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# Shading Percentage Effects on Energy Consumption for Bahraini Residential Buildings

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***Abstract*****—**Energy consumption is a very important topic these days especially regarding air conditioning in residential buildings, since this takes the biggest amount of energy in buildings total consumption, residential buildings constitute the biggest percentage of energy consumption in Bahrain.

This research reflects on the effects of shading percentage in different solar orientations on the energy consumption inside residential buildings (domestic dwellings).

The research as found that, there are different effects of shading in changing building orientation:

- 0.69% for the shading percentage 25% when the building is oriented to the north (0º);
- 18.59% for 75% of shading in north-west orientation (325º);
- The best effect for shading is in north-west orientation (315º);
- The less effect for shading was in case of the building orientation is the north (0º).

***Keywords*****—**Bahraini buildings, Building shading, energy consumption, residential buildings, shading effects.

## I. Introduction

THE problem of energy consumption is becoming one of the most relevant research issues all over the world. The pollution caused by the consumption of fossil fuels and the general shortage of energy sources as increased generally. This condition encourages many researchers in researching on reducing energy consumption in different fields.

Reducing energy consumption has turn out to be a key issue in most energy policies, especially for buildings as one of the highest energy consumers. [1]

Designing buildings that consume less energy has become extremely important, and the ability to evaluate buildings energy consumption before construction can save money in design changes. [2]

According to the data of US Energy Information Administration, Fig. 1 shows that since the year 2000, the world energy usage has and will increase tremendously. [3]

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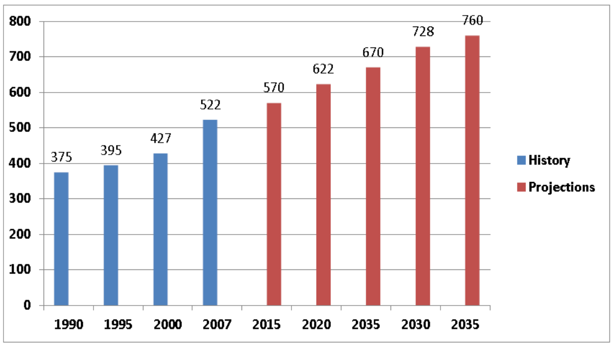



Fig. 1 World marketed energy consumption, 1990-2035 [3]

In the Kingdom of Bahrain, energy consumption has risen, between 1998 and 2007, from 5,773 GW to 10689 GW. According to Bahrain Ministry of Electricity & Water [4] Residential buildings in Bahrain consumed 54.5% of the total energy use (Fig. 2), with an increasing rate of 7.5% in energy consumption every year. [4]

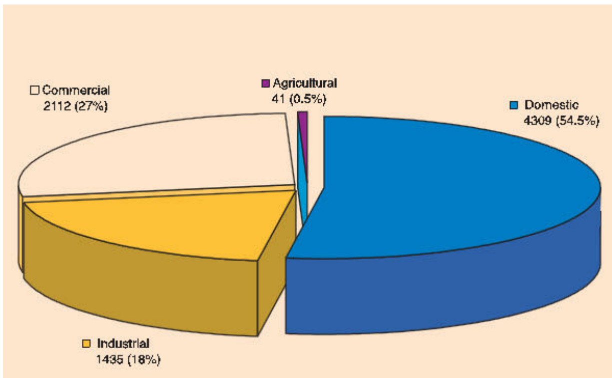



Fig. 2 Sectorial Consumption of Electricity in Bahrain [4] (BMEW, 2005)

## II. Previous Studies

Many studies have taken place for the effects of shading. Some of these studies will be discussed in this research as follows:

A- Justin Shultz, L. W., and Je_rey R. [5] studied the shadings' effect. They found that Solar Panels shade the roofs of buildings reducing 0.57% of the cooling demand and 0.4% the electricity bill in the month of July. Another important conclusion was that, locating a large tree to the south of the building could save approximately 4.7% in cooling demand and 3.3% on the electricity bill in the month of July. Justin Shultz studies did not include the effect of the building's change orientation.

