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Energy and Comfort Management in Energy Efficient Buildings Using RETSCREEN Software-A Case Study Analysis

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ABSTRACT
Smart and energy-efficient buildings have recently become a trend for future building industry. The major challenge in the control system design for such a building is to minimize the power consumption without compromising the customers comfort. Buildings have the physical potential to harness diluted and sometimes unpredictable renewable energy. The building envelope and the ground constitute the basic resources for energy autonomous buildings. It is widely accepted that if any country has to reduce greenhouse gas emissions it must aggressively address energy end use in the building sector.

Simulation of building performance is increasingly being used in design practice to predict comfort of occupants in finished buildings. In this thesis, the simulation results shows that the proposed intelligent control system successfully manages the user’s preferences for thermal and illuminance comfort, indoor air quality and the energy conservation by using RETSCREEN software. The present work attempts to overcome certain inadequacies of contemporary simulation applications with respect to environmental control systems, by developing novel building control systems modeling schemes. These schemes are then integrated within a state-of-art simulation environment so that they can be employed in practice.

***Keywords* –** Building materials, Energy Efficient buildings, Energy performance index, HVAC parameters, RETSCREEN software.

I. INTRODUCTION

Energy consumption of buildings (both residential and commercial) has steadily increased, reaching figures between 20% and 40% in developed countries. The rise of energy demand in buildings will continue in the near future because of growth in population, long-term use of buildings, and increasing demand for improved building comfort levels. Therefore, the energy efficiency of buildings is of prime concern for anyone wishing to identify energy savings. To this end, automated meter reading and smart metering systems have been employed to collect building energy data [1]. The aim of these data is to provide greater insight into how a building consumes energy and, therefore, what improvements are likely to be most effective in reducing consumption. Energy Efficient Building (EEB) design has become a high priority for present situations where power crisis is escalating to higher levels. The present study of EEB is a challenging task for multi-disciplinary technology, because designing a EEB involves the knowledge of civil, mechanical, electrical, environmental and architectural engineers. The scientific evidences for climate changes and the associated impacts of greenhouse gas emissions are becoming increasingly obvious. Most of the countries, buildings are responsible for 47% of national energy consumption. Scientists and built environment professionals are trying to find advanced technologies, renewable energies, and useful strategies to reduce carbon dioxide emissions [2].

The concept of EEB has gained wide international attention during last few years and is now seen as the future target for the design of buildings. However, before being fully implemented in the national building codes and international standards, the EEB concept requires clear and consistent definition and a commonly agreed energy calculation methodology.

This paper focuses on the review of the most of the existing EEB definitions and the various approaches towards possible EEB calculation methodologies. It presents and discusses possible answers to the above mentioned issues in order to facilitate the development of a consistent EEB definition and robust energy calculation methodologies are provided [3].

II. AN APPROACH TO PLAN EEB

Buildings are usually evaluated according to the amount of energy required by the building and therefore expressed in terms of kWh/m^2/year and termed as Energy Performance Index (EPI). The assessment of the energy demand for the climatic control of a building can only be dealt with if the level of the indoor environmental comfort and it is directly related to EPI. If the value of EPI is less, then the consumption of energy is less and hence the electricity bills will be less. But, all these can be achieved without compromising the comforts and luxuries of the consumer.

A systematic approach is required to plan an EEB without sacrificing the requirements of the consumer. A good EEB design requires the technologies of civil, thermal, mechanical, electrical and architectural tools. Hence the below flow chart shown in "Fig.1" will gives an approach to plan an EEB.

