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Introduction

As a consequence of globalization, glass is now one of the most widely used and dominant materials in buildings all over the world. And due to its transmittance, it affects the light levels and energy consumption of a space directly. Apart from that, the manufacturing, transportation, and fixing of glass at a particular place, is associated with certain energy use and also contribute towards gas emissions. And so, glass, being one of widely used material, has high embodied energy. Which makes the selection of glass, in tune with the desired daylight performance, and with controlled energy consumption for a particular space, a crucial or rather a complex decision, and therefore, it offers serious research opportunity.

Goals

- To analyze Farnsworth house, which has complete glass façade on all of its four sides, for its daylight performance considering the properties of glass actually used in Farnsworth house.

- To use illuminance (Lux Levels) as a metric to improve the daylight performance in the house by suitable glass selection, and also to address the glare situation by means of shading integration.

- To analyze the influence of the selection of glass on the total energy demand of house by means of quantitative comparative analysis.

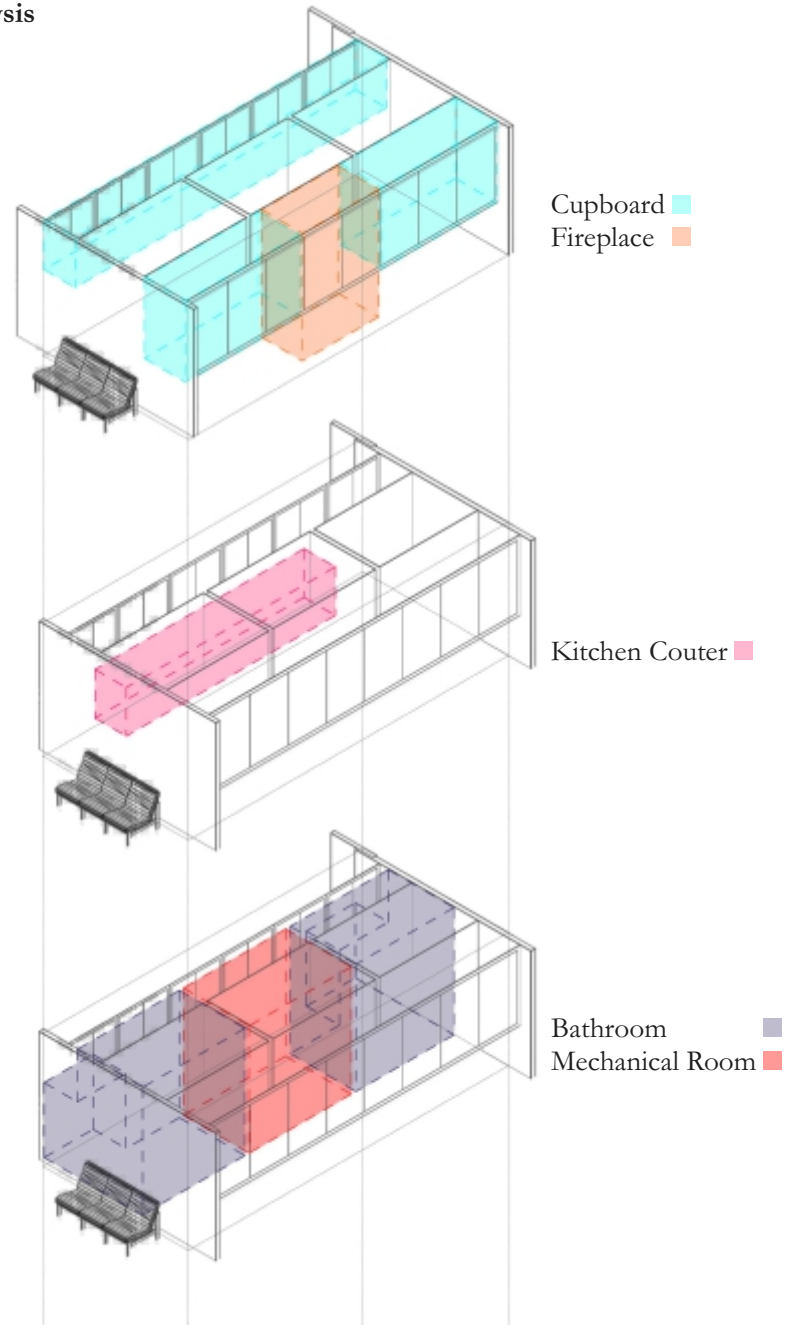
Background

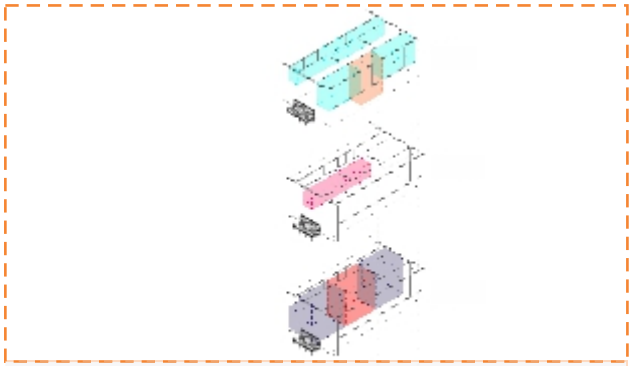
Farnsworth House was designed and constructed by Ludwig Mies van der Rohe between 1945-51. It is a one-room weekend retreat in a once-rural setting, located 55 miles (89 km) southwest of Chicago's downtown on a 60-acre (24 ha) estate site, adjoining the Fox River, south of the city of Plano, Illinois.

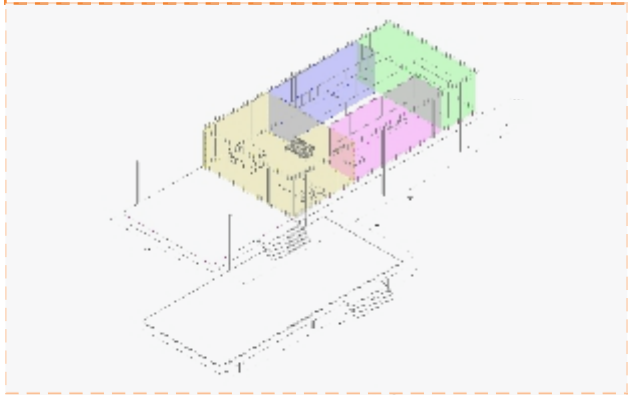
The steel and glass house was commissioned by Dr. Edith Farnsworth, a prominent Chicago nephrologist, as a place where she could engage in her hobbies: playing the violin, translating poetry, and enjoying nature.

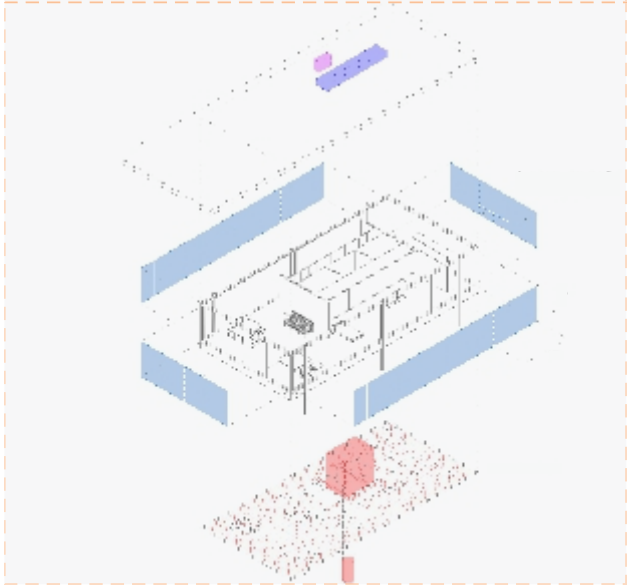
Mies created a 1,500-square-foot (140 m2) house that is widely recognized as an iconic masterpiece of International Style of architecture. The home was designated a National Historic Landmark in 2006, after joining the National Register of Historic Places in 2004. The house is currently owned and operated as a house museum by the historic preservation group, National Trust for Historic Preservation.

