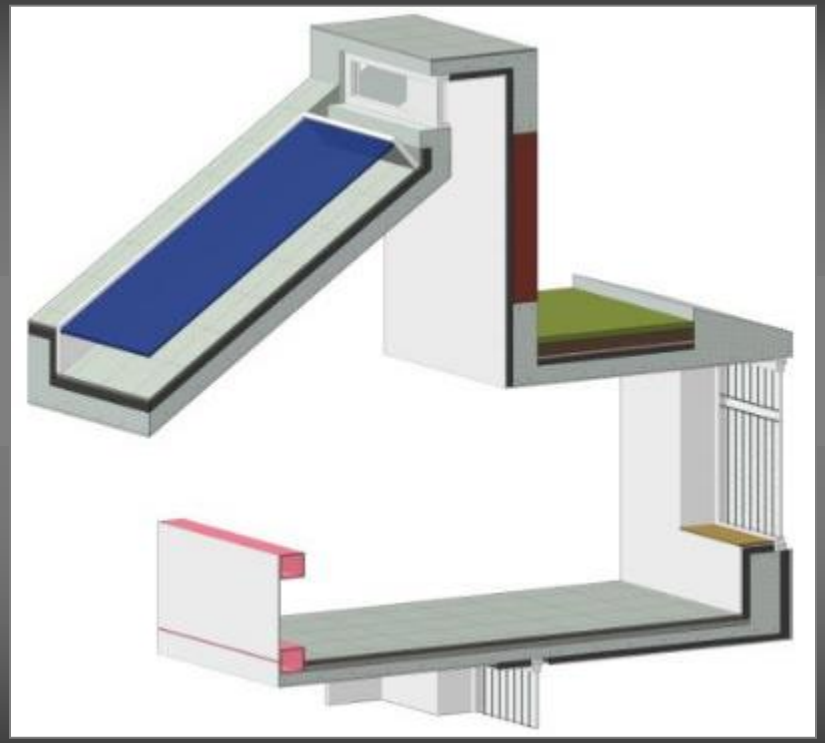
Bundled Measures: Results



Progression of Energy Efficiency



BIM Model for Quantity Estimates



INT. FLOOR FINISH

Type	Area	Cost	Comments
BASEMENT FLOOR			
15mm Ceramic Tile	212.419 m²		Floor Finish
	212.419 m²		
GROUND FLOOR			
15mm Ceramic Tile	97.460 m²		Floor Finish
	97.460 m²		
FIRST FLOOR			
15mm Ceramic Tile	122.311 m²		Floor Finish
	122.311 m²		
SECOND FLOOR			
15mm Ceramic Tile	67.204 m²		Floor Finish
	67.204 m²		

CONCRETE SLAB/WALL/COLUMN

Material	Material: Volume	Cost	Comments
Exposed Concrete	283.22 m³		

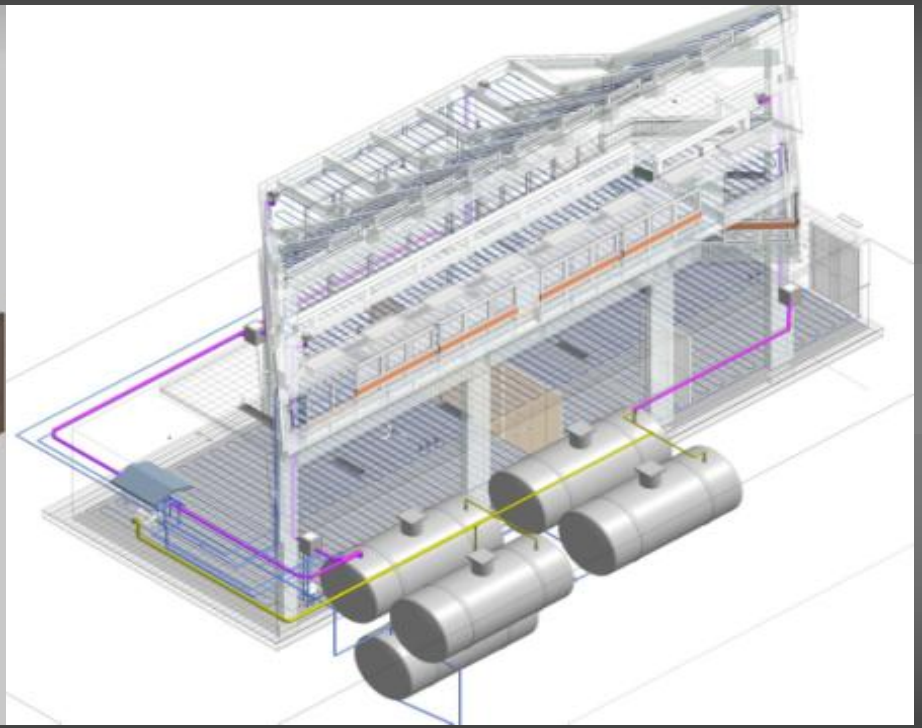
XPS/POLY STYRENE FOAM INSULATION

Material	Material: Area	Cost	Comments
XPS/Poly Styrene Foam Insulation	757.170 m²		