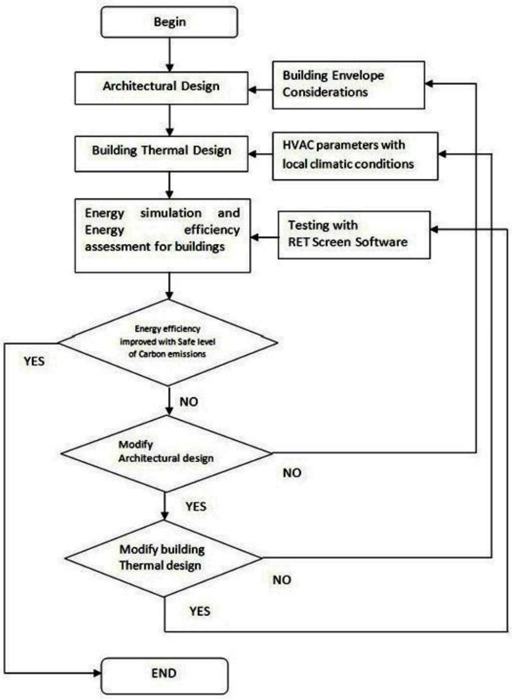


Fig. 1: Planning of an EEB through flow chart

A base building will be measured with initial EPI and if it measures 350 kwh/m^2/year. By envelope optimization and with building materials in roof and walls the EPI can decrease to 225 kWh /m^2/year. Similarly with lighting optimization to 175 kwh/m^2/year and with HVAC optimization 125 kwh/m^2/year and finally with Controls, sensors, rain and waste water harvesting it will reach to 95 kwh/m^2/year. All these results will be simulated by using RETSCREEN software by considering a case study.

III. MATHEMATICAL MODELING OF EEB

A Simplified Building Energy model will be analyzed by considering a room with thermal parameters. The net heat energy loss (or gain) of a building can be defined at any moment from the thermal balance of the building (first law). For example for the calculation of the thermal load the instantaneous steady-state thermal balance of a building is given by

$$q_H = (q_{cond} + q_{inf}) - (q_{sol} + q_{int}) \qquad (1)$$

Where, q_H is the thermal load of the building in watts. The first two terms on the right express the thermal losses ($Q_{loss} = q_{cond} +$), which is the more important part of any building study, while the last two terms are the thermal gains of the building q_{cond} are the thermal losses through the building's envelope, q_{inf} are the infiltration loss caused by the entrance of fresh air. Respectively, q_{sol} are the net solar thermal gains and q_{int} are the internal thermal gains (people, lighting, equipment operation etc.).

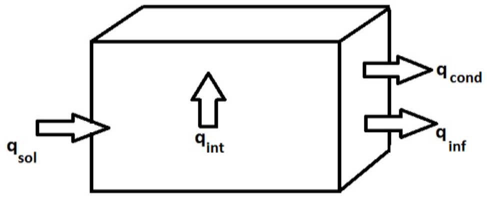


Fig.2: Building model

For a building, a state of balance practically means $Q_{loss} = Q_{gain}$ and therefore the thermal load $q_H = 0$ shown in "Fig.3". All building losses are depended for the temperature difference ($\Delta T = T_i - T_o$) of the internal (T_i) and the external (T_o) of the building. Thus, when, $Q_{loss} > Q_{gain}$ something that usually happens during the winter period where the temperature differences ΔT are high, then $q_H > 0$, and so q_H expresses the additional thermal load in watts that the building demands in order to return to its thermal equilibrium state and in the end specifies the building's heating demand in time.[5]

The thermal load of a building, after the introduction of a Building total Loss Coefficient (BLC) is given then by:

$$Q_H = Q_{Loss} - Q_{gain} = BLC \times (T_i - T_o) - Q_{gain} \qquad (2)$$

Where Q_H is the thermal load in watt, T_i is the necessary internal temperature of the building (or even the design temperature of the building in ^0C) and T_0 is the outside temperature.

The BLC is calculated in Watt/^{0}C, modified to include both the thermal losses through the buildings envelope and the infiltration losses. For any building, BLC can be normally calculated as:

$$BLC = \sum_{n=1}^{N} U_{T,i} \times A_i + m_{inf} \times C_{pa} \qquad (3)$$

Where $U_{T,I}$ is the thermal conductance in Watt/(m^2 K) of the building components (outside walls, floors, doors, windows etc.,) A_i is the respective components areas in m^2, m_{inf} is the mass flow rate of infiltration air in kg/sec (Lt/sec), C_{pa} is the specific heat capacity of air at constant pressure in KJ/(Kg^{0}K). In the BLC, they are also considered the relative heat capacities of the building components within which it is stored an additional thermal load that might come either from the heat gains or the heat losses of the building[6].

IV. CASE STUDY ANALYSIS BY RETSCREEN

The RETSCREEN Software Building Envelope Model can be used worldwide to evaluate the energy use and savings, costs, emission reductions, financial viability and risk for building envelope energy efficiency measures. The software can model a wide variety of projects ranging from passive solar designs for houses, to energy efficient window use in commercial buildings, to complete energy efficient construction practices on the entire building envelope for large institutional and industrial buildings [7]. The software also includes product, project and climate databases, and a detailed user manual.

