Green Building Parameters & Case Studies

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Mumbai

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Presentation Coverage

1. Energy Scenario in the Country
2. Green / Energy Efiicient Buildings
3. Case Study 1 – Large Commercial Building, Punjab
    i. Fenestration Optimization
    ii. Life Cycle Cost Analysis

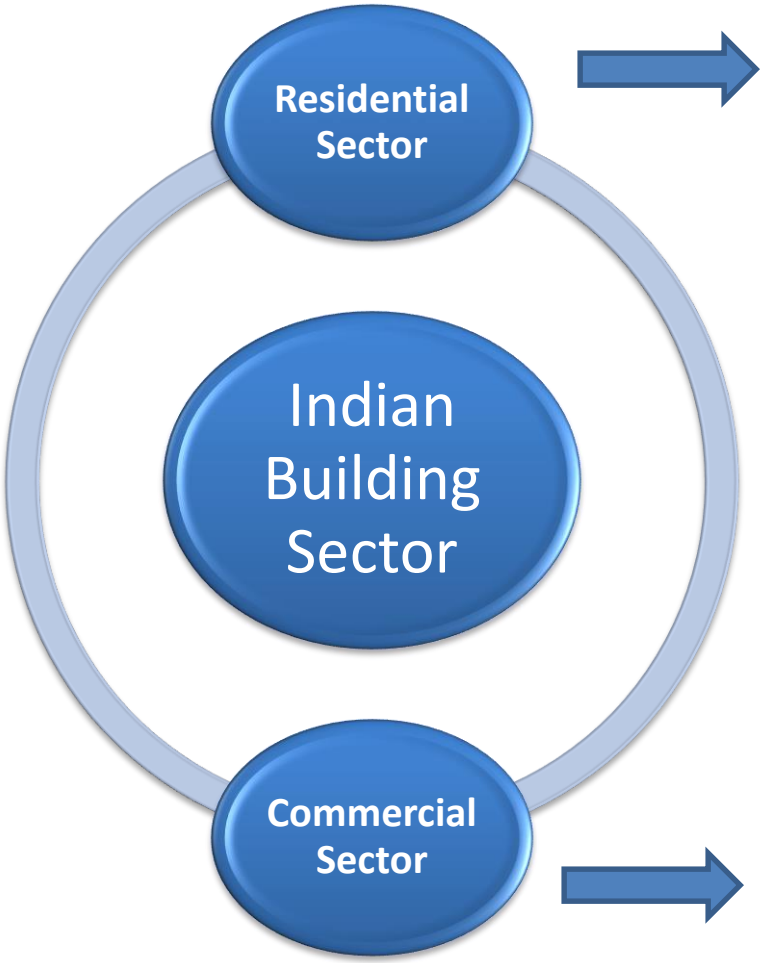
    Results & Calculations
4. Case Study 2 – Multi-storey Office Tower
    i. HVAC System selection
    ii. Fenestration Optimization
    iii. ASHRAE 90.1 appendix G savings
    iv. Cooling loads for TES tank

    Results & Calculations
5. Question and Answers

Introduction

- In 2020 almost **500 Million people will be living in Urban India**
- Cities have a central role to play in the reduction of CO_2 emissions and the fight against climate change.
- Cities can mitigate climate change by reducing energy consumption in the construction, maintenance and refurbishment of buildings.
- Building sector contribution to overall electricity consumption has grown from **15% in 1970-71 to 34% in 2010-11** and therefore offer the largest cost-effective opportunity for savings.

Overview of Indian Building Sector



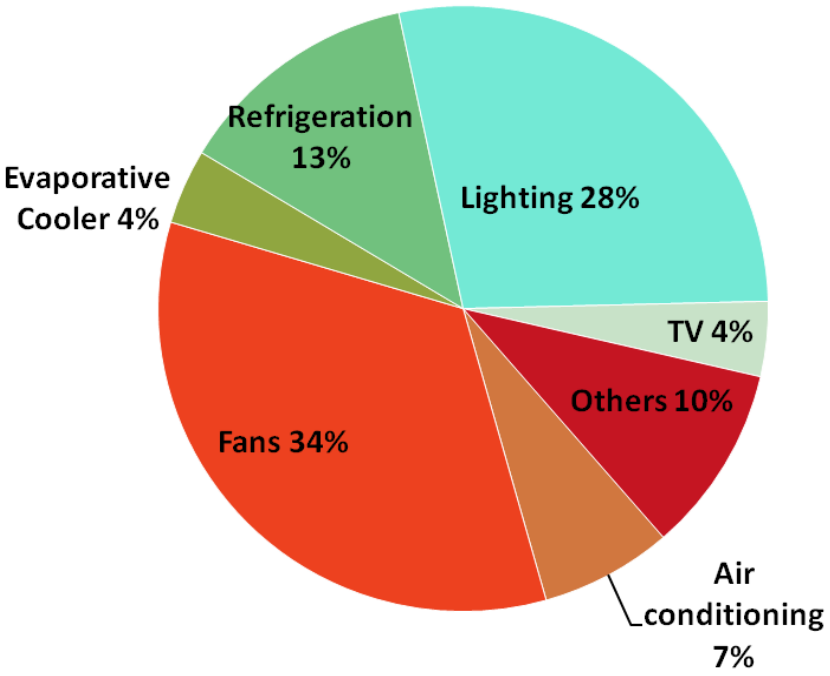
*Contributes to **24% of total electricity consumption***

***Annual Electricity consumption** by Indian Building sector was **236,620 GWh** (2010-11(p))*

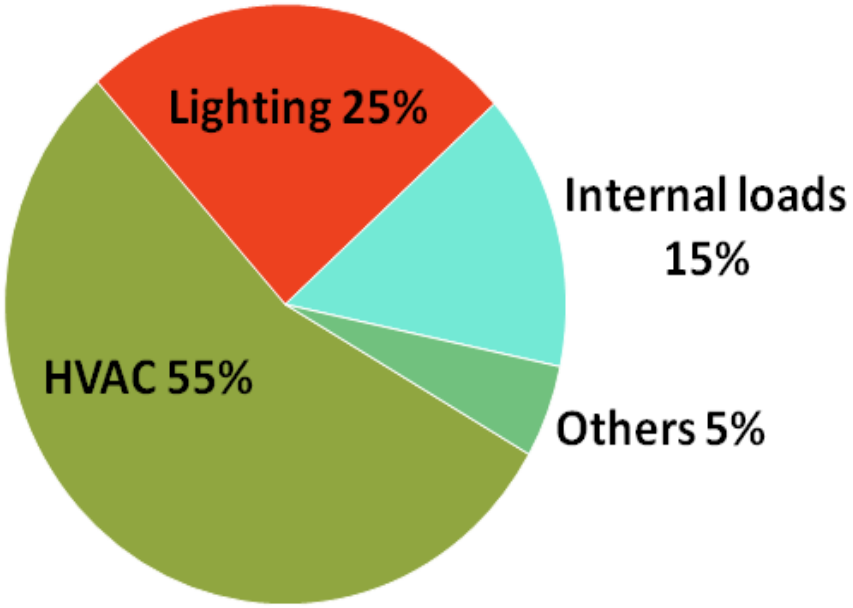
*Contributes to **10% of total electricity consumption***

Source: CEA

Electricity Consumption comparison



Electricity Consumption Pattern in Residential Buildings

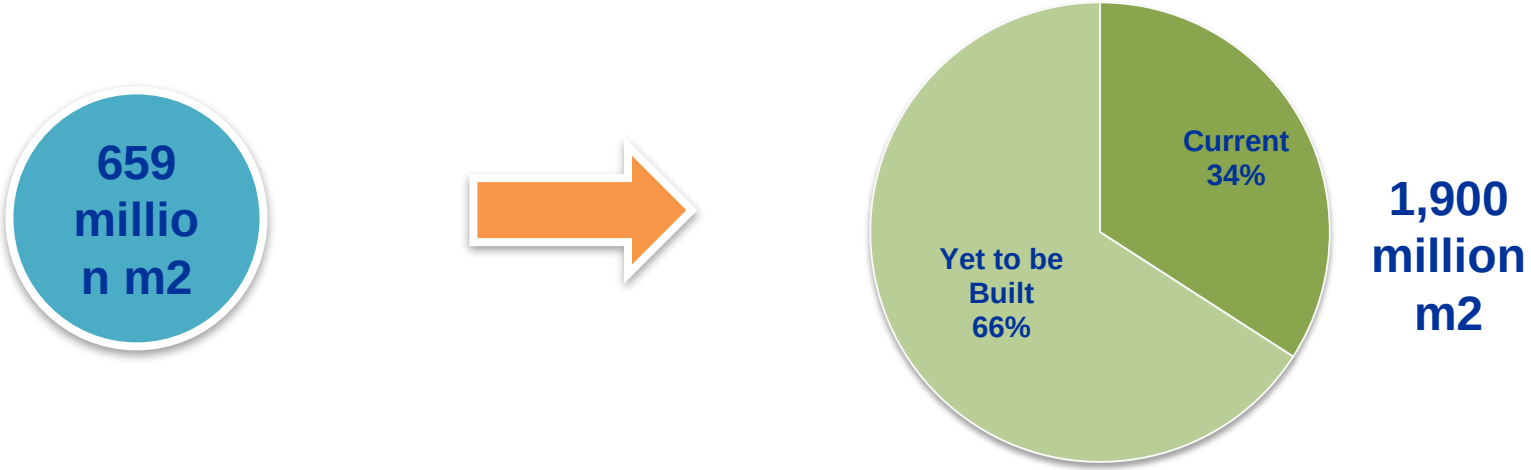


Electricity Consumption Pattern in Commercial Buildings

Growth in the Indian Building Sector

Commercial Buildings Floor Area - Growth Forecast

- Currently, ~ 659 million m2 (USAID ECO-III Internal Estimate Using MOSPI, CEA and Benchmarked Energy Use data)
- In 2030,~ 1,900 million m2 (estimated)*
  - 66% building stock is yet to be constructed



Policy/ Regulatory Framework for Buildings

Design Standards

NBC/ Municipal Building bye-laws

- Ensures Comfort
- Ensures Safety
- Attempts but doesn't ensure energy efficiency

Energy Standard

- Energy Conservation Building Code

Linkage of NBC with ECBC

Harmonization of ECBC with NBC 2005 has been finalized by including a chapter "Approach to Sustainability" which would be adopted in all future constructions in the country.