B- Geoffrey H. Donovan and David T. Butry, [6] have studied the shade's value by estimating the effect of urban trees on summer time electricity use. They also concluded that Trees provide significant carbon benefits both directly and indirectly. Because homeowners have no knowledge regarding the carbon benefits of tree planting, a subsidy to encourage tree planting may be warranted. Donovan and Butry in their studies have shown that urban street trees can increase the property value of houses within 100 feet but they did not show the effect of different shading percentage on the same building.

C- McPherson et al. [7] have shown that trees can reduce storm water runoff. Several studies have shown that trees can increase physical and mental well-being. Even if a house is oriented north–south, planting trees to the west of the house may not be possible. Setting aside space for shade trees is an important aspect of design that should be considered when planning residential developments, not simply something that is done as an afterthought.

D- Matthew A. Jungclaus and Quinn S. Weber [8] anticipate that household energy consumption will decrease as the shading system optimizes heat flow. As a result the residents can expect lower energy bills throughout the year. In addition, the feedback provided by the LCD display will educate the residents and visitors about both the motivating problem and the proposed solution. The team hopes that this technology will make a lasting impact on the field of sustainability and contribute as effective solution that inspires homeowners to make the needed change.

All previous studies did not scale the shading effects on the same building in different orientations and different shading percentages on the energy consumptions inside residential buildings.

## III. Research Limitation

This research used the most common residential design in all residential project constructed by the ministry of housing in Bahrain (Table I) with a gross area of 125 square meters divided in two floors. The energy consumption was calculated in a simulation (eco-design program) for eight different orientations with four different shading cases. The selected house design considered fixed building materials (concrete blocks for wall, precast concrete for the roofs, aluminum window frame and aluminum door) for all different cases, to calculate the shading effects on energy consumption.

## IV. Case Study

According to the reports of the Ministry of Housing projects and development of dwelling units, [9] in the Kingdom of Bahrain, more than 15099 houses units were built and more than 58 different samples were used in all of these houses. Table I is showing the Projects names, Number and Location for dwelling units that were built by ministry of housing in Bahrain.

TABLE I
Projects, Number and Location of Dwelling Units Built by Ministry of Housing in Bahrain [9]

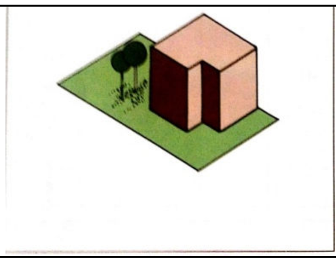
| No. | **Region** | **Location** | **Houses No.** |
|---|---|---|---|
| 1- | Muharraq and Hidd | Muharraq | 122 |
| 2- | | Busaytin | 101 |
| 3- | | Arad | 669 |
| 4- | | Hidd | 123 |
| 5- | Um Al-hassam | Um Al-hassam | 165 |
| 6- | Jiddhafs | Jiddhafs | 196 |
| 7- | | Sanabis | 178 |
| 8- | | Karranah | 20 |
| 9- | Northern region | Alduraz | 40 |
| 10- | | Albudaiya | 20 |
| 11- | Sitra | Sitra | 165 |
| 12- | Aali | A'ali | 740 |
| 13- | Isa town | Isa town | 4668 |
| 14- | Riffa and southern region | West riffa | 56 |
| 15- | | East riffa | 1216 |
| 16- | | Asker | 55 |
| 17- | | Jau | 46 |
| 18- | | Aldur | 8 |
| 19- | Western region | Aljassra | 67 |
| 20- | | Dumistan | 62 |
| 21- | | Alzallaq | 52 |
| 22- | Hamad town | Lawzi dist. | 2012 |
| 23- | | Rawdah dist. | 1486 |
| 24- | | Wadi dist. | 922 |
| 25- | | Nuzha dist. | 1910 |
| 26- | Total | | 15099 |

This research was analyzed all projects' samples regarding the 15099 houses [9], which have been built by the Ministry of Housing in Bahrain, and finds the most common house sample in all these projects (the most repeated sample in all Bahraini projects).