Component Analysis

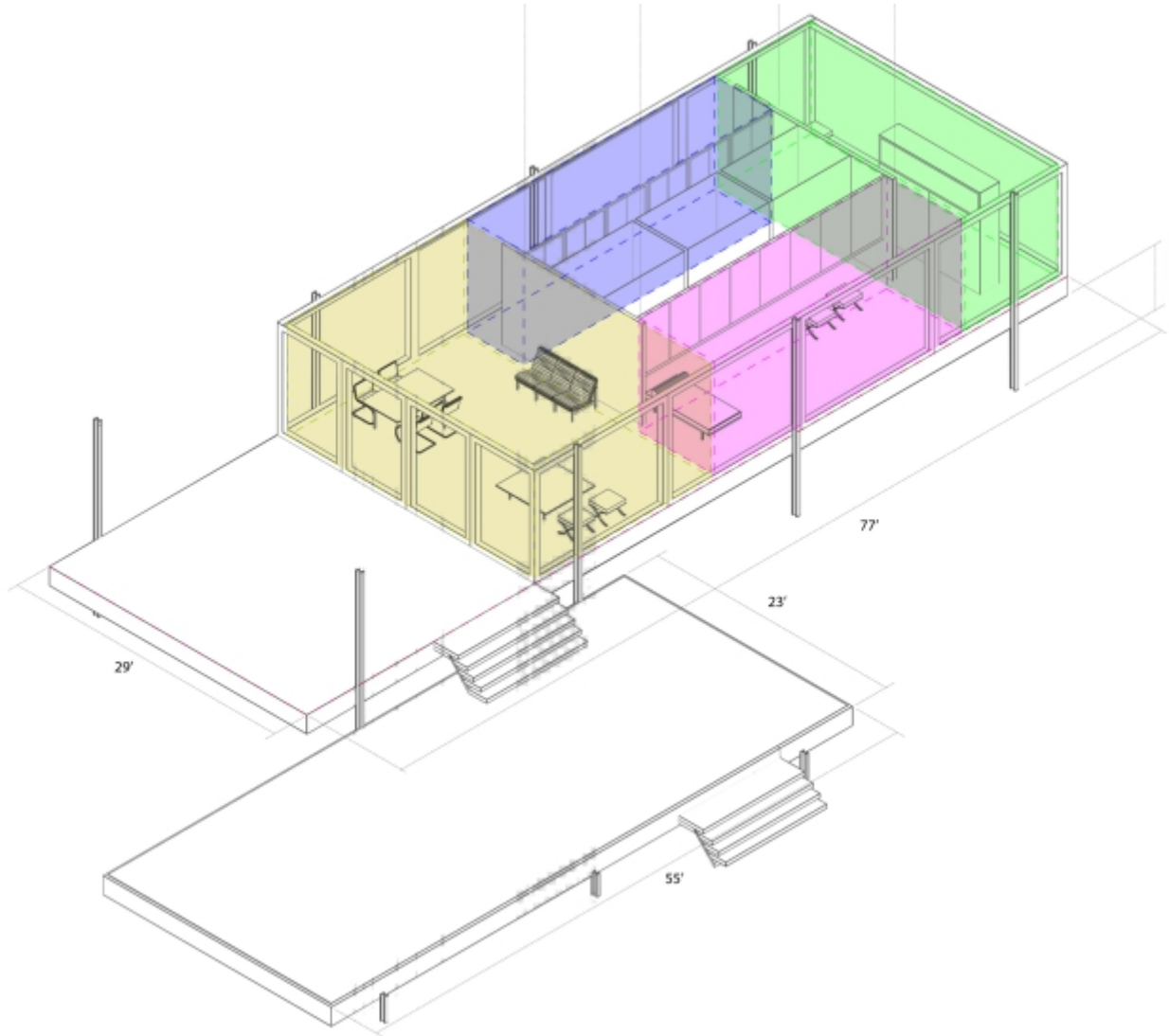




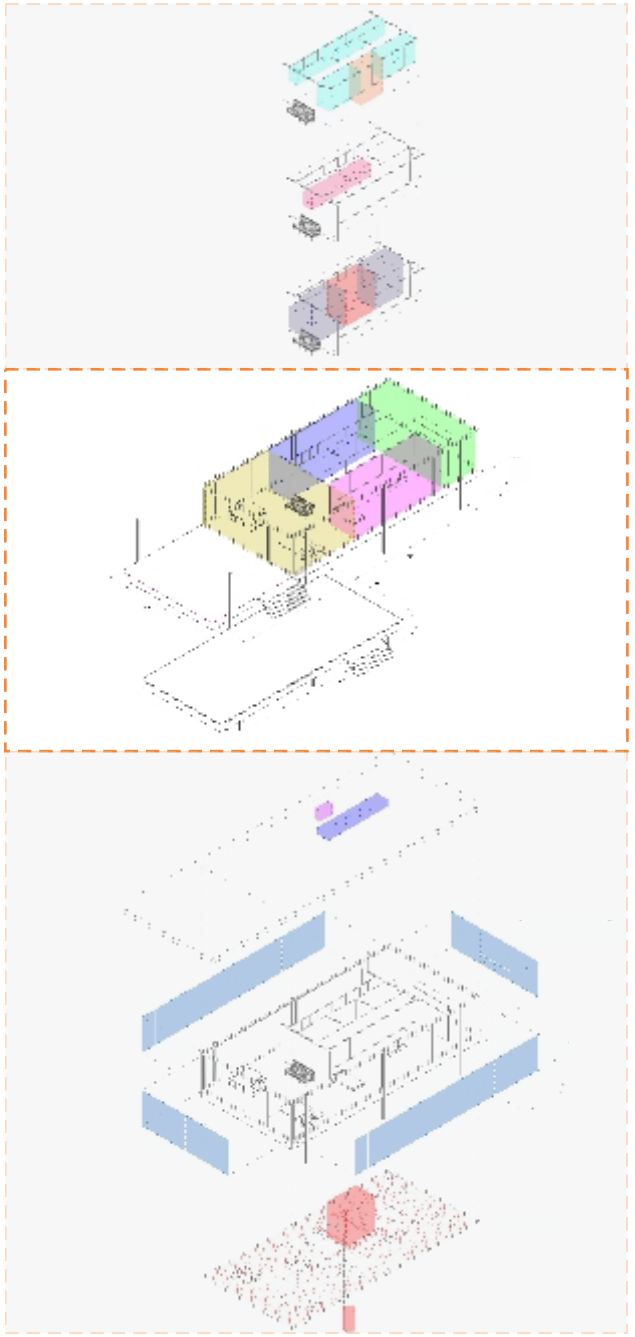




Component Analysis

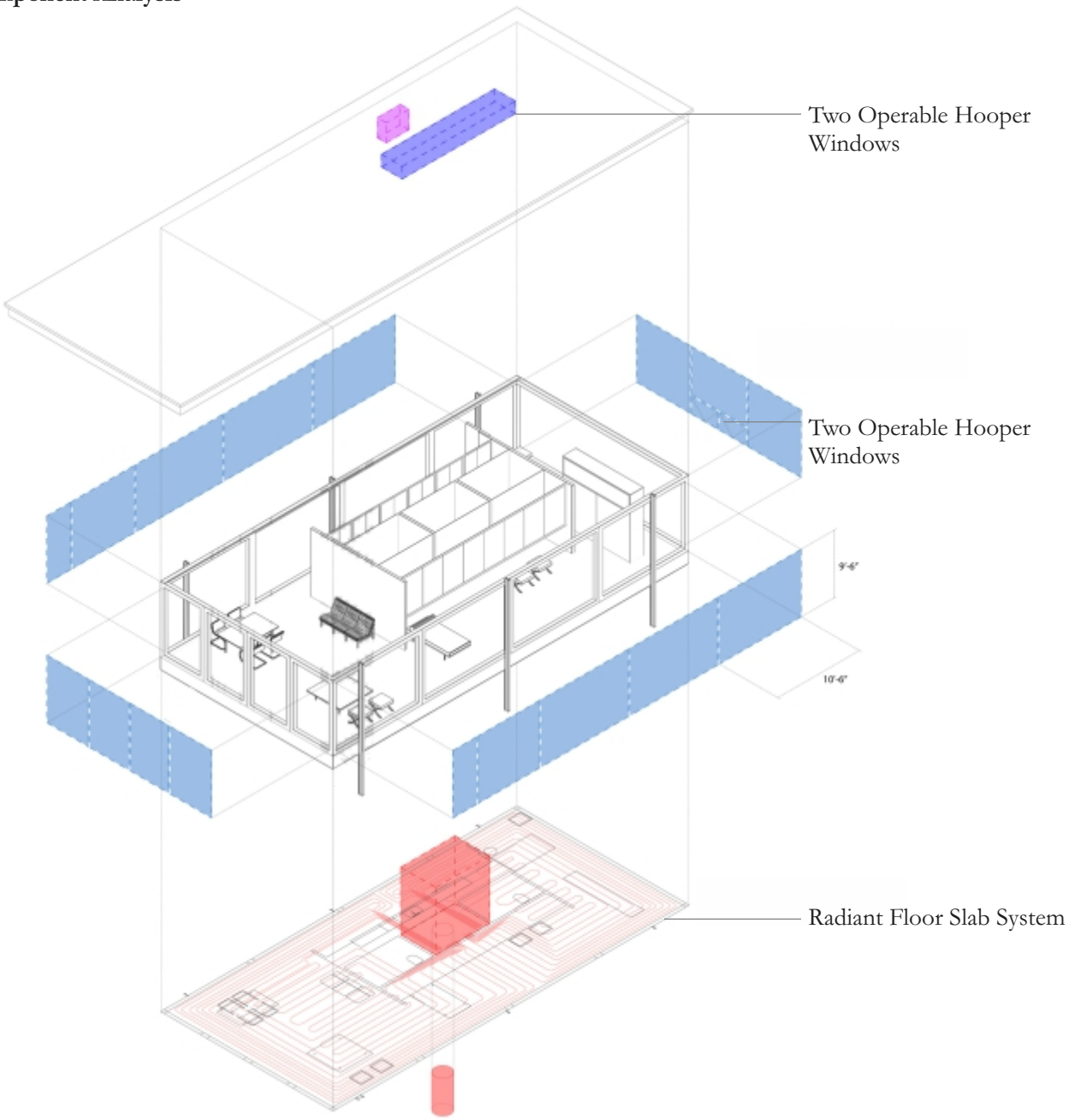


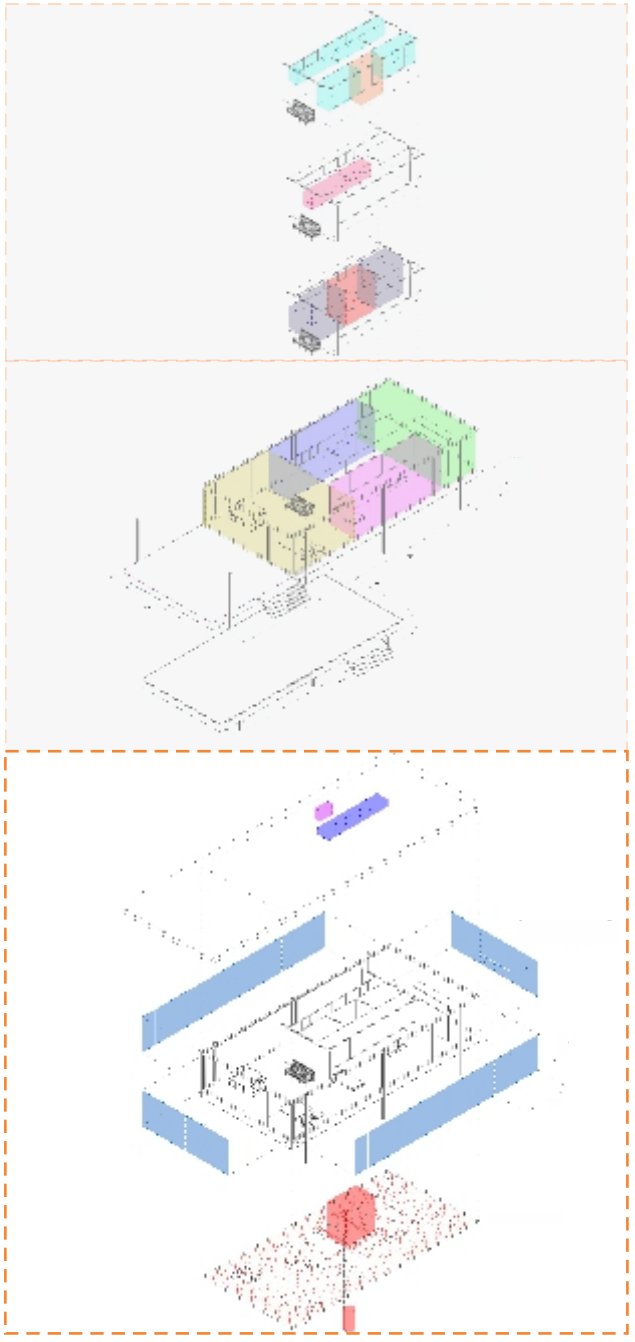
5'-3"
Above
Ground



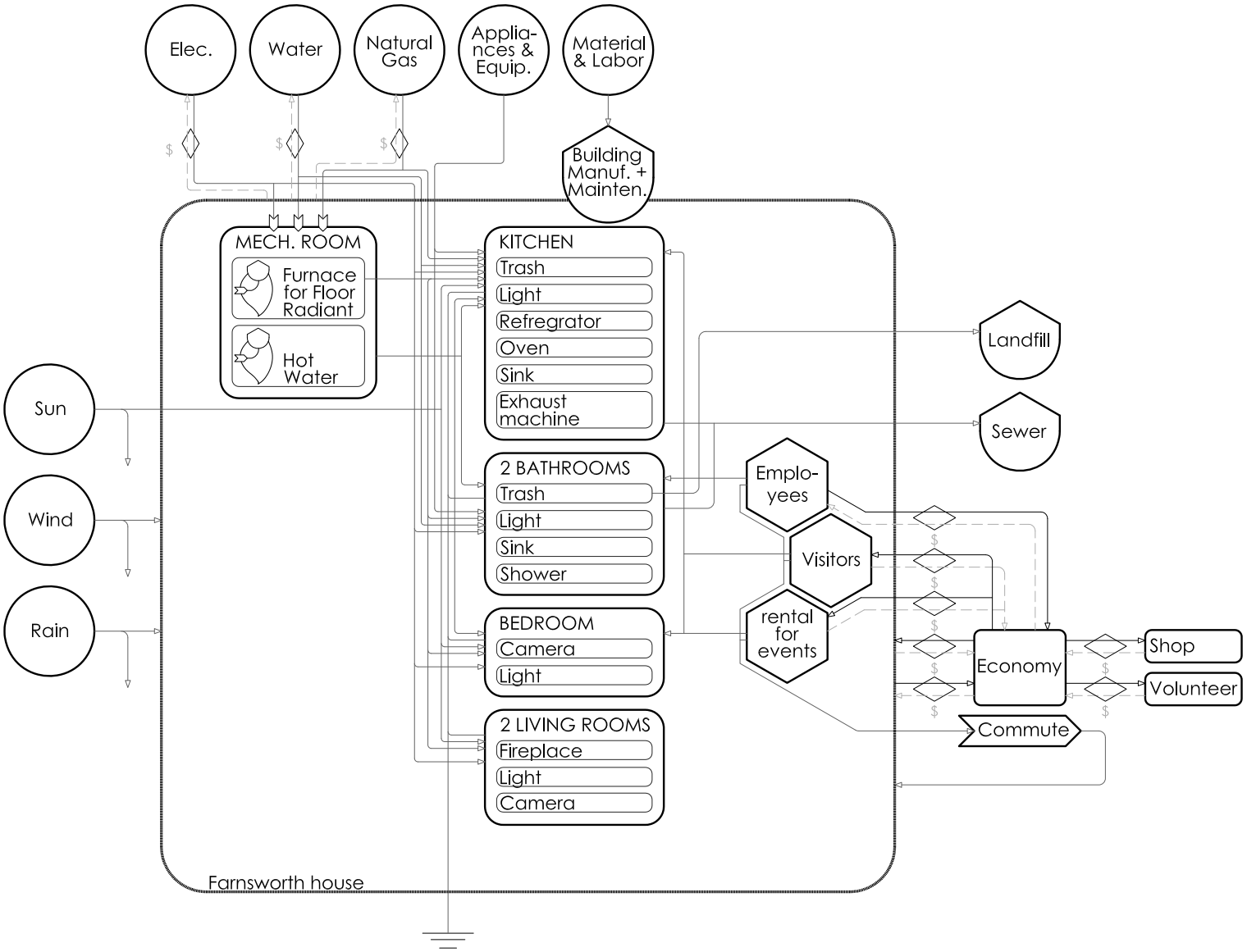
Zone 01 Zone 02 Zone 03 Zone 04

Component Analysis





Emergy Diagram



System Frame
A rectangular box drawn to represent the boundaries of the system selected.

Pathway Line
A pathway whose flow is proportional to the quantity in the storage or source upstream.

Source
Also known as a "Constant Force", is an outside source, delivering energy according to a program controlled from outside.

Storage
Also known as 'Tank', is a compartment of energy storage within the system, storing the quantity as balance of outflow and inflows.

Interaction
Interaction of two pathways coupled to produce an outflow in proportion to a function of both inflows. Action of one flow on another. Limiting factor action. Work gate.

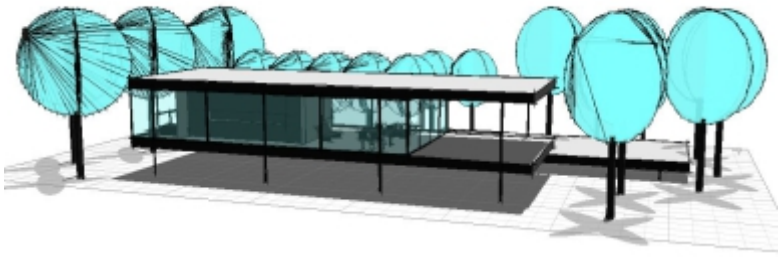
Heat Sink
Dispersion of potential energy into heat that accompanies all real transformation processes and storage. Loss of potential energy from further use by the system.

Producer
A unit that collects and transforms low-quality energy under control interactions of high quality flows

Consumer
A unit that transforms energy quality, stores it, and feeds it back autocatalytically to improve inflow

Transaction
A unit that indicates sale of goods or services(solid line) in exchange of payment of money(dashed line)

Box
Miscellaneous symbol for whatever unit or function is labeled



PILKINGTON
NSG Group Flat Glass Business

Pilkington Sun Management Calculator Results

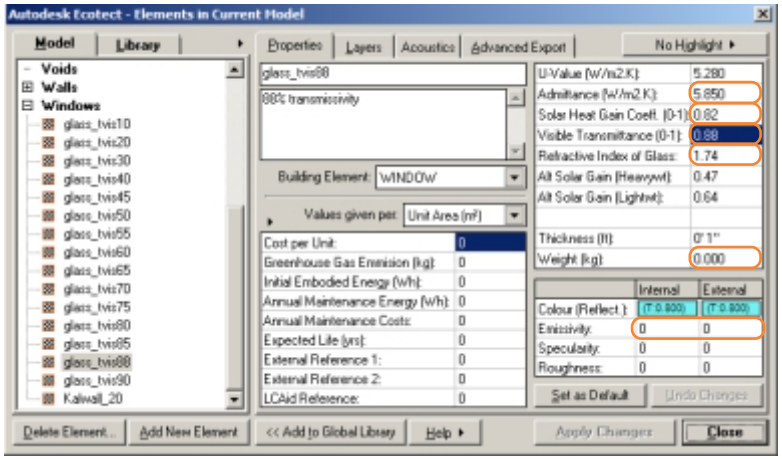
30 November 2012, 14:43

Details

Outboard: 6 mm (1/4") Pilkington Optifloatâ„¢ Clear
Fill:
Inboard:

Visible Light	Transmittance	88%	UV Transmittance	63%
	Exterior Reflectance	8%	U-Factor Summer (W/m2 °C)	5.28
	Interior Reflectance	8%	U-Factor Summer (Btu/hr.sq.ft.°F)	0.93
Total Solar Energy	Transmittance	77%	U-Factor Winter (W/m2 °C)	5.85
	Reflectance	7%	U-Factor Winter (Btu/hr.sq.ft.°F)	1.03
Damage-Weighted Trans. Tdw - ISO		0.81	Solar Heat Gain Coefficient	0.82
			Shading Coefficient	0.94

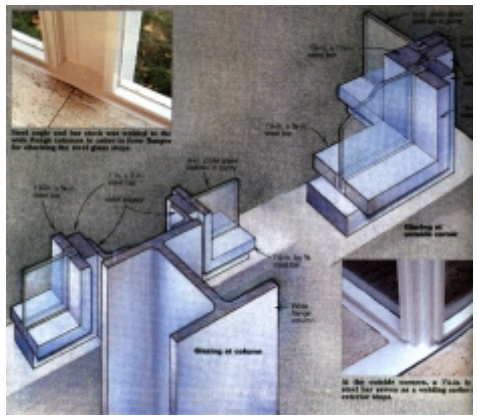
IGDB Version 16.1 (July 2008) Values are calculated using LBNL Window 5.2 program and represents the ' Center' region of glazing



Baseline Glass Parameters

Since, it's an exiting building, in order to form a baseline, actual glass used in Farnsworth house was verified.

Farnsworth house has single pane clear glass windows on all the sides, and the glass sheet is 6 mm thick with minor bluish tint.



Simulation Strategy

In order to simulate the actual glass used in Farnsworth house, a study was conducted to find the glass of similar properties by looking at major glass manufactures.

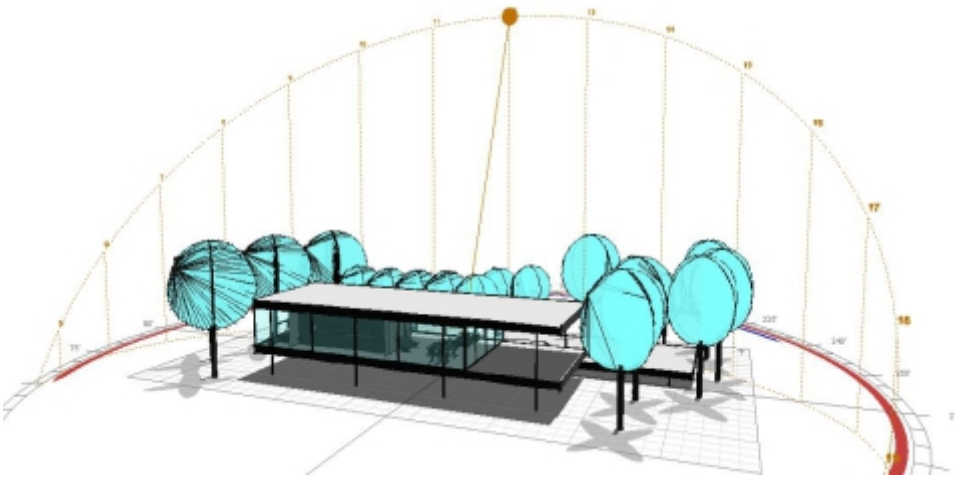
As a result of the study, **Pilkington Optifloat Clear** was found close enough to be used for baseline analysis.

