

## The Role of sustainable Design with Local Environmental Materials to Reduce the Carbon Footprint of Urban Areas in Siwa Oasis

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**Abstract:** Climate change is one of the most difficult environmental challenges facing humanity caused by modern man, and requires global efforts to confront it by implementing policies and measures that help reduce harmful emissions and improve air quality. It has become necessary to take urgent measures to confront climate change, by reducing gas emissions and protecting the environment; the use of local materials in Siwa hotels is an ideal model for comprehensive sustainability and encouraging ecotourism, as it combines environmental conservation, providing local job opportunities, and enhancing the distinctive cultural and environmental identity of Siwa Oasis, and contributes to improving environmental and economic sustainability. This approach reduces waste, thus reducing pollution and costs associated with transporting materials from outside the region. It also helps enhance social sustainability by providing local job opportunities, thus strengthening the local economy. The aim of this research is to study the impact of local materials in hotel buildings in Siwa Oasis on reducing the carbon footprint and achieving sustainable design. This was achieved through an analytical study of buildings in Siwa Oasis and through an applied study using the designbuilder V 7.0 program. The results indicate that using local environmental materials, such as 40 cm kerchief, can reduce CO<sub>2</sub> emissions by 6.6% compared to the base case.

Keywords: global warming, carbon footprint, Siwa Oasis, local materials, Sustainable hotel.

### 1. Introduction

Siwa Oasis is a magical and quiet place with a unique and distinctive environment. It is located in Matrouh Governorate in Egypt and is famous for its natural beauty and unique architectural and cultural heritage. <sup>(1)</sup> This oasis is characterized by being a natural oasis, as it has not been significantly affected by architectural, urban and industrial development, making it a destination for those seeking tranquility, relaxation and an escape from the hustle and bustle of modern life. <sup>(2)</sup> It contributes to improving environmental and economic sustainability by <sup>(3)</sup> reducing waste and costs associated with transporting materials from outside the region. It also helps promote social sustainability by providing local job opportunities and strengthening the

local economy <sup>(4)</sup>. The buildings in Siwa Oasis are famous for using local, environmentally friendly materials such as mud bricks, local wood and limestone. Clay is collected from nearby valleys and mixed with straw, dry grass and water to make local mud bricks. Siwa Oasis is a distinct and unique city in the use of local environmental materials in the sustainable building process, as mud mixed with salt is used to build walls, straw to cover roofs, and wood to make doors and windows. Environmental design is an important tool to mitigate the negative impact of the modern construction sector, which helps reduce the carbon footprint and provides local materials with thermal insulation for buildings, making them suitable for living in the desert environment <sup>(5)</sup>. Limestone is used in the construction of walls and columns, and buildings can be decorated with local artistic decorations with local materials that represent the culture and traditional heritage of Siwa Oasis and help preserve its cultural identity. The use of local environmental materials is less expensive due to their availability in Siwa Oasis compared to other materials, in addition to their ability to withstand the harsh climate in the oasis <sup>(6)</sup>; This trend in construction contributes to enriching ecotourism in Siwa Oasis by exploring the unique local environmental natural construction method for all those interested in this unique architectural and urban trend in construction in the world. The following are some of the unique local natural materials that can be used in buildings in Siwa Oasis:

1. Limestone: It is abundantly available in Siwa Oasis and is used in the construction of floors, columns and walls, and it can be built with and used to give a traditional character to hotel buildings in Siwa Oasis. <sup>(7), (8)</sup>
2. Wood: Wood is available from palm trunks and palm fronds in limited quantities in the Siwa Oasis and is used in building roofs from palm trunks, doors and windows. <sup>(11)</sup>
3. Mud bricks: Clay is collected from the nearby valleys in the Siwa Oasis and mixed with straw, dry grass and water to make mud bricks. Mud bricks are used in building roofs, floors and walls. <sup>(9), (10)</sup>.
- 4- Kerchief is a mixture of salt, clay, palm supports and olive trees. When this mixture dries, it becomes very hard and resistant to demolition and collapse. Building with this material provided homes with warmth in the winter and moisture in the summer. <sup>(12)</sup>

