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The Application of Building Modifications and their Effects on Energy Consumption in Buildings

Ali Fathi El Bakkush
Centre of Excellence for Sustainable Building Design, School of Energy, Geoscience, Infrastructure and Society. Heriot-Watt University-UK.

Francis K. Bondinuba (Corresponding author)
Institute for Social Policy, Housing, Environment and Real Estate (I-SPHERE) School of Energy, Geoscience, Infrastructure and Society, Heriot-Watt University-UK.

Douglas J. Harris
Centre of Excellence for Sustainable Building Design, School of Energy, Geoscience, Infrastructure and Society. Heriot-Watt University-UK.

Abstract
A huge amount of energy is used for air-conditioning in residential buildings in hot climates. Passive design features such as shading and advanced glazing can help to reduce energy use and carbon emissions, and thus mitigate the impact on climate change. This paper aimed at demonstrating how the application of selected modification devices such as solar films and shading devices affects the energy consumption patterns and levels in a residential building. A model of a building was constructed with VE using "Model IT" module, which was then analysed in a variety of different ways. A Virtual Integrated Environmental Solutions (IES-VE) was used to assess the energy gain and consumption parameters such as solar gains, shading devices, solar cloud and chilli clouds in residential buildings in Tripoli, Libya. The findings indicate that the best way to control and reduce the energy gains pattern in a building is to introduce energy modification devices such as shading device, solar films, emissivity paints and roof slab absorbers among others. In specific terms, the best device would be the application of external solar film, follow by shading device and internal solar film. An application of emissivity paints and roof slab absorbers does not contribute significantly to the energy reduction in the building. The study concludes that the application of modification devices in buildings can reduces the heat gain significantly. This study underscores the need and importance of the applications of energy modification devices in buildings in order to reduce their energy gains in the context of tropical regions. Though the climatological characteristics of tropical regions are similar, the generalisation of the findings in this study requires caution since the findings are limited in geographical context. Future research should also explore the impact of urban forms, street layout and orientation on solar penetration and energy use in buildings.
Keywords: Architecture, Buildings, Climate change, Energy consumption, Energy gains, Libya

1. Introduction

The issue of energy gains and use in buildings in the built environment are teething issues which has gained a wider global attention (*cf.* Santamouris *et. al.,* 2001; Torcellini *et.al.,* 2006; Rijal *et. al.,* 2007; du Can and Price, 2008). In the tropical regions such as Tripoli in Libya, there is a growing concern about energy use in buildings and its likely adverse effect on the environment ((Ealiwa *et.al.,* 2001; El-Osta and Kalifa, 2003; Chowdhury *et.al.,* 2008). Although Libya has a lot of indigenous fuels of her own and need not rely on imported fossil fuels such as coal, natural gas and oil products, the increase in economic growth has been marked with an increase in energy consumption. Buildings, in addition to offering shelter and fulfilling aesthetic requirements, should provide conditions of comfort for their occupants. During summer, especially in hot climate, buildings are exposed to high intensities of solar gain, which may result in over-heating, causing discomfort to users. Under such conditions, energy conservation in the building is very important. The energy conservation processes can include diverse measures from simple natural cooling techniques, evaporative cooling and natural ventilation, to mechanical cooling systems (Santamouris and Asimakopoulos, 1996). Natural energy conservation systems which involved natural methods such as breezes flowing through windows, water evaporating from trees and fountains, as well as large amounts of stone and earth absorbing daytime heat are well known methods used particularly in developing countries. These ideas were developed over thousands of years as an integral part of all building designs and are known by many (*cf.* Givoni, 1991; Santamouris and Asimakopoulos, 1996; Breesch *et. al.,* 2005; Hatamipour and Abedi, 2008) as "passive cooling". These researchers further argue that by engaging passive cooling techniques in new buildings, the designer can often eliminate the need for mechanical cooling or at least reduce the size and cost of the cooling equipment and therefore reduce the overall cost of the cooling and energy conservation bill.

Despite these cost effective natural systems of energy conservations as suggested earlier by (Watson, 1979; Fathy, 1986), modern building designers often use a wide range of technologies to reduce the amount of energy that buildings need for cooling and energy conservation (Florides *et.al.,* 2002; Hughes *et.al.,* 2011). These modern technologies includes the application of shading device, external solar film, internal solar film, emissivity paints, roof slab absorbers among others. In the case of Tripoli during the summer, various sources of heat gain have to be dealt with, which includes direct solar radiation from outside, ventilation, and internal heat gains from inside the building such as lighting and other equipment. The estimation of the energy gains and consumption of buildings has received significant attention in the past few years, with the dual goal of reducing energy cost (cost concerns), and reducing the amount of greenhouse gases released in the atmosphere (environmental concerns). However, there is also limited research into how these heat or energy gains could be minimise to make occupants not only comfortable but less costly to them. Several methods and tools can be used to evaluate the energy gains and consumption in buildings, ranging from simple spreadsheets to full computer simulation programs. Also, there is still limited research in the context of Libya about the solar gains on an existing building.

2. Building Energy Conservation Strategies in Architecture

The issue of energy conservation is important in architecture simple because it is the greater consumer of the energy used throughout the world (Li and Colombier, 2009; Dixit *et. al.,* 2010). In the most advanced countries, from 35% to 40% of the total overall main use of energy is spent in buildings, a figure which approaches 50% when taking into account the energy costs of building materials and the infrastructure to serve building (Aitken, 2003). Buildings have traditionally been seen as energy and resource consumer. However, a new view is emerging in which newly designed buildings aim at making them a net contributor to the energy supply system by dropping their energy demand and act as energy supply source (Pitts, 2008). Langston, (2012) suggests that the main energy used in buildings is for heating, cooling and lighting. Meanwhile, Jarmul, (1980) suggests earlier that one major challenge facing designers and users of buildings is how to contain or prevent both heat lose and gains through the building envelope. This is especially during winter and summer periods. The energy consumption pattern in building are affected by so many factors and variables such as its design, the environment in which it is located and the way in which it is being use and operated.