In this case the analysis is considered for JNTU College of Engineering Kakinada. For this analysis the procedure is as follows:

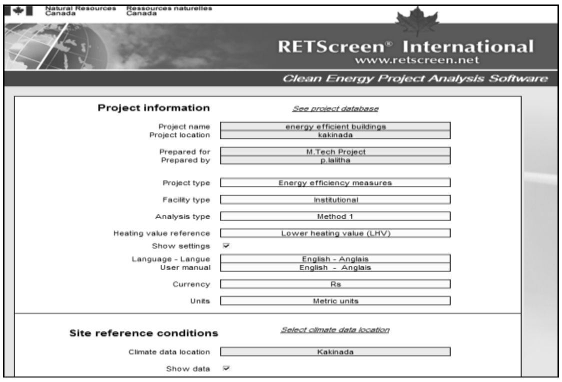
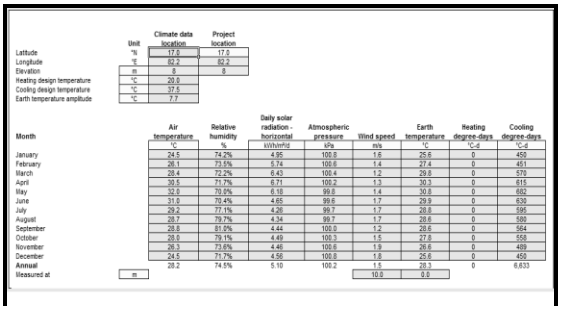


Fig. 3: Energy model sheet of RETSCREEN

The project type is of Energy efficient Measures, this is of institutional facility type and the analysis method is considered as method 1. The Heating value reference is considered as LHV. Higher heating value is typically used in cold locations like Canada and USA, while lower heating value is used in the rest of the world. Hence LHV is selected. This is of International wide software hence we can get the currency what we required. The climatic data conditions are obtained for this location which is included in Site reference conditions.



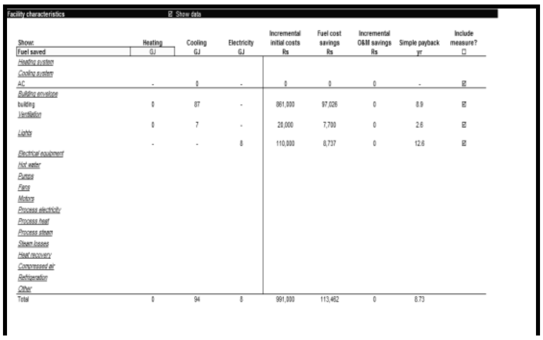
	Unit	Climate data location	Project location
Latitude	°N	17.0	17.0
Longitude	°E	82.2	82.2
Elevation	m	8	8
Heating design temperature	°C	20.0	
Cooling design temperature	°C	37.5	
Earth temperature amplitude	°C	7.7	

Month	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	24.5	74.2%	4.95	100.8	1.6	25.6	0	450
February	26.1	73.5%	5.74	100.6	1.4	27.4	0	451
March	28.4	72.2%	6.43	100.4	1.2	29.8	0	570
April	30.5	71.7%	6.71	100.2	1.3	30.3	0	615
May	32.0	70.0%	6.18	99.8	1.4	30.8	0	682
June	31.0	70.4%	4.65	99.6	1.7	29.9	0	630
July	29.2	77.1%	4.26	99.7	1.7	28.8	0	595
August	28.7	79.7%	4.34	99.7	1.7	28.6	0	580
September	28.8	81.0%	4.44	100.0	1.2	28.6	0	564
October	28.0	79.1%	4.49	100.3	1.5	27.8	0	558
November	26.3	73.6%	4.46	100.6	1.9	26.6	0	489
December	24.5	71.7%	4.56	100.8	1.8	25.6	0	450
Annual	28.2	74.5%	5.10	100.2	1.5	28.3	0	6,633
Measured at (m)					10.0	0.0		

Fig.4: Climate data base

To access the RETSCREEN Climate Database click on the "Select climate data location" hyperlink or use the RETSCREEN menu or toolbar.