ROOF GARDEN

Type	Area	Cost	Comments
50mm Vegetation	47.340 m²		Vegetation

BIM System Integration



As 6 in 1

What did we design?

Developer, Architect, Contractor, Construction manager, Occupier, Facility manager

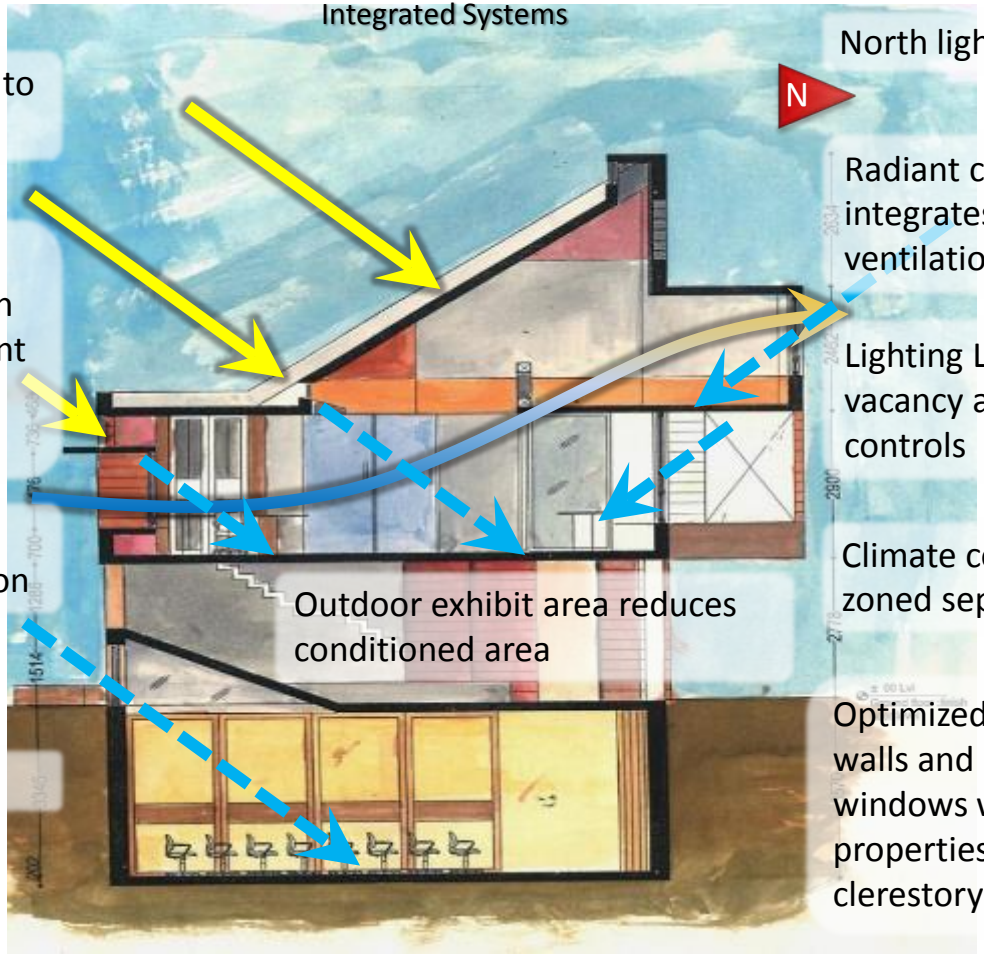
Integrated Systems

South facing PV panels tilted to latitude angle

Vision, clerestories, lightshleves on south bring in diffuse daylight with occupant control

