MEASURING ENERGY IMPACT ON ARCHITECTURAL DESIGN BY USING ENERGY MODELING TOOLS

With the development of Computer Aided Design (CADD), building energy simulation and analysis is an important component in an Integrated Building Design Methodology.

Climate analysis is the starting point of all design projects. Solar analysis is extremely helpful at the early stages of design development, where day lighting and solar gains are important factor in defining the footprint and basic envelope.The Sun path analysis, design of exterior shading, Shading masks to determine the extent of overshadowing for selected objects on a sun path diagram, would provide environmental design details to an architect at the initial stage of the design to create high energy performing buildings. This analysis is quite possible with energy modeling tools like Ecotect.

This article would emphasize using of energy modeling software for building architectural design to improve the energy performance of the building. The effort is made to examine the relationship between building design process and building energy simulation from the architect's point of view.

Building thermal performance calculations are made for two primary reasons. They are made to size and select mechanical equipment or to predict the annual energy consumption of a structure.

- *Sizing programs* are primarily designed to calculate peak hourly loads during the heating and cooling seasons.
- *Energy programs are primarily designed to predict the annual energy consumed by a structure in terms of BTUs, Rupees, or pollution avoidance.. Today energy analysis tools are becoming more common and are being applied earlier in the design process.*

There are many benefits of performing energy modeling on your building:

- Energy simulation provides an independent evaluation of the energy efficiency of your proposed new design
- Energy simulation can provide you with the most cost effective design to meet your environmental goals
- Energy simulation quantifies the operational savings over the life of the building
- Energy simulation is needed to qualify for utility and government incentives and for LEED certification
- You can do the design right the first time instead of paying more to correct it later.

TYPICAL ENERGY CONSUMPTION FOR THE OFFICE BUILDING:

Estimated annual energy use in % for lighting, cooling, fans, and plug loads for typical office building in a cooling dominated climate condition is shown in Fig 1. During Pre-Design phase, it is possible to document the adopted energy goals and general strategies by using proper building energy modeling tool. We can emphasize goals that relate to large energy uses that can produce the largest savings. Priorities of the goals may change greatly from one climate to another and from one building to another. For example, differences in building orientation can have profound impacts on the selection of various energy goals and strategies.

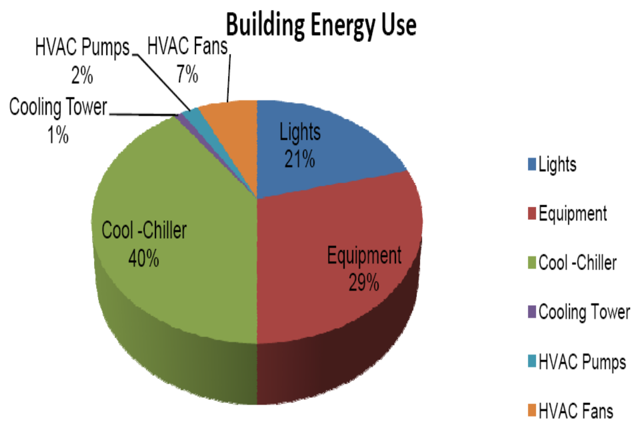


Fig 1

TYPICAL COOLING LOADS ENERGY CONSUMPTION FOR THE OFFICE BUILDING:

Estimated annual energy impact on the cooling system through various building components are given in Fig 2. Various components that affect the operational cost for cooling the building can be identified and various strategies can be adopted for achieving energy saving in new construction. These analyses are quite possible by using energy modeling tools like Visual DOE, Energy Plus, and EQuest etc.