After counting all the houses samples (58 different house samples [9]) in all locations, the research found that the sample number 21 is the most common building sample. The sample 21 is a building with two floors containing one living room, one hall, three bed rooms, one kitchen, two toilets, one store, garden and garage for one car.

For the previous reason, the sample number 21, shown in (Fig. 3) is the chosen model for the simulation program.

**HOUSE TYPE 21**



Three dimensions model (built up area 125 square meters)

Real view for the sample


Ground floor & First floor plans

Fig. 3 House type number 21 according to the ministry of housing [8]

## V. Simulation Program

Many simulation programs and tools are available nowadays to aid designers execute new technologies and evaluate innovative ideas to increase energy savings in their proposed designs.

These building energy simulation programs have different features and a range of capabilities such as: general geometry modeling; zone internal loads; building envelope properties, day lighting and solar; infiltration, ventilation and multi-zone airflow; renewable energy systems; electrical systems and equipment; HVAC systems and equipment; environmental emissions; economic evaluation; climate data availability, results reporting and validation, calculate the envelope heat gains or loss, (annual and peak) space heat and cooling load, evaluate indoor thermal conditions, predict energy performance of buildings and analyze the life cycle costing. Detailed simulation tools perform their computation on hourly or sub hourly bases for better consideration of the dynamic interactions between all thermal based elements associated with comfort and energy consumption. [10], [11].

This research used the environmental Auto desk simulation software tool "eco-design program" [12].

The elected case study model was examined for the simulation in four building cases:

1- Exposed: the shading percentage for this case is 0%.
2- Shaded: the shading percentage for this case is 25%.
3- Slightly shaded: the shading percentage is 50%.
4- Very shaded: the shading percentage for this case is 75%.

The simulation will not be done for the case of 100% shaded building because there is no case with this condition as design proposal in reality.

The calculations will be done in different orientations. The orientations will be for each (45º) starting from the north (0º) and ending on North West (315º) as following: (0, 45, 90, 135, 180, 225, 270 and 315) º). Every one of these orientations will be done in four building's shading cases (Exposed, Shaded, Slightly shaded, Very shaded). The building orientation depends on the main entrance direction, so the orientation (0º) refers to that where the buildings main entrance in the simulation model is oriented to the north and so on.

## VI. Results

The "eco designer" simulation program reveals 28 results sheets for the residential model. These sheets are showing the buildings energy consumption and energy consumption/meter. The following selected results consider the orientations (0º) and (315º) in different shading cases.

- The first result for the residential building in exposed case (0%) shading (Fig. 4);
- The second result for the residential building in shaded case: (25%) shading (Fig. 5);
- The third result for the residential building in slightly exposed case (50%) shading (Fig. 6);
- The fourth result for the residential building in very shaded case (75%) shading (Fig. 7).

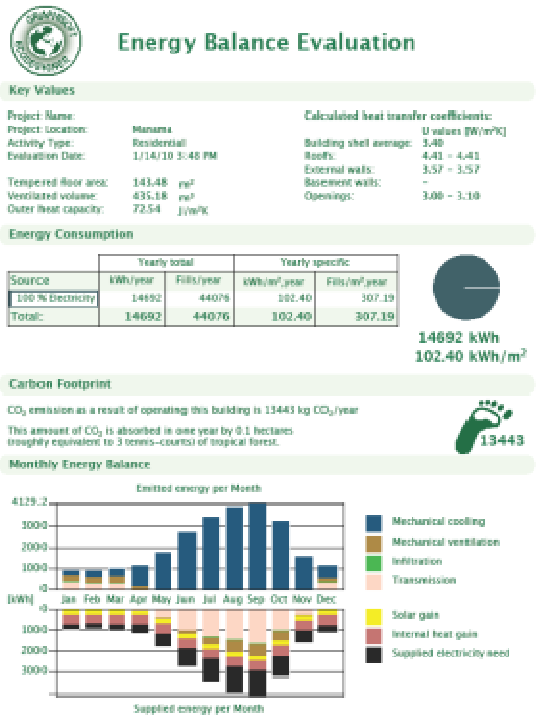



Fig. 4 Result of the graphisoft eco designer software for the residential building in exposed case (0%) shading for orientation (0º)