## 2. Literature review:

Siwa Oasis is a magical and peaceful place with a unique environment. <sup>(1)</sup> Siwa Oasis is the northernmost of the five oases in the Western Desert of Egypt, located 120 km east of the Libyan border and 300 km south of the Mediterranean coast. The oasis extends east to west in a depression 17 m below sea level. The oasis is bordered to the north and west by the rocky hills of the Daffa Plateau, while to the south and east by the sand dunes of the Great Sand Sea. This depression contains four large salt lakes and several natural springs used for irrigation purposes. <sup>(13)</sup> A report issued by the World Meteorological Organization said that greenhouse gases rose to new record levels in 2023, this suggests that the planet will continue to warm over the coming years. The atmosphere is accumulating carbon dioxide at a rate unprecedented in human history, with levels rising by more than 10% in just twenty years. <sup>(14)</sup> - A study published in the journal "Nature Climate Change" in 2018, which pointed out that the consequences of global warming affect various domains, including health, food, water resources, energy, and security. <sup>(15, 16, 17)</sup> Confronting this phenomenon requires global and continuous efforts, through the identification of policies and measures that help reduce harmful emissions to the environment and improve air quality, in addition to promoting innovation, clean, and sustainable technology.

Siwa Oasis in Matrouh Governorate, Egypt, is considered a region of ancient heritage and culture, characterized by the presence of well-preserved historical buildings that represent the region's culture and reflect local craftsmanship. <sup>(18)</sup> However, some people use modern and non-

local building materials, leading to the deterioration of the built environment in the oasis and the loss of cultural and heritage identity. <sup>(19, 20)</sup>

To protect the buildings in Siwa Oasis and preserve the cultural and heritage identity while reducing CO<sub>2</sub> emissions rate, it is necessary to encourage the use of traditional local materials in hotel buildings and other structures. Local residents and residents of Siwa Oasis should be educated about the importance of using local materials in construction and encouraged to preserve the cultural and heritage identity of the area.

### 3. Research Problem:

The wrong choice of local materials for the outer shell of hotel buildings in Siwa Oasis leads to increased carbon dioxide emissions, and thus an increased carbon footprint.

### 4. Research Questions:

How can the carbon footprint be reduced and carbon emissions in hotel buildings be reduced by using local building materials in Siwa Oasis?

### 5. Objectives:

Studying the impact of using local environmental materials as treatments that reduce the carbon footprint and reduce carbon dioxide emissions for hotel buildings in Siwa Oasis, by using the Design Builder v7.0 simulation program.

### 6. Hypothesis:

Local environmental building materials in the exterior shell of hotel buildings in Siwa Oasis, Egypt, contribute to reducing carbon footprint and reducing carbon dioxide emissions.

### 7. Methodology:

In this research, the theoretical approach will be followed, which is based on the narration of previous studies, their results and their impact on the study. The analytical approach will also be used to derive the optimal model for local environmental building materials for hotel buildings in Siwa Oasis, Egypt, which work to reduce the carbon footprint. The applied approach will also be used in simulation using the Design Builder v7.0 tool program to study the environmental impacts, using local building materials in the building envelope, which helps to reduce the carbon footprint of hotel buildings in Siwa Oasis. The results of simulation for each case will be presented, compared and analyzed to achieve the research objectives and prove the hypothesis. <sup>(38)</sup>