Energy Conservation Building Code

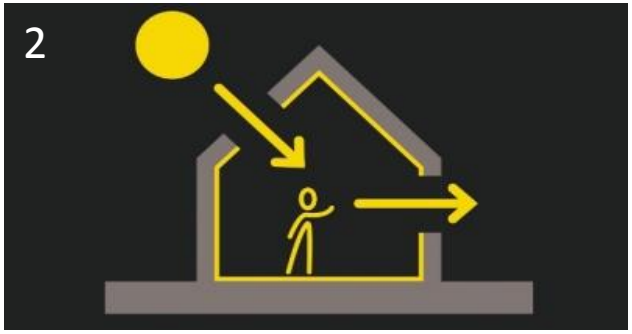
- ECBC has been developed as a voluntary code for all new commercial building having a connected load of **100 kW** and above. ECBC provided minimum performance standards for following components :
  - Building Envelope (Walls, Roofs, Windows)
  - Lighting (Indoor and Outdoor)
  - Heating Ventilation and Air Conditioning (HVAC) System
  - Solar Hot Water Heating
  - Electrical Systems

- Voluntary introduction of ECBC in May 2007; mandatory after capacity building and implementation experience

Introduction to EE buildings

Buildings are designed for **PEOPLE**, and for specific **TASK**

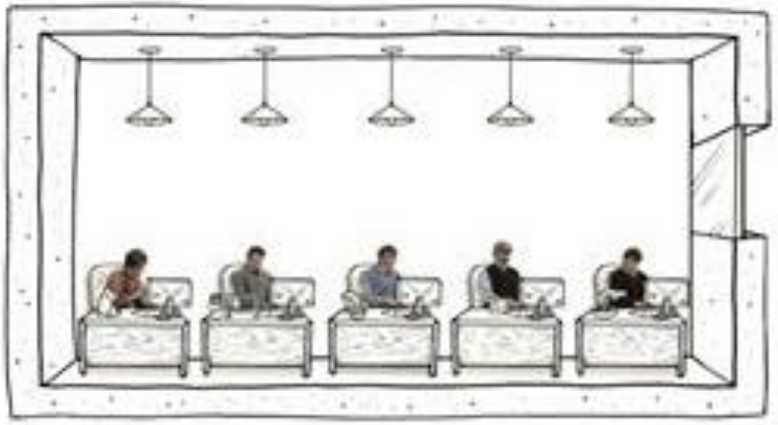
- ✓ The building needs to keep people **comfortable, efficient, healthy**.
- ✓ **Energy Efficient design** seeks to create buildings that keep people **comfortable** while minimizing **Energy Consumption**.



Comfort categories:

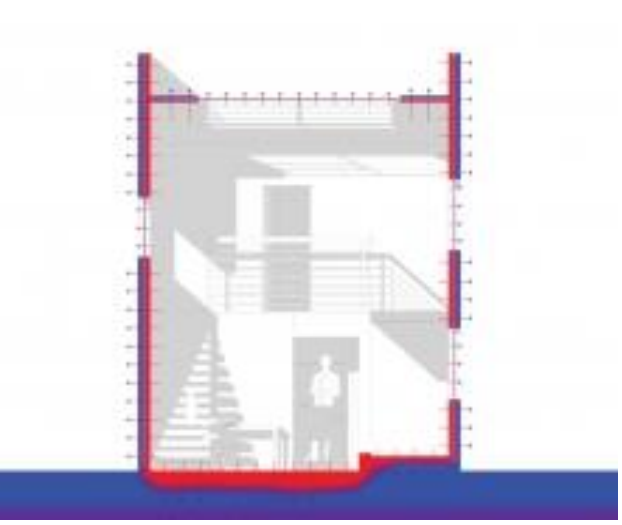
1. Thermal comfort
2. Visual Comfort
3. Air Quality
4. Acoustic Comfort

Heat Transfer in Buildings

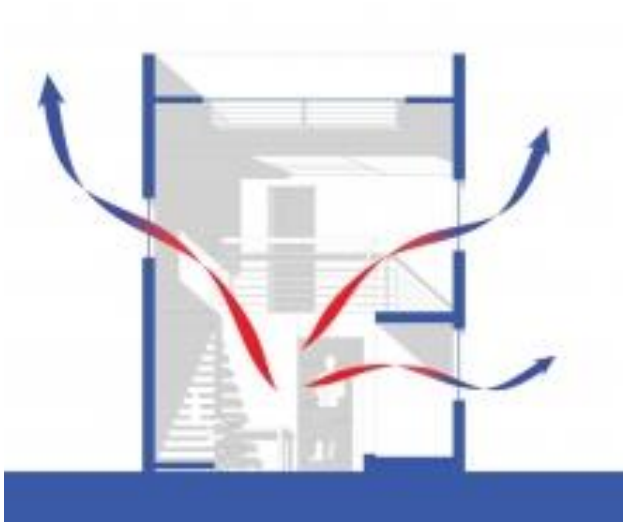


INTERNAL LOADS

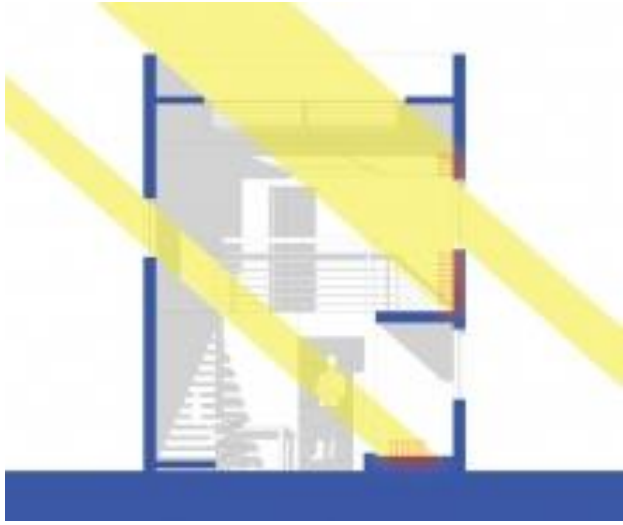
Heat Transfer in Buildings



Conduction



Convection



Radiation

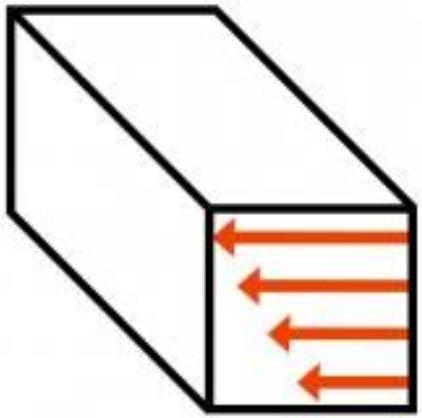
Building Envelope properties

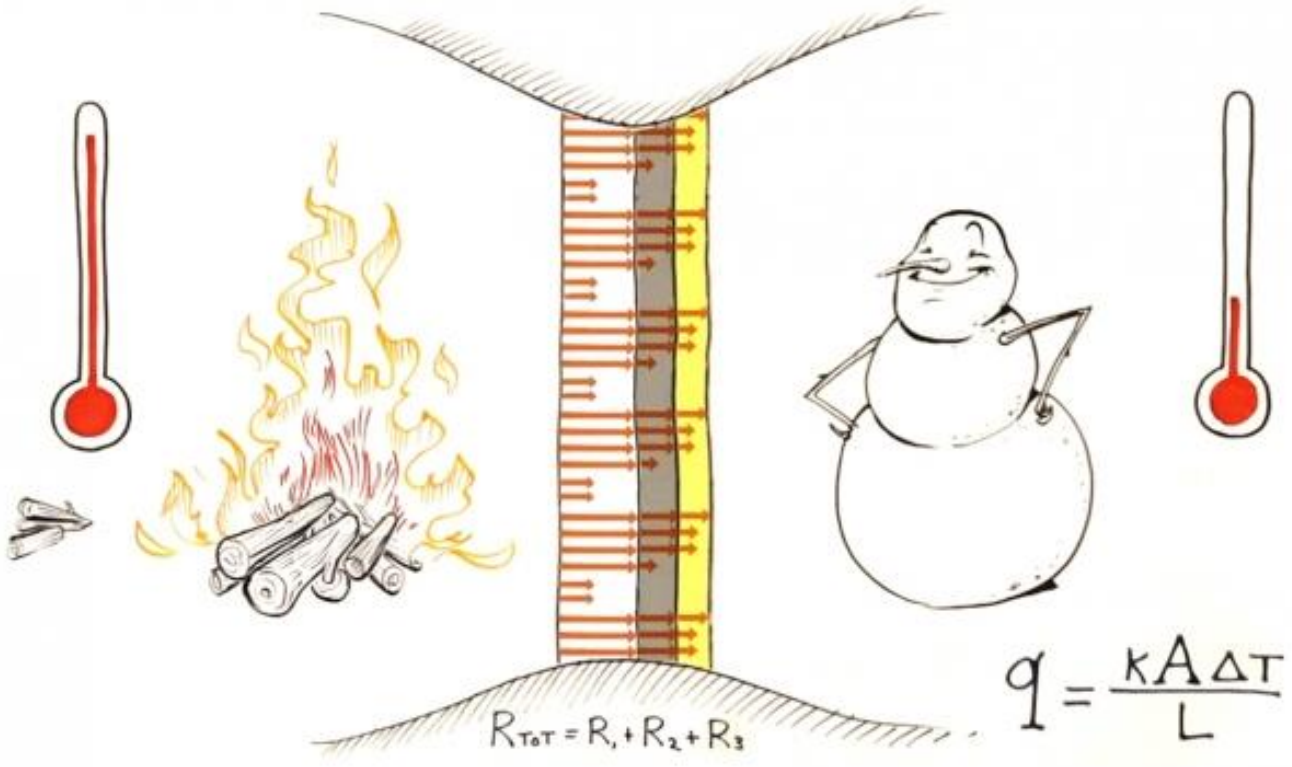
U-Factor (U)

- Overall conductance of a building element.
- Used for layered building assemblies.
- expressed in terms of **W/m2 K**

Thermal Resistance (R-value = 1/U)

- A material's ability to resist heat flow.
- expressed in terms of **m2 K/W**

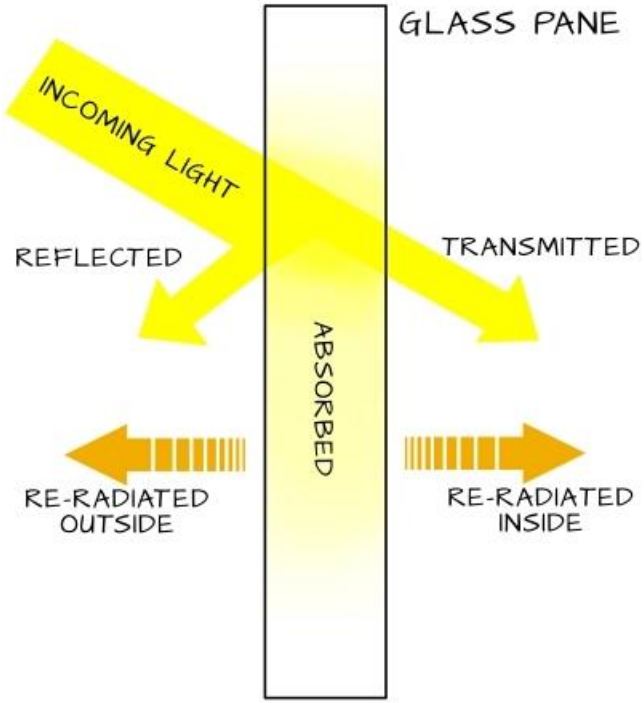




Building Envelope properties - Fenestration

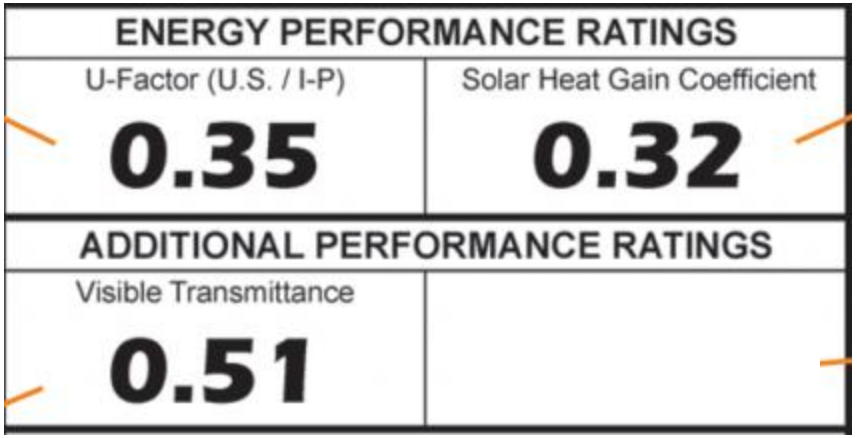
Solar Heat Gain Coefficient (SHGC)

- measures how much of the incoming heat from sunlight gets transmitted into the building, versus how much is reflected away.