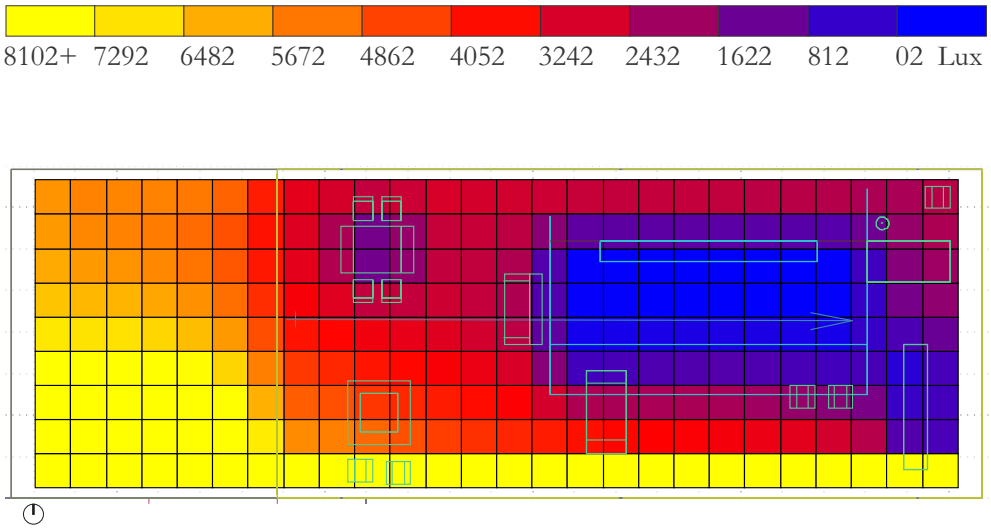
In addition to that, the ideal illumination (Lux levels) have been used to examine and improve the daylighting performance of the house.

The lux levels have been examined at 750 mm level from the floor and checked for uniform distribution of light for all the seasons.

Required Lux levels for Residential Use

Kitchen	General	300 lux
	Counter top	750 lux
Bedroom (Adult)	General	300 lux
	Task	500 lux
Bedroom (Child)	General	500 lux
	Task	800 lux
Bathroom	General	300 lux
Living Room/Den	General	300 lux
	Task	500 lux
Family Room	General	300 lux
	Task	500 lux
TV viewing	General	150 lux
Laundry/Utility	General	200 lux
Dining Room	General	200 lux
Home Office	General	500 lux
	Task	800 lux





Baseline 01

21st June @ 12 noon (Sunny Sky)

Illuminance@ 2'6" level

Since the glass used in baseline is 6mm thick with 88% transmittance, the illluminance in the are of study is excessive.

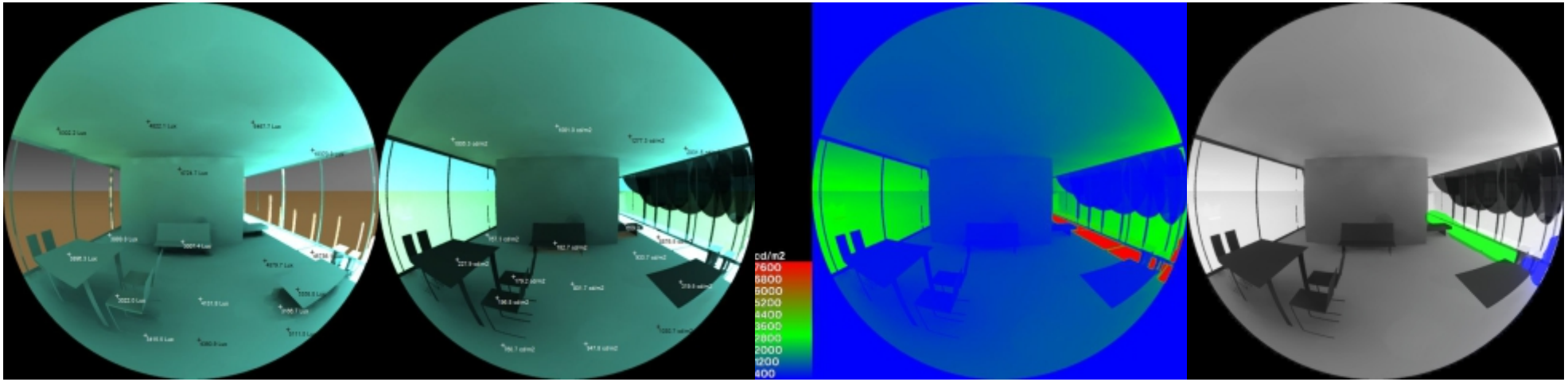
Illluminance in the are of study needs to be changed and to be reduced in order to achieve comfortable condition during summer season.

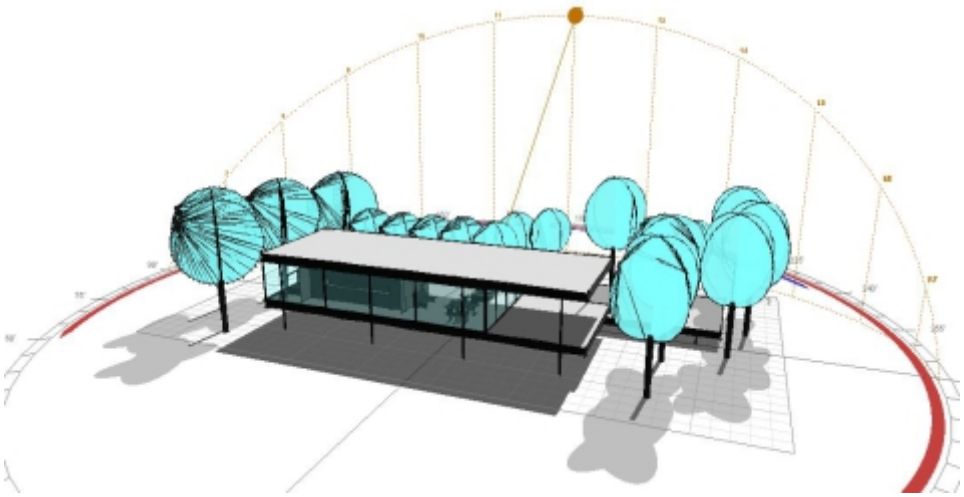
Illuminance

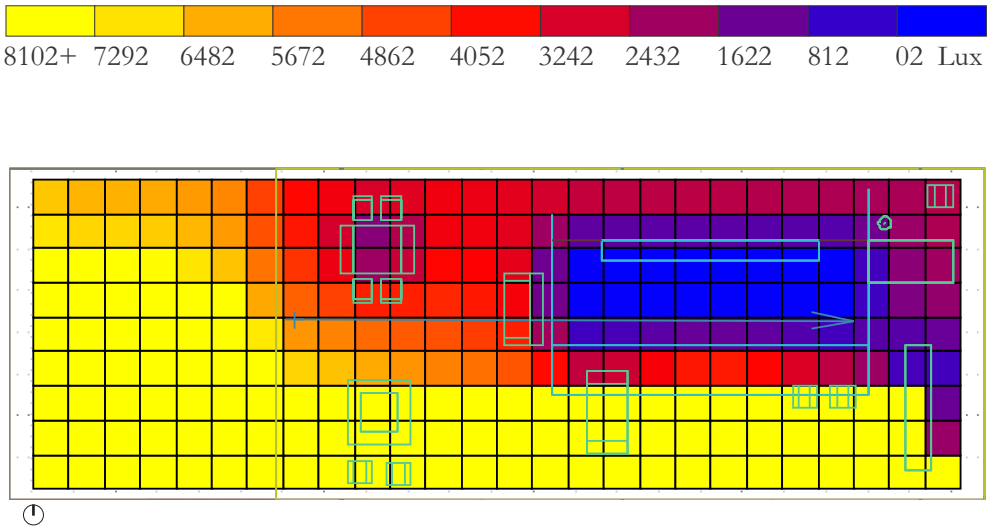
Luminance

False Color

Glare





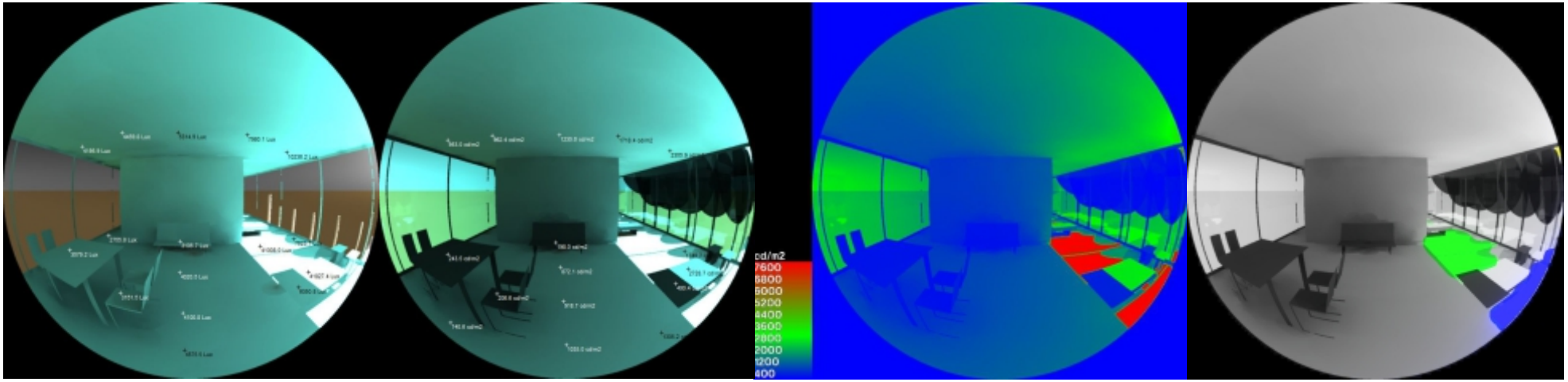


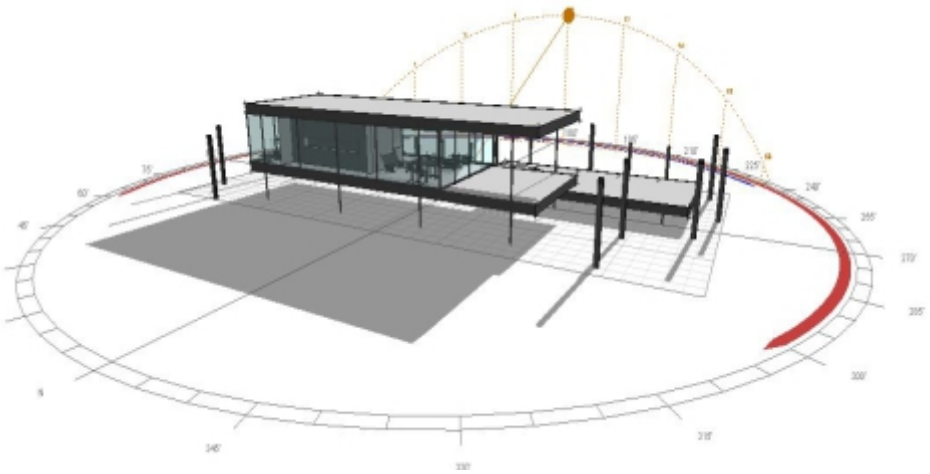
Baseline 02 **21st September @ 12 noon (Sunny Sky)** **Illuminance@ 2'6" level**

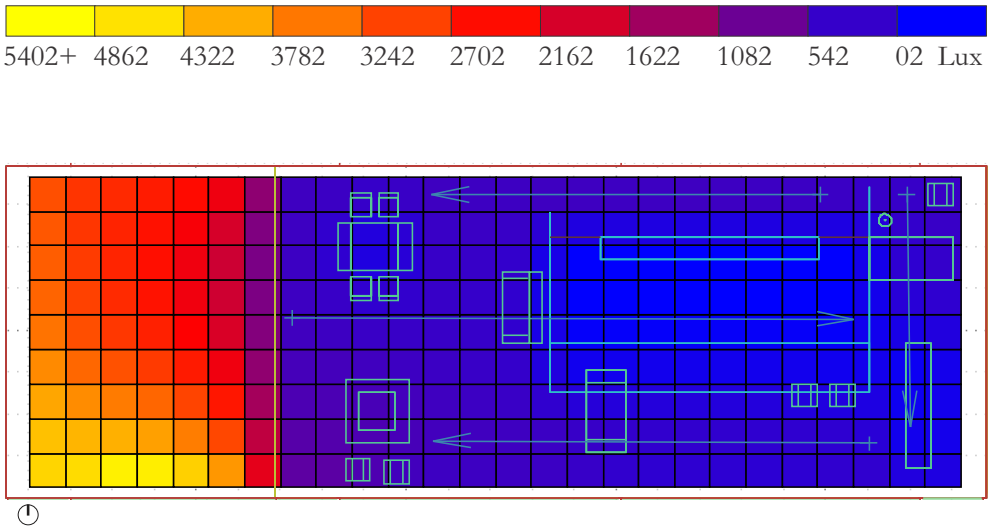
September sun penetrates further deep into the building. However, in the absence of any shading mechanism, September sun creates a serious glare situation.

Illuminance in study areas remains above the recommended lux levels for a residential use, and needs to be brought down.