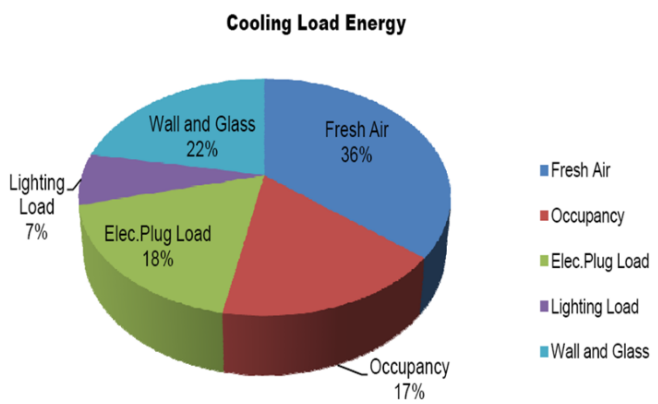


Fig 2

Energy Simulation for LEED Compliance:

During design phase, the team can develop the energy strategies into building plans, sections, details and specifications. The sequence of many design decisions, such as building and glazing orientation, as well as other identified strategies can be taken based on the output of the energy modeling. The case study of energy impact of the various building components on the building energy performance is given in Table 1.

The analysis can be further carry forwarded to work out the LCCA & PBA (Life Cycle Cost Analysis & Pay Back Analysis) to take financial decision with the additional investment details to implement a better technology to improve the energy performance of the building.

BUILDING THERMAL ANALYSIS REPORT - CASE STUDY IT Building Carpet Area: 1,46,000 SFT Location : Hyderabad					
Sr.No.	Description	Annual Energy Consumption in KWHr.	Annual Energy Cost in Rs. (Rs.6.2/KWHr)	Savings in Energy Cost wrt Conventional Case in Rs.	% of Savings wrt Conventional Case %
1	Conventional Case : Wall: U:1.95 W/M^{2}K LPD: 1.5W/Sft,Roof U:0.25W/M^{2}K; GLASS U:1.5 W/M^{2}K with SHGC:0.31,VLTS:60%, Chiller COP: 4.9	4782326	29650421		
2	Case 1: LPD changed to 0.8 W/Sft	4032797	25003341	4647080	15.67%
3	Casse 2: Wall U value Changed to 0.439 W/M^2 K	4654095	28855389	795032	2.68%
4	Case 3: Roof U value Changed to 0.378 W/M^2 K	4722843	29281627	368795	1.24%
5	Case 4: Glazing Uvalue: 1.77 W/m2K & SHGC : 0.18	4660978	28898064	752358	2.54%
6	Case 5: Adding HRW	4588720	28450064	1200357	4.05%
7	Case 6: Add Daylight Control	4758414	29502167	148254	0.50%
8	Case 7: Add High Albedo Paint	4707146	29184305	466116	1.57%
9	Case 8: Change Chiller COP to 5.5	4633023	28724743	925679	3.12%
10	Case 9: Change in the AHU Motor,drive, fan,pump systems to high efficiency, VFD&VAV for AHU and VFD for Cooling Tower etc.	4495386	27871393	1779028	6.00%
11	**Base Case As per Ashrae 90.1.2004:** Wall: U:0.439 W/M^{2}K LPD: 1.0W/Sft,Roof U:0.066W/M^{2}K; GLASS U:4.6 W/M^{2}K with SHGC:0.25,VLTS:32%, Chiller COP: 4.9	3963961	24576558	5073863	17.11%
12	**Proposed Case:** Wall: U:0.439 W/M^{2}K LPD: 0.8W/Sft,Roof U:0.066W/M^{2}K; GLASS U:1.77 W/M^{2}K with SHGC:0.18,VLTS:25%, Chiller COP: 5.5 + HRW+High Albedo Paint+Day light Control	3085400	19129480	10520941	**35.48%**
	Improvement between Base case to Proposed Case to meet LEED			5447078	**22.16%**