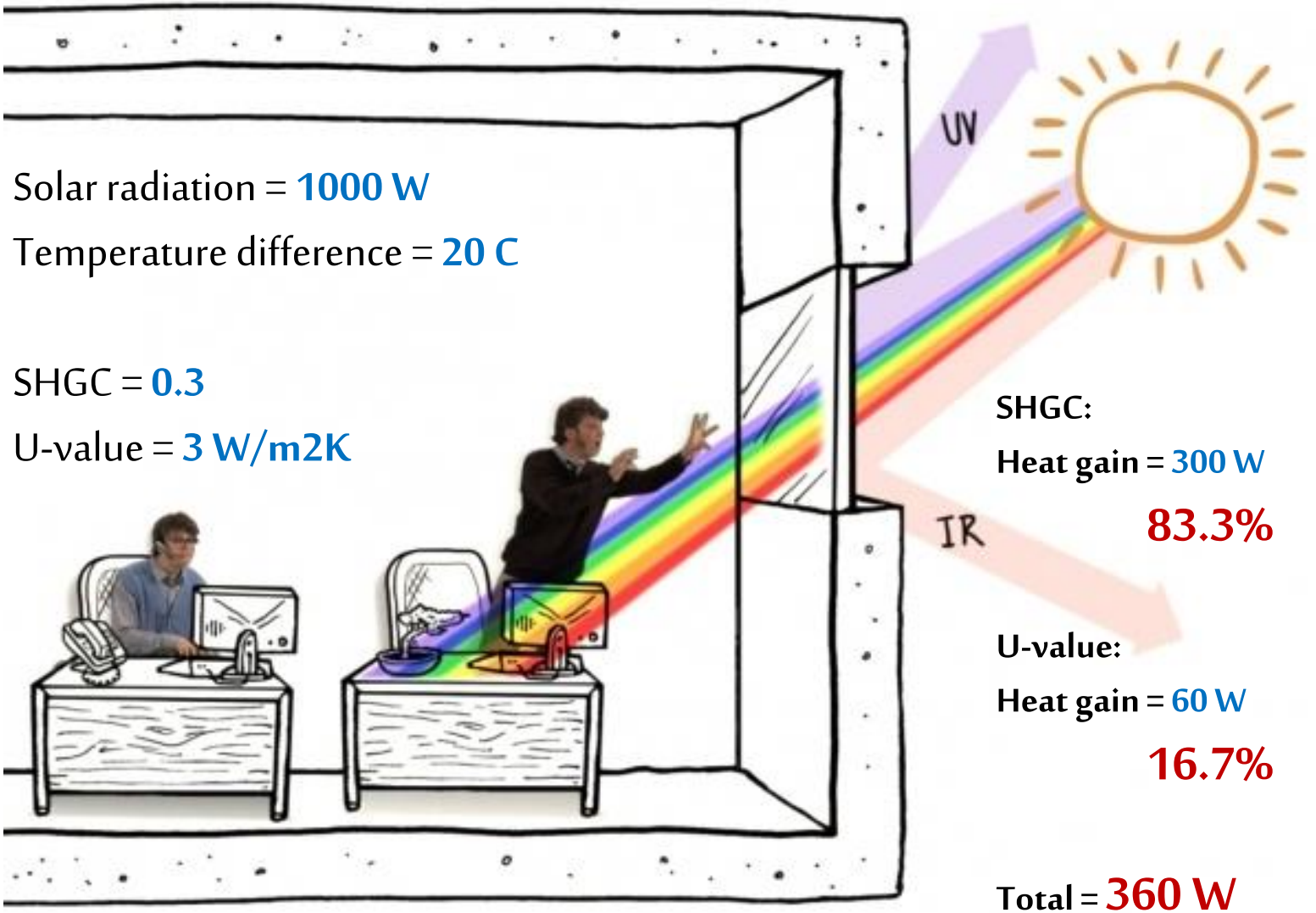


Visible Light Transmittance (VLT)

- Fraction of visible light that passes through a window or other glazing unit is called the Visible Light Transmittance (VLT).
- VLT does not measure shorter-wavelength light like UV or longer-wavelength light like infrared - **only visible light**.

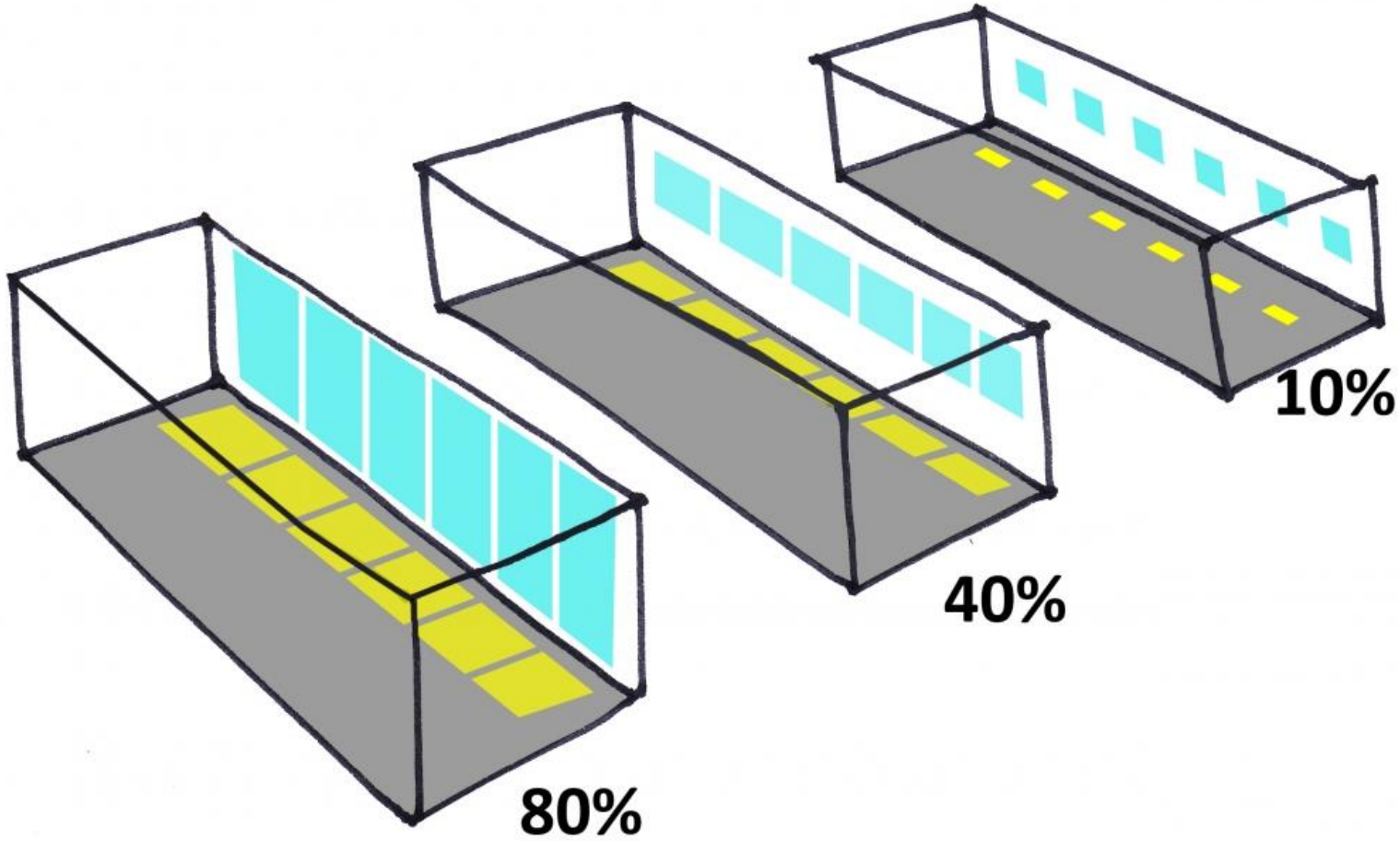


Building Envelope properties - Fenestration

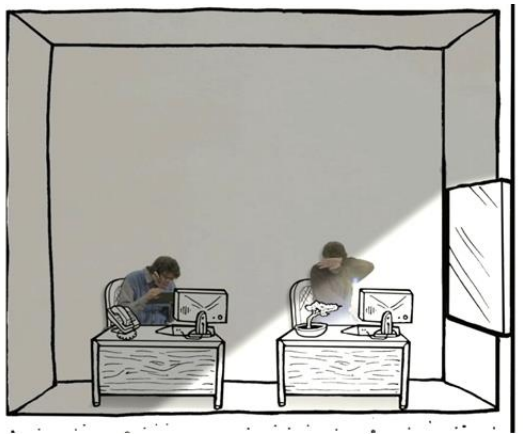


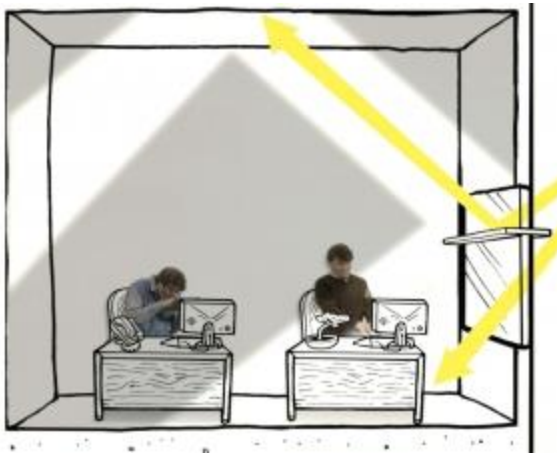
EE Design – Daylighting

WINDOW TO WALL RATIO (WWR)