Illuminance Luminance False Color Glare





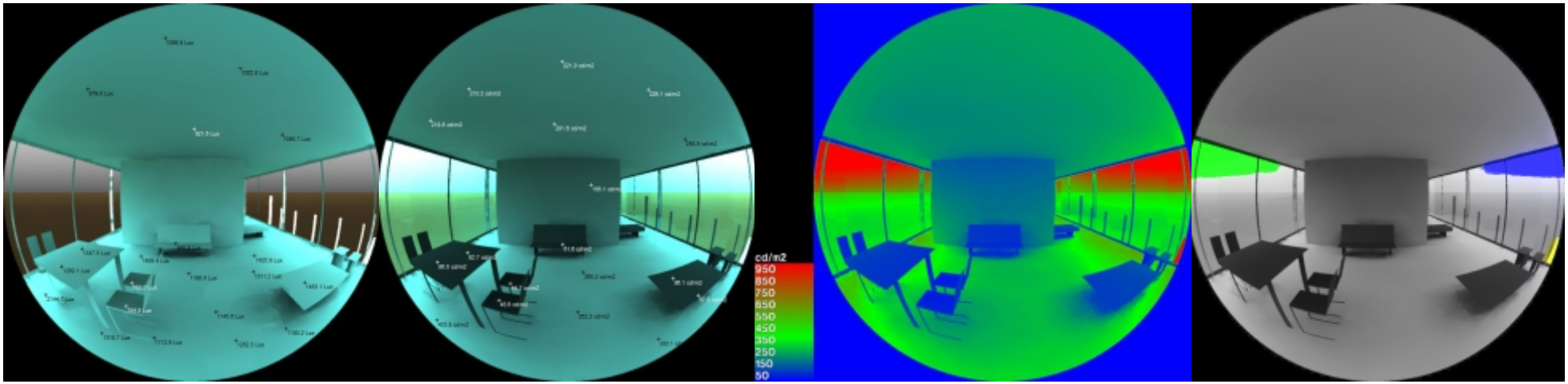


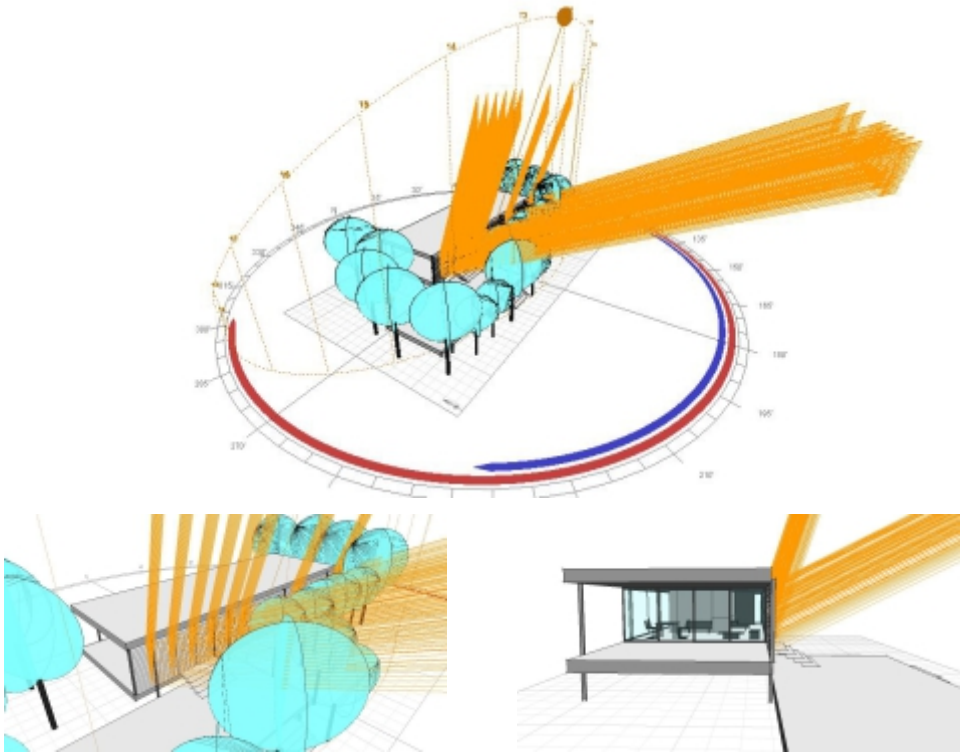
Baseline 03 **21st December @ 12 noon (Overcast Sky)** **Illuminance@ 2'6" level**

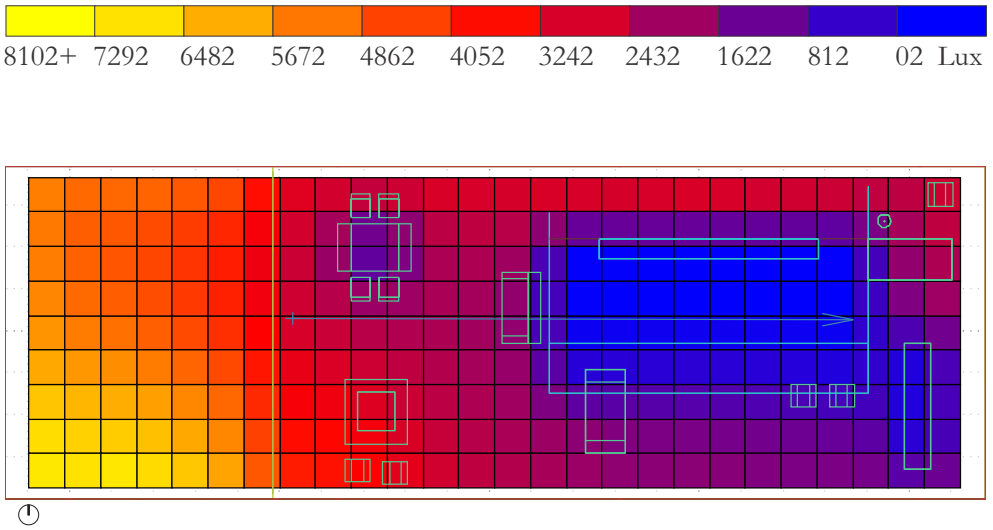
In order to simulate the winter scenario, the foliage of the trees has kept off during the

The illuminance levels achieved for this time during the year were well into the recommended ideal range of lux levels for a residential space.

Illuminance Luminance False Color Glare



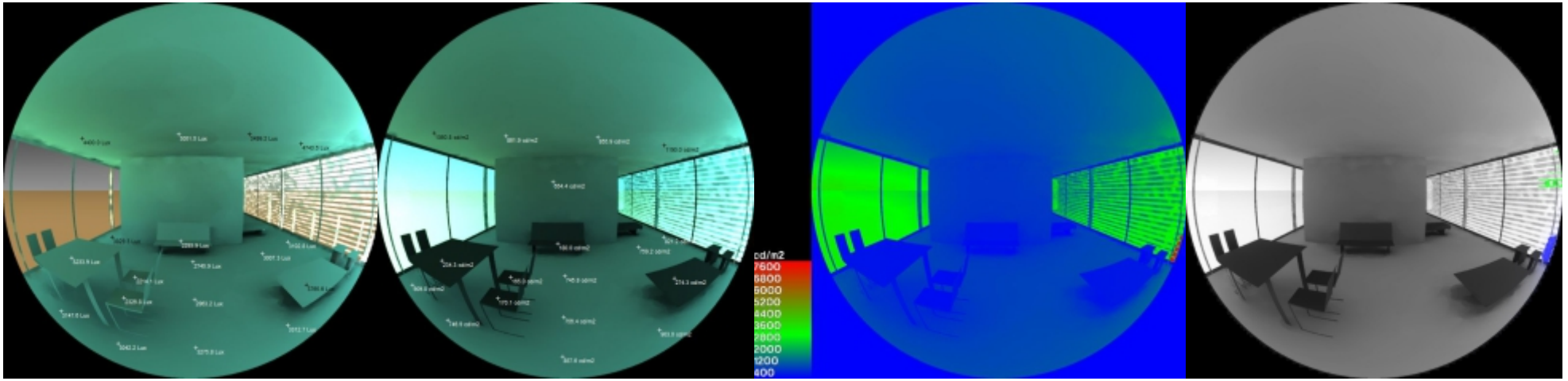




Design Case 01 **21st June @ 12 noon (Sunny Sky)**

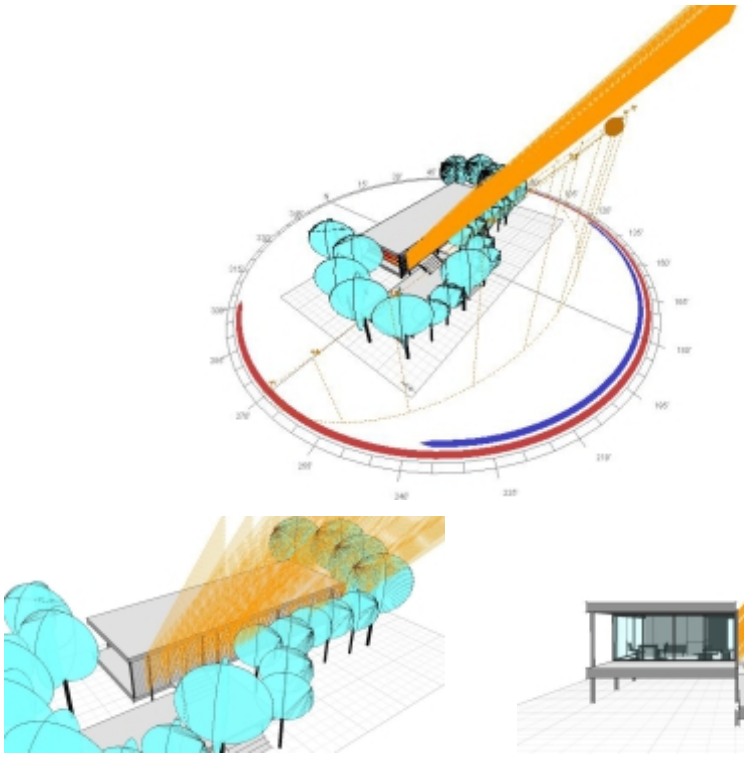
The louvers were kept perpendicular to September 21st sun. however, they effectively block the June 21st sun as well and addresses the glare situation primarily. The lux levels remains to be above recommended range.

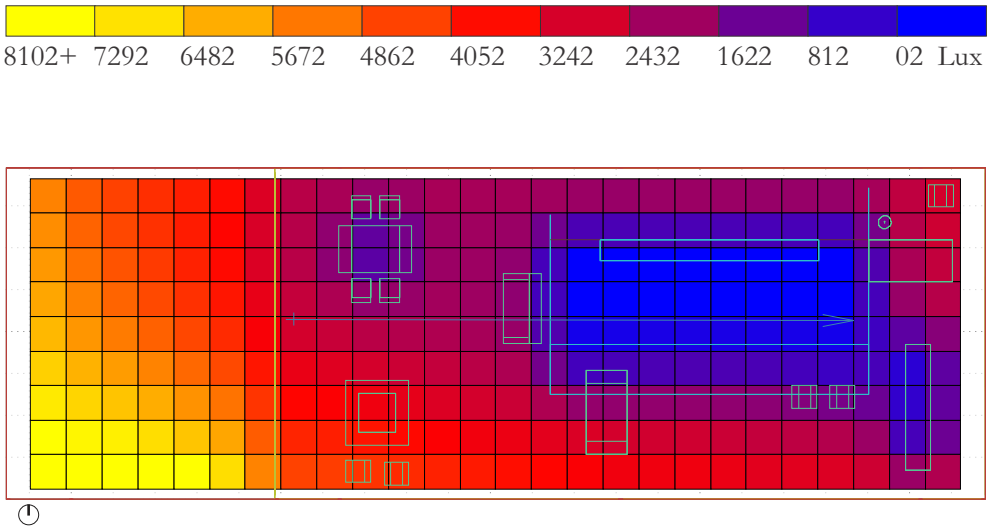
Illuminance Luminance False Color Glare



Farnsworth House
Energy Analysis as a tool for selecting Glass

M.E.B.D. / **2012**
Advisor / **William Braham**

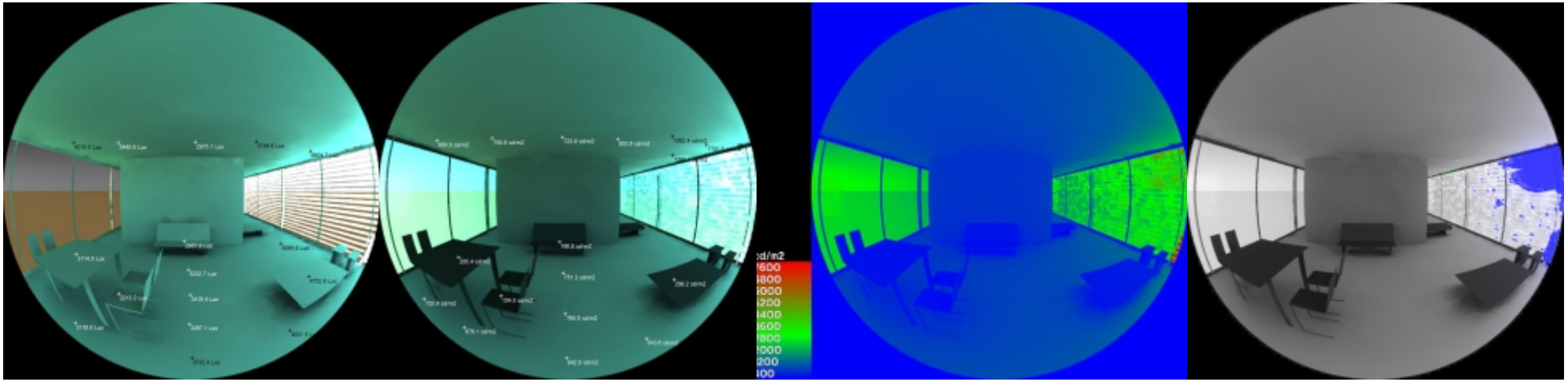


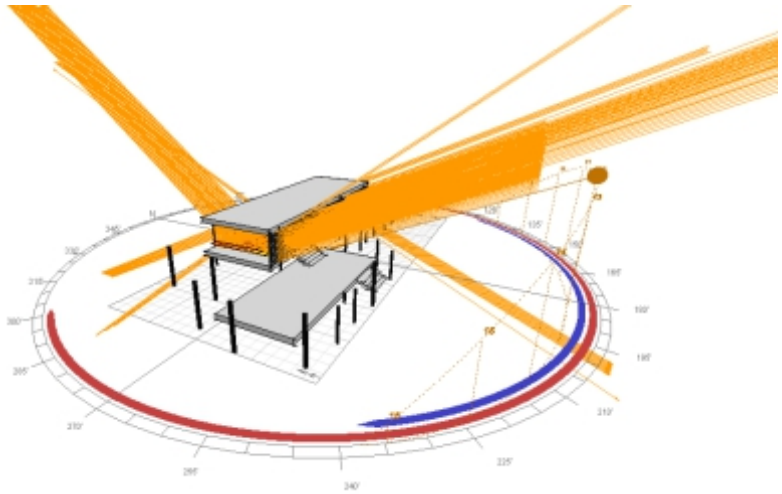


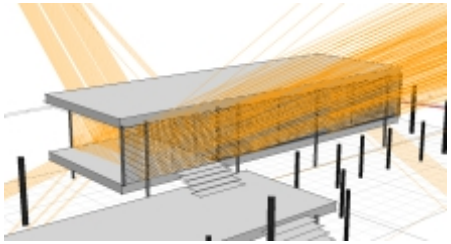
Design Case 02 **21st September @ 12 noon (Sunny Sky)**

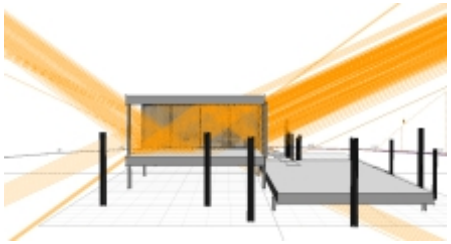
The louvers were kept at an angle of 115 degrees from horizontal axis and perpendicular to September 21st sun. The louvers help in reducing the glare for this scenario. However, the lux levels remains to be above recommended range for a residential space.