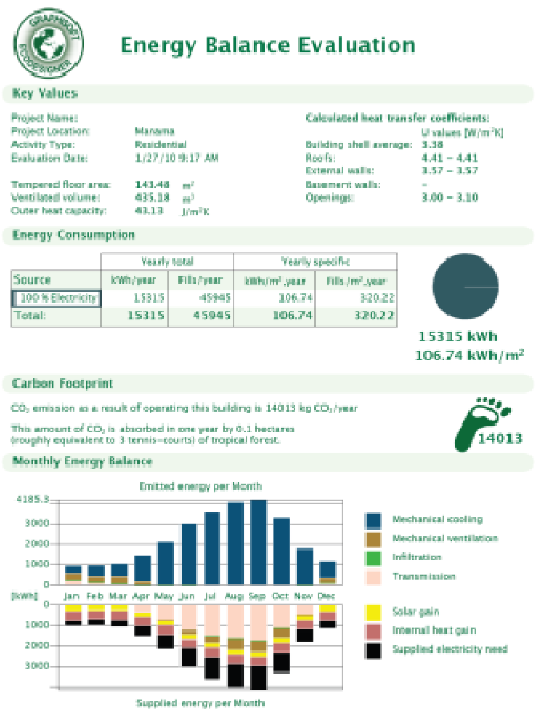



Fig. 6 Result of the graphisoft eco designer software for the residential building in slightly shaded case (50%) shading for orientation (0º)

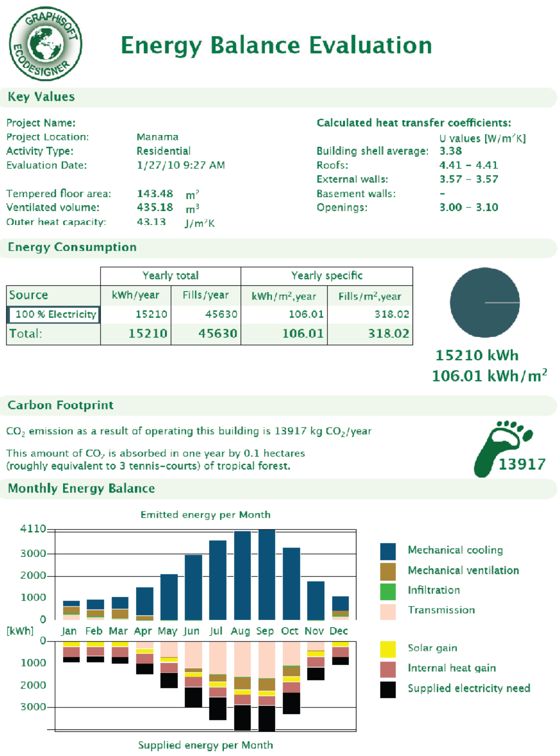



Fig. 5 Result of the graphisoft eco designer software for the residential building in shaded case (25%) shading for orientation (0º)