Stack effect design, solar chimney for natural ventilation

Ground heat exchange



North light for daylighting

Radiant cooling and DOAS integrates with natural ventilation

Lighting LPD at 4.7 w/m2 and vacancy and daylighting controls

Climate controlled spaces zoned separately

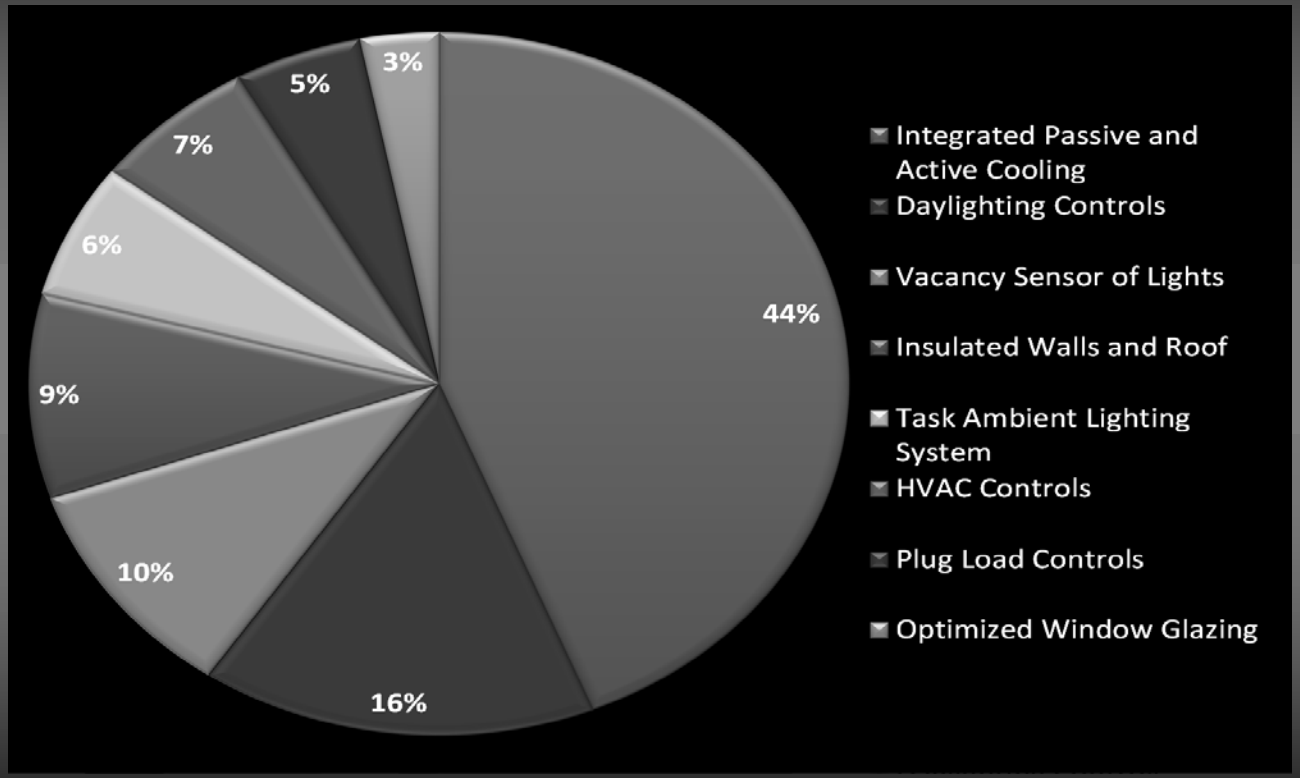
Optimized envelope: Insulated walls and roof, efficient windows with separate properties for vision and clerestory