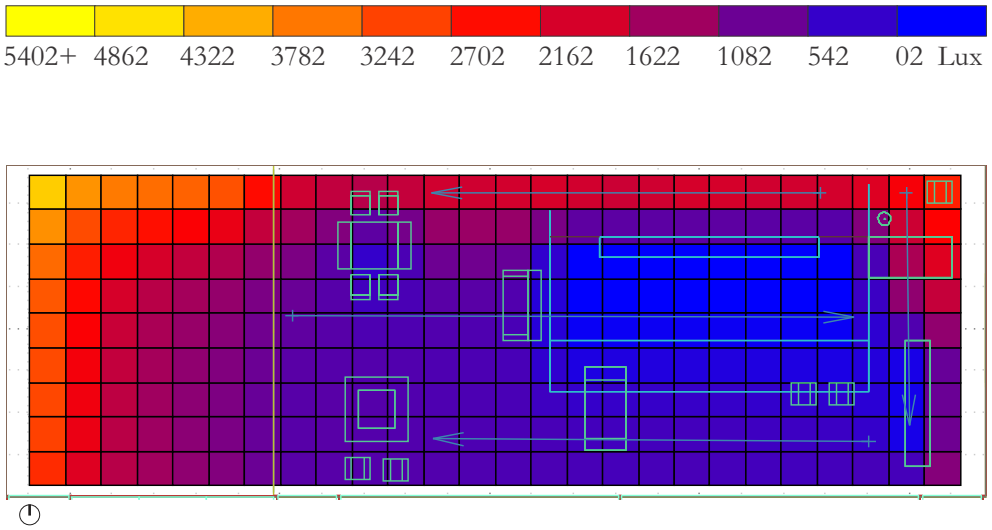
Illuminance Luminance False Color Glare







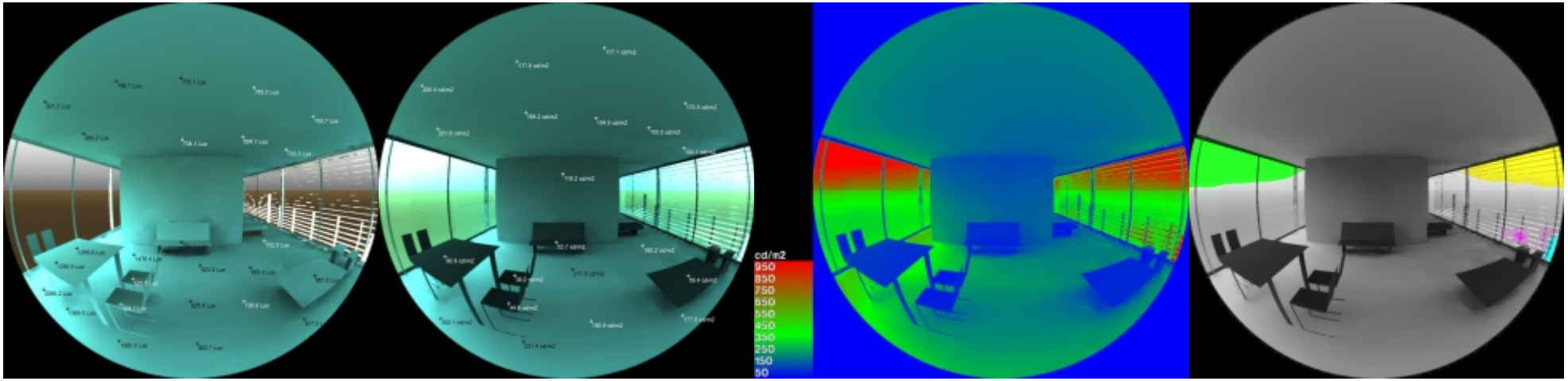


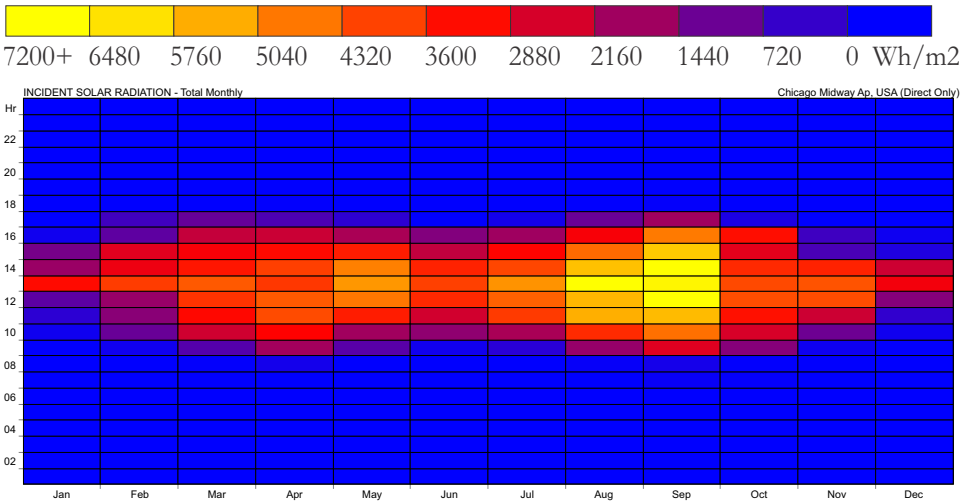


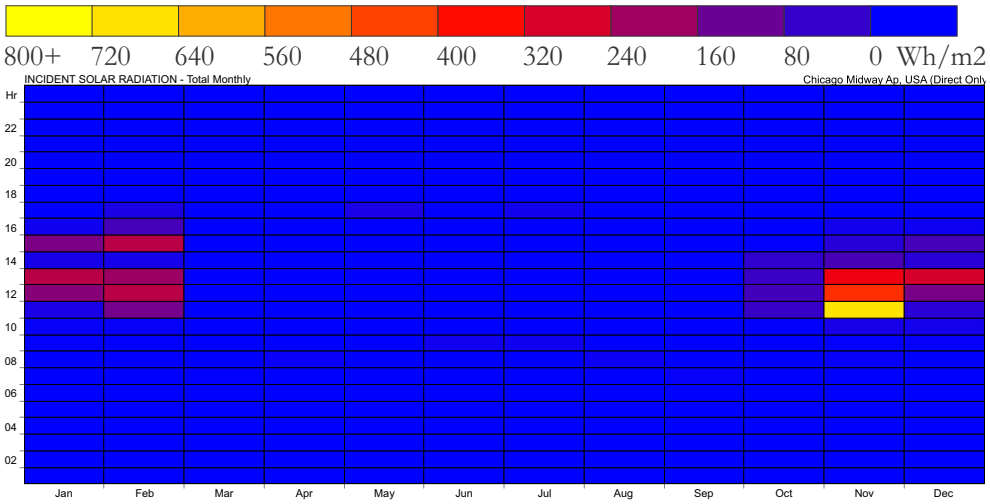
Design Case 03 **21st December @ 12 noon (Overcast Sky)**

The louvers were kept at an angle of 0 degrees from horizontal axis in order to allow the December 21 sun into the area of study. The lux levels were found to be within the recommended range for residential use.

Illuminance Luminance False Color Glare







Monthly Solar Radiation_Before

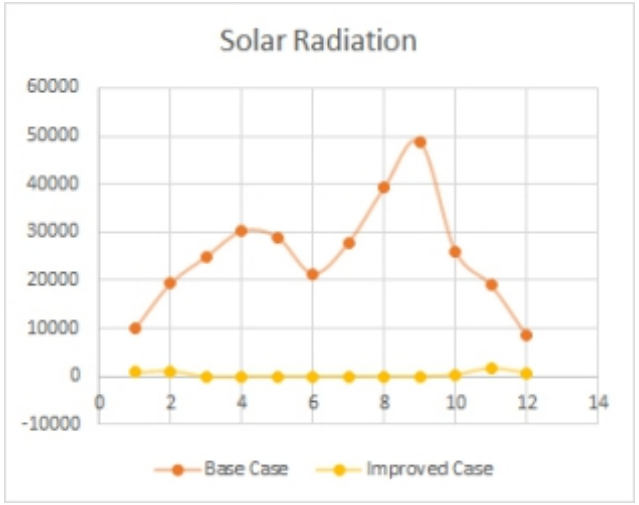
	January	February	March	April	May	June	July	August	September	October	November	December
Base Case	9876	19309	24885	30215	29022	21415	27878	39317	48896	26032	19016	8497

Monthly Solar Radiation_After

Reduced by 98%

Month	January	February	March	April	May	June	July	August	September	October	November	December
Improved Case	802	1131	2	14	41	26	49	20	10	427	1746	735

Looking at the solar radiation values across all the months of a year, it was noted that during September month the south facing facade of the house received maximum solar radiation and also the maximum amount of glare.



After introducing the louvers, it was found out that solar radiation received by the south facing facade of the house was reduced by 98% and remained uniform throughout the year.

Glass Optimization

21st September (Sunny Sky)

Considering 21st September as a worst case, illuminance was checked for a glass having 25% transmittance and same thickness as the base case, and resulting lux levels were found to be below recommended range. However, in the case of a glass option having 30% transmittance, the lux levels were found to be within the range.

Optifloat Clear_Transmittance 88%

PILKINGTON
NSG Group Flat Glass Business

Pilkington Sun Management Calculator Results

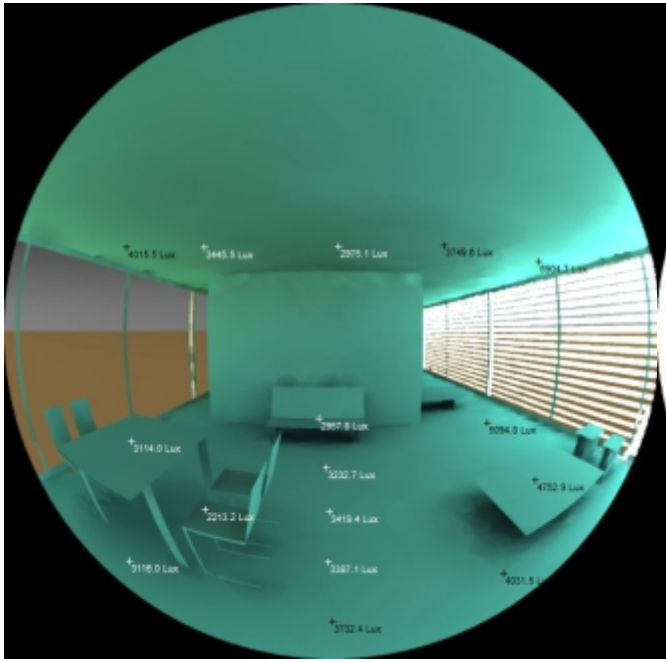
30 November 2012, 14:43

Details

Outboard: 6 mm (1/4") Pilkington **Optifloat_c** Clear
Fill:
Inboard:

Visible Light	Transmittance	88%	UV Transmittance	83%
	Exterior Reflectance	8%	U-Factor Summer (W/m2 °C)	5.28
	Interior Reflectance	8%	U-Factor Summer (Btu/hr.sq.ft.°F)	0.93
Total Solar Energy	Transmittance	77%	U-Factor Winter (W/m2 °C)	5.85
	Reflectance	7%	U-Factor Winter (Btu/hr.sq.ft.°F)	1.03
Damage-Weighted Trans. Tdw - ISO		0.81	Solar Heat Gain Coefficient	0.82
			Shading Coefficient	0.94

Illuminance



Solar-E Pulsa Gray_Transmittance 25%

PILKINGTON
NSG Group Flat Glass Business

Pilkington Sun Management Calculator Results

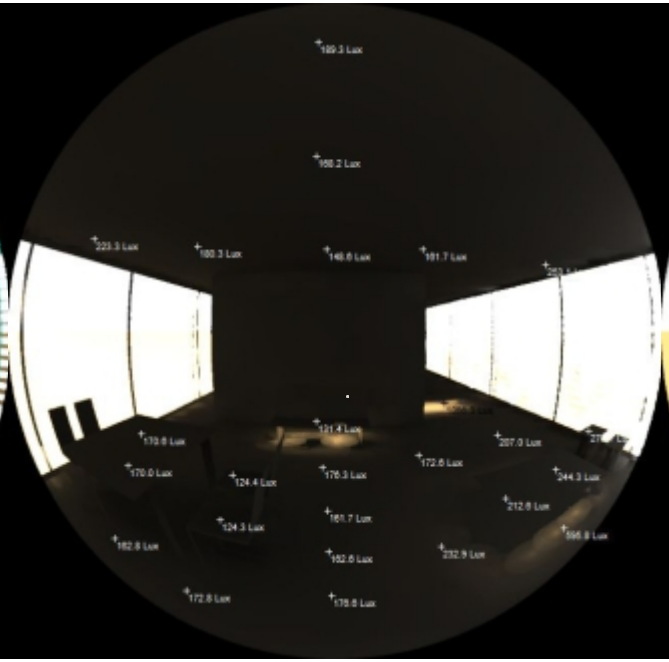
2 December 2012, 4:58

Details

Outboard: 6 mm (1/4") Pilkington **Solar-E Pulsa_g** Grey on the #2 surface
Fill:
Inboard:

Visible Light	Transmittance	25%	UV Transmittance	13%
	Exterior Reflectance	5%	U-Factor Summer (W/m2 °C)	2.95
	Interior Reflectance	8%	U-Factor Summer (Btu/hr.sq.ft.°F)	0.50
Total Solar Energy	Transmittance	19%	U-Factor Winter (W/m2 °C)	3.69
	Reflectance	5%	U-Factor Winter (Btu/hr.sq.ft.°F)	0.65
Damage-Weighted Trans. Tdw - ISO		0.24	Solar Heat Gain Coefficient	0.34
			Shading Coefficient	0.39