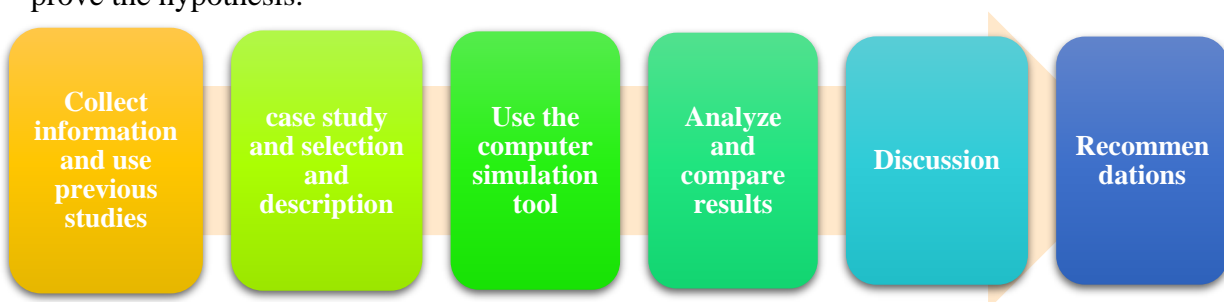


Figure (1) shows the research methodology

## 8. Eco-tourism :<sup>(21),(22)</sup>

Ecotourism is a good approach and behavior to support the preservation of the environmental identity and natural environment of each climate and provide a financial return for individuals within communities in protected areas. It has a good role because it contributes to the economic aspect and contributes to the preservation of protected areas through: a) the financial income that can be spent to contribute to the management of protected areas permanently and sustainably, b) working to generate employment opportunities for individuals within their local community, c) community participation and a sense of community ownership (Galani, 2012).

The International Ecotourism Society (TIES) of 1991 defines ecotourism as "conscious and responsible travel to natural areas that preserve the environment and improve the well-being and care of local people." The principles of ecotourism are: a) minimizing negative environmental impacts, b) building environmental awareness, respect and cultural sensitivity, c) providing positive experiences for both visitors and hosts, d) generating sustainable and environmentally-oriented financial returns, e) generating income for and empowering local populations, and d) increasing climate sensitivity for host countries. The Quebec Declaration on Ecotourism (2002) recognizes the principles of sustainable tourism, in relation to both the environmental and economic aspects of tourism. The declaration states that ecotourism:

- contributes significantly, effectively and strongly to the conservation of local natural and cultural heritage.
- involves local and indigenous people and communities in its development, planning and operation, and contributes to their well-being.
- explains the local natural and cultural heritage of the destination to visitors.
- is best suited to individual travelers as well as small organized group tours.

This type of tourism is witnessing increasing demand and continuous and remarkable growth, as it is one of the fastest growing sectors in the tourism sector, recording about 15% of the total global tourism spending. According to estimates by the World Tourism Organization, the number of international tourists who take eco-tourism trips is about 30 million people, equivalent to 5% of the average number of tourists worldwide.

### 8-1 Concept of Eco-tourism and Sustainability)<sup>:(23),(24)</sup>

Ecotourism represents a form of travel centered on safeguarding the environment and fostering community development. Its goal is to offer travelers distinctive experiences that encourage meaningful engagement with both nature and local cultures in a responsible way. This approach not only introduces visitors to natural surroundings but also actively involves them in preserving these environments. In contrast, sustainable tourism focuses on the careful utilization of tourist destinations while ensuring a balanced influx of visitors who are conscious of the value of these sites and interact with them responsibly. It emphasizes managing resources—whether economic, social, aesthetic, or natural—while respecting heritage and cultural elements. A fundamental principle across all forms of tourism discussed is maintaining respect for the physical and cultural environment, as well as promoting activities that neither harm nor degrade these settings. Integrating an economic perspective into conservation efforts, as proposed by Goodwin, provides financial resources essential for protecting natural and cultural heritage. Furthermore, ecotourism can also be described as tourism that minimizes environmental impact and contributes to the preservation of biodiversity and traditional practices. This contribution can take place directly through active participation in conservation initiatives or indirectly via generating sufficient income to support such efforts.

### 8-2 The importance of Ecotourism (25),(26)

Ecotourism occupies a prominent position due to its important role in supporting the tourism sector and preserving the environment. The following are the most important points that illustrate its importance:

1. Environmental protection: Ecotourism contributes to the preservation of natural landscapes, biodiversity, and wildlife resources. By promoting sustainable tourism practices and increasing environmental awareness, it contributes to protecting the environment and reducing pollution and environmental degradation.
2. Supporting the economy: Ecotourism is a vital source of income and provides job opportunities for members of the local community. It also encourages the participation of local communities and attracts investments to develop sustainable tourism projects. This in turn enhances economic growth and improves the living conditions of local residents.
3. Environmental knowledge: It plays a crucial role in increasing environmental knowledge among tourists. Through travel experiences related to nature and the environment, tourists learn a lot about environmental challenges and the importance of preserving natural resources.
4. Preserving cultural and urban heritage: Ecotourism includes a focus on local culture, heritage and architecture. Tourists are encouraged to interact with local communities and enjoy unique cultural experiences. This contributes to the preservation of unique cultural and urban heritage and enhances understanding and respect for different cultures.
5. Promoting sustainability: It is an essential element of sustainability, with a focus on meeting the current needs of tourists without compromising the ability of future generations to meet their own needs. Tourism development is directed in ways that achieve environmental, social and economic sustainability.
6. Human Importance of Eco-Tourism: Eco-tourism is a human activity that contributes to providing a healthy life for individuals. It offers relief from anxiety and stress, provides comfort, harmony, revitalization, and restores mental and emotional balance and clarity of mind.
7. Urban and Architectural Importance of Eco-Tourism: It involves utilizing planning patterns that harmonize with nature, relying on traditional architectural patterns, and using local building materials that do not cause visual or environmental distortions resulting from the use of foreign architectural patterns and materials in the areas where these facilities and buildings are constructed.

#### 8-3 Eco-tourism from an economic perspective: <sup>(27)(28)</sup>

Previous definitions emphasize the importance of the economic aspect in eco-tourism for protection efforts and the involvement of local communities in environmental conservation instead of excluding them. In the end, eco-tourism projects should meet the following criteria:

- They should be sustainable, meeting present needs without exhausting environmental capacities to meet future needs. They should provide visitors with a unique and excellent experience characterized by clarity.

- They should maintain the quality of the environment.

- Economic and developmental benefits of eco-tourism :<sup>(29)(30)</sup>

1. Support rural economies through eco-tourism by highlighting natural assets and tourist attractions.
2. Eco-tourism helps regional development as a source of income for local populations in tourist attraction areas.
3. Tourism destinations in the face of intense competition in the global market and consumer protection legislation.
4. Marketing, where the environment has become a good element for tourism markets in general.

## 9. The Eco-lodge as an Architectural and Planning Solution for Sustainable Tourism Development in General: <sup>(31)·(32)</sup>

### 9-1 Concept of Eco-lodge:

Eco-lodges, also known as eco-friendly hotels, are tourist facilities that are designed, built and managed in a way that contributes to the conservation of natural resources and the preservation of cultural heritage. The term “eco-lodge” is a brand used in the tourism industry to refer to a specific type of accommodation that relies on natural elements. The focus is primarily on the characteristics of the site, the natural environment and cultural landmarks, as well as the management and marketing of ecotourism trips, with the involvement of local communities in the development of eco-lodge projects. Hence, the eco-lodge project contributes to enhancing the economic value of natural resources and cultural experiences. In the Egyptian context, eco-lodges can be considered a new type of tourist facilities that provide an environmental educational experience for tourists about the surrounding natural and cultural life, which contributes to deepening their knowledge of environmental issues, its importance and the vital role of the surrounding heritage.

The architectural approach known as environmental planning is used in the design of eco-lodge projects, as this approach is based on three main principles that must be taken into account:

1. The necessity of design solutions being inspired by the natural environment surrounding the site, while ensuring their harmony with the cultural character of the area.
2. Involving local communities in the design and implementation stages, to benefit from their long-standing expertise and experiences.
3. Achieving design integration with the surrounding nature through architectural forms that are in harmony with the site without compromising its natural aesthetics.

It is clear from this that the essential element in establishing eco-lodges is to achieve balance and harmony between the climate, culture, and nature of the surrounding area.