Table 1: Building Thermal Analysis Report

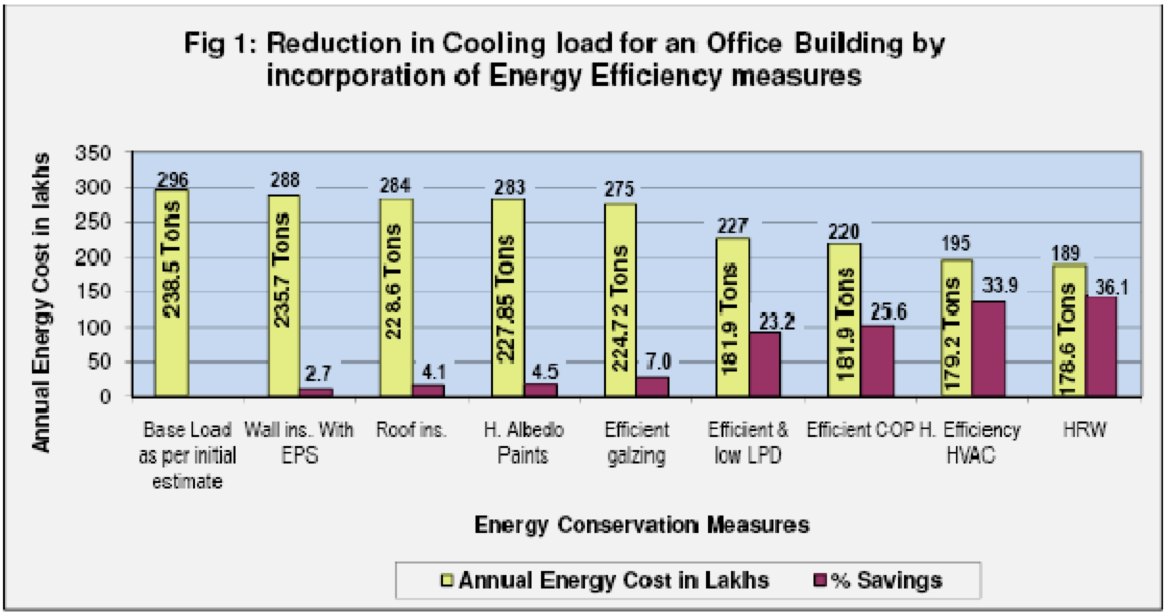


Table 2: Reduction in cooling load for an Office building by incorporation of various Energy Efficiency Measures

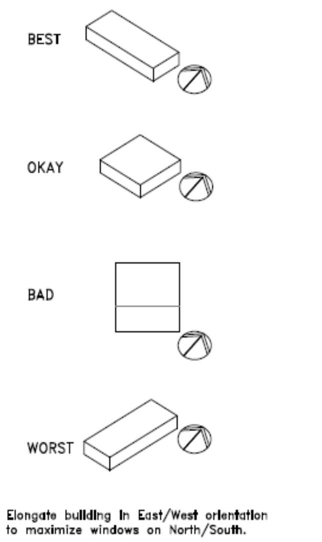
Table 2 shows that the energy impact on cooling load operational cost and reduction is the initial capacity of the cooling equipment by implementing various Energy Conservation Measures (ECM) on the building envelope and on the mechanical system.

Case Study conclusion:

The case study shows that the proposed case building energy performance is **22.16%** better than the Base case established as per ASHRAE 90.1.2004 for the same building.

Having discussed the energy impact on the building performance by various building components, an architect plays a vital role in improving the building energy performance. The measure that can be adopted during design stage is:

MEASURE-1: BEST ORIENTATION + EFFICIENT FAÇADE + Day Lighting

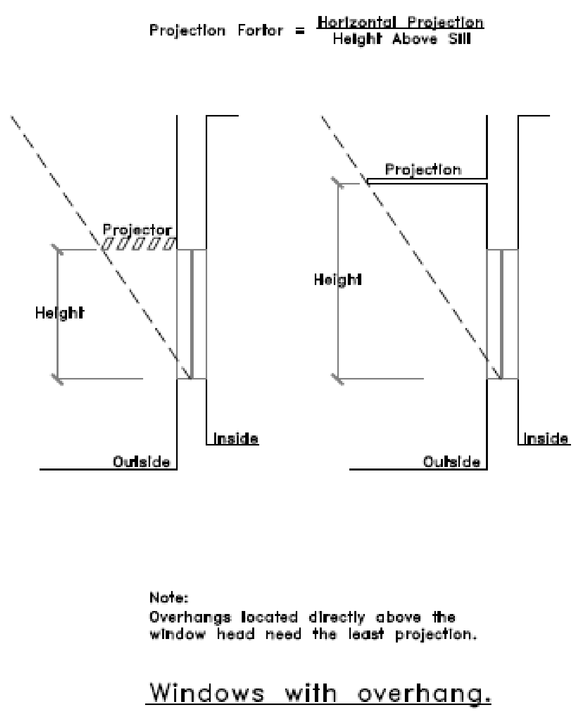


Building and window orientation.