Illuminance



Solar-Ea Gray_Transmittance 30%

PILKINGTON
NSG Group Flat Glass Business

Pilkington Sun Management Calculator Results

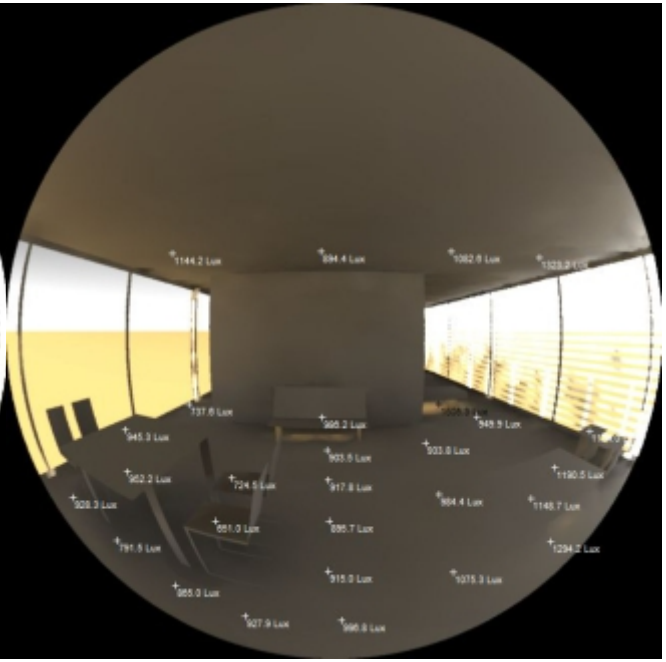
2 December 2012, 14:53

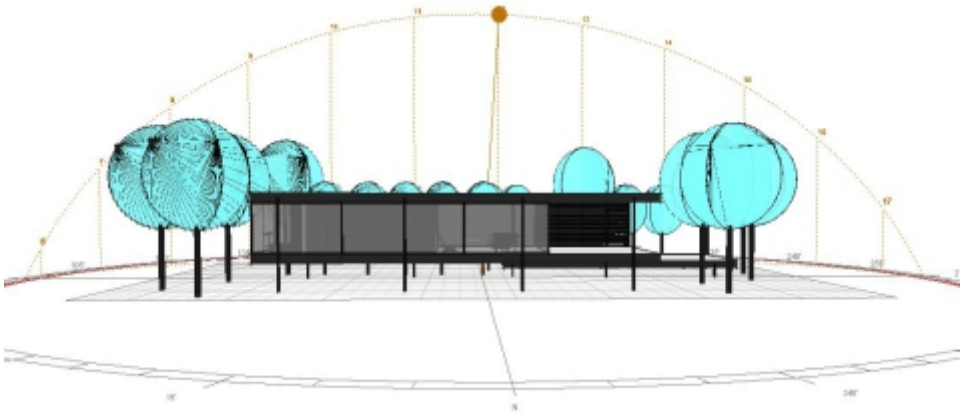
Details

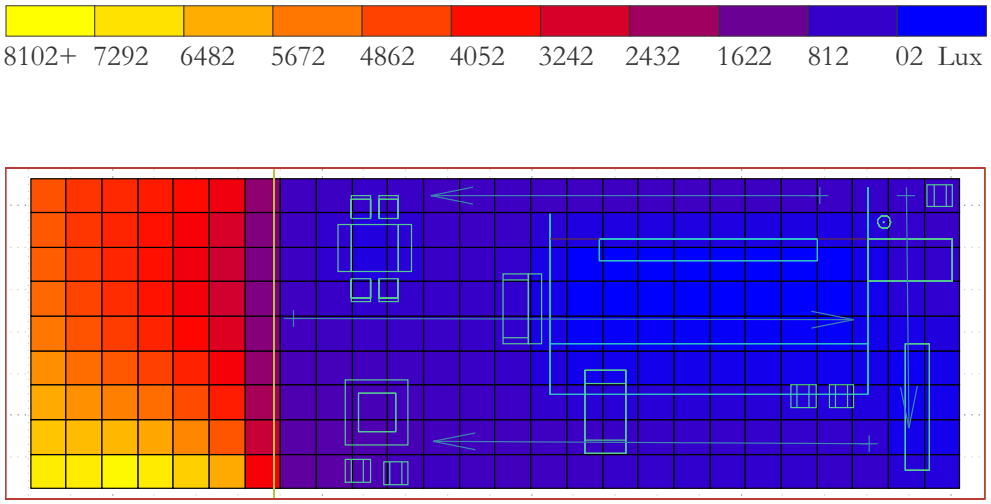
Outboard: 6 mm (1/4") Pilkington **Solar-Ea_g** Grey on the #2 surface
Fill:
Inboard:

Visible Light	Transmittance	30%	UV Transmittance	15%
	Exterior Reflectance	5%	U-Factor Summer (W/m2 °C)	2.94
	Interior Reflectance	8%	U-Factor Summer (Btu/hr.sq.ft.°F)	0.50
Total Solar Energy	Transmittance	23%	U-Factor Winter (W/m2 °C)	3.69
	Reflectance	6%	U-Factor Winter (Btu/hr.sq.ft.°F)	0.65
Damage-Weighted Trans. Tdw - ISO		0.27	Solar Heat Gain Coefficient	0.36
			Shading Coefficient	0.42

Illuminance

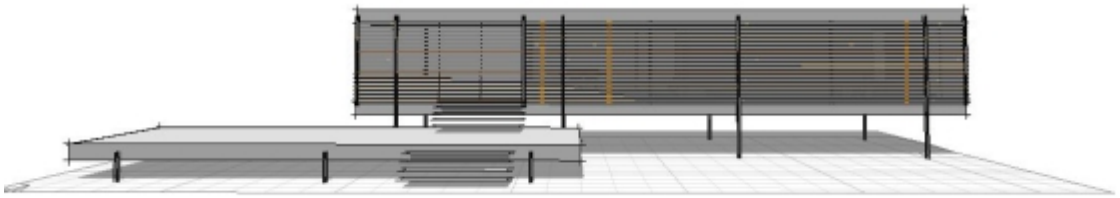




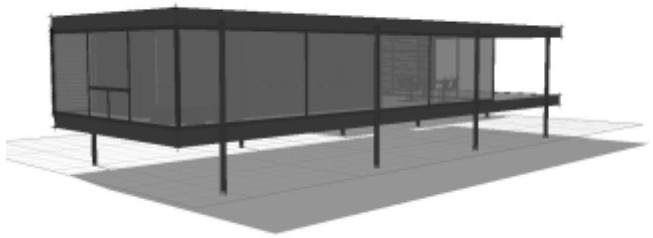


Final Design with Pilkington Solar-Ea Gray_Transmittance 30% Glass

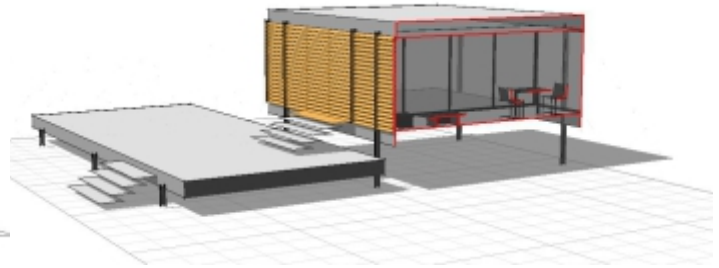
21st September @ 12 noon (Sunny



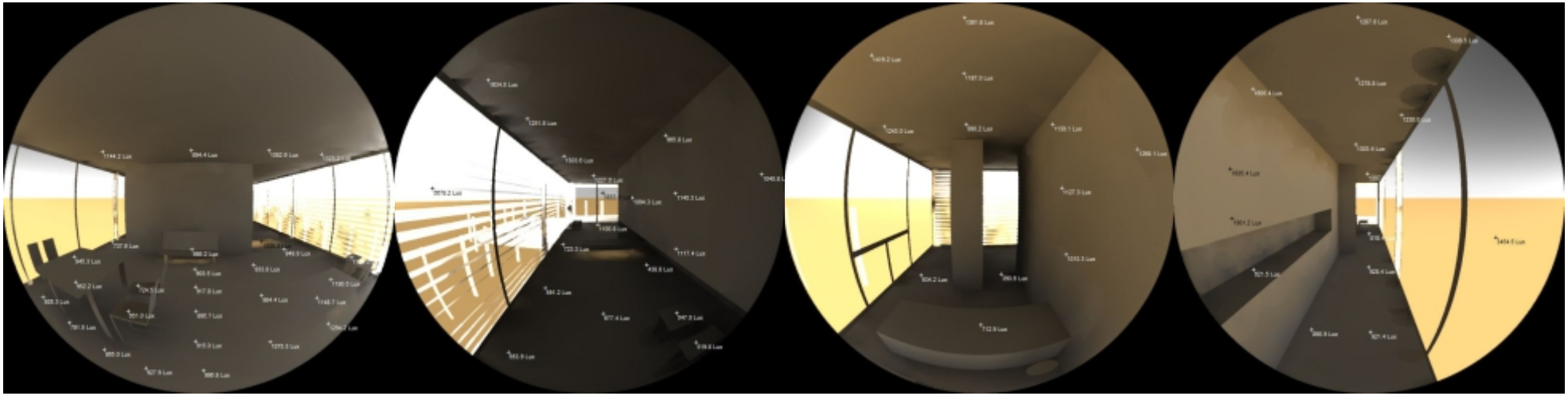
Horizontal adjustable Louvers on South facing windows



Pilkington - 6 mm Solar-Ea Gray with transmittance 30%

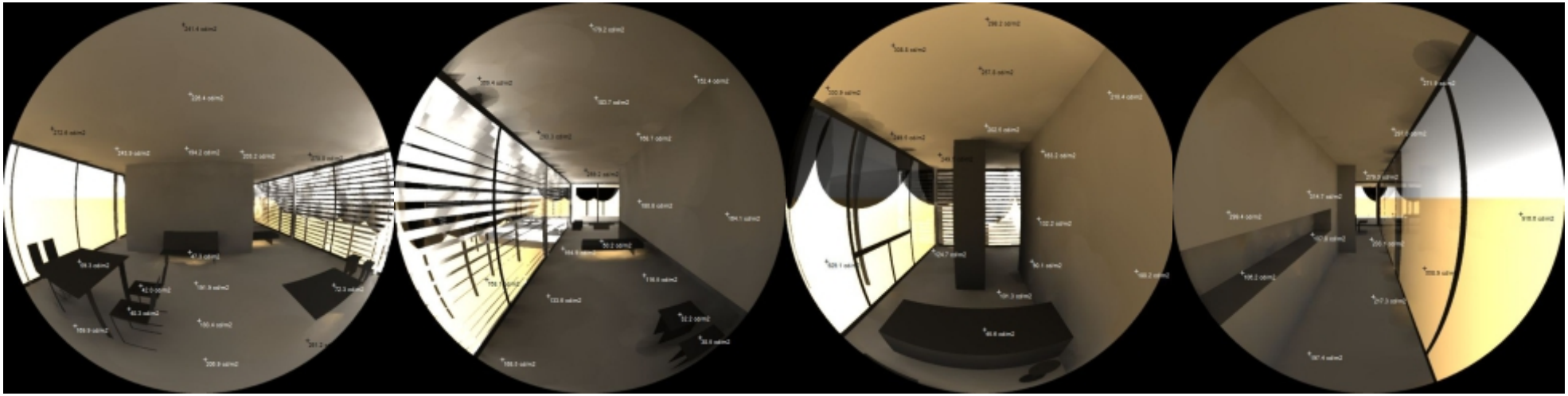


Final Rendering with Radiance



Achieved Illuminance

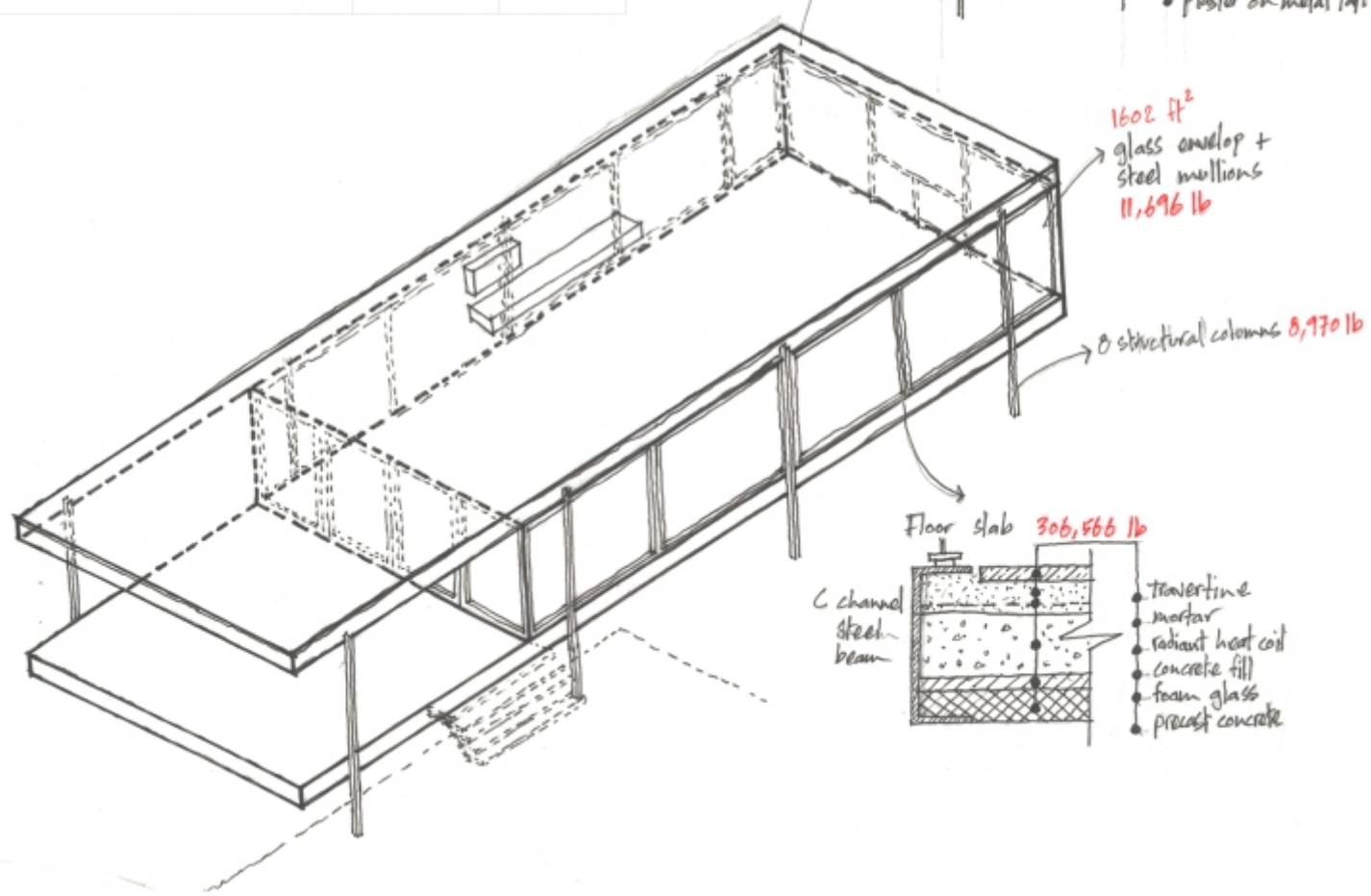
21st September @ 12 noon (Sunny Sky)



Luminance

21st September @ 12 noon (Sunny Sky)

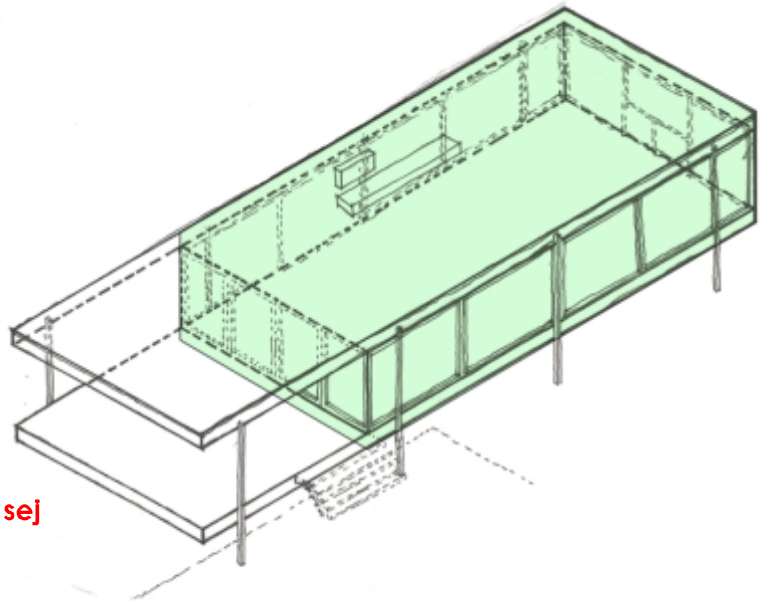
	CEILING SLAB + FLOOR SLAB+ GLASS ENVELOP + STRUCTURAL COLUMNS BASECASE		
		total weight (lb)	emergy (10^15 sej)
1	ceiling	168,924.30	227.99
2	floor	306,565.87	313.97
3	glass envelop	11,696.18	24.51
4	structural columns	8,970.00	28.24
	TOTAL	**248.08 ton**	**594.70**