Building External Views

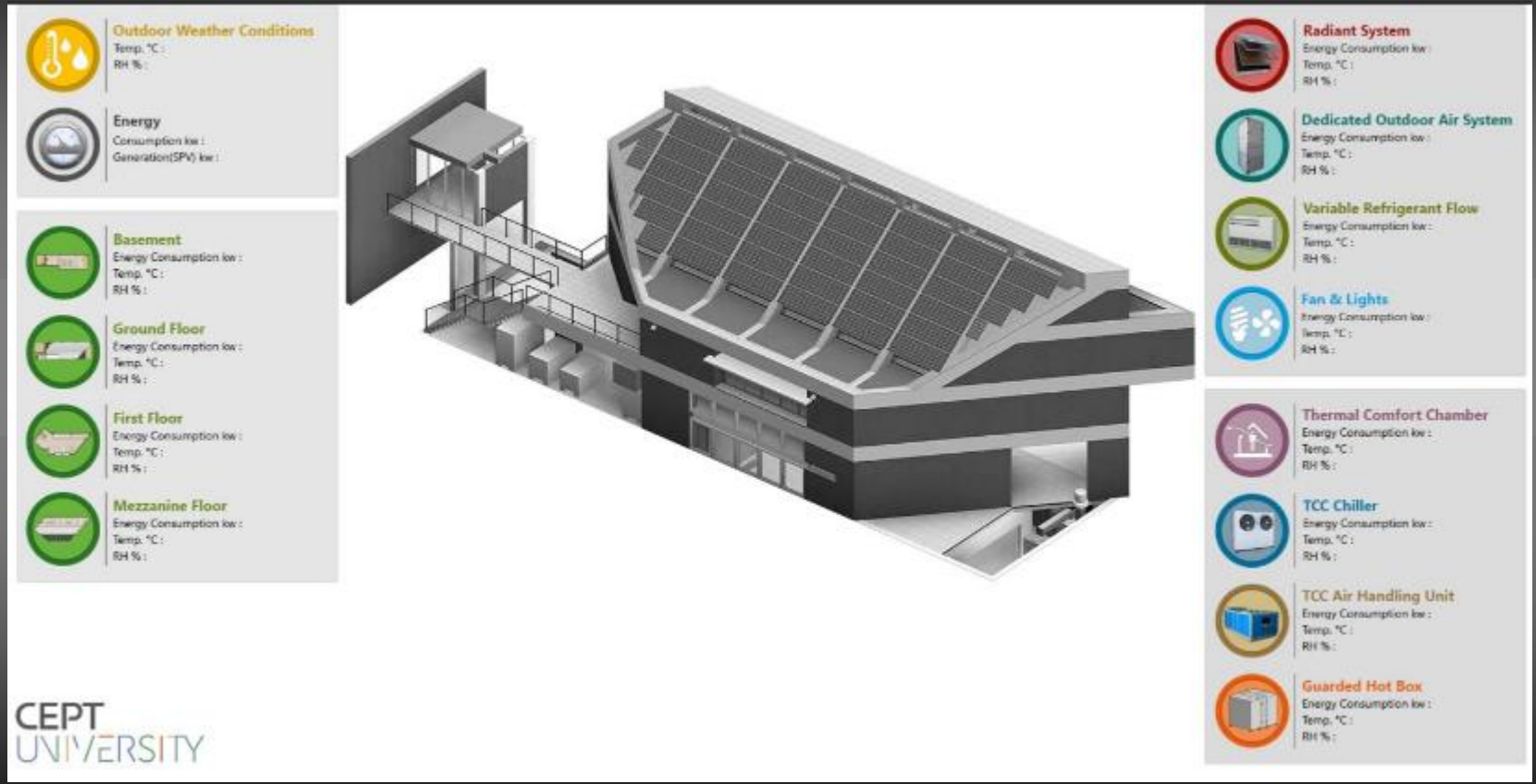
Building External Views

Building Internal Views

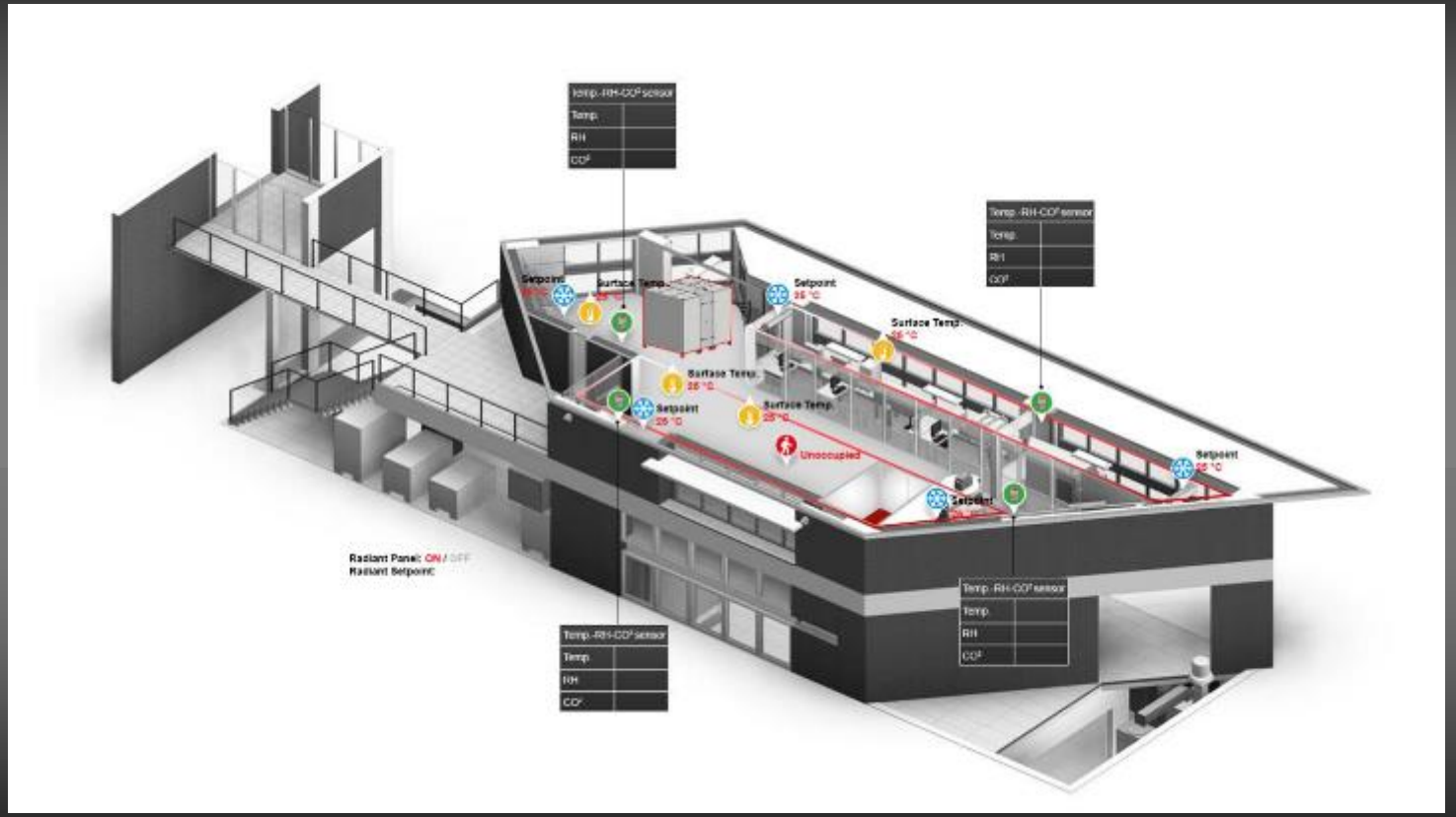
Savings by Measure Type



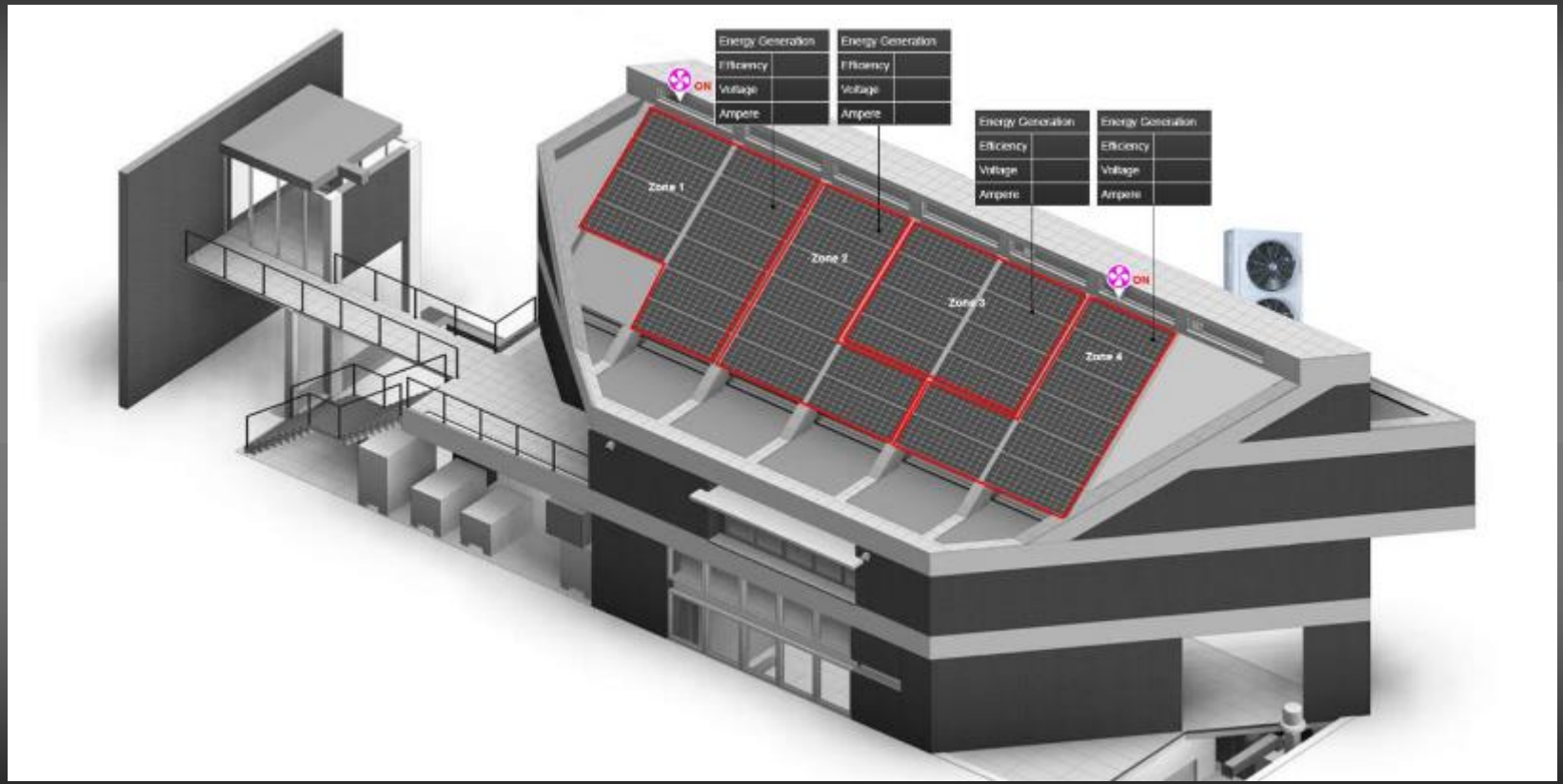
Building Energy Monitoring System



