Grid Electricity Demand Reduction through Applying Passive Strategies for a House in Baghdad - Iraq

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ABSTRACT

This paper is investigating the electricity demand reduction due to the use of passive strategies for typical house in Baghdad. The motive was to reduce the depended of the national electricity grid which is not reliable and suffers frequent daily interruptions. Simulation methodology was used to carry out this study according to the flexibility to simulate the energy consumption, calculate, and evaluate the power consumption and energy saving due to reduction in the cooling load. The study covered the following strategies: shading devises, insulations materials, and glazing. Increasing the roof's insulation was the most effective single element refurbishment option and could result in cooling load savings upto 11.9%. Wall insulation was the second best strategy with cooling load savings upto 10.3%. Upgrading the glazing system resulted in cooling load saving of just under 4%. The reduction in the cooling load achieved by employing all three refurbishment strategies was upto 29.3% when the house was virtually refurbished to ESTIDAMA's 2 Pearls. The results show good potential of passive strategies in reducing the cooling load, and thus power consumption.

KEYWORDS: *Passive strategies, energy saving, IES simulation*

1. INTRODUCTION

Over the last decade, rapid growth in economic and population accompanied by depletion of the energy resources lead to serious impacts on the environment and humanity. Therefore, principle of passive design has been required in order to reducing this negative impact.. Passive design architecture approach aims to use of specific building design principles to minimize the required energy to achieve thermal comfort. In many instances, the design approach neglected these parameters to provide the new contemporary concept of design building while the traditional building considered them in despite of limitation in knowledge and technologies. The building should be more than a shelter; it should be a series of characteristics, which create the indoor comfortable construction Thus, architects, and designers must considered many parameters during the concept and design phases to achieve the passive design strategies such as, orientation, natural ventilation, insulation material, shading devices, and thermal mass etc. There have been a number of studies concerning on this issue, such as Stevanović, (2013) Ralegaonkar and Gupta, (2010) and Kaklauskas *et al*. (2012) assess the most important components of passive design strategies, which significantly can reduce the cooling, heating and lighting load energy consumption. Although Dili (2010), AboulNaga and Elsheshtawy (2001) point out that the majority of building design neglected the passive methods to provide the required thermal conditions, which forced people to depend on mechanical system that associated with high-energy consumption especially in the warm –humid climatic zone. They are also exploring a comparison of thermal comfort between modern and traditional buildings during various seasons to conclude that traditional residential buildings are very efficient to provide a comfortable indoor environment for all seasons, because of the virtue of design, a special method of construction and the type of materials. More recently, Frontczak *et al* (2012), Gong *et al* (2012) concluded that passive strategies are the most practical and economical efficient way to enhance energy performance and saving. The research focusing on shading devices and insulation materials through reducing the U-Values of roofs, walls. In addition, the study examines different solar heat gain coefficient (SHGC) of glazing system as will be explained in the next sections.

2. PARAMETRIC STUDY

According to Ministry of Electricity, Iraq is generating 8,000 megawatts only while the currently required power is rising to 13-15,000 megawatts. According to International- Agency information and analysis Unit (IAU) reported in July 2010 for UN that households were receiving just eight hours of electricity per day in 2007.The United Nations Development Program (UNDP) noted that the electricity supply has been deteriorated in some area especially Baghdad. Since 2003 the public approval of the electricity demand has never records over 39% even during low demand periods. Observations done by the author in July 2012 associated with the facts that have been mentioned above create the outline of the problems which are highlighted as follows:

- Electrical power disconnects for several hours daily
- Private electricity generators are located between the residential zones and operated by unprofessional labourers as shown in Figure 1
- Electricity connection cables have been added randomly without any level of safety and secure Although, many families depend on these private generators, the amount of providing energy is very limited and it could not cover the actual demand of each house
- Almost every house should apply a converter to switch from the grid electricity to the private generators. This device could be damaged continuously and should be replaced by another one which cost money and effort.
- Many Iraqi families could not apply the electricity for their houses because of the lower income

Figure1. Private electricity generator in the middle of the residential area of which runs by unprofessional labourers in (Baghdad July 2012 taken by author)

In order to form a database that can help identify the impact of passive strategies on energy consumption, a typical house located in a popular area in Baghdad was selected to serve as a base case for this research. The selected house was two stories high with a land plot area of 780 m^2. The model was used to evaluate the impact of several passive refurbishment options on the cooling load requirements of the house. Table 1 includes the highlights of the selected house.