STRATEGIES & RECOMMENDATIONS

- In Warm Climates, N and S glass can be more easily shielded – less solar heat gain & less glare than E or W facing glass
- Preference should be given to sites that permit elongating the building in the E-W direction
- (W window area x W SHGC) + (E window area x E SHGC) < (N window area x N SHGC) + (S window area x S SHGC)
- Detailed sun path study to be done during initial stage of the design

Fig 3



STRATEGIES & RECOMMENDATIONS

- Use Double Unit Glass with lower SHGC < 0.2
- Maximize the benefit of day lighting by choosing higher VLTS>0.3 for view windows
- Plan separate Day lighting controls
- Design Overhangs directly located above the window head
- Use separate Controls for lighting in areas near windows
- Use automatic controls to turn off lights when not in use

Fig 4

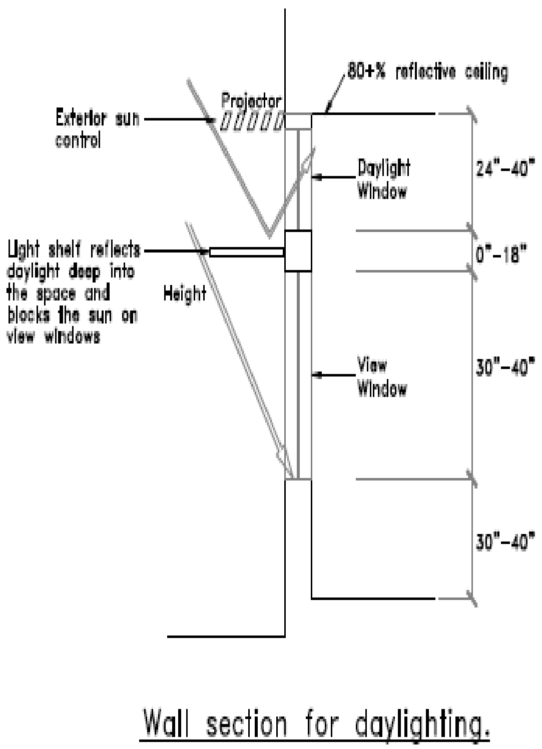


Fig 5

STRATEGIES & RECOMMENDATIONS

- Use 2 layer glazing; Day light window & View Window
- Maximize the benefit of day lighting by choosing higher VLTS>0.6 for daylight windows
- More day light realized if Ceiling heights >10ft and window is high, continuous
- Preferred Window to Wall ratio (WWR) is 20% to 30%

MEASURE-2: EXTERIOR SHADING

The building in tropical climate conditions requires external shading to ensure the solar radiation infiltration into the building is greatly minimized throughout the year. The optimum size and the orientation of the external shading can be designed by using the energy modeling tools.