In order to achieve the heating, cooling and lighting goals of buildings, there are three require perspectives that come into consideration. These are architectural design, natural energy, and mechanical equipment requirement perspectives. The architectural design perspectives of the building are concern with the minimization of heat loss during winter, heat gain in the summer and the use of light efficiently throughout the life span of the building. Any poor or unprofessional design decisions taken at this stage can easily double or triple the cost and the size of mechanical equipment requirement in particular and the energy requirement and usage in the building. The second perspective involves the use of natural energy conservation methods such as passive heating, cooling, and daylighting systems. A good decision at this point can greatly reduce the unresolved problems arising from the architectural design perspectives. The mechanical equipment requirement perspectives are achieved through the adaptation of non-renewable energy sources to handle the loads that remain after the two perspectives described above to reduce the loads as much as possible (Pehnt, 2006)

There are so many main sources of factors influencing the energy use in buildings in the built environment. These are factors arising from the building services, building envelope, the climate and human factors as showed in figure 1. Whiles the building envelope is influenced by factors such as location, orientation, size, built form, shape/layout, the building services are influenced by the type and size of systems, type of energy need and supply, plant efficiency, plant control, operating regime among others. Human factors include comfort requirements, occupancy regime, human activities, management and maintenance. The energy used in building is central to any strategy adopted to conserve the energy supply and demand with the aim of contributing to the current effort of reducing global warming. Many have therefore suggested that, the impacts of buildings upon the energy consumption and global warming comes in four separate folds. These are the production of materials and products used in constructing the building, the fabrication and construction process, the heating, cooling, ventilation, and lighting of the buildings in use (Edwards, 1995). The most important drivers of growth in energy gains and consumption in buildings are population growth (which effects on total consumption) poor residential building design increased interest of energy appliances in households to improve amenity (Price *et .al.,* 1998; Roth *et.al.,* 2002). Such practices are very prevalence in Libya.

2.1 The Building as an Energy System

A building can be describe in several ways including its being a concrete blocks insulation with windows, heating, cooling and ventilation systems. Its energy system requirement must consider the social interactions between the occupants, environment and the building. The activities that take place in and outside the building either generate or gain heat through so many ways. For instance, (Liu and Harris, 2013) suggests that heat transfer particularly convective heat is influence by the temperature, the speed and direction of the wind of the building surroundings. The influential factors influencing the thermal performance of a building are as shown in figure 2. These factors inevitably need careful considerations during the design, construction and maintenance period of the building.

2.2 The Energy consumption pattern in Libya

Libya's consumption of electrical energy in particular is distributed into four major sectors: the industrial sector, the agricultural sector and the residential and commercial sectors as shown in figure 3. Close to 40% of the total primary energy in Libya is used in power generation and almost 100% of the fuel used to generate power is from fossil fuel and 0% renewables (GECOL, 2013). It is well recognized from the above figures that residential and industrial buildings account for a large percentage of all delivered energy consumption in the country. Although Libya is an oil producing country, there is an energy crisis in Libya for many reasons that include extensive use of conventional energy sources which are leading to their depletion, and the increase in the individual annual consumption of electrical energy. Again, most of the energy consumption is of non-renewable sources while the use of renewable sources is still in the foundation stages. There is inefficiency in electricity generation, which could lead to depletion of oil reserves in the near future. The total CO_2 emissions in Libya are around 60 million tonnes CO_2 per year (55% due to oil and 45% due to Natural gases) (GECOL, 2013) as shown in figure 4.

2.3 Climatological analysis of the city of Tripoli

The city of Tripoli lies on the far north of the continent of Africa overlooking the Mediterranean Sea. The ordinates of the city are within latitude 32^{o}47" N and longitude 13^{o}04" E respectively. The city is classified as a hot dry climate usually being found around latitudes 20° and 35°. The main shelter challenges facing inhabitant in such regions is overheating. The mean summer temperatures are around 25^{o}C but can reach a maximum of 45^{o}C. However, clear nocturnal skies sometimes cool the temperatures down to as low as -10°C. The building studied is located in the city of Tripoli, which incidentally is only 21Km north of the area where the hottest air temperature ever recoded of 58°C (Hocine and Sharples, 2010). Table 1 show the yearly temperature condition readings for the average minimum and average maximum daily temperatures of the city where the building is located.

2.4 The effects of solar gains, chiller clouds and CO_2 on the building

In a tropical region such as Tripoli, the indoor comfort depends largely on so many factors such as air temperature, air humidity and air movement. The convective heat removed makes up the sensible cooling load, and the excess water vapour removed constitutes the latent cooling load. The cooling load of the space within a building according to (Zain-Ahmed *et. al.,* 2002.p.1725) is *the heat that must be removed by mechanical means to maintain the space at the desired conditions.* They further argue that whiles the external heat gains in building consist of the solar radiation conducted through the opaque building materials and transparent openings, the internal heat loads are caused by the occupants, artificial lighting and mechanical and electrical equipment

The importance and paybacks on light roof colour has gain the attention of many especially in areas where the sun is right overhead single story buildings (Eilert, 2000). Also, Parker *et.al.,* (1996) Parker *et.al.,* (1997) demonstrates in a study of Florida homes in which after the application of a reflective roof coatings the space cooling requirements decreased by 19% and the interior comfort was also improved after the grey bitumen roof surface was painted white. In another study (Suehrcke, 2001) also demonstrate with the use of numerical simulation that the peak values of heat flow from a roof could be reduce by as much as 60% when a white surface replaces a corroded galvanised one. It has been argue that the thermal performance of a building is affected by the solar absorptance of the roof and other parts of the building. Suehrcke *et.al.,* (2008.p.2224) supports this argument that *during clear sky conditions up to about 1 kW/m^2 of solar radiation can be incident on a roof surface, and between 20% and 95% of this radiation is typically absorbed*. Black surface with low visible reflectance often suggests a high solar absorptance and this indicates that the colour of roof gives an indication of the value of solar absorption in buildings. The above studies attest to the fact that heat flow from roof can be significantly reduces by the application of modification devices.

The issue of carbon dioxide (CO2) emission has become a major concerned for researchers and policy makers in both developed and developing countries all over the world. It is reported that in 2004, the total emissions of CO_2 from residential and commercial buildings were 2236 million metric tons which was more than either the transportation or industrial sectors in USA (USGBC, 2008; Hartgen *et.al.,* 2011). It is again projected that in the next 25 years, CO_2 emissions from grow faster than any other sector, with emissions from commercial buildings projected to grow the fastest. Modern technology has made it possible for the easy quantification of the amount of CO_2 as a *gauge* to enable and ensure ventilation systems are design and delivered to the recommended minimum quantities of outside air to the building's occupants (Prill, 2000).