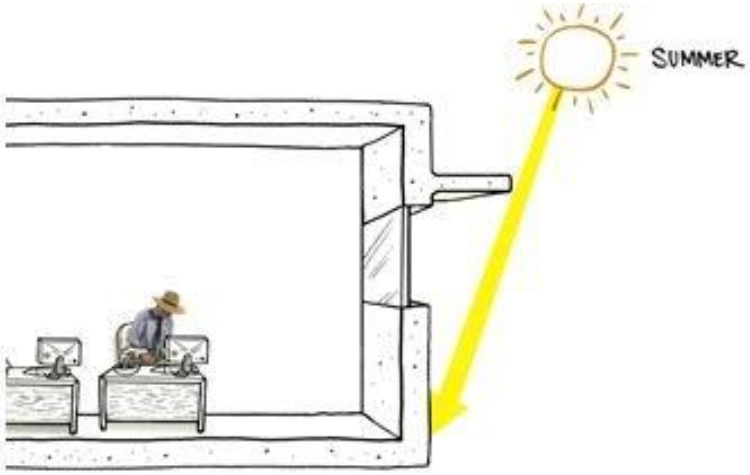


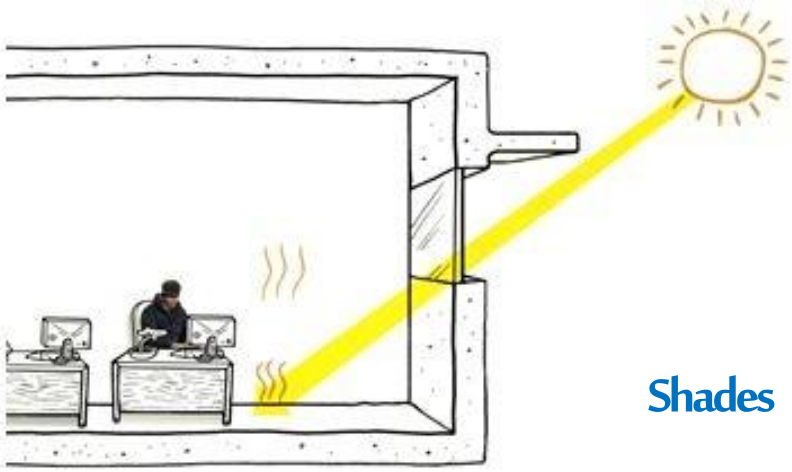
EE Design – Daylighting





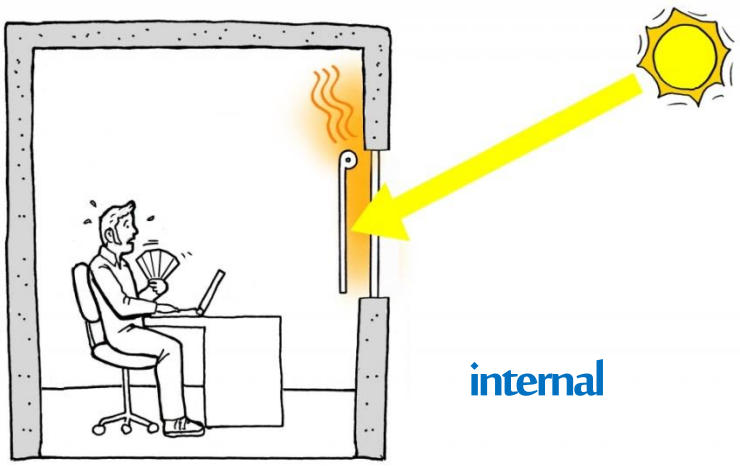
Light shelf



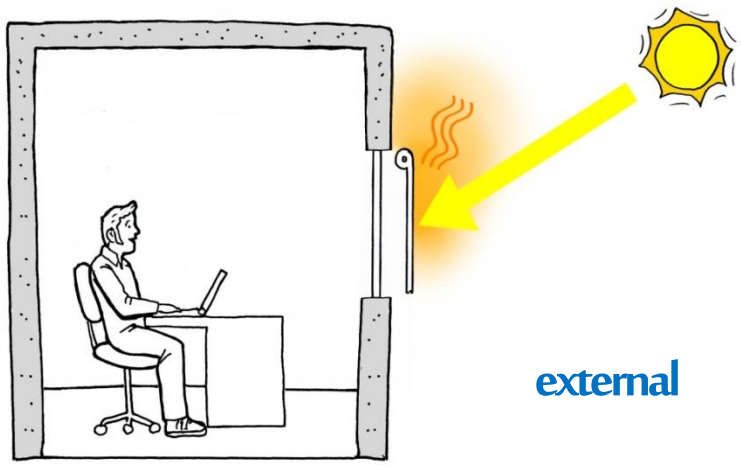


Shades

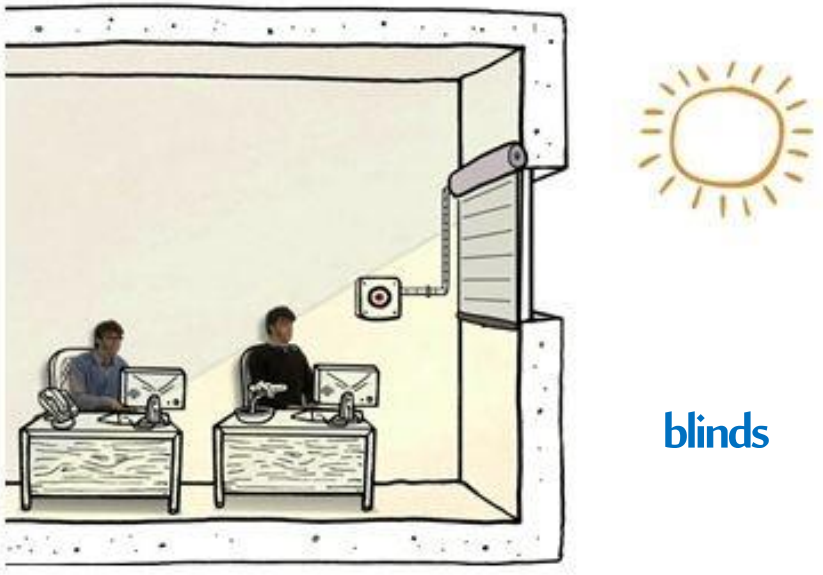
EE Design – Daylighting



internal



external

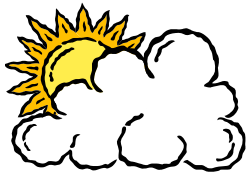


blinds

You can't manage what you can't measure.

Energy Modeling Basics

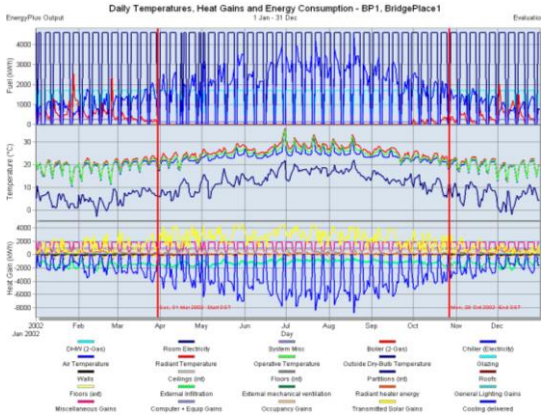
Weather Data



Calculation Engine

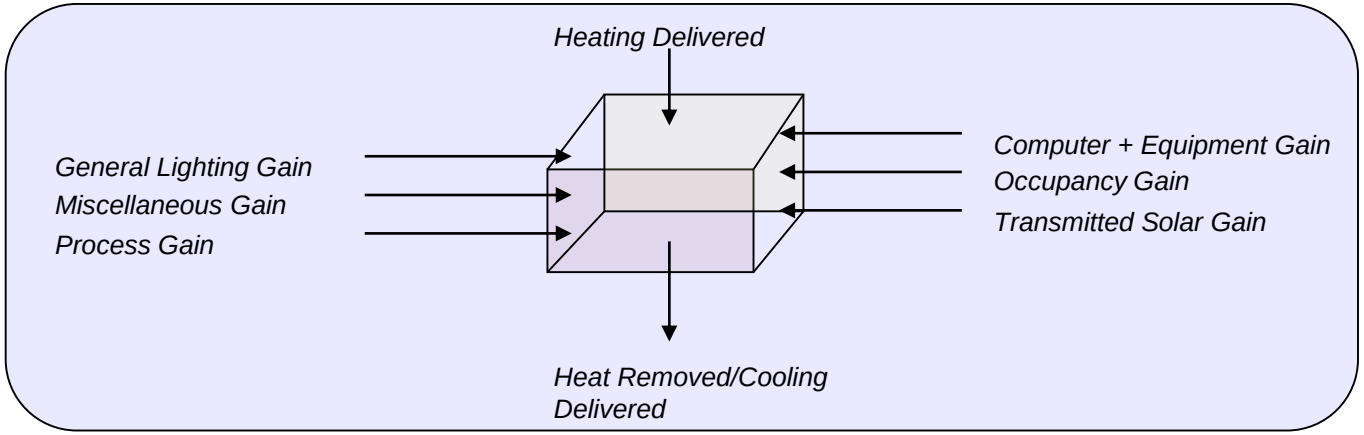
1. *Conductive, convective and radiative heat transfer calculation*
2. *Heat and Mass transfer Calculation*
3. *Thermal Inertia Calculation*
4. *Equipment Sizing Algorithms*
5. *Geometry, surface and Shading Algorithms*

Results/Patterns



8760 Times

Building Envelop



Input

Building Envelope

- ❑ Wall / Internal Partitions (U Factor)
- ❑ Windows (U Factor, SHGC, Visible Transmittance)
- ❑ Roof (U Factor, Reflectance)
- ❑ Floor (U Factor)

Heating, Ventilating & Air-Conditioning

- ❑ Ventilation type (mechanical)
- ❑ Heating & Cooling (type, schedule, energy source)

Service Water Heating

- ❑ Type, Operation schedule

Other Equipment

- ❑ Equipment Power Density / Receptacle Loads

Activity Schedule

- ❑ Schedule - hours, days (holidays)

Lighting

- ❑ Control (auto), Lighting energy (LPD)
- ❑ Operation schedule, Luminaries type, Radiant Fraction
- ❑ Task / display light (gain, operation schedule)

Software

- **DOE2 -** Free interface for detailed modeling available, well validated with research
- **eQUEST-** easy-to-use building energy analysis tool, provides professional level results in an affordable level of effort
- **DesignBuilder -** comprehensive user interface to the EnergyPlus, dynamic thermal simulation engine, accurate environmental performance data.
- **EnergyPlus -** Advanced modeling capabilities, modular programming structure, free software, no interface
- **ECOTECT -** Reasonable 3D modeling interface, imports .dxf files, nice graphical results viewing, export to powerful simulation tools (Radiance, EnergyPlus), no real HVAC analysis
- **HVACSIM+ -** Simulation model of a building HVAC system plus HVAC controls, the building shell, the heating/cooling plant and energy management & control system (EMCS) algorithms.
- **TRANSYS -** Difficult interface, detailed modeling options