Table.1 Case study descriptions (typical house in Iraq/Baghdad)

Item	Ground floor	1^{st} floor
Floor area (m^2)	259.7	166.8
Total enclosed volume (m^3)	779.2	500.5
Outside wall area (m^2)	240.6	178.1
Glazing area (m^2)	35	16.1
Window/wall ratio (%)	14.5%	8.9%

The house was modeled using ModelIT which is the model building component of the Integration Environment Solutions- Virtual Environment (IES-VE) modeling software. The ModelIt allows the user to create 3D models required by other components and enable appropriate levels of complexity to be incorporated within a model across the entire design. However spaces may be created graphically or by manual input. The main drawing has been created by the AutoCAD software to export as DXF file as and underlay for zone creation as seen in Figure 2. In order to be sure that the model working properly, the 3D model is checked and modify during the modeling period as shown in Figure 3.

Figure 2 Base case plans by CAD

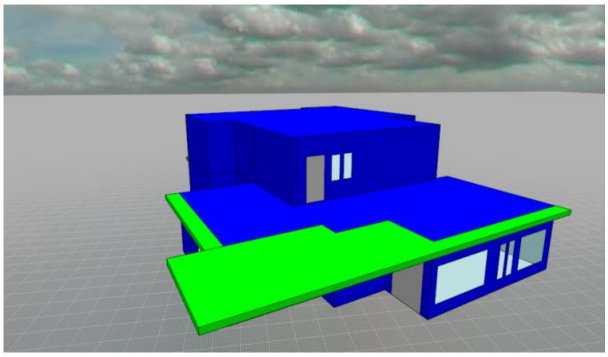

Figure 3 Base case model by IES

The IES – VE software offers the ability of creating different type of profiles for the same project. It is usually used to scheduled occupancy, HVAC system, and lighting, equipment, used according to the variation over a year. The operation profile of this study is based on the typical lifestyle of an Iraqi family. Three types of profiles have been setup which are; daily profile, weekly profile, and annual profile to provide accurate input data to obtained results with high level of validity. The daily profile assumes that from 8 am to 2 pm people will be out for work and education. Consciously the occupancy and the used of HVAC will be zero while it will be 1 unit when people will be back. (1 means 100% used in the software consideration) As well as the use of HVAC is linked to the occupancy profile. Meanwhile, weekend days have been assumed as full day occupancy and used (Iraqi families usually spend the weekend mainly at home).Thus it assumes the occupancy profile and HVAC system will be on continuously during the weekend days (Friday and Saturday). The annually profile is a frequently repetition of the weekly profiles, as exceptions it has adopted two types of profiles, for summer and winter. All these profiles have been considered for each simulation to increasing the reliability of the results. The IES-VE software provides the ability of creating different layers of constructions and finish materials according to the scenario of the simulation. The template includes the thermal properties of each construction elements such as, roof, ceiling, wall, and windows to be applied in the module of simulations.

Description and specifications of the base case construction material are highlighted in Table 2 As both Iraq and the UAE have similar hot climate conditions, the Abu Dhabi-UAE ESTIDAMA specifications were used as a guide to the refurbishment levels applied to the base case, i.e. insulation and glazing (ESTIDAMA 2013). ESTIDAMA has five certification levels ranging from (1-5 Pearls), the study select two values of them to be applied in the model: 1Pearl and 2Pearls. According to Awadhi et al. (2013) these values used to examine the impact of low U-Values on energy consumption in existing building in UAE.. Due to the large forecasted demand of electricity in summer; the results show that the maximum energy consumption occurred in July and August which represents the peak months for high temperatures. The total lighting energy has less consumption while the equipment energy consumed a little more than lighting energy consumption.

Table 2 Materials properties of the base case (case 1)

	Materials	Thickness (m)	Density (kg/m2)	Conductivity W/(m.K)	ASHRAE U- Value W/m2 K
	Concrete tiles	0.025	2100	1100	
	Sand	0.05	0.208	0.35	2.0896
	Concrete undried aggregate	0.2	2243	1.73	
	Plaster	0.03	1300	0.5	
Wall	Cement plaster aggregate	0.03	0.72	1860	
	Common brick	0.24	0.727	1922	1.7197
	plaster	0.03	0.5	1300	
Floor	Concrete tiles	0.025	1.1	2.1	
	Concrete un dried aggregate	0.2	1.73	22430	2.7322
	Tile bedding	0.05	1.4	2.1	
			SHGC		
Glazing	Windows	0.004	0.811	1.06	5.8744