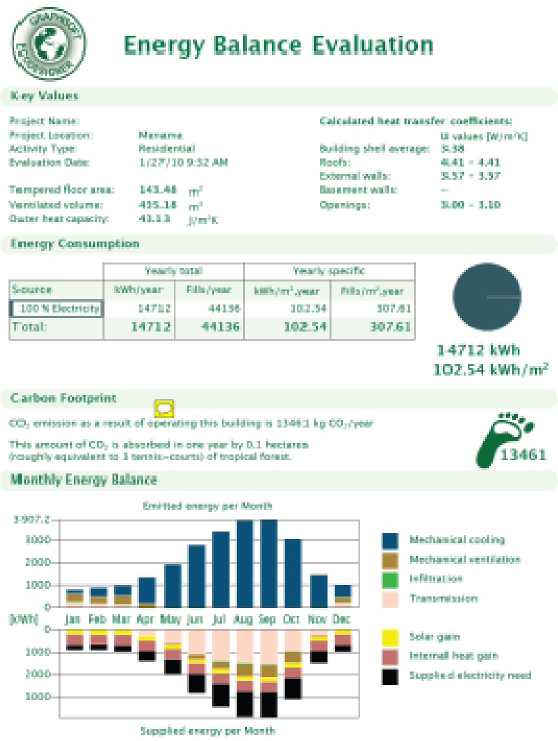



Fig. 7 Result of the graphisoft eco designer software for the residential building in very shaded case (75%) shading for orientation (0º).

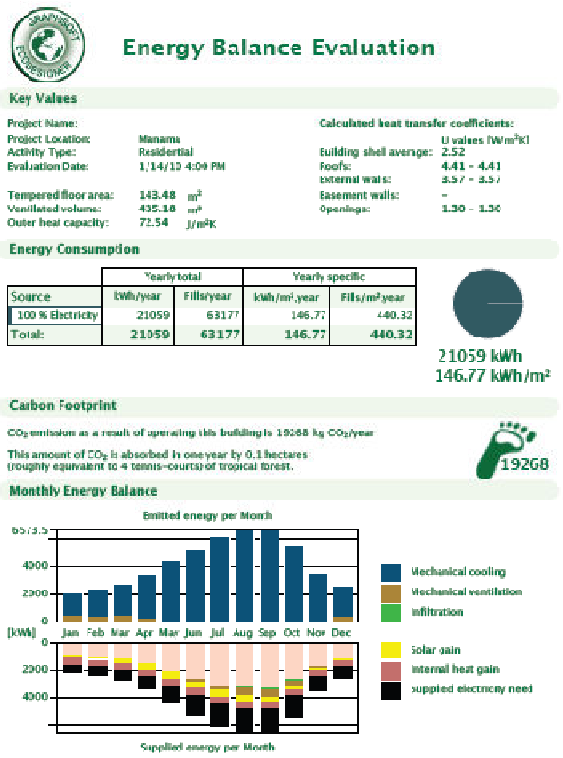



Fig. 8 Result of the graphisoft eco designer software for the residential building in exposed case (0%) shading for orientation (315º)

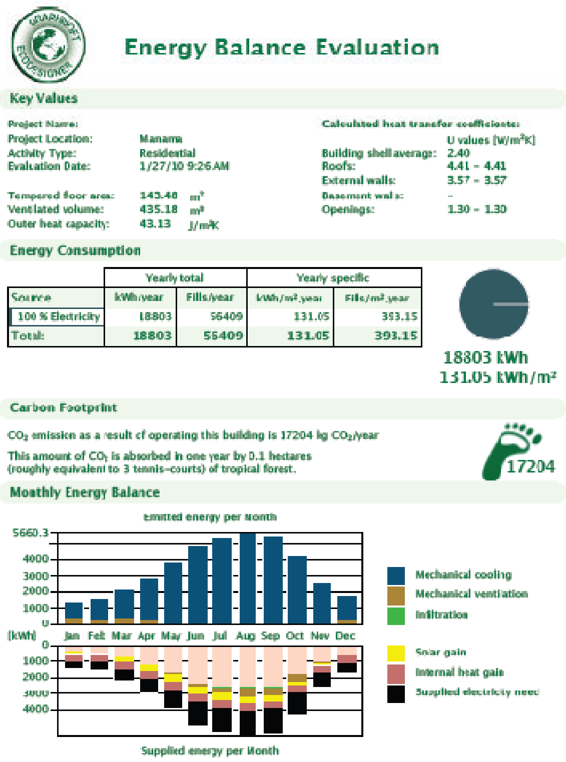



Fig. 10 Result of the graphisoft eco designer software for the residential building in slightly shaded case (50%) shading for orientation (315º)