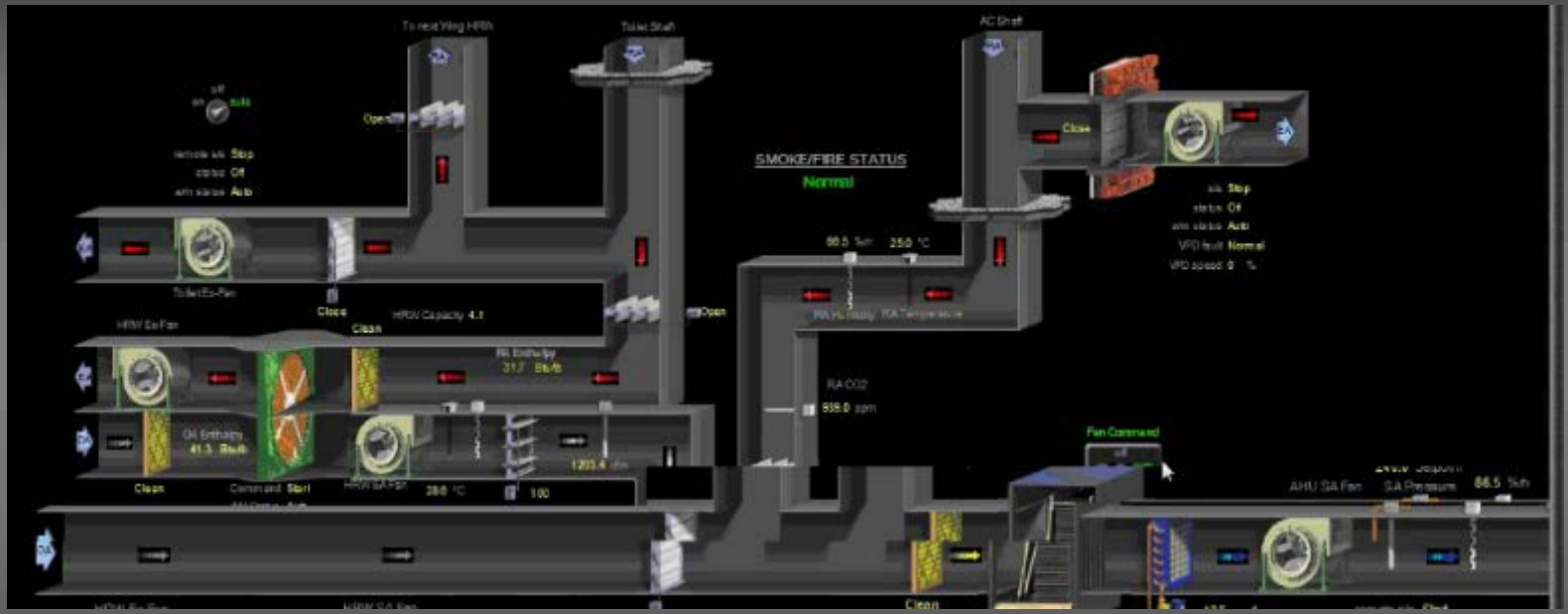
Building Energy Monitoring System



Building Energy Monitoring System



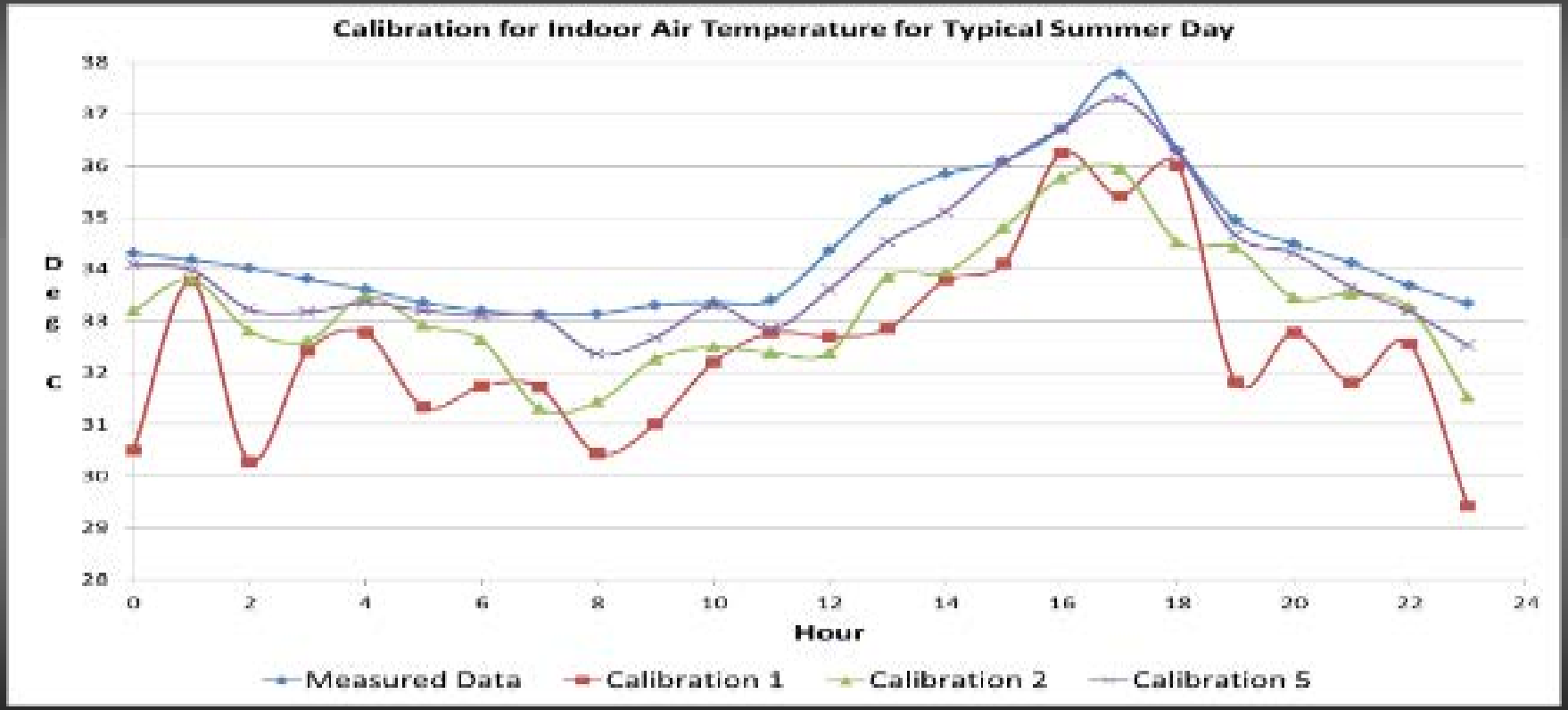
Building Energy Monitoring System



Appx. 1000 points – Indoor Environment – Energy Consumption – Energy Generation – Outdoor weather conditions – End use, lighting, HVAC, Plug and Process.

Building Energy Monitoring System

Calibration of Energy Models



What we are learning?

Analysis is Part of Design

ITERATIVE ANALYSIS, DESIGN & COMMITMENT TO PERFORMANCE-DRIVEN SOLUTION

GOT US THERE WITH

LOW ADDED COSTS

Respect Entropy

USE ENERGY IN

THE FORM IT IS IN

NZE Architecture Has Focus

DAYLIGHTING, PASSIVE COOLING

AND

RESPONDING TO ACTIVE SYSTEMS

Context Makes Sense

ALL GLASS BUILDINGS ARE

NOT THE FUTURE

OF LOW-ENERGY SOLUTIONS.