3 SIMULATION RESULTS

3.1 Impact of adding extra shading devices (Cases 2 and 3)

The existing case study has many shading devices, the main one covered the entrance of the house at the North while the other type is shaded the windows which are located in the South. This study examines two types of shading the first one extends the roof of the ground floor which known as pergola Case2 which provides more shaded. The expected impact of this scenario will be limited because of the existing shading devices as. However, passive strategies should be integrated whatever the level of improvement to achieve energy performance and saving combined from each strategy. The results of this scenario Case 2 using the pergola shading reduce the chiller load from 106.5 MWh to 105.6 MWh representing 0.8% of reduction. While the reduction of windows shading devices Case 3 has very less reduction which is from 106.5 MWh to 106.1 MWh is 0.3% only

3.2 Impact of adding additional insulation to the roof (Cases 4 and 5)

This scenario considered the Polyurethane Board as insulation materials added to the conventional layers of roof. Case 4 examines the U-Value of 1 Pearl which is 0.1405 W/m2 K while Case 5 examines 0.1205 W/m2 K as U-Value of 2 Pearls. The result of Case 4 shows that the chiller load has been reduced from 106.5 MWh to be 94 MWh and percentage of 11.7%. While the chiller loads reduced from 106.5 MWh to be 93.8 MWh in Case 5, the percentage of this reduction is 11.9% According to Al-Ragom (2002) the used of roof insulation reduced the cooling load by 2% only while the results of Cases 4 and 5 can achieve more reduction significantly. Further, the difference between 1Pear and 2 Pears is very little.

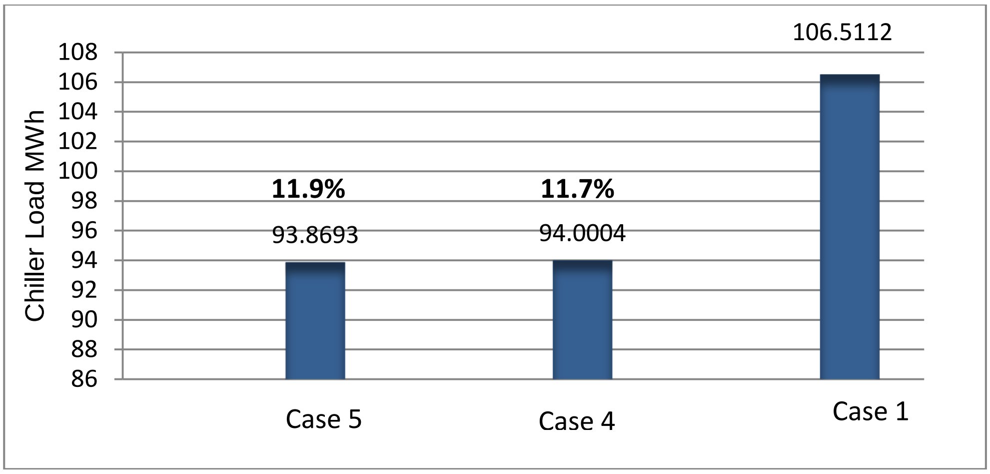

Figure 4 Chiller loads due to additional roof insulation (cases 4 & 5)

3.3 Impact of adding additional insulation to the walls (Cases 6 and 7)

This scenario examines the impact of wall insulations such as the Polyurethane Board on total energy performance. The U- Values have been reduced from 1.7197 W/m^2 K to be 0.3224 W/m^2 refers to ESTIDAMA 1 Pearl. Regard to the incorporated insulation improvements the chiller loads has been reduced from 106.5 MWh to be 95.7 MWh which represents 10.1% in Case 6. In Case 7 reduce to be to be 95.5 MWh provides a percentage 10.3% as shown in Figure 5.