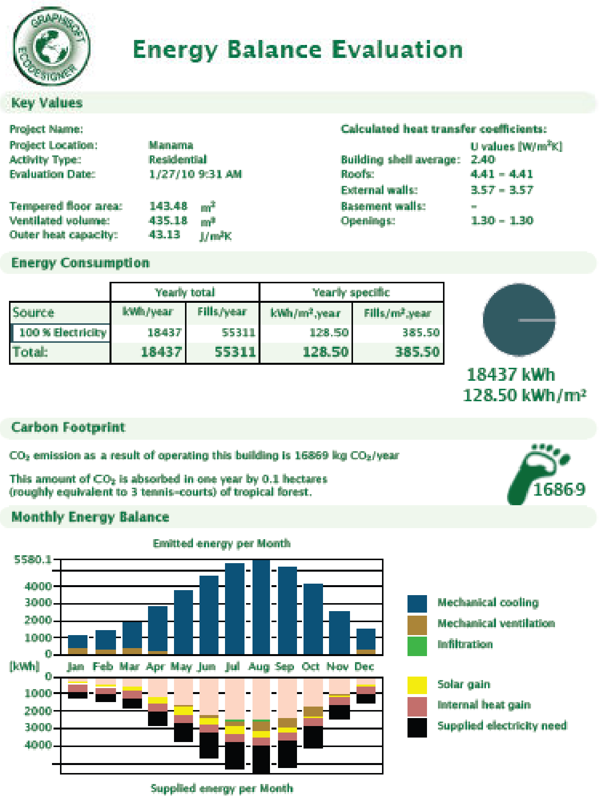



Fig. 9 Result of the graphisoft eco designer software for the residential building in shaded case (25%) shading for orientation (315º)

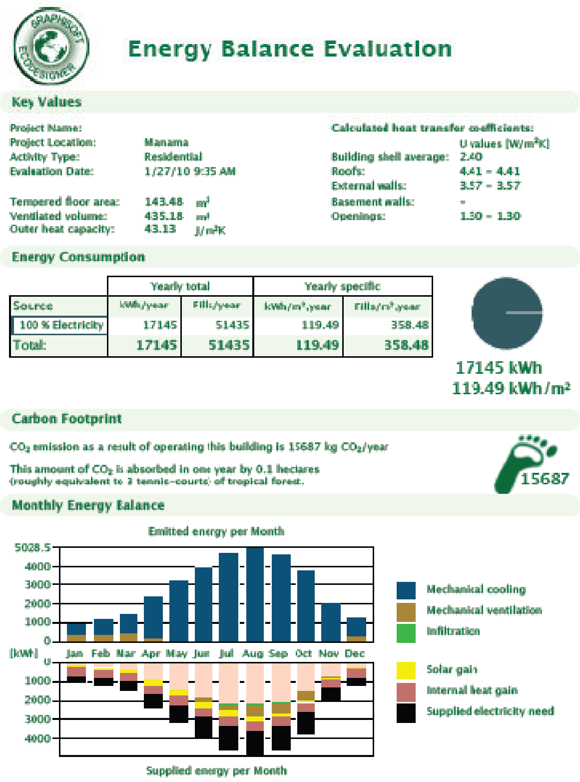



Fig. 11 Result of the graphisoft eco designer software for the residential building in very shaded case (75%) shading for orientation (315º)

- The fifth result for the residential building in exposed case (0%) shading (Fig. 8);
- The sixth result for the residential building in shaded case (25%) shading (Fig. 9);
- The seventh result for the residential building in slightly shaded case (50%) shading (Fig. 10);
- The eighth result for the residential building in very shaded case (75%) shading (Fig. 11).

## VII. Results Discussion

The program results are shown in 28 calculation; these results are for the energy consumption in all eight selected orientations for four shading cases (exposed, shaded, slightly shaded and very shaded) in kWh/m2 yearly as shown in Table II. Fig. 12 shows the graph differences between the energy consumption for different shading percentage. The Table III is showing the reduce percentage for energy consumption or each shaded percentage according to the different orientations.