3. Methodology

The paper adopted computer simulation software that was validated via comparison between the field measurements and the simulation results for the hot period. The calibration model shows that the difference between them was less than 1°C. Virtual Environment by Integrated Environmental Solutions (IES-VE) is a modern example of dynamic building energy simulation software which was used for the simulation. IES-VE consists of a suite of integrated analysis tools, which can be used to investigate the performance of a building either retrospectively or during the design stages of a construction project figure 6. IES enables the specific understanding of the site to automatically outline suitable bioclimatic architecture strategies for the project; such as pre-design sustainability direction among others. The selected building was a renovated project which enables IES-VE to identify the best passive solutions, comparing low-carbon technologies, and drawing conclusions on energy use, CO_2 emissions, occupant comfort, light levels, and much more. IES-VE for engineers also allows easily visualising and communicating results at a highly detailed level. A carefully and cautiously building details and materials where used in the construction of the building where input to the IES software for the dimensions of windows, openings, which were all incorporated in the program as shown in figure 7.

Calculations were done for the position of the sun in the sky, tracks solar penetration throughout the building interior and shadows were all done. Using a central simulation process enables the user to assess every aspect of the thermal performance as well as share results and input across a wide variety of other VE engineering modules. The building was modelled by IES software as far as possible exactly as it was on the site with no major changes, except those inevitably required by the conditions of modelling. Once the base model was simulated and validated, modifications to the building were simulated through four steps. The first step involves the provision and application of shading device on both sides of the east and west elevations of the building. This was followed by placing an external and internal solar film on the glazing with low transmission ones. Thirdly the roof was painted with white lower emissivity paints and finally a concrete roof slab insulation absorber was added to the roof slab. Figure 9 show the building after the addition of 700 x 700 x 100mm thickness horizontal and vertical shading devices.

4. Discussions of the simulation results

4.1 Solar gain result

Figure 10 show the south, east, north, west and roof simulation results for the outer surface solar gain in KWh/m^2. The east façade was in the average of 3.81KWh/m^2, while the ground floor on the south façade was less than the first floor with 1.25KWh/m^2 compared to the first floor with 2.28KWh/m^2. The roof is the biggest absorber of heat gain in the building with figures above 7.61KWh/m^2. The North façade has the lowest heat absorption among all the elevations with less than 0.76KWh/m^2, and the west façade had almost the same as the east façade with 3.81KWh/m^2. After simulating the building to ascertain the solar gains for the whole year and comparing the figures with the modification simulation figures as depicted in table 2. It shows that the building for the period of summer, solar gains was above 4.5MW/h. It's also shows the solar gains of 51.4697 MW/h presumably this is 100% into the building. However, after the additions of the modification mechanisms, the results shows that 18.5% of solar gain could be reduce by just adding a shading device on the eastern and western facades of the building. Also, the impressive results shows that by adding an external solar film to the glazing width can reduce the solar gains by 62%. Moreover, painting the roof with white colour paints and adding roof slab absorber could not change the results in any significant way. Additionally, an application of an internal solar film on the glazing also reduces the solar gains by extra 3% bringing the total solar gains reduction to about 65%. Table 1 depicts the simulation results for the solar gain figures for each additional modification device to the building. To make it more clear figure 11 shows a significant impact on reducing the solar gains of the various measures and modification mechanisms.

4.2 Chillers louds

One of the largest energy user units in a typical building is air-conditioning. Figure 12 shows how the changes can affect the chiller loads which could lead to savings on energy consumption of varying degrees according to the modifications made to the building. Table 2 shows the total chiller load for each month during the year, which indicates the building uses 56.94MW/h before the modification. However, after the addition of the shading devices, the chiller loads reduces by 15.8% of the total chiller load. Therefore, for the best savings to be achieved, an addition of an outside solar film on the glazing saves up to 45.2% of the total chiller loads. Furthermore, adding to the roof lower emissivity paints and slab absorber would add not more than 1% extra savings. While 2% more can be saved by adding internal solar film on glazing, this is probably not worth doing since the impact of natural lighting to the building could also offsets such gains.

4.3 CO2 produced by the building

From global viewpoint, the most important aspect or concern was to analyse how much the building under study could make some savings in the production of CO_2. Figure 13 clearly indicates how much savings of CO_2 in Kg each month that could be made on the building for the whole year. It is clear that summer times are the peak CO_2 production time simple because the building uses air-conditioning more than the rest of the year. The higher the temperature increase during such periods the more the production of CO_2 and this often results in a positive relationship. Table 4 shows the total amount of CO_2 in Kg for each month during the year. The results show that the building produced 62995Kg CO_2 yearly. However, after the addition of the shading devices, it became 60644Kg, indicating a reduction of 3.8% less than the total. It also reduces by 11.20% to become 55951Kg, after adding external solar film. Moreover, the rests shows that adding roof lower emissivity, roof lower slab absorber, and solar film inside the glazing could not change more than even 0.5%.

4.4 Chiller energy

Figure 14 shows the chiller energy for the whole year, illustrating that the greatest use of energy is in summer time, especially July to October. The energy consumption starts from March and increase gradually to reach the peak in August, and then retreats gradually until October and falls in November. In winter time it starts from December to February and chiller energy is almost non-existent or insignificant compared to the summer months. Chiller energy is one of the things that the study was able to reduce approximately by half of the total. Table 4 shows the simulation results for the whole year. Before the application of the devices, the building uses 22.78MWh/year and after the application of the shading devices it became 19.25MWh/year, representing a 15.6% reduction. Huge reduction was achieved after placing solar films on the lower transmission outside the glazing with 45.20% to 12.49MWh/year. For more reduction solar film can be placed inside the glazing and this could reduce it by extra 2%.

5. Conclusion

In order to measure the energy use in a building, the chiller energy use has often been used as the main benchmark. From the simulations results as compare with that of the unstimulated, the following conclusions could be made. It could be concluded that the best way to control, reduce the energy consumption pattern in a building is to introduce energy modification devices such as shading device, external solar film, internal solar film, emissivity paints, roof slab absorbers among others. In specific terms, the best device for reducing solar gains would be the application of external solar film, follow by shading device and internal solar film. An application of emissivity paints and roof slab absorbers would amount to waste of resources. Similarly for chiller louds reduction, the best device would still be the application of external solar film, follow by shading device and internal solar film. An application of emissivity paints and roof slab absorbers would still not add much and therefor would consider as waste of resources.