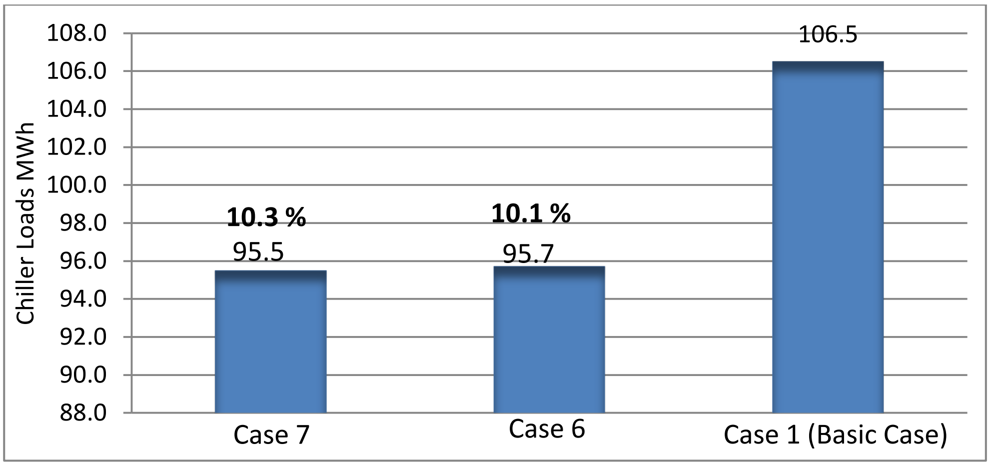

Figure 5 Chiller loads due to additional wall insulation (cases 6 & 7)

3.4 Impact of changing the glazing Solar Heating Gain Coefficient (Cases 8 and 9)

This scenario examines the impact of glazing coefficient on energy consumption through adopting two values of minimum ESTIDAMA thermal requirements. Solar Heating Gain Coefficient of 1 Pearl is 0.4 (SHGC) represents Case 8 whereas Case 9 adopting 2Pearls 0.3 (SHGC). The glazing configuration of SHGC is highlighted according to ASHRAE. Standard external wall area of the ground floor is approximately 259.7 m2, the windows ratio is 35 m2 which means 13.5% only exposed to direct solar gain through the glazing. The external wall area of the first floor is almost 166.8 m2 and the window area is only about 16.1 m2 provides 9.6% windows to wall ratio. According the ratio of opening area, the expected energy demand reduction through glazing scenario seems to be less comparing with insulation scenarios. the chiller load in Case 8 has been reduced from 106.5 MWh to 102.9 MWh representing 3.4% while it records slight different in Case 9 to be 102.2 MWh which is equivalent to 4%, only which means that difference between adopting 1 Pearl and 2 Pearls is 0.6% load reduction. Figure 5.18 shows a comparison between Cases 8 and 9 with Case1 (basic case) to realize the impact of using of glazing coefficient on chiller loads. Maximum reduction of energy consumption is noticed in Case 9 which adopted 2Pearls considering that the opening area is only about 11.9% of the entire building while the whole wall area is approximately about 425.8 m2. This could be partially due to the relatively low window/wall ratio which means that the solar gain contribution to the total load is low to start with and thus not much improvement can be achieved. This passive strategy should consider the windows/wall ratio before applying to the building.

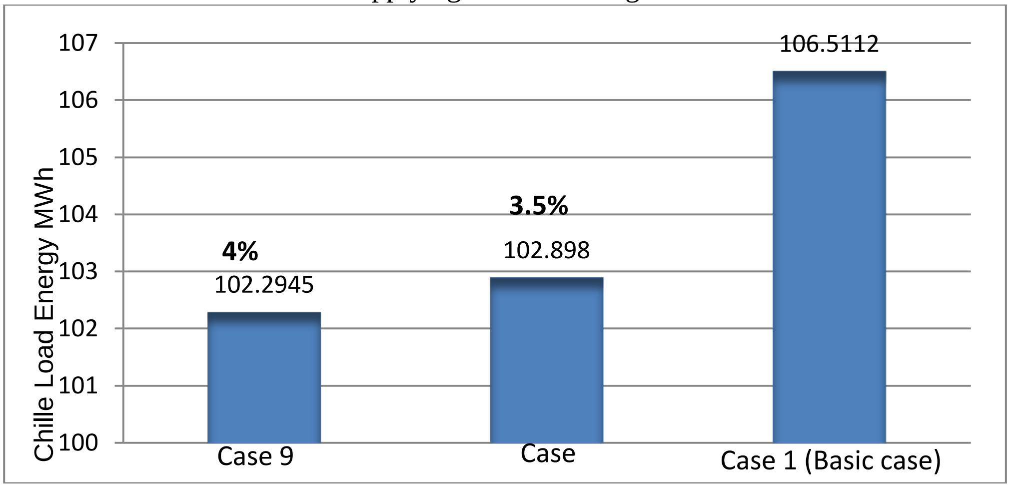

Figure 6 Chiller loads due to additional wall insulation (cases 8 & 9)