TABLE II
Kilo Watt Yearly (Kwh/M2, Year) Energy Consumption for Each Square Meter

| No | Orientation | Exposed 0% | Shaded 25% | Slightly shaded 50% | Very shaded 75% |
|---|---|---|---|---|---|
| 1 | 0 ° | 106.74 | 106.01 | 102.54 | 102.4 |
| 2 | 45 ° | 146.44 | 139.82 | 135.89 | 124.33 |
| 3 | 90 ° | 109.84 | 108.73 | 104.19 | 103.56 |
| 4 | 135 ° | 146.89 | 139.59 | 135.79 | 124.01 |
| 5 | 180 ° | 109.99 | 108.87 | 104.38 | 104.33 |
| 6 | 225 ° | 146.64 | 140.59 | 135.97 | 122.94 |
| 7 | 270 ° | 110.22 | 108.93 | 104.34 | 103.98 |
| 8 | 315 ° | 146.77 | 131.05 | 128.50 | 119.49 |

TABLE III
Reduce Percentage to Each One Square Meter for Energy Consumption to Each Shaded Percentage According to the Different Orientations

| No | Orientation | Exposed 0% | Shaded 25% | Slightly shaded 50% | Very Shaded 75% |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0.69 | 3.94 | 4.07 |
| 2 | 45 | 0 | 4.53 | 6.21 | 15.1 |
| 3 | 90 | 0 | 1.02 | 5.15 | 5.72 |
| 4 | 135 | 0 | 4.97 | 7.56 | 15.58 |
| 5 | 180 | 0 | 1.02 | 5.11 | 5.15 |
| 6 | 225 | 0 | 4.13 | 7.28 | 16.17 |
| 7 | 270 | 0 | 1.18 | 5.34 | 5.67 |
| 8 | 315 | 0 | 11.72 | 12.45 | 18.59 |

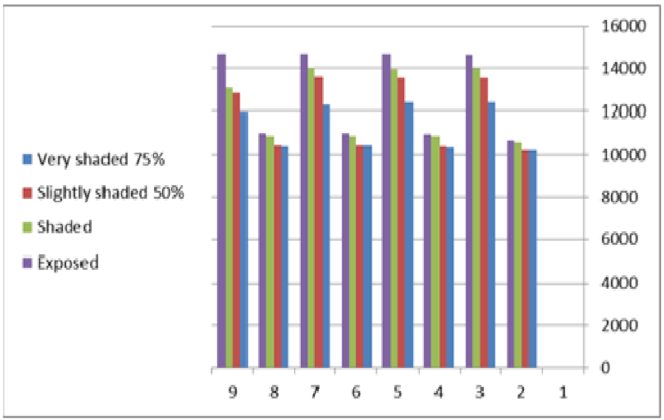



Fig. 12 Graph for the differences between the orientations for the different shading percentage

## VIII. Conclusion

The research found that there are many effects for shading on the energy consumption in Bahraini residential buildings. These are shown in the following conclusions:

First: The shading effects in different orientations:

For the shading percentage 25%, the minimum shading effects on the energy consumption was: when the main entrance of the model faced north (0º), the total use of energy was reduced 0.69 %.

1. For the shading percentage 25%, the maximum shading effects on the energy consumption was: when the main entrance for the model faced the north-west (315º), the total use of energy was reduced 11.72 %.
2. For the shading percentage 50%, the minimum shading effects on the energy consumption was: when the main entrance for the model faced the north (0º), the total use of energy was reduced 3.94%.
3. For the shading percentage 50%, the maximum shading effects on the energy consumption was: when the main entrance for the model faced the north-west (315º), the total use of energy was reduced 12.54 %.
4. For the shading percentage 75%, the minimum shading effects on the energy consumption was: when the main entrance for the model faced the north (0 º) the total use of energy was reduced 3.94%.
5. For the shading percentage 75%, the maximum shading effects on the energy consumption was: when the main entrance for the model faced the north-west (315º), the total use of energy was reduced 18.59 %.

Second: The best effect for shading occurs in the building orientation towards north-west (315º).

Third: The less effect for shading occurs in the building orientation towards north (0º).

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