External solar film devices are again suitable mechanism for the reduction of CO2 in buildings. This is followed by shading device and the rest may not contribute and significant values in this regards. Surprisingly internal film device stand out to be the best device for chiller energy reduction in buildings. This is also followed by external solar film and shading device. The contribution of emissivity paints and roof slab absorbers are again insignificant. Finally and more importantly, the application of both external solar film and shading devices would together reduce the effects of energy consumption in buildings significantly. How, an addition of internal solar film device would complete in some cases particularly in the reduction of solar gains and chiller energy. Future research should also explore the impact of urban forms, street layout and orientation on solar penetration and energy use in buildings.

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Table 1: The simulation results for the building solar gain.

Solar Gain (MWh)						
Date	**Before shading devices**	**After shading**	**Glazing outside lower Transmission (solar Film)**	**Roof lower emissivity (paint white)**	**Roof lower slab absorb**	**Glazing inside lower transmit (solar film)**
Jan 01-31	3.6635	2.9811	1.3679	1.3679	1.3679	1.2625
Feb 01-28	4.2717	3.3177	1.5138	1.5138	1.5138	1.3960
Mar 01-31	4.6725	3.6413	1.6920	1.6920	1.6920	1.5662
Apr 01-30	4.6347	3.7567	1.7473	1.7473	1.7473	1.6167
May 01-31	4.5811	3.9543	1.8370	1.8370	1.8370	1.7001
Jun 01-30	4.5549	4.0155	1.8561	1.8561	1.8561	1.7174
Jul 01-31	4.5493	3.9519	1.8455	1.8455	1.8455	1.7092
Aug 01-31	4.6540	3.7503	1.7717	1.7717	1.7717	1.6424
Sep 01-30	4.6060	3.5556	1.6666	1.6666	1.6666	1.5436
Oct 01-31	4.8113	3.6846	1.7467	1.7467	1.7467	1.6213
Nov 01-30	3.5165	2.8613	1.3301	1.3301	1.3301	1.2295
Dec 01-31	2.9544	2.4766	1.1675	1.1675	1.1675	1.0814
Total	**51.4697**	**41.9468**	**19.5420**	**19.5420**	**19.5420**	**18.0863**
%	**100%**	**-18.5%**	**-62.00%**	**-62.00%**	**-62.00%**	**-64.86%**

Table 2: Chillier load figures for each additional adding on the building.

Chiller Load (MWh)						
Date	**Before shading devices**	**After shading**	**Glazing outside lower Transmission (solar Film)**	**Roof lower emissivity (paint white)**	**Roof lower slab absorb**	**Glazing inside lower transmit (solar film)**
Jan 01-31	0.6647	0.4506	0.0379	0.0379	0.0379	0.0379
Feb 01-28	1.0130	0.6003	0.1039	0.1039	0.1039	0.0939
Mar 01-31	2.5839	1.6763	0.5394	0.5423	0.5359	0.5004
Apr 01-30	3.9747	3.0220	1.2925	1.2620	1.2608	1.1799
May 01-31	5.3953	4.6359	2.5902	2.5644	2.5526	2.4252
Jun 01-30	6.2117	5.5248	3.4344	3.3687	3.3590	3.2363
Jul 01-31	8.1078	7.3182	5.2971	5.2414	5.2319	5.1029
Aug 01-31	8.9501	7.8493	5.9582	5.9058	5.9002	5.7843
Sep 01-30	8.5826	7.4236	5.6161	5.5920	5.5812	5.4678
Oct 01-31	7.8018	6.6190	4.7862	4.7794	4.7714	4.6475
Nov 01-30	3.1922	2.6099	1.4557	1.4692	1.4666	1.4229
Dec 01-31	0.4602	0.3398	0.1044	0.1044	0.1044	0.1004
Total	**56.9381**	**48.0697**	**31.2159**	**30.9714**	**30.9058**	**29.9993**
%	**100%**	**-15.6%%**	**-45.2%**	**-45.6%**	**-45.7%**	**-47.3%**

Table 3: CO2 figures for each additional modification devices to the building

Total system CE (kgCO2)						
Date	Before shading devices	After shading	Glazing outside lower Transmission (solar Film)	Roof lower emissivity (paint white)	Roof lower slab absorb	Glazing inside lower transmit (solar film)
Jan 01-31	3997	3998	4058	4050	4052	4072
Feb 01-28	3731	3670	3697	3696	3697	3714
Mar 01-31	4645	4367	3980	3981	3979	3972
Apr 01-30	4999	4728	4148	4136	4136	4104
May 01-31	5580	5368	4729	4722	4719	4675
Jun 01-30	5701	5512	4873	4852	4849	4810
Jul 01-31	6403	6184	5575	5561	5557	5517
Aug 01-31	6649	6344	5776	5762	5761	5726
Sep 01-30	6405	6085	5543	5536	5532	5497
Oct 01-31	6282	5954	5406	5403	5401	5361
Nov 01-30	4721	4552	4174	4178	4177	4164
Dec 01-31	3881	3882	3993	3978	3981	3999
Total	**62995**	**60644**	**55951**	**55856**	**55842**	**55611**
%	**100%**	**-3.8%**	**-11.2%**	**-11.3%**	**-11.4%**	**-11.7%**

Table 4: Shows chillier energy simulation results

Chiller Energy (MWh)						
Date	Before shading devices	After shading	Glazing outside lower Transmission (solar Film)	Roof lower emissivity (paint white)	Roof lower slab absorb	Glazing inside lower transmit (solar film)
Jan 01-31	0.2659	0.1802	0.0152	0.0152	0.0152	0.0152
Feb 01-28	0.4052	0.2401	0.0416	0.0416	0.0416	0.0375
Mar 01-31	1.0336	0.6705	0.2158	0.2169	0.2143	0.2002
Apr 01-30	1.5899	1.2088	0.5170	0.5048	0.5043	0.4719
May 01-31	2.1581	1.8544	1.0361	1.0257	1.0210	0.9701
Jun 01-30	2.4847	2.2099	1.3738	1.3475	1.3436	1.2945
Jul 01-31	3.2431	2.9273	2.1188	2.0966	2.0928	2.0411
Aug 01-31	3.5801	3.1397	2.3833	2.3623	2.3601	2.3137
Sep 01-30	3.4330	2.9694	2.2465	2.2368	2.2325	2.1871
Oct 01-31	3.1207	2.6476	1.9145	1.9118	1.9086	1.8590
Nov 01-30	1.2769	1.0440	0.5823	0.5877	0.5866	0.5692
Dec 01-31	0.1841	0.1359	0.0418	0.0418	0.0418	0.0402
Total	22.7753	19.2279	12.4864	12.3886	12.3623	11.9997
%	100%	-15.6%	-45.2%	-45.6%	-54.8%	-47.3%