Two additional configurations were studied, Cases 10 & 11, which corresponded to complete 1 Pearl and 2 Pearl refurbishment (i.e. wall & roof insulation + glazing), respectively. Case 10 represents the “economical” refurbishment option, lower initial cost, while case 11 represents the more “energy efficient” refurbishment option. The results of Case10 show that the chillers load has been reduced from 106.5 MWh to 76.4 MWh which is approximately 28.3%. The monthly consumption data show that the biggest reduction in the energy consumption occurred in the hot months, i.e. June, July and August. Thus the reduction in the U-Values of construction elements by adding insulation materials can easily enhance the energy performance of the building. The energy demand reduction has a slight difference when going from 1Pearl to 2 Pearls thermal requirements. Overall, the energy demand reduction due to the use of the passive strategies achieved 8.2% for 1 Pear and 8.6% for 2 Pearls. Meanwhile, the cooling load achieves 28.3% for 1Parl and 29.3% for 2 Pearls. This percentage of reduction can be increased by adopting more efficient insulation materials to reduce the U-Values of the construction elements. The passive strategies can reduce the demand of energy by 8.2-8.5% in typical house in Iraq, Which means adopting these solutions as regulations for housing in Baghdad can achieve high level of electricity demand reduction generally. In addition the insulation materials are available in Iraq and can be added to the roof and wall easily to enhance the energy performance of the buildings. According to the slight difference in energy reduction between I Pearl and 2 Pearls as shown in Figure 7, it seems that adopting1Pearl is the most proper optimized case considering the benefit and the cost issues.

Table 3 shows the summary results of all 11 cases included in this study. It is clear that the most effective scenario is the addition of extra roof insulation while adding extra wall insulation and changing the glazing SHGC are second and third, respectively. The shading strategy has the least energy reduction. The data show the consumption of each case which included lighting, equipment, boiler, chillers energy and the amount of their reductions. The data illustrated the difference between 1 Pearl and 2 Pearls for each scenario. The comparisons between passive cases are based on the percentage of energy reduction and saving.

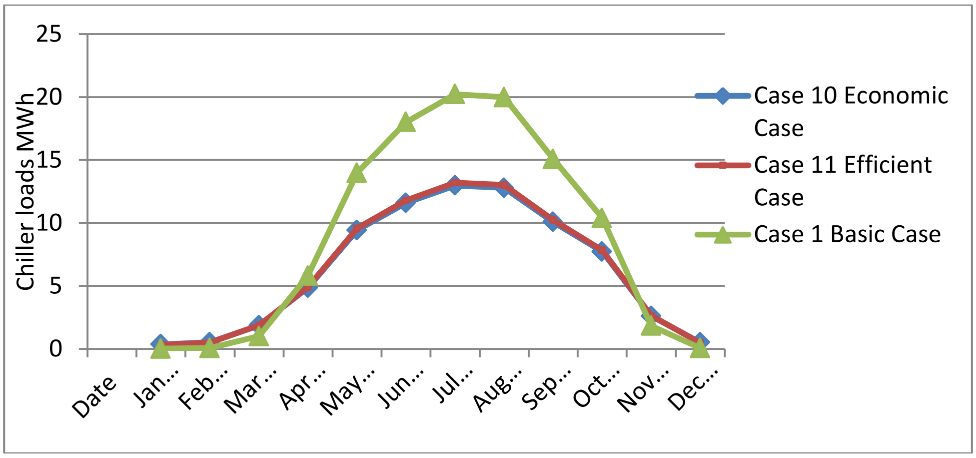

Figure 7 Comparison of the monthly chiller loads of the 1 Pearl & 2 Pearls configurations (Cases 10 & 11) with the base case configuration (Case 1)

Table 3 Energy consumption and reductin of nine cases

Cases	Chiller load (MWh)	Percentage of reduction %
Case 1 (Base Case)	106.5	NA
Case 2 (Shading by Pergola)	105.6	0.82
Case 3 (Windows shading)	106.2	0.33
Case 4 (Roof insulation 1Pearl)	94	11.7
Case 5 (Roof insulation 2Pearls)	93.9	11.9
Case 6 (Wall insulation 1Pearl)	95.7	10.1
Case 7 (Wall insulation 2Pearls)	95.5	10.3
Case 8 (Glazing 1Pearl)	102.9	3.39
Case 9 (Glazing 2Pearls)	102.3	3.96
Case 10 Economic Case	76.4	28.3
Case 11 Efficient Case	75.3	29.3