Case Study 1 – Large Commercial Building, Punjab

Scope:

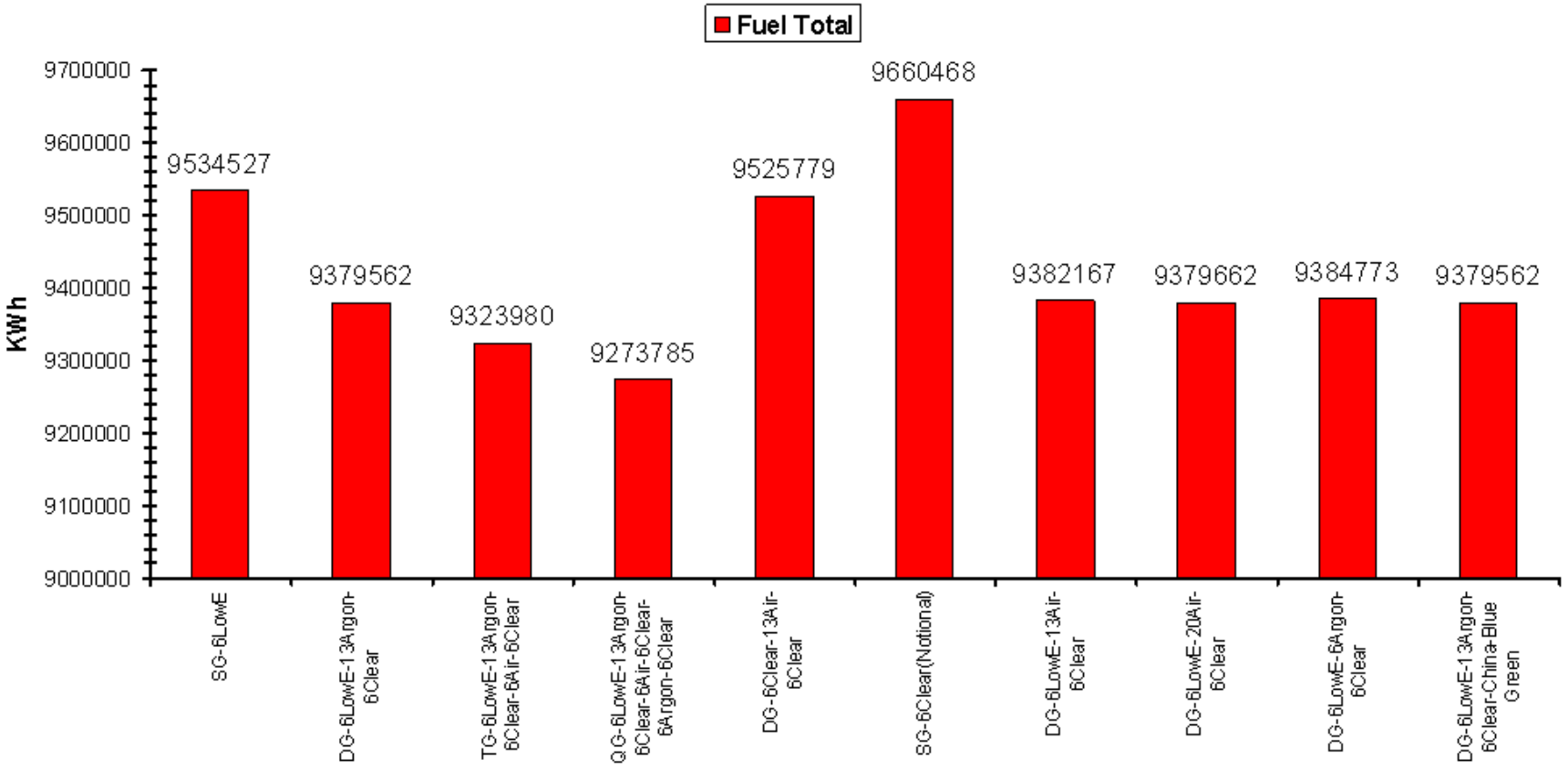
1. What is the best glazing option available? And how far are they in terms of relative operational cost?
2. Why not to use an inexpensive glass and what will be the financial consequences of operation?
3. What percent operational efficiencies would we get if we use a better glass compare to a notional building façade?
4. What are the figure of relative saving in INR for all the ten façade options?
5. What is the total fraction of electricity bill for building with all the ten façade options?
6. What are the life cycle cost (LCC) for the different option compared with notional option?
7. What is the pay back with 3% to 4% energy inflation over the period of 25 year?

Case Study 1 – Large Commercial Building, Punjab

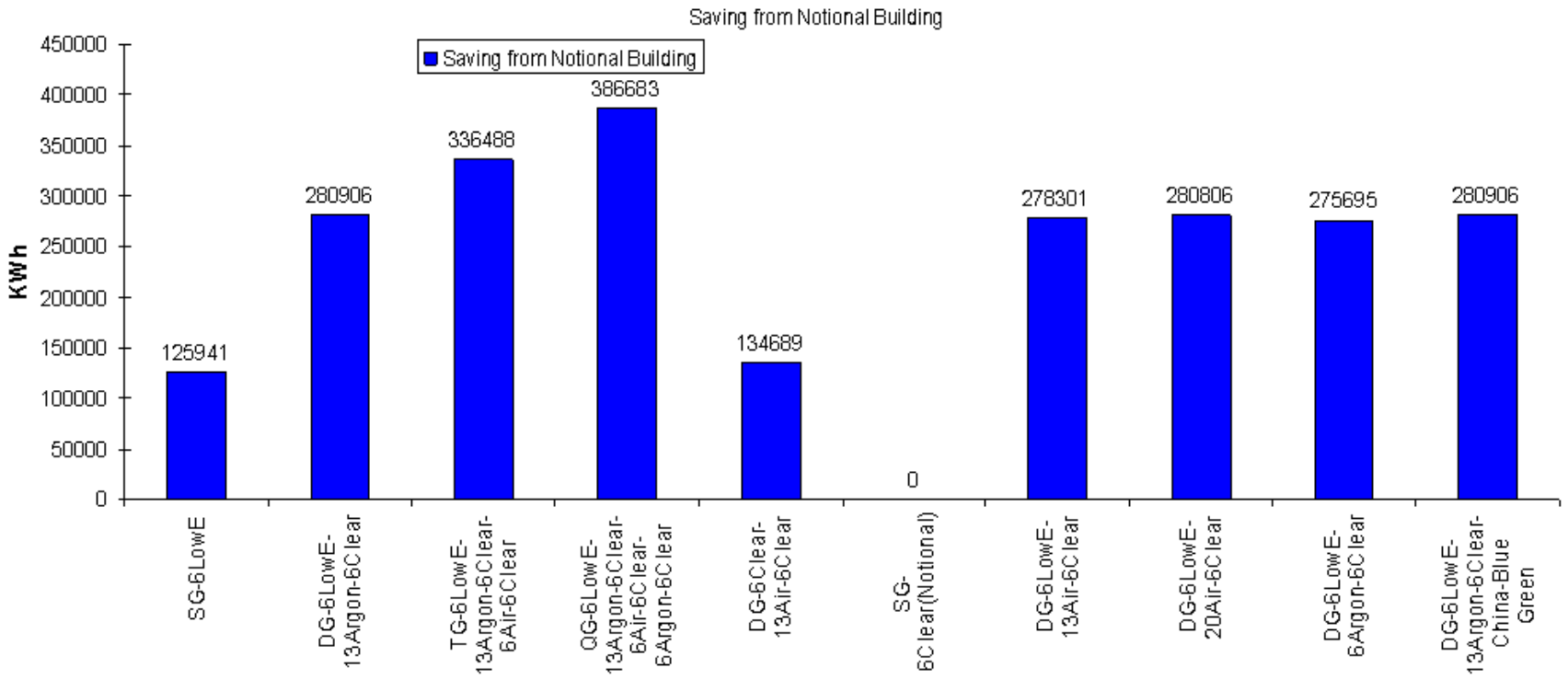
Options Evaluated:

1. SG-6LowE (INR1300/m2)
2. DG-6LowE-13Argon-6Clear (INR2500/m2)
3. TG-6LowE-13Argon-6Clear-6Air-6Clear (INR4000/m2)
4. QG-6LowE-13Argon-6Clear-6Air-6Clear-6Argon-6Clear (INR6000/m2)
5. DG-6Clear-13Air-6Clear (INR2000/m2)
6. SG-6Clear (INR600/m2)
7. DG-6LowE-13Air-6Clear (INR2800/m2)
8. DG-6LowE-20Air-6Clear (INR2200/m2)
9. DG-6LowE-6Argon-6Clear (INR3000/m2)
10. DG-6LowE-13Argon-6Clear-China-Blue Green (INR2100/m2)

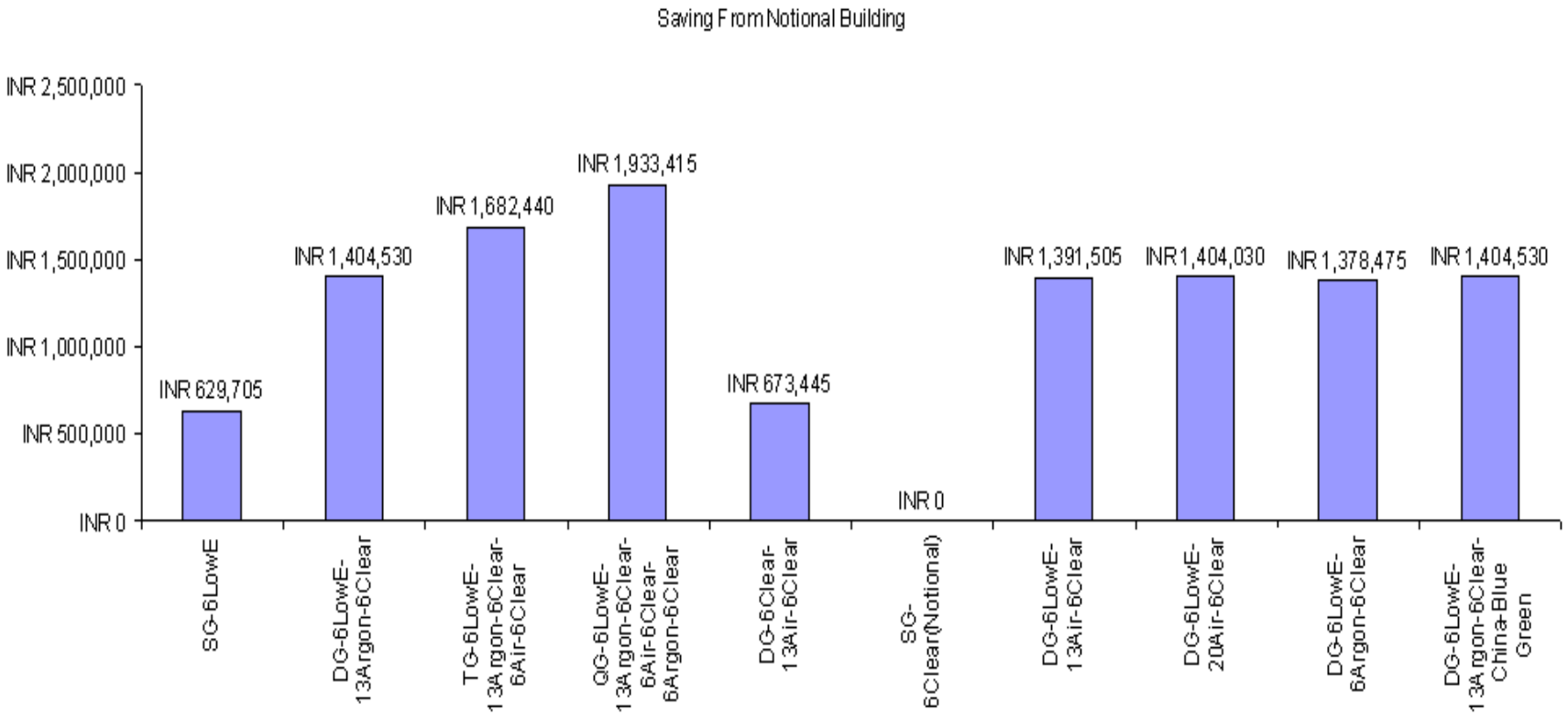
Total Annual Fuel Usage with Standard Operation