This is the extension of first window which show the data of climatic conditions of the considered location. While the latitude and longitude values are entered, the values of Air temperature, Relative humidity, Daily radiation-horizontal, Atmospheric, wind speed, Earth temperature, Heating Degree days, Cooling degree days are obtained for monthly basis. The data obtained is only for reference purpose not to run the model.



Facility characteristics ☑ Show data

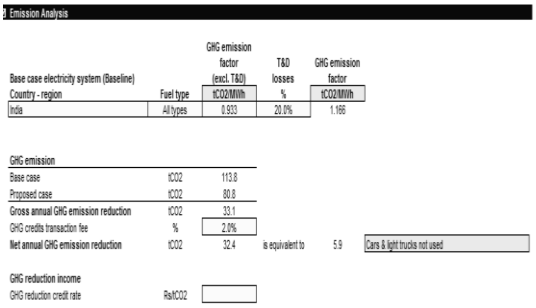
Show: Fuel saved	Heating GJ	Cooling GJ	Electricity GJ	Incremental initial costs Rs	Fuel cost savings Rs	Incremental O&M savings Rs	Simple payback yr	Include measure? ☐
Heating system								
Cooling system								
AC	-	0	-	0	0	0	-	☑
Building envelope								
building	0	87	-	861,000	97,026	0	8.9	☑
Ventilation	0	7	-	20,000	7,700	0	2.6	☑
Lights	-	-	8	110,000	8,737	0	12.6	☑
Electrical equipment								
Hot water								
Pumps								
Fans								
Motors								
Process electricity								
Process heat								
Process steam								
Steam losses								
Heat recovery								
Compressed air								
Refrigeration								
Other								
Total	0	94	8	991,000	113,462	0	8.73	

Fig 5: Building parameters

In this tool, enter the information about the facility characteristics, for the base case and the proposed case facilities. The user clicks on the blue hyperlinks (e.g. Heating system, Cooling system, Building envelope, ventilation, lighting etc.) to access the data entry forms used to describe the facility. In addition, the key results of the model are displayed in this section (e.g. fuel saved, simple payback, etc.).

In this analysis the electrical equipments like fans, tube lights and computer are taken. For these equipments the base case and proposed case are considered. By using efficient devices the power saving is of 36.2%. Although the initial cost may be high, at last there is a lot of saving. For building envelope the payback period is 8.3 years and for electrical equipments there is no payback period means when we invest the money immediately we can get the savings.

A. Emission Analysis:



Emission Analysis

Base case electricity system (Baseline) Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh
India	All types	0.933	20.0%	1.166

GHG emission					
Base case	tCO2	113.8			
Proposed case	tCO2	80.8			
Gross annual GHG emission reduction	tCO2	33.1			
GHG credits transaction fee	%	2.0%			
Net annual GHG emission reduction	tCO2	32.4	is equivalent to	5.9	Cars & light trucks not used
GHG reduction income					
GHG reduction credit rate	Rs/tCO2				

Fig.6: Emission analysis

Comparing to base case the proposed case will cut short the emissions to 28%. That is equivalent to 6 cars not used per year. In a larger scale it can earn the carbon credits to the project and it will support the additional revenue to the project.

B. Financial analysis:

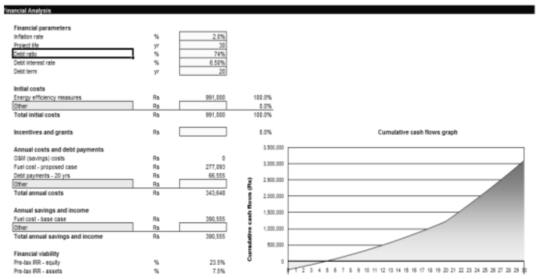


Fig.7: Financial analysis

In financial analysis, the fuel rate for base case with proposed cases are compared even though the initial investment is high the payback period is very less in some times it may be neglected also. Here the project life is considered for 30years.

V. CONCLUSIONS

The results obtained by using RETSCREEN software can be very realistic and gives very promising results for Energy Efficient Buildings. The main feature of this software is; it will integrates the local climatic conditions and hence planning of energy models are simpler.

The building simulation results, found that how various parameters in energy dependence can be decreased by step by step and finally gives the reduction in energy needs. However, as the consideration of equipments was done optimistically for the desired building load and net profits will be higher than the results in simulation by considering carbon credits and subsidies from government organizations.

VI. ACKNOWLEDGEMENTS

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