4. CONCLUSIONS

The results of simulations show that the most effected parameter is the roof insulations (1Pearl and 2Pearls) which achieve a significant chiller loads reduction among other passive scenarios. That means the roof insulation should take the priority when considering the passive solutions due to cooling loads reduction and energy saving. The second effected issue is the wall insulation. Meanwhile, the glazing system has less cooling loads reduction for 1Perl and 2Pearls. These results varied from project to another regarding the ratio of opening to walls. However, it founds that shading devices scenario has the minimum impact on cooling loads depending on the locations, and size of the shaded elements. Overall the passive strategies combined using (1Pearl) represents the economic case can achieve 28.3% chiller loads reduction. While the efficient case that adopting 2Pears have a little improvement to record 29.3% of energy reduction. The study concluding that a little benefit occurs when going from

1Pearl to 2 Pearls refurbishment level. Thus 1 Pear evaluated to be more practical and economic options.

REFERENCES

AboulNega,M. & Elsheshtawy,Y(.2001) Environmental sustainability assessment of buildings in hot climate: the case of the U.A.E. *Renewable Energy 24 (2001) 55-563* [online] Available from: http://www.sciencedirect.com/science/article/pii/S0960148101000416 [Accessed 8 May 2012]

Aboulnaga, M.(2006) Towards green buildings: Glass as a building element—the use and misuse in the gulf region *Renewable Energy* 31 (2006) 631–653 [online] Available from: http://www.sciencedirect.com/science/article/pii/S0960148105002132. [Accessed 8 June 2012]

Al-Ragom, F. (2003) Retrofitting residential buildings in hot and arid climates *Energy Conversion and Management 44 (2003) 2309–2319* [online] Available from: http://www.sciencedirect.com/science/article/pii/S019689040200256X [Accessed 17 April 2013]

Al Awadhi1,W., AlNaqbi1,A. , Manneh, A., Kazim, A., Abu-Hijleh, B. (2013) Energy Saving Potential Due to Refurbishment of Federal Public Housing in the UAE *Engineering*, 2013, 5, 132-136 [online] Available from: http://www.scirp.org/journal/PaperInformation.aspx?paperID=26647&

Dili ,A.S. Naseer, M .A Zacharia Varghese, T. (2010) Thermal comfort study of Kerala traditional residential buildings based on questionnaire survey among occupants of traditional and modern buildings *Energy and Buildings* 42 (2010) [online] Available from : http://www.sciencedirect.com/science/article/pii/S0378778810002203 [Accessed 24 February 2013

ESTIDAMA http://estidama.org/?lang=en-US [Accessed 16th August 2013]

Frontczak, M., Andersen R., Wargocki, P. (2012) Questionnaire survey on factors influencing comfort with indoor environmental quality in Danish housing *Building and Environment* 50 (2012) 56e64 [online] Available at http://www.sciencedirect.com.ezproxy.aus.edu/ [Accessed 23 February 2013]

Gong ,X., Akashi ,Y. and Sumiyoshi, D.(2012) Optimization of passive design measures for residential buildings in different Chinese areas *Building and Environment* 58 (2012) 46e57 [online] Available from: http://www.sciencedirect.com/science/article/pii/S0360132312001734 [Accessed 10 Jun 2013]

Kaklauskasa. A, , Rutea. J, E, Zavadskasa, Daniunasa. A, Pruskusa. V, Bivainisa. J, Gudauskasb. R, Plakysa. V (2012) Passive House model for quantitative and qualitative analyses and its intelligent system *Energy and Buildings 50 (2012) 7–18* online] Available from: http://www.sciencedirect.com/science/article/pii/S0378778812001569 [Accessed 19 March 2013]

Ralegaonkar, R, & Gupta, R. (2010) Review of intelligent building construction: A passive solar architecture approach *Renewable and Sustainable Energy Reviews* 14 (2010) 2238–2242 [online] Available from: http://www.sciencedirect.com/science/article/pii/S1364032110001279 [Accessed 11 Junary 2013]

Stevanović, S. (2013) Optimization of passive solar design strategies: A review *RenewableandSustainableEnergyReviews25 (2013)177–196* [online] Available from: http://www.sciencedirect.com/science/article/pii/S1364032113002803 [Accessed 24 May 2013]

U.N (2009). Meeting Coverage [online]. United Nations, Department of Public Information, News and Media Division, New York: [accessed 21 October 2011] Available at http://www.un.org/News/Press/docs/2009/envdev1069.doc.htm