Table 5: Summary of the results after application of the modification devices

Modification devices Before	Solar gains reduction	Chiller louds reduction	CO_2 reduction	Chiller energy
	51.47MW/h	56.94MW/h	62995Kg	22.78MW/h
Shading device	18.50%	15.80%	3.80%	15.60%
External solar film	62.00%	45.20%	11.20%	45.20%
Internal solar film	3.00%	2.00%	0.50%	47.30%
Emissivity paints	0.00%	1.00%	0.50%	0.00%
Roof slab absorber	0.00%	1.00%	0.50%	0.00%

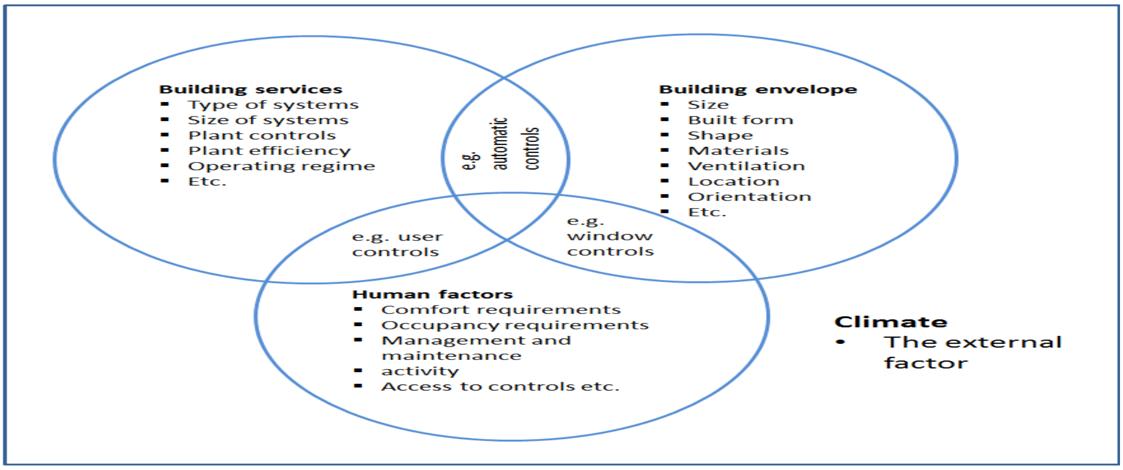

Figure 1: Key factors influencing energy use in buildings

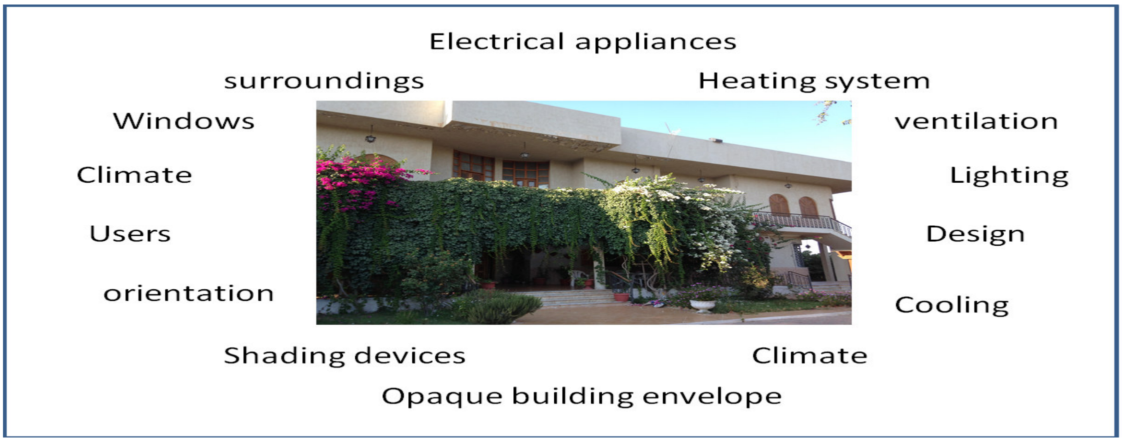

Figure 2: Different aspects and their effect on the energy need of a building

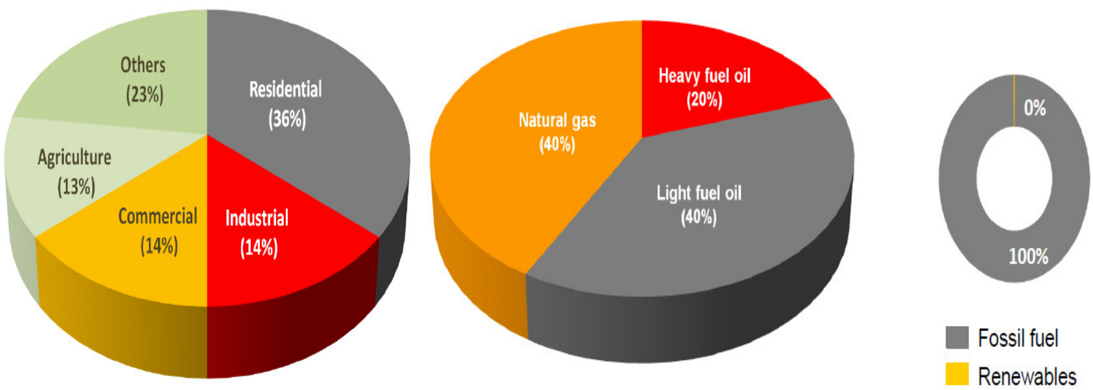

Figure 3: Electricity consumption per sector and by fuel type in Libya, Source: GECOL, (2013)