Annual Saving kWh compared to Notional Building



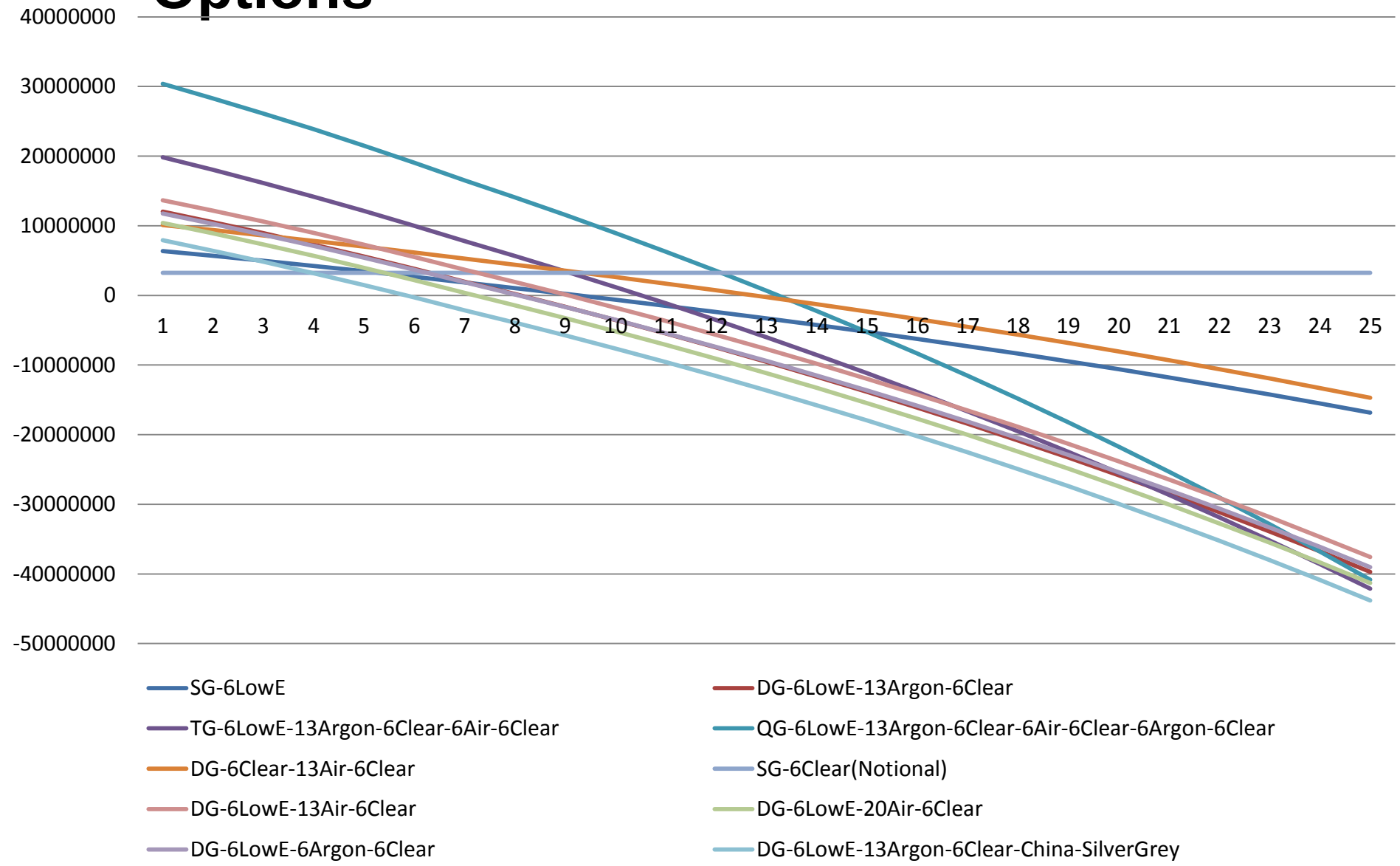
Annual Saving INR compared to Notional Building



Life Cycle Cost Assessment of Glazing Options

Year	Energy Price Escalation Rate for the years	Capital Cost/ Investment Year	SG-6LowE	DG-6LowE-13Argon-6Clear	TG-6LowE-13Argon-6Clear-6Air-6Clear	QG-6LowE-13Argon-6Clear-6Air-6Clear-6Argon-6Clear	DG-6Clear-13Air-6Clear	SG-6Clear(Notional)	DG-6LowE-13Air-6Clear	DG-6LowE-20Air-6Clear	DG-6LowE-6Argon-6Clear	DG-6LowE-13Argon-6Clear-China-Blue Green
2008	%/100	Capital→	7020000	13500000	21600000	32400000	10800000	3240000	15120000	11880000	16200000	9396000
2009	0.04	1	-654893	-1460711	-1749738	-2010752	-700383	0	-1447165	-1460191	-1433614	-1460711
2010	0.04	2	-681089	-1519140	-1819727	-2091182	-728398	0	-1505052	-1518599	-1490959	-1519140
2011	0.04	3	-708332	-1579905	-1892516	-2174829	-757534	0	-1565254	-1579343	-1550597	-1579905
2012	0.04	4	-736666	-1643101	-1968217	-2261822	-787835	0	-1627864	-1642517	-1612621	-1643101
2013	0.04	5	-766132	-1708826	-2046946	-2352295	-819349	0	-1692979	-1708217	-1677126	-1708826
2014	0.04	6	-796778	-1777179	-2128823	-2446387	-852123	0	-1760698	-1776546	-1744211	-1777179
2015	0.04	7	-828649	-1848266	-2213976	-2544242	-886208	0	-1831126	-1847608	-1813979	-1848266
2016	0.03	8	-797691	-1779217	-2131265	-2449192	-853100	0	-1762717	-1778583	-1746211	-1779217
2017	0.03	9	-821622	-1832593	-2195203	-2522668	-878693	0	-1815598	-1831941	-1798597	-1832593
2018	0.03	10	-846271	-1887571	-2261059	-2598348	-905054	0	-1870066	-1886899	-1852555	-1887571
2019	0.03	11	-871659	-1944198	-2328890	-2676299	-932205	0	-1926168	-1943506	-1908132	-1944198
2020	0.03	12	-897809	-2002524	-2398757	-2756587	-960172	0	-1983953	-2001811	-1965376	-2002524
2021	0.03	13	-924743	-2062600	-2470720	-2839285	-988977	0	-2043472	-2061865	-2024337	-2062600
2022	0.03	14	-952485	-2124478	-2544841	-2924464	-1018646	0	-2104776	-2123721	-2085067	-2124478
2023	0.03	15	-981060	-2188212	-2621187	-3012198	-1049205	0	-2167919	-2187433	-2147619	-2188212
2024	0.03	16	-1010492	-2253858	-2699822	-3102563	-1080682	0	-2232957	-2253056	-2212048	-2253858
2025	0.03	17	-1040806	-2321474	-2780817	-3195640	-1113102	0	-2299946	-2320648	-2278409	-2321474
2026	0.03	18	-1072031	-2391118	-2864241	-3291510	-1146495	0	-2368944	-2390267	-2346761	-2391118
2027	0.03	19	-1104192	-2462852	-2950169	-3390255	-1180890	0	-2440012	-2461975	-2417164	-2462852
2028	0.03	20	-1137317	-2536737	-3038674	-3491963	-1216317	0	-2513213	-2535834	-2489679	-2536737
2029	0.03	21	-1171437	-2612840	-3129834	-3596721	-1252806	0	-2588609	-2611909	-2564370	-2612840
2030	0.03	22	-1206580	-2691225	-3223729	-3704623	-1290390	0	-2666267	-2690267	-2641301	-2691225
2031	0.03	23	-1242777	-2771961	-3320441	-3815762	-1329102	0	-2746255	-2770975	-2720540	-2771961
2032	0.03	24	-1280061	-2855120	-3420054	-3930235	-1368975	0	-2828643	-2854104	-2802156	-2855120
2033	0.03	25	-1318462	-2940774	-3522656	-4048142	-1410044	0	-2913502	-2939727	-2886221	-2940774
LCC Saving			-16,830,034	-39,696,479	-42,122,301	-40,827,963	-14,706,684	3,240,000	-37,583,158	-41,297,541	-36,009,648	-43,800,479
Façade Area			5400	Sqm								