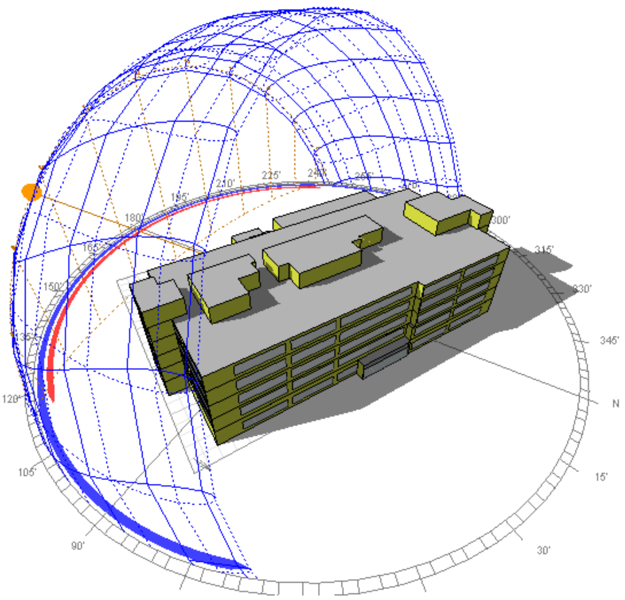


Fig 6: Front Elevation of the building in the sun path diagram

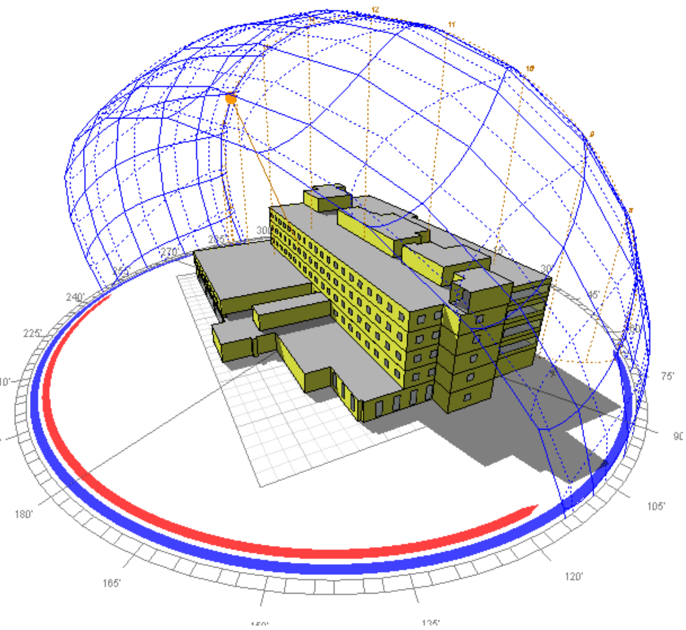


Fig 7: Rear Elevation of the building in the sun path diagram

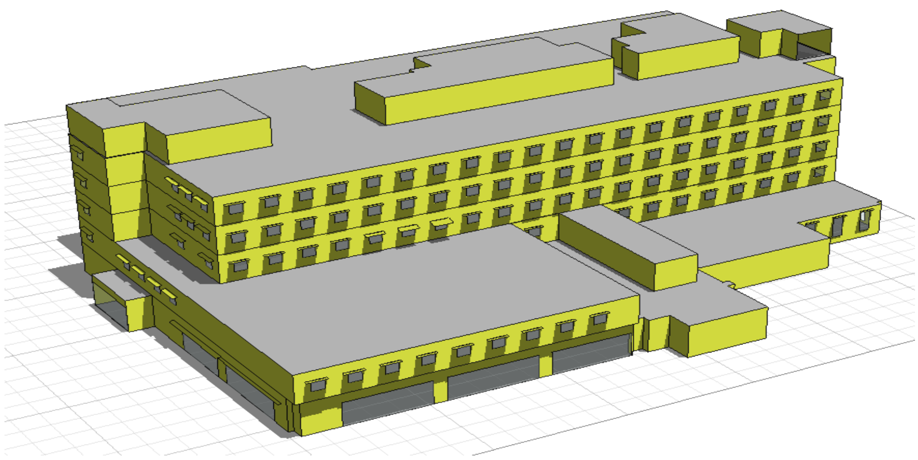


Fig 8: Typical Building with exterior shading for Windows

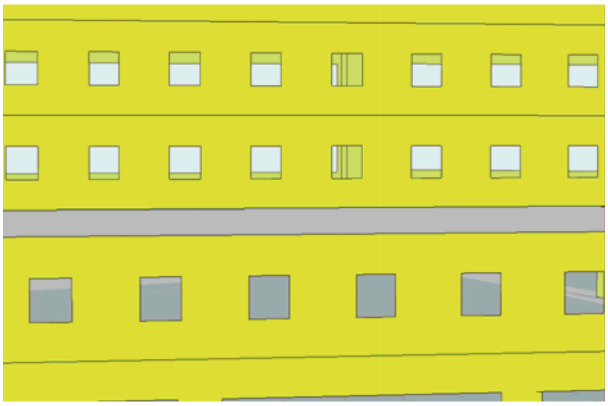


Fig 9: South side Windows without Shading

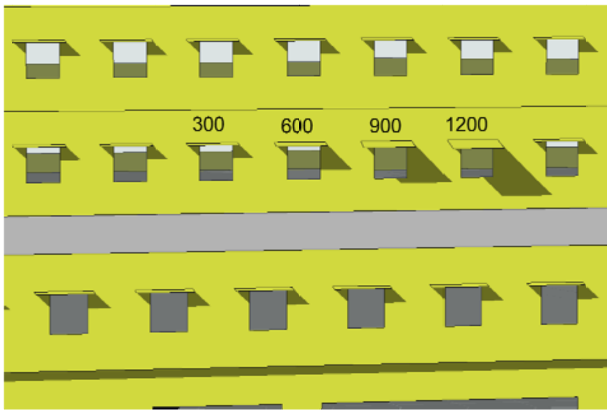


Fig 10: South side Windows with External Shading

Consider exterior shading to prevent the direct solar radiation through window atleast during 11:00 to 16:00 hrs in peak summer time. Figure 10 shows the shading effect on 21sth April at 4:00 PM. and also shows the effect of shadow with various depth of windows, 300 mm, 600mm, 900 mm, 1200 mm , mentioned in the figure to decide the optimum size of the exterior shade.

MEASURE- 3: ROOF & WALL INSULATION

The building wall, glass and roof construction hugely affect the energy performance of the building. The specification of the wall, fenestration and roof details are given in the Table 3, which is considered in our case study. The energy performance of these components in the proposed case is also mentioned in Table 1.

DESCRIPTION	CONVENTIONAL CASE	PROPOSED CASE
	BUILDING ENVELOPE	
WALL CONSTRUCTION	9" Brick Wall 1/2" plasterin U-0.32 BTU/Hr F^2	Solid Block Wall of 20% Flyash content, 200mm thick masonry with 60mm thick insulation. U-factor of 0.439 W/sqmºK
GLASS WINDOW CONSTRUCTION	DUG = 6 mm +12 mm air gap+6mm Uvalue:1.0 BTU/Hr F^2 SHGC:0.6	DUG = 6 mm +12 mm air gap+6mm Uvalue:0.31 BTU/Hr F^2 SHGC:0.18
ROOF CONSTRUCTION	275 mm thick concrete with weather proofing	275 mm concrete + 75 mm thick Extruded Polysterene(R-15)+weather proof

Table 3: Envelope Specifications

MEASURE- 4: Use of High Reflective Albedo Paints / Roof Garden