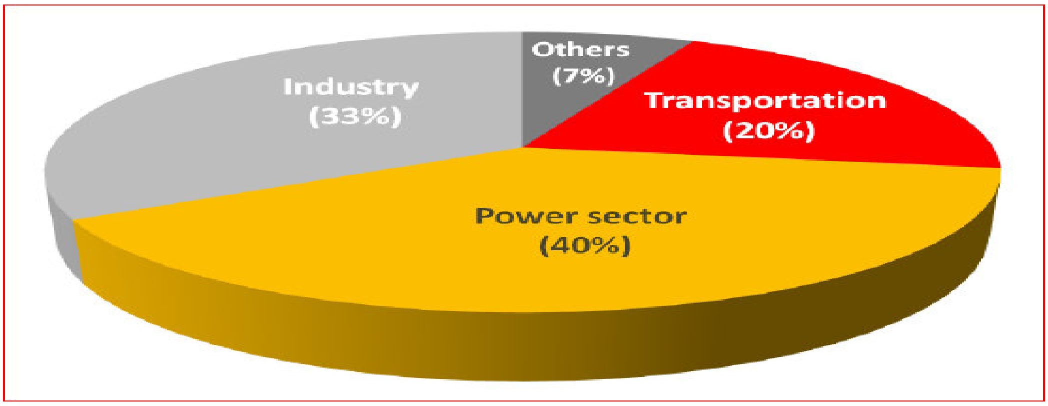

Figure 4: CO_2 emissions in Libya, Source: (GECOL, 2013)

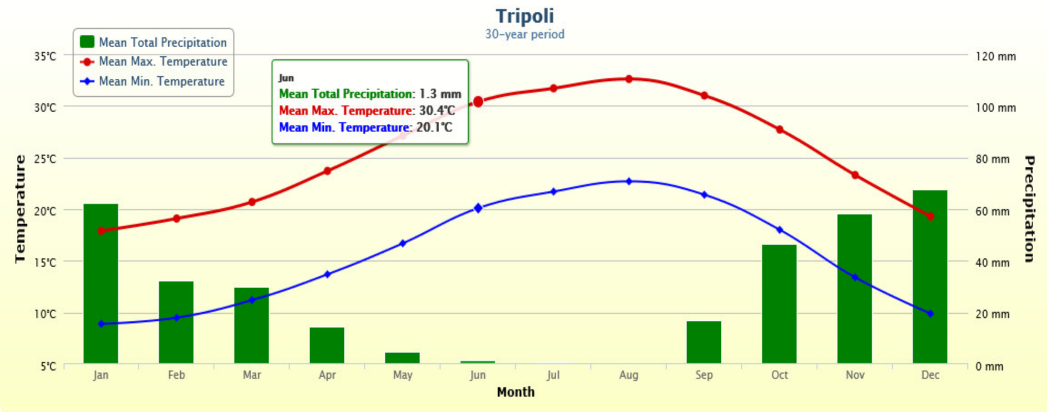

Figure 5: Ambient temperature in Tripoli, Source: World Meteorological Organization, (2014)

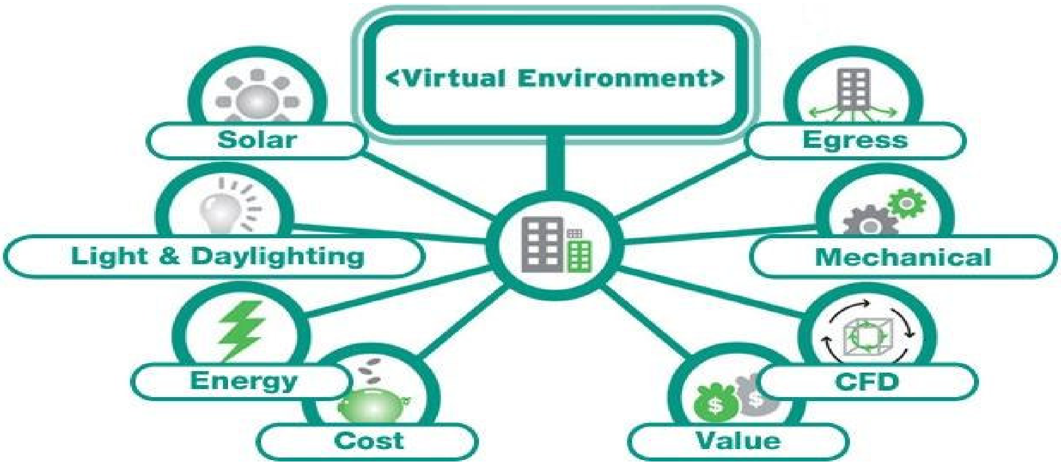

Figure 6: How the IES program works

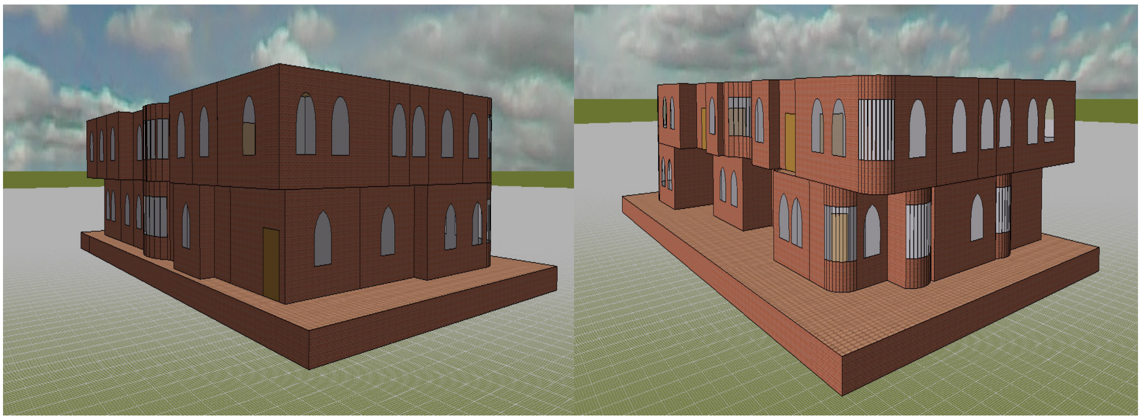

Figure 7: South and east and north and west elevations of the building after modelling it with IE