Life Cycle Cost Assessment of Glazing Options



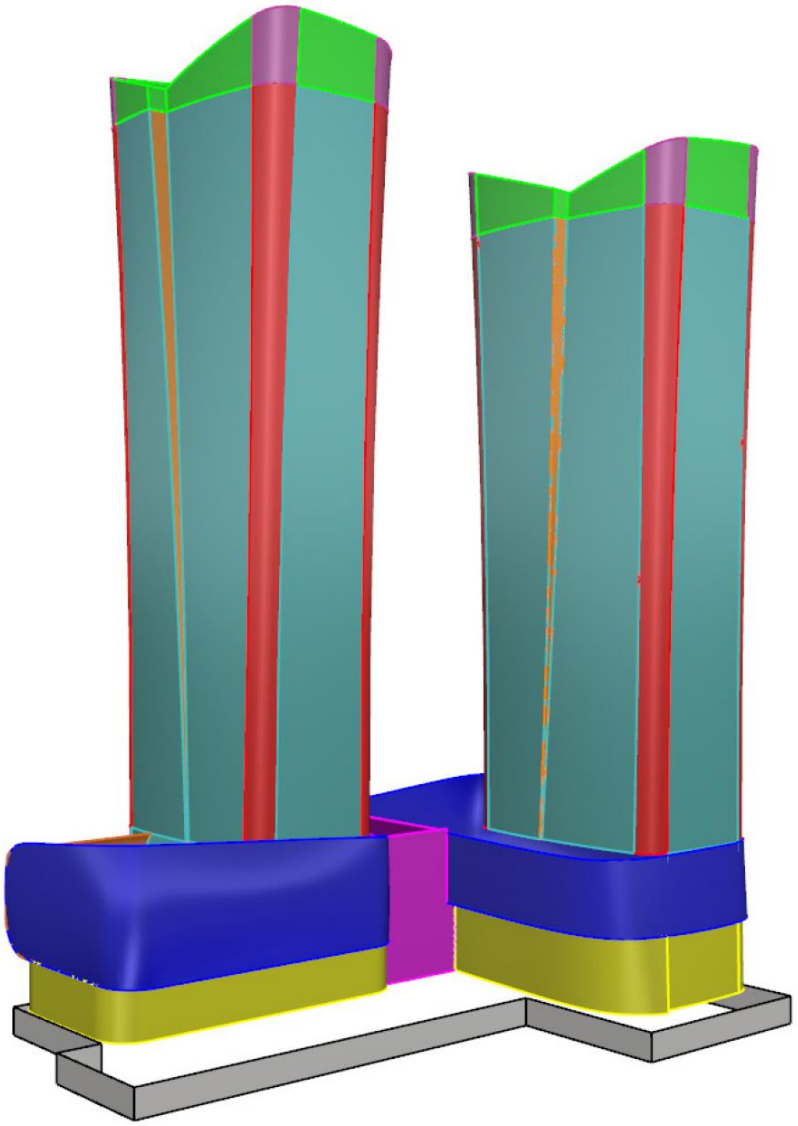
Results and Conclusions

1. The highest operational saving is 387 MWh which is attributed to quadruple glazing. But the LCC analysis does not recommend this glazing due to its huge initial capital.
2. Considering building life of 25 yr. and an inflation in energy price till 2015 as 4% and after that a constant 3 % LCC has been evaluated. Which indicates that highest LCC come out to be of the poorest option that is clear single glazed units which is about (INR +3240,000)
3. Similarly the LCC of china Blue green option whose U value is 1.24 W/m2.C, acceptable SHGC and VT, is coming out to be very less due to its low initial capital and high performance compared to other in this investment range.
4. Primary estimate depicts that using china glass for 25 yr would be saving about (INR -4.38 Cr.) where as other Double glazed façade options are showing a saving of (INR -1.4 to INR -3.0 Cr.)

Case Study 2 – Multistorey Office Tower

Scope:

1. HVAC System selection
    a. FCU
    b. Chilled beam
2. Fenestration Optimization
    a. SHGC – 0.30
    b. SHGC – 0.35
    c. SHGC – 0.40
3. ASHRAE 90.1 2007 App G savings
4. Cooling loads for TES tank



Scenario Summary

BaseCase
Fenestration: 40%
U-value: 3.69 W/m²K
- VLT: 0.70, SHGC: 0.25
- No shading elements
- Exterior Wall U-value: 0.479 W/m²K
- System 7: VAV Water Cooled
- LPD of 12 W/m2

ProposedCase
- Fenestration: as actual
- U-value: 1.8 W/m²K
- VLT: 0.50
- Shading elements
- Exterior Wall U-value: 0.4 W/m²K
- LPD of 9 W/m2