The heat island effect raises the localized temperature, impacting local microclimate. Garden Roof / roofs with high Solar Reflectance Indexes reduce costs associated with cooling and HVAC equipment. Green roofs typically require an additional up-front investment. However, any up-front investment is likely to result energy cost savings throughout the lifecycle of the project. Building in very hot climates may experience year-round energy benefits from reflective roofing due to high emittance and low absorption, which may decrease cooling costs. As shown in case study Table 1, the energy saving is achieve about 1.57% for Green roof with high Albedo paint and the pay back for this would be within 3 years.

Fig 11: Terrace Garden

STRATEGIES AND RECOMMENDATIONS

- Use High Albedo Reflective paints with high emissivity atleast 0.9 for a minimum of 75% of the roof area or
- Install a “green” (vegetated) roof for atleast 50% of the roof area or
- Install high Albedo and vegetated roof in combination

CONCLUSION

To apply simulation tools and techniques successfully, a clear understanding of the building design process and its relationship with the simulation environment is advisable since humans (in other words architects) and not computers dictate the creative and evaluation process. In practice, Energy Simulation Software’s like Energy Plus and Visual DOE are currently, widely being used to analyze the energy performance of the building.

To evaluate building performance and achieve energy efficiency goals, architects and building designers should take full advantage of computer simulation tools that are readily available. With a better understanding of building energy simulation through education and training, it is possible for us to establish confidence and efficiency in the use of simulation based design tools.