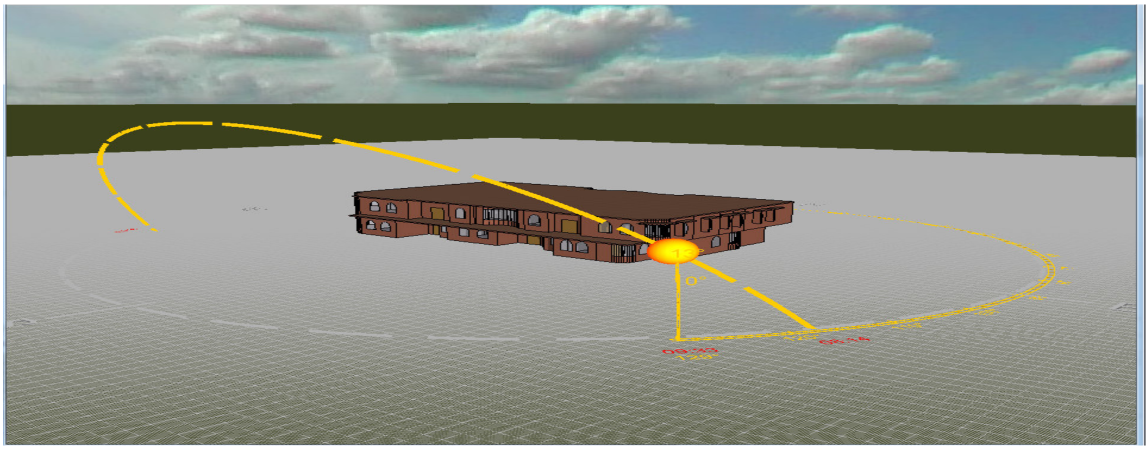

Figure 8: The building while the sun cast is calculated

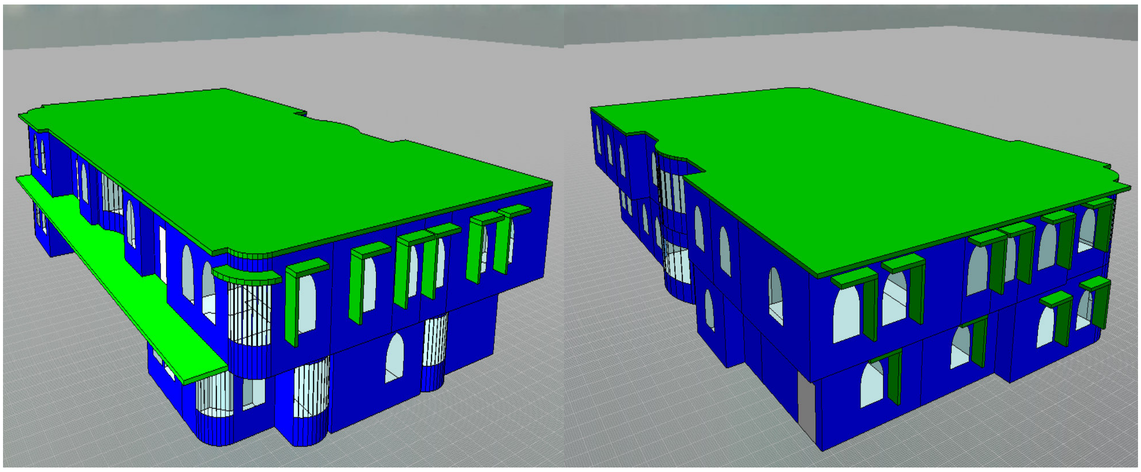

Figure 9: The south and east, north and west elevations of the building after adding shading

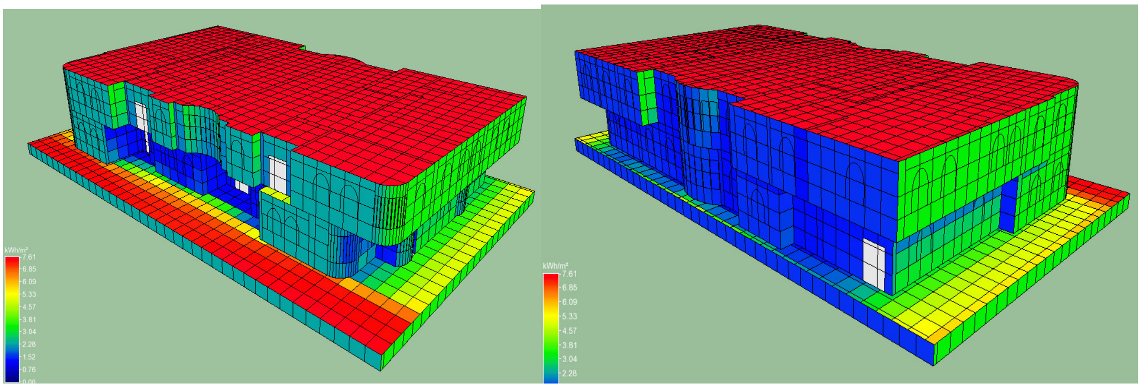

Figure 10 South and East, North and West and roof solar gain simulation result

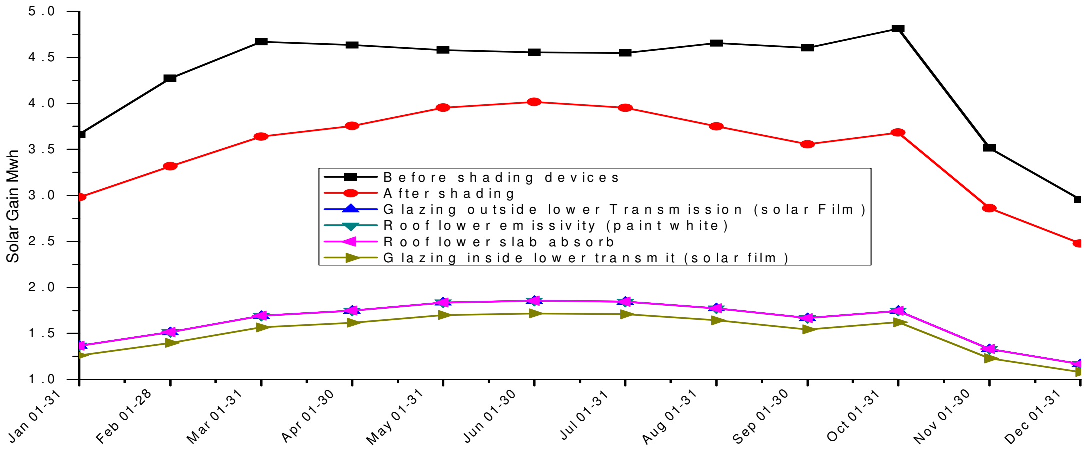

Figure 11: The building monthly solar gain.