Use Every Opportunity

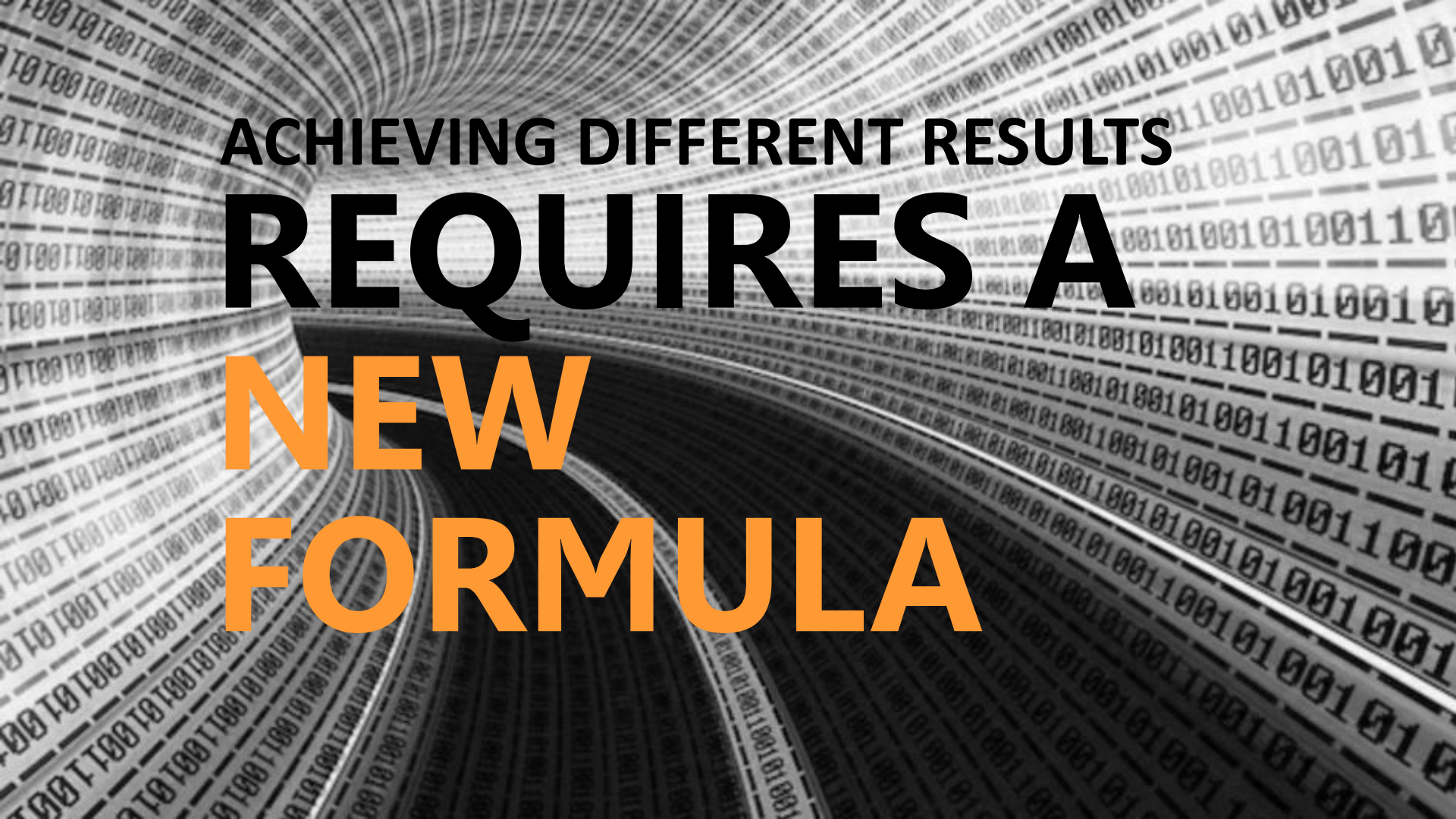
THERE IS NO SILVER BULLET

EVERY kWh COUNTS

User Matters

BUILDING USERS AND OWNERS WHO UNDERSTAND USE AND OPERATION ARE CRITICAL

AND THEY MUST BE PART OF THE PROCESS


ACHIEVING DIFFERENT RESULTS
REQUIRES A
NEW
FORMULA

THANK YOU

rajanrawal@cept.ac.in
www.carbse.org