Water-type FCU + heat recovery
Cooling: 7-12°C
Heating: 80-60°C

SHGC Iteration

Case #I 0.30
Case #2 0.35
Case #3 0.40

Chilled Beam + heat recovery
Cooling: 15-18°C
Heating: 35-45°C

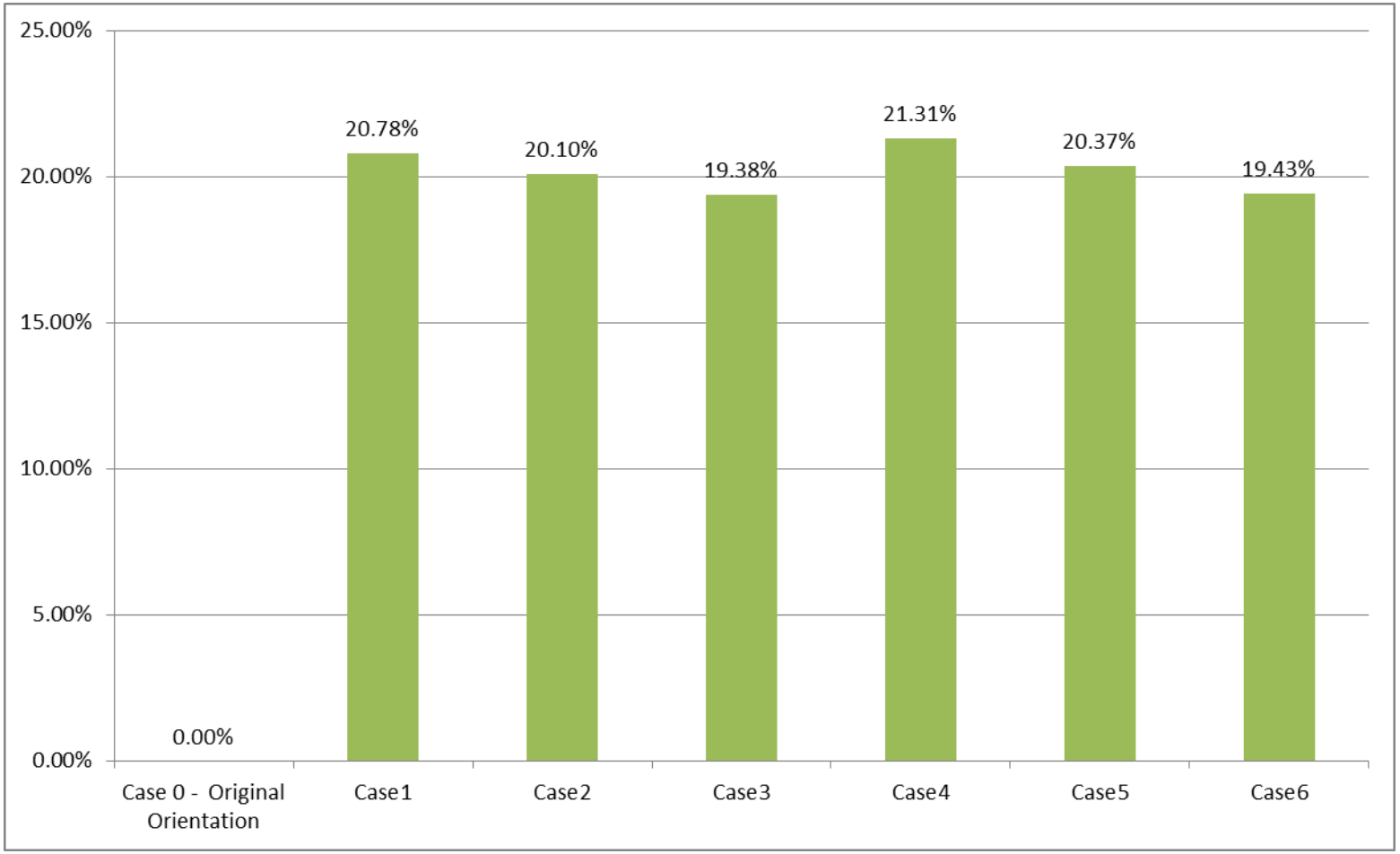
SHGC Iteration

Case #4 0.30
Case #5 0.35
Case #6 0.40

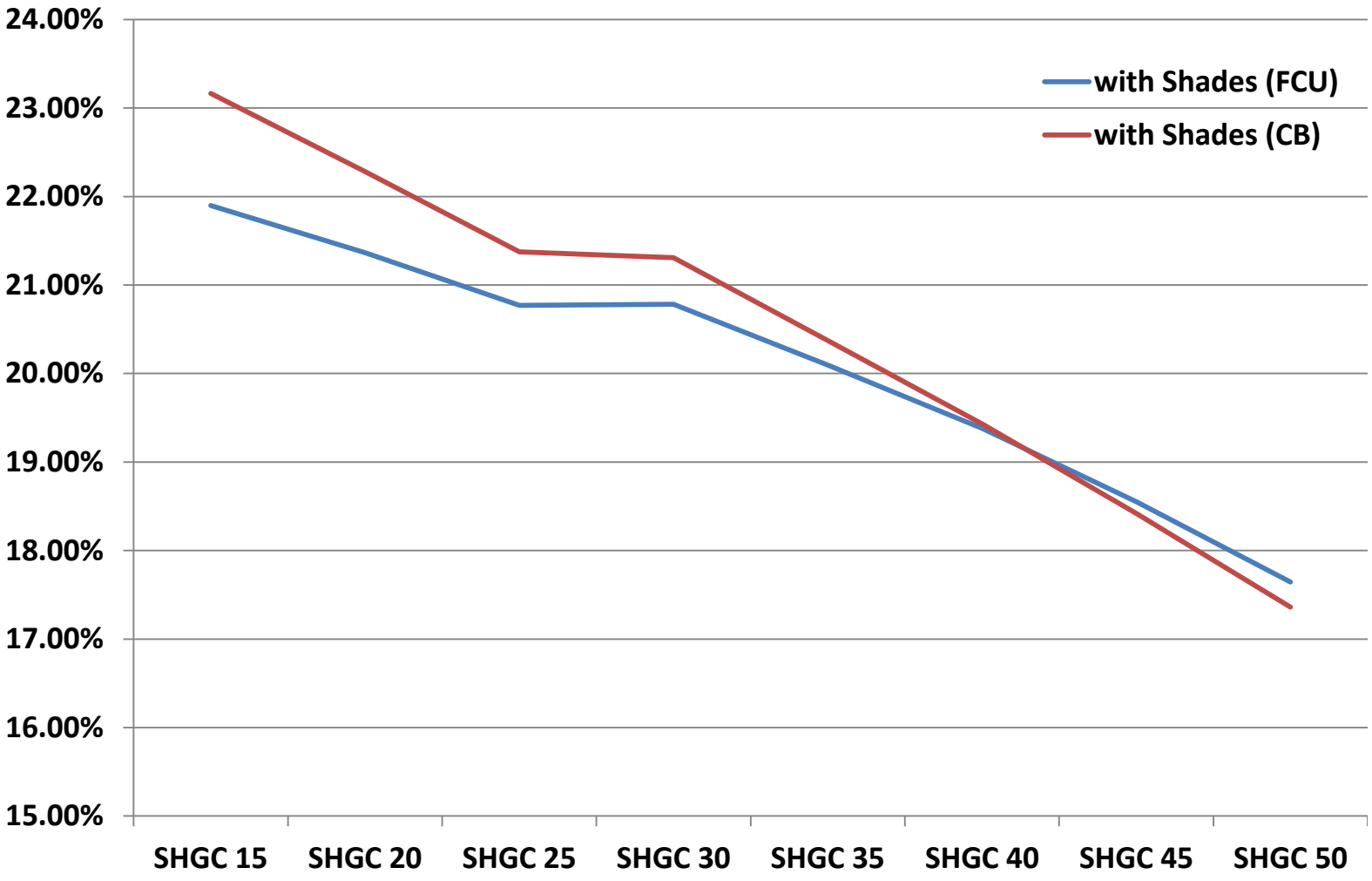
Output Summary

Parameters	BaseCase of 90.1 Appendix G	Case #1	Case #2	Case #3	Case #4	Case #5	Case #6
Chiller COP	6,1	5,96	5,96	5,96	8,4	8,4	8,4
Chiller IPLV	6.3	8,98	8,98	8,98	11,88	11,88	11,88
Boiler Efficiency	82%	93%	93%	93%	93%	93%	93%
Window Wall Ratio	40% (ASHRAE)	As is in dwgs	As is in dwgs	As is in dwgs	As is in dwgs	As is in dwgs	As is in dwgs
Exterior Shading	None	As is in dwgs	As is in dwgs	As is in dwgs	As is in dwgs	As is in dwgs	As is in dwgs
U (glass + frame)	3,69	1,8	1,8	1,8	1,8	1,8	1,8
U (opaque walls)	0,479	0,4	0,4	0,4	0,4	0,4	0,4
Tvis	0,7	0,5	0,5	0,5	0,5	0,5	0,5
Int. Set Temps	W:22 S:24	W:22 S:24	W:22 S:24	W:22 S:24	W:22 S:24	W:22 S:24	W:22 S:24
Fresh Air	No Heat Recovery	AHUs with heat recovery (eff:%75)	AHUs with heat recovery (eff:%75)	AHUs with heat recovery (eff:%75)	AHUs with heat recovery (eff:%75)	AHUs with heat recovery (eff:%75)	AHUs with heat recovery (eff:%75)
Population	1 person / 10 m2	1 person / 10 m2	1 person / 10 m2	1 person / 10 m2	1 person / 10 m2	1 person / 10 m2	1 person / 10 m2
Lighting	12 W/m2 in office areas	9 W/m2 in office areas	9 W/m2	9 W/m2	9 W/m2	9 W/m2	9 W/m2
SHGC	0.25	0,3	0,35	0,4	0,3	0,35	0,4
HVAC System	VAV/Reaheat - Chilled and Hot water supply	FCU	FCU	FCU	Chilled Beam	Chilled Beam	Chilled Beam
Saving over Appendix G	0.00%	21.90%	21.37%	20.77%	20.78%	20.10%	19.38%

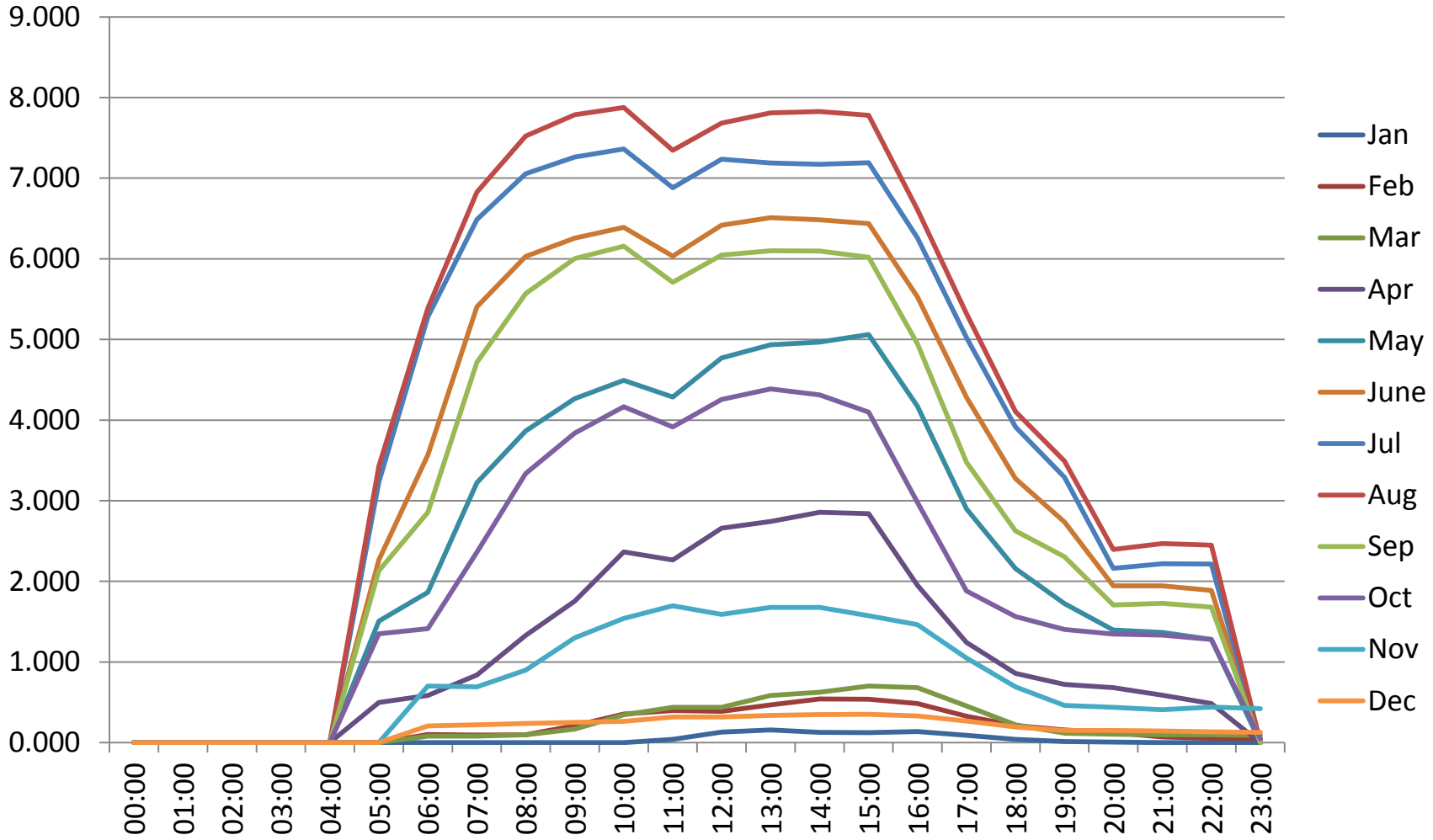
Savings over ASHRAE Appendix G 90.1 2007



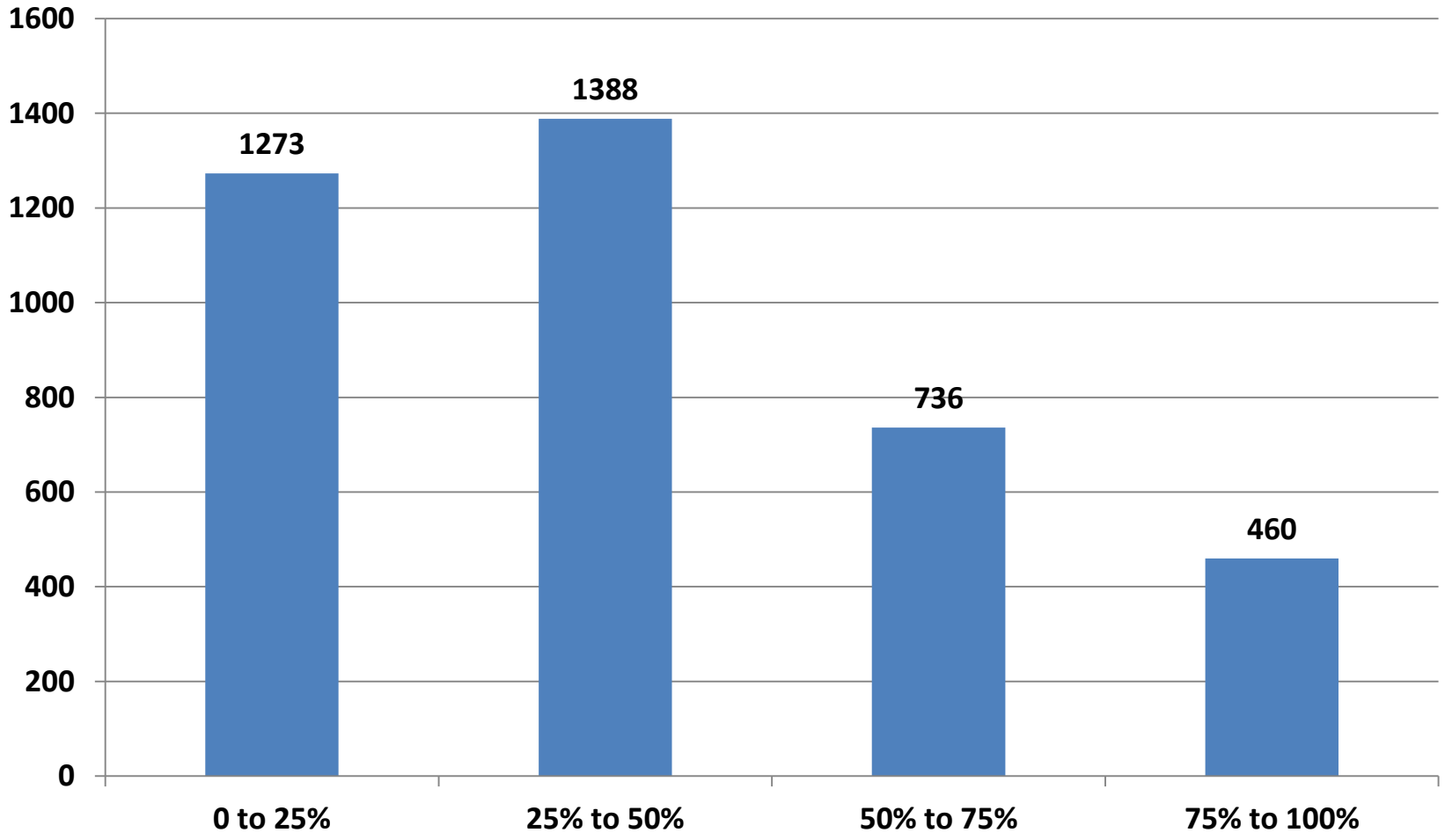
Savings over ASHRAE Appendix G 90.1 2007



Average Cooling Load (kW/m2 of Office Space)



Cooling Load Ratio in Annual Operation



References

1. AUTODESK, Sustainability Workshop
2. ASHRAE 55 Thermal Comfort – 2004
3. Energy Conservation Building Code, ECBC 2007

Questions??

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Thank You