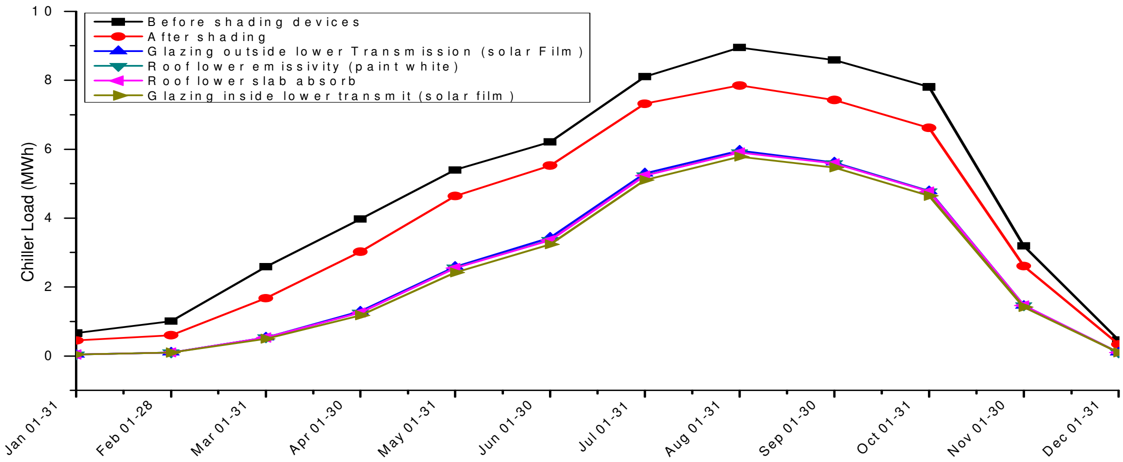

Figure 12: Building chiller loads per MWh

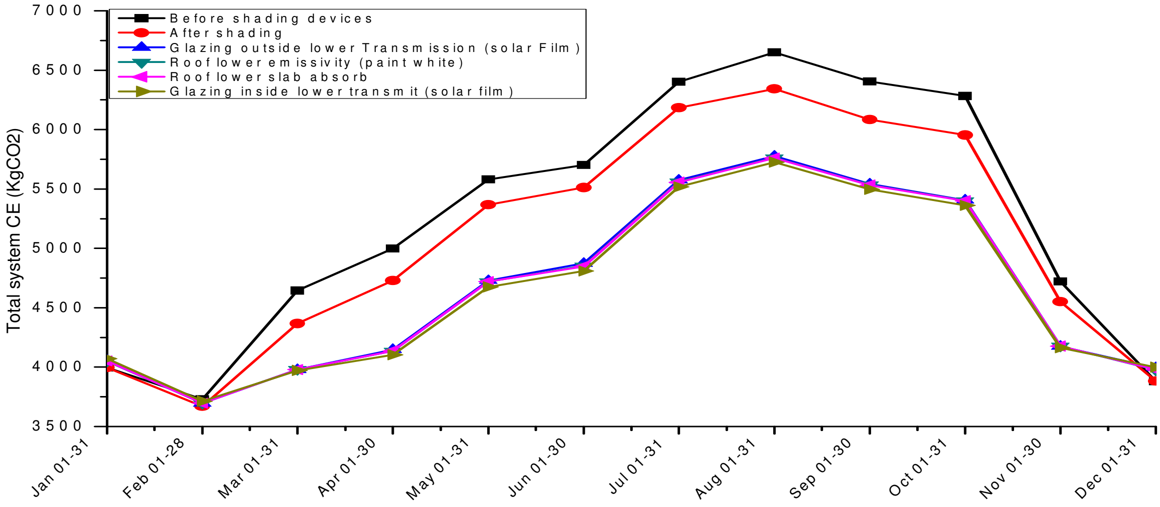

Figure 13: The total CO_2 produced by the building

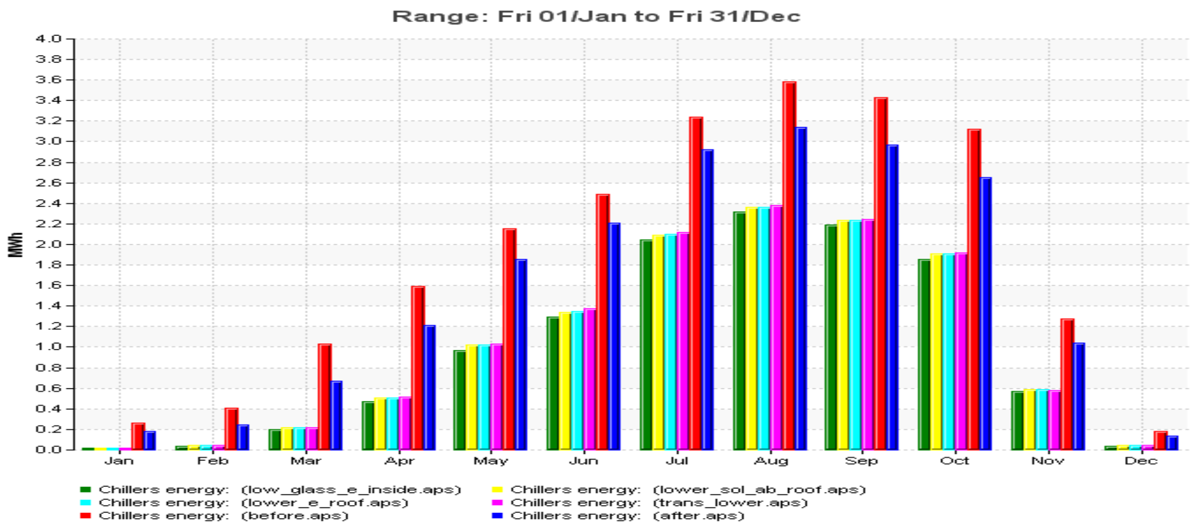

Figure 14: shows the chillier energy for the whole year