CEILING SLAB + FLOOR SLAB+ GLASS ENVELOP + STRUCTURAL COLUMNS BASECASE

		length (ft)	Area (ft²)	volume (ft³)	unit weight		reference	total weight (lb)	specific emergy (10^12 sej/lb)	emergy (10^15 sej)
1	15" C channel section beam, wrapping the slab (ceiling)	210.80			50.00	lb/ft	[2]	10,540.15	3.15	33.18
2	2.3"x14" cork insulating the C channel beam interior (ceiling)	210.80		47.14	14.00	lb/ft³	[1]	659.93	1.09	0.72
3	Precast concrete (ceiling)			704.55	138.00	lb/ft³	[1]	97,228.12	0.82	79.82
4	Foam glass insulation (ceiling)			469.67	8.70	lb/ft³	[3]	4,086.12	4.01	16.40
5	concrete fill under flashing (ceiling)			17.15	100.00	lb/ft³	[1]	1,715.20	0.82	1.41
6	steel facia + angle (ceiling)	212.00			14.00	lb/ft	comparison with [2]	2,968.00	3.15	9.34
7	felt roofing (ceiling)		2,269.45		3.00	lb/ft²	calculated based on [4]	6,808.34	0.22	1.46
8	I beam rafters + steel angles behind suspended ceiling (ceiling)	319.00			35.00	lb/ft	[2]	11,165.00	3.15	35.15
9	creosoted wood to support suspended ceiling (ceiling)			38.75	36.00	lb/ft³	[5]	1,395.00	1.59	2.21
10	plaster on metal lath, suspended ceiling (ceiling)		2,157.23		15.00	lb/ft²	[1]	32,358.43	1.49	48.29
11	15" C channel section beam, wrapping the slab (floor)	210.80			50.00	lb/ft	[2]	10,540.15	3.15	33.18
12	Precast concrete (floor)			704.55	138.00	lb/ft³	[1]	97,228.12	0.82	79.82
13	Foam glass insulation (floor)			469.67	8.70	lb/ft³	[3]	4,086.12	4.01	16.40
14	travertine (floor)		2,157.23		16.26	lb/ft²	[6]	35,076.54	1.11	38.82
15	mortar bed beneath travertine (floor)		2,157.23		10.00	lb/ft²	[1]	21,572.29	1.50	32.39
16	lightweight concrete fill, thickness of 8 in. (floor)		17,257.83		8.00	lb/ft²	[1]	138,062.64	0.82	113.35
17	I beam steel columns 8 Pcs 17.25 ft each (façade)	138.00			65.00	lb/ft	[2]	8,970.00	3.15	28.24
18	1/4" thick single-pane glass (façade) 192 x 9.5 ft		1,517.57		3.24	lb/ft²	[7]	4,916.92	0.64	3.17
19	Steel mullions (façade)							6,779.26	3.15	21.34
	1" x 2" steel bar framing the glass + steel door frame	668.74			6.80	lb/ft	[8]			
	1.25" x 5/8" steel bar framing the glass	683.74			2.66	lb/ft	[8]			
	2" x 2" x 1/4" steel angles welded to columns	114.00			3.19	lb/ft	[2]			
	4" steel C channel above door	7.00			7.25	lb/ft	[2]			
							TOTAL ENVELOP WEIGHT (lb)	**496,156.34 lb**		
							TOTAL ENVELOP WEIGHT (ton)	**248.08 ton**	**EMERGY**	**594.70 x 10^{15} sej**

	ENVELOP OF INDOOR ONLY (green zone in sketch) BASECASE		
		total weight (lb)	emergy (10^15 sej)
1	72% of the whole ceiling	121,363.14	163.80
2	72% of the whole floor	220,251.31	225.57
3	glass envelop	11,696.18	24.51
4	structural columns (6 columns without 5' 3" of its length since its below floor slab)	4,680.00	14.73
		15	
	TOTAL	**179.00 ton**	**428.61 x 10^{1} sej**



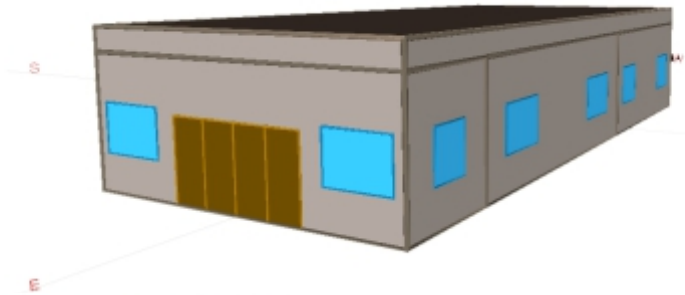
	ENVELOP OF INDOOR ONLY (green zone in sketch) BASECASE						
		total weight (lb)	embodied energy (MJ/lb)	specific emergy (10^12 sej/lb)	reference	embodied energy (MJ)	emergy (10^15 sej)
1	steel	36,758.15	14.51	3.15	[2]	533,543.56	115.71
2	cork	474.13	4.90	1.09	[2]	2,322.67	0.52
4	Foam glass*	5,871.32	13.74	4.01	[2] + [4]	80,694.63	23.57
3	concrete	240,129.45	0.54	0.82	[2]	130,705.22	197.15
7	felt roofing**	4,891.43	30.21	0.22	[3] + [5]	147,766.62	1.05
9	wood	1,002.24	1.13	1.59	[3] + [4]	1,136.52	1.59
10	plaster	23,247.82	3.54	1.49	[2]	82,251.36	34.69
14	travertine***	25,200.63	0.91	1.11	[1] + [2]	22,861.65	27.89
15	mortar	15,498.54	0.05	1.50	[2]	703.00	23.27
18	glass	4,916.92	3.08	0.64	[2]	15,165.90	3.17
	TOTAL	**179.00 ton**				**1,017,151.14 M**	**428.61 x 10^{1} sej**

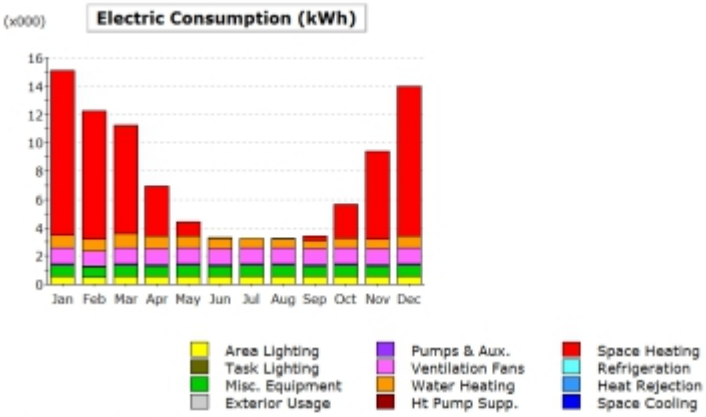
ENVELOP OF INDOOR ONLY, SOME GLASS REPLACED WITH SOLID WALL

PROPOSEDCASE

		Area (ft^2)	unit weight		weight reference	total weight (lb)	embodied energy (MJ/lb)	specific emergy (10^12 sej/lb)	emergy & energy reference	embodied energy (MJ)	emergy (10^15 sej)
1	steel - window mullions (6,779.26 lb)					29,978.86	14.51	3.15	[2]	435,142.35	94.37
2	cork					474.13	4.90	1.09	[2]	2,322.67	0.52
3	Foam glass*					5,871.32	13.74	4.01	[2] + [4]	80,694.63	23.57
4	concrete					240,129.45	0.54	0.82	[2]	130,705.22	197.15
5	felt roofing**					4,891.43	30.21	0.22	[3] + [5]	147,766.62	1.05
6	wood					1,002.24	1.13	1.59	[3] + [4]	1,136.52	1.59
7	plaster					23,247.82	3.54	1.49	[2]	82,251.36	34.69
8	travertine***					25,200.63	0.91	1.11	[1] + [2]	22,861.65	27.89
9	mortar					15,498.54	0.05	1.50	[2]	703.00	23.27
10	glass	360	8	lb/ft^2	[6]	2,880.00	3.08	0.64	[2]	8,883.16	1.86
11	Solid wall										
	external plaster 0.75" thick	1268.1	2.97	lb/ft^2	[2]	3,766.05	3.54	1.49	[2]	13,324.36	5.62
	plaster 0.4" thick	1268.1	1.485	lb/ft^2	[2]	1,883.02	3.54	1.49	[2]	6,662.18	2.81
	air brick 4" thick	1268.1	10.32	lb/ft^2	[2]	13,090.26	1.22	1.67	[2]	16,031.65	21.85
	external air brick 4.7" thick	1268.1	17.2	lb/ft^2	[2]	21,817.09	1.22	1.67	[2]	26,719.41	36.42
	insulation 2.4" thick	1268.1	0.369	lb/ft^2	[2]	467.51	42.82	4.01	[2]	20,018.35	1.88
	mortar	1268.1	0.41	lb/ft^2	[2]	519.45	0.05	1.50	[2]	23.56	0.78
	TOTAL					**390,717.80**				**995,246.71**	**475.31 x 10^{15} sej**
						195.36					

Pilkongton_Optifloat Clear_Transmittance 88%



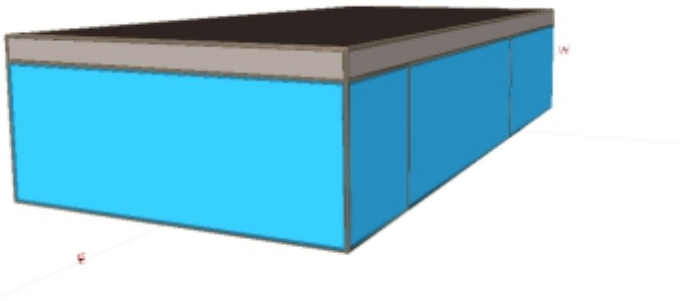


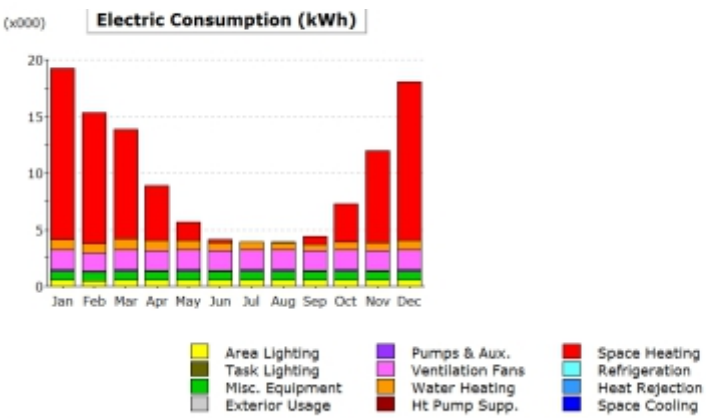
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	11.63	9.04	7.70	3.54	0.97	0.09	-	0.02	0.33	2.39	6.17	10.55	52.43
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.91	0.88	0.98	0.93	0.86	0.74	0.67	0.63	0.60	0.66	0.72	0.84	9.41
Vent. Fans	1.13	1.02	1.13	1.09	1.13	1.09	1.13	1.13	1.09	1.13	1.09	1.13	13.32
Pumps & Aux.	0.09	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	1.06
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.79	0.71	0.79	0.76	0.79	0.76	0.79	0.79	0.76	0.79	0.76	0.79	9.28
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.57	0.51	0.57	0.55	0.57	0.55	0.57	0.57	0.55	0.57	0.55	0.57	6.69
Total	15.12	12.24	11.26	6.96	4.40	3.32	3.25	3.23	3.42	5.63	9.38	13.97	92.18

Proposed Case from Emergy Calculation

Total Electric Consumption kwh = **92**





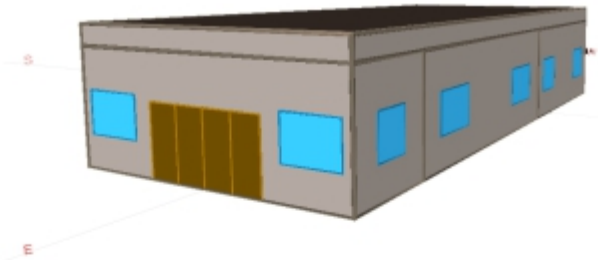
Electric Consumption (kWh x000)

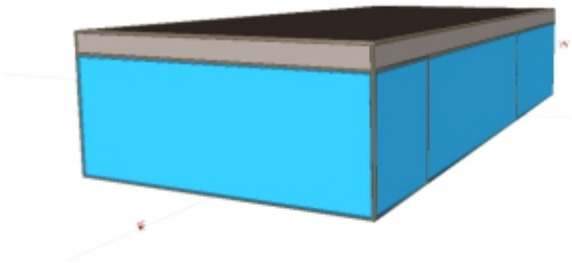
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	15.06	11.53	9.62	4.80	1.55	0.25	0.03	0.09	0.67	3.40	8.09	13.99	69.07
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.91	0.88	0.98	0.93	0.86	0.74	0.67	0.63	0.60	0.66	0.72	0.84	9.41
Vent. Fans	1.76	1.59	1.76	1.70	1.76	1.70	1.76	1.76	1.70	1.76	1.70	1.76	20.73
Pumps & Aux.	0.11	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.32
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.79	0.71	0.79	0.76	0.79	0.76	0.79	0.79	0.76	0.79	0.76	0.79	9.28
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.57	0.51	0.57	0.55	0.57	0.55	0.57	0.57	0.55	0.57	0.55	0.57	6.69
Total	19.21	15.33	13.83	8.85	5.63	4.12	3.93	3.94	4.40	7.29	11.93	18.05	116.49

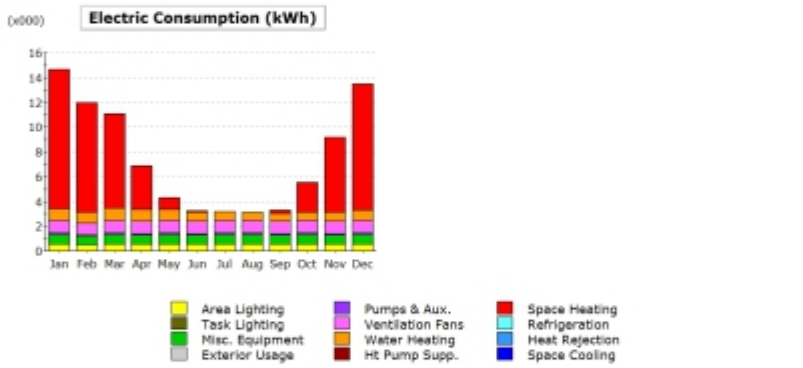
Farnsworth House

Total Electric Consumption kwh = **117**

Pilkongton _ Solar-E-Pulsa Gray_Transmittance 25%

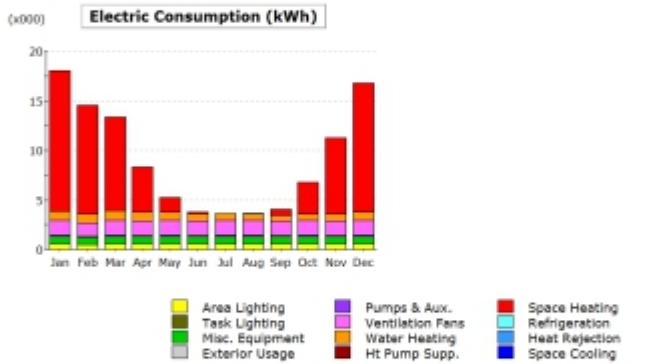






Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	11.26	8.84	7.62	3.57	0.98	0.10	-	0.02	0.32	2.40	6.06	10.16	51.32
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.91	0.88	0.98	0.93	0.86	0.74	0.67	0.63	0.60	0.66	0.72	0.84	9.41
Vent. Fans	1.05	0.94	1.05	1.01	1.05	1.01	1.05	1.05	1.01	1.05	1.01	1.05	12.32
Pumps & Aux.	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.99
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.79	0.71	0.79	0.76	0.79	0.76	0.79	0.79	0.76	0.79	0.76	0.79	9.28
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.57	0.51	0.57	0.55	0.57	0.55	0.57	0.57	0.55	0.57	0.55	0.57	6.69
Total	14.66	11.96	11.09	6.90	4.32	3.24	3.16	3.13	3.33	5.55	9.18	13.48	90.01



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	14.19	11.02	9.41	4.57	1.45	0.22	0.01	0.07	0.59	3.20	7.70	12.99	65.43
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.91	0.88	0.98	0.93	0.86	0.74	0.67	0.63	0.60	0.66	0.72	0.84	9.41
Vent. Fans	1.48	1.34	1.48	1.43	1.48	1.43	1.48	1.48	1.43	1.48	1.43	1.48	17.45
Pumps & Aux.	0.10	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.22
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.79	0.71	0.79	0.76	0.79	0.76	0.79	0.79	0.76	0.79	0.76	0.79	9.28
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.57	0.51	0.57	0.55	0.57	0.55	0.57	0.57	0.55	0.57	0.55	0.57	6.69
Total	18.04	14.56	13.33	8.35	5.25	3.81	3.63	3.64	4.04	6.80	11.26	16.77	109.47

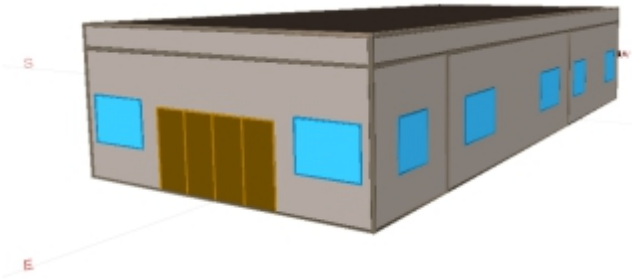
Proposed Case from Emergy Calculation

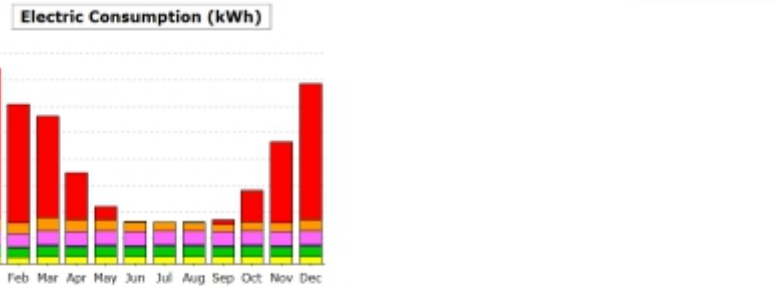
Total Electric Consumption kwh = **90**

Farnsworth House

Total Electric Consumption kwh = **110**

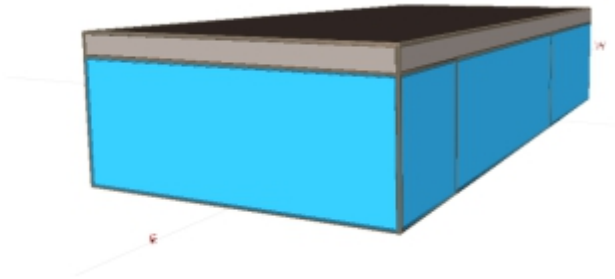
Pilkongton _ Solar-Ea- Gray_Transmittance 30%

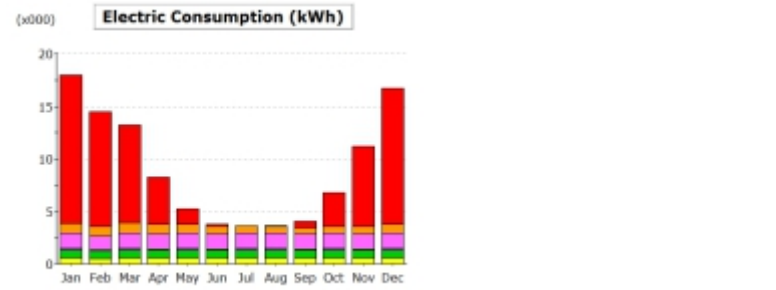




Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	11.46	8.98	7.74	3.60	0.99	0.10	-	0.02	0.32	2.43	6.15	10.34	52.13
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.91	0.88	0.98	0.93	0.86	0.74	0.67	0.63	0.60	0.66	0.72	0.84	9.41
Vent. Fans	1.07	0.97	1.07	1.04	1.07	1.04	1.07	1.07	1.04	1.07	1.04	1.07	12.64
Pumps & Aux.	0.09	0.08	0.09	0.08	0.09	0.08	0.09	0.09	0.08	0.09	0.08	0.09	1.02
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.79	0.71	0.79	0.76	0.79	0.76	0.79	0.79	0.76	0.79	0.76	0.79	9.28
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.57	0.51	0.57	0.55	0.57	0.55	0.57	0.57	0.55	0.57	0.55	0.57	6.69
Total	14.89	12.13	11.24	6.96	4.36	3.27	3.19	3.16	3.36	5.61	9.30	13.69	91.16





Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	14.10	10.93	9.30	4.51	1.42	0.21	0.01	0.07	0.58	3.16	7.63	12.92	64.84
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.91	0.88	0.98	0.93	0.86	0.74	0.67	0.63	0.60	0.66	0.72	0.84	9.41
Vent. Fans	1.48	1.34	1.48	1.43	1.48	1.43	1.48	1.48	1.43	1.48	1.43	1.48	17.44
Pumps & Aux.	0.10	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.22
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.79	0.71	0.79	0.76	0.79	0.76	0.79	0.79	0.76	0.79	0.76	0.79	9.28
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.57	0.51	0.57	0.55	0.57	0.55	0.57	0.57	0.55	0.57	0.55	0.57	6.69
Total	17.95	14.46	13.22	8.29	5.22	3.80	3.63	3.64	4.03	6.76	11.19	16.70	108.88

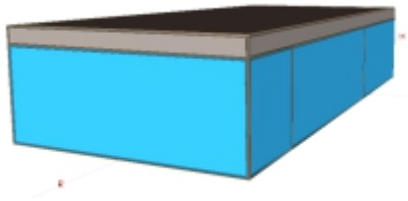
Proposed Case from Emergy Calculation

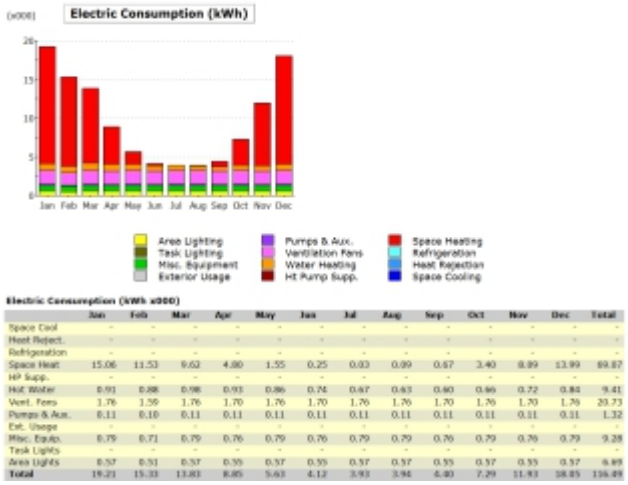
Total Electric Consumption kwh = **91**

Farnsworth House

Total Electric Consumption kwh = **109**

Pilkongton
Optifloat - Clear_Transmittance 88%





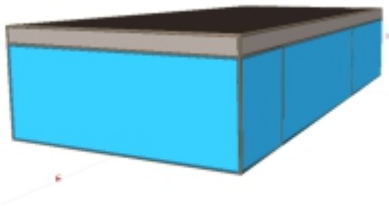
Electric Consumption (kWh x000)

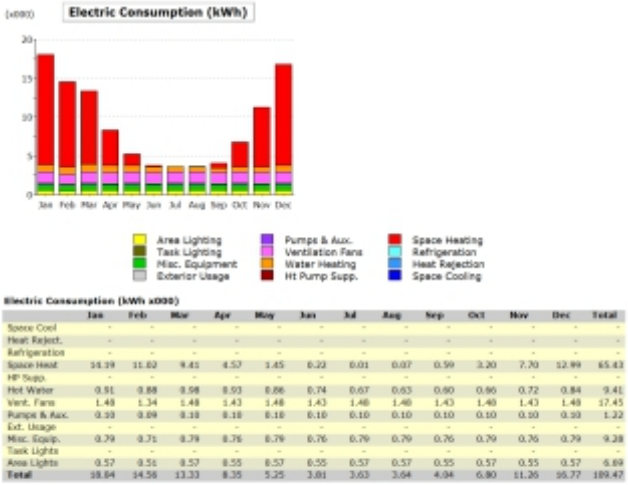
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	15.06	11.53	9.62	4.80	1.55	0.25	0.03	0.09	0.67	3.40	8.89	13.99	69.87
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.91	0.88	0.98	0.93	0.86	0.74	0.67	0.63	0.60	0.66	0.72	0.84	9.41
Vent. Fans	1.76	1.59	1.76	1.70	1.76	1.70	1.76	1.76	1.70	1.76	1.70	1.76	20.73
Pumps & Aux.	0.11	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.32
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.79	0.71	0.79	0.76	0.79	0.76	0.79	0.79	0.76	0.79	0.76	0.79	9.28
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.57	0.51	0.57	0.55	0.57	0.55	0.57	0.57	0.55	0.57	0.55	0.57	6.69
Total	19.21	15.33	13.83	8.85	5.63	4.12	3.93	3.94	4.40	7.29	11.93	18.85	136.49

Farnsworth House

Total Electric Consumption kwh = **117**

Pilkongton
Solar-E-Pulsa Gray_Transmittance 25%





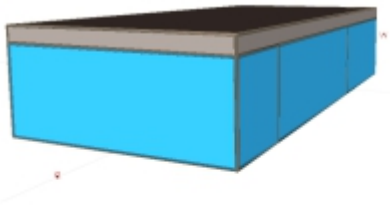
Electric Consumption (kWh x000)

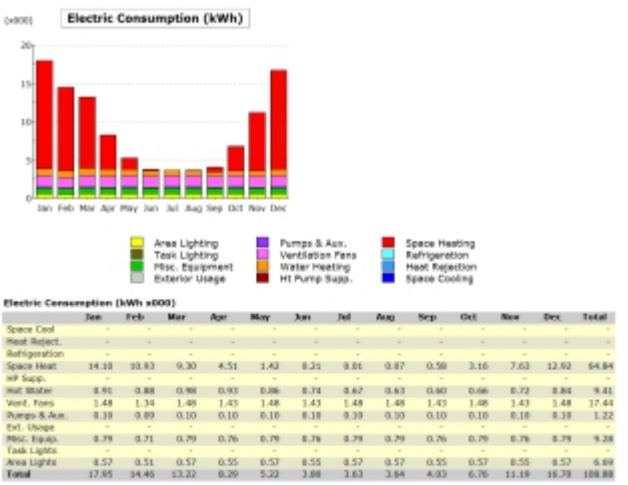
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	14.39	11.02	9.41	4.57	1.45	0.23	0.01	0.07	0.59	3.20	7.70	12.99	65.43
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.91	0.88	0.98	0.93	0.86	0.74	0.67	0.63	0.60	0.66	0.72	0.84	9.41
Vent. Fans	1.48	1.34	1.48	1.43	1.48	1.43	1.48	1.48	1.43	1.48	1.43	1.48	17.45
Pumps & Aux.	0.10	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.22
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.79	0.71	0.79	0.76	0.79	0.76	0.79	0.79	0.76	0.79	0.76	0.79	9.28
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.57	0.51	0.57	0.55	0.57	0.55	0.57	0.57	0.55	0.57	0.55	0.57	6.69
Total	18.84	14.56	13.33	8.35	5.25	3.81	3.63	3.64	4.04	6.80	11.26	16.77	109.47

Farnsworth House

Total Electric Consumption kwh = **110**

Pilkongton
Solar-Ea- Gray_Transmittance 30%





Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	14.10	10.83	9.30	4.51	1.42	0.21	0.01	0.07	0.58	3.16	7.63	12.92	64.84
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.91	0.88	0.98	0.93	0.86	0.74	0.67	0.63	0.60	0.66	0.72	0.84	9.41
Vent. Fans	1.48	1.34	1.48	1.43	1.48	1.43	1.48	1.48	1.43	1.48	1.43	1.48	17.44
Pumps & Aux.	0.10	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.22
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.79	0.71	0.79	0.76	0.79	0.76	0.79	0.79	0.76	0.79	0.76	0.79	9.28
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.57	0.51	0.57	0.55	0.57	0.55	0.57	0.57	0.55	0.57	0.55	0.57	6.69
Total	17.95	14.45	13.22	8.29	5.22	3.88	3.63	3.64	4.03	6.76	11.19	16.78	108.88

Farnsworth House

Total Electric Consumption kwh = **109**

Conclusion

In the case of Farnsworth house, since it has complete glass façade on all the four sides of it, the solar radiation that enters the house, and the illuminance received by the house is excessive and is clearly out of the comfort range. Also, the absence of any shading assembly creates serious glare situation which needs treatment.

Considering the design idea of the house; "to be within the nature," any design recommendation needed to be as subtle as possible and in tune with the language of the house. However, it was found out that, only changing the glass parameters did neither help in achieving the required illuminance levels, nor did it help in addressing the glare situation. Therefore, louvers were introduced on the south facing side (Back side) of the house. Changing the transmittance value of glass in addition to the introduction of louvers collaboratively helped in achieving the required illuminance for this particular house and for the particular climate, and thus in selecting the best glass for higher daylight performance.

The influence of glass selection on the energy consumption of the house was mainly attributed to the U-factor (rate of heat transfer through unit area of glass), and there was substantial reduction from the baseline glass option (88% transmittance) to final selected glass option (30% transmittance). For the purpose of analysis, Farnsworth house was compared with a proposed case for its emergy value and energy consumption , and as a result, it was found out that, in proposed case the energy value is substantially lower than the Farnsworth house.

[Energy consumption in proposed case = 92 Kwh. Whereas, Energy consumption in Farnswoth house is = 117 Kwh.]

Whereas, the emergy value for the proposed case is greater than the emergy value for the Farnsworth house.

[Emergy value for the proposed case = 475.31 x 10^15 sej. Whereas, Emergy value for Farnswoth house is = 428.61 x 10^15 sej.]

All in all, in this analysis, where reduction in energy consumption was successfully achieved in proposed case by reducing glass area in facade and by adopting insulating wall section. However, in doing that, the emergy value of the proposed case increases and becomes greater than the the emergy value for the baseline case. Also, the proposed louvers undermine the openness the original design offers with its full glass windows on all sides. It is understood from the process that, in the process of developing an environmental solution for a problem, the design of the space and its spatial quality shall also be given equal importance. An environmental solution bereft of overall design thinking does not provide the best possible result.