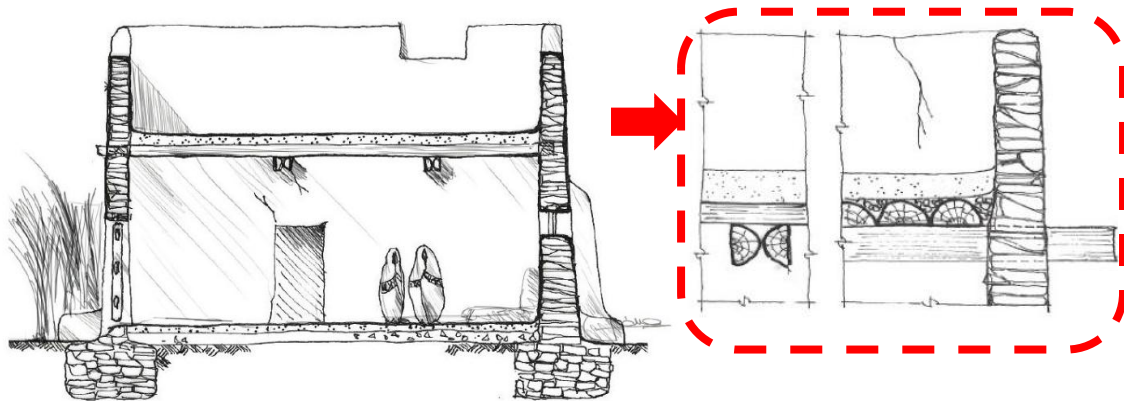


Figure (2) Model of construction with local materials in Siwa Oasis

Source: [http://urbanharmony.org/siwa\\_book2022/mobile/index.html](http://urbanharmony.org/siwa_book2022/mobile/index.html) 10 -12-2023

### 9-2 Design and Planning Considerations for Eco-lodges :<sup>(33)·(34)</sup>

Eco-lodge exist in different environments and countries around the world thanks to the efforts of international organizations, such as Panama, France, Tunisia, Kenya, Australia, and others. There are all categories of Eco-lodges that differ from those that focus on adventure tourism or on nature discovery trips (such as understanding the surrounding flora and fauna) or the history of the area from a local expert. The creation and design of an Eco-lodge should include two basic elements: preserving the surrounding natural environment while providing support and benefits to local communities and individuals. According to (TIES), an effective Eco-lodge should:

1. Provide comfortable accommodation and public spaces that reflect local design, culture and identity.

2. Preserve the local natural environment that is carefully preserved.
3. Use locally-sourced, sustainable, reusable and recyclable building materials.
4. Provide food for visitors that is grown locally and by the surrounding population.
5. Use new and renewable energy resources, water management techniques and waste management methods.
6. Provide opportunities, interaction and communication to interact with individuals and communities from locals, guides and administrators.

Some additional details about eco-hotels:

1. Sustainable construction.
2. Conservation of energy.
3. Water efficiency.
4. Waste management and recycling.
5. Biodiversity conservation.
6. Community engagement.
7. Certifications and standards.
8. Environmental education and interpretation.
9. Responsible tourism: Encouraging visitors to reduce local environmental impacts, respect local cultures and local traditions, support the local economy, participate in nature -directed activities such as walking long distances, and educating visitors about the importance of preserving the environment for protected areas.

## 10 Egypt contains eight climatic regions. <sup>(37)</sup>

Egypt contains eight climatic regions, and under each climatic region there is a group of governorates, as shown:

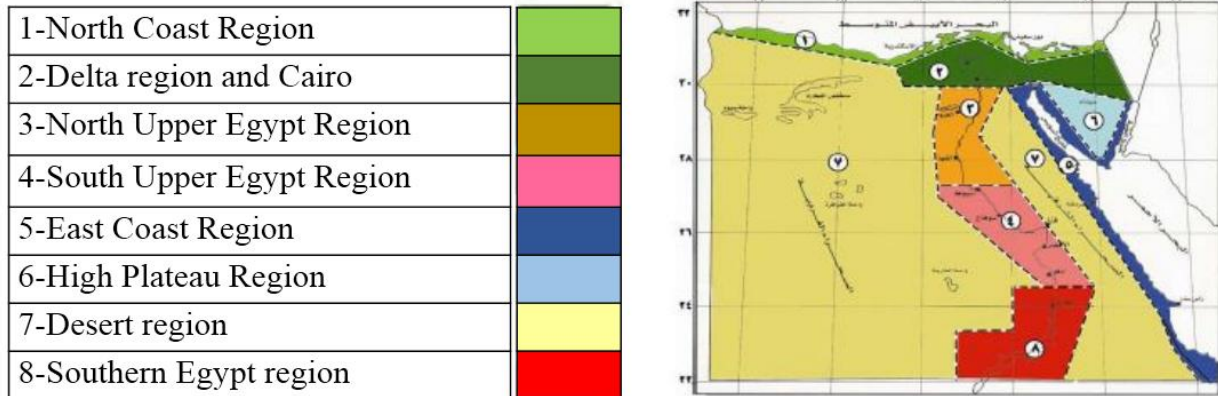


Figure (3) Egypt contains eight climatic regions.

## 11 Case study: Adrar Amalal Hotel in Siwa Oasis:

Adrar Amalal in the language of the Siwa people means the white mountain that stands tall in the oasis guarding a hotel that bears its name, its founder and owner is the environmental expert Mounir Nehme and the hotel designers are the engineers Imad Farid Mikhail and Ramez Ibrahim Azmy, they won the Mubarak Award in Arts - Architecture of Tourist Facilities

- Location: Adrar Amalal Hotel is located around (the white mountain) Jabal Jaafar in a village called Al-Maraqi, 18 km away from Siwa, where old Siwa houses were located surrounding the mountain. A complete restoration of those houses was carried out and some architectural modifications were made in addition to adding all the architectural elements (hotels) that allow the hotel to be used at the highest hotel level.

- The hotel contains:

- The hotel consists of several regions that give a distinctive character to Siwa.

- 1- A car park building in addition to a group of stores and (6) employees rooms.
- 2- The reception building consists of a reception hall, a multi-purpose hall, and a surface for the administration rooms.
- 3- The adequate building and the restaurant and its accessories.
- 4- A group of covered and exposed surfaces, which make up the bar building
- 5- 32 rooms of different buildings that make up the hotel rooms in the project.
- 6- The healthy bathroom building, the pool building and the garden attached to it.<sup>(35), (36)</sup>



Figure (4) shows adrere-amella hotel in Siwa Oasis <sup>(40)</sup>

The main objective of the design process is to create a structure that harmonizes with its surroundings and integrates seamlessly with them, giving the impression that it has been there since ancient times and cannot be uprooted and placed elsewhere in the world. It belongs solely to this location with its own characteristics and atmosphere. The architects sought the assistance of the indigenous people of the area. The walls were constructed is carried out by local craftsmen from the Siwa Oasis using a traditional material known as "kerchief". This material consists of a mixture of clay, sand and salt extracted from the salty lakes in the Siwa area. This mixture is characterized by its ability to integrate the building in harmony with the surrounding natural environment, in addition to its role as a natural thermal insulator, which contributes to preserving moderate temperatures inside the building throughout the hot and cold seasons.

#### 11-1 Integration of design with the environment:

The architects decided to abandon all technological elements in order to provide an isolated atmosphere for visitors, giving them the opportunity to get away from the hustle and bustle of daily life and enjoy the surrounding simplicity in peace. To achieve this, electricity was dispensed with and replaced with arrangements based on candles placed on candlesticks. The thick "Kerchief" walls were specially designed to accommodate these candles, in addition to incorporating lanterns lit using candles. Even the sewage system was designed in a way that is in line with natural simplicity, by relying on palm groves and bamboo.

The Kerchief walls, as previously mentioned, provide effective natural insulation. The living room was oriented towards the north to avoid direct sunlight, while the southern facade included small, evenly distributed openings overlooking the palm grove, helping to protect the interior spaces from the effects of sand winds.

#### 12- Discussion of the Results of Carbon Footprint Reduction Using Local Materials in Siwa Oasis by using simulation the DesignBuilder v 7.0 software tool:

Through the simulation program, the CO<sub>2</sub> emission rate and the amount of decrease were measured by using the wall thickness of local materials and the difference in orientation. This will be explained as follows:

- The first case: the results of simulation of the rate of co<sub>2</sub> in the case of using the wall with a thickness of 25 cm, red bricks, with different orientations, as shown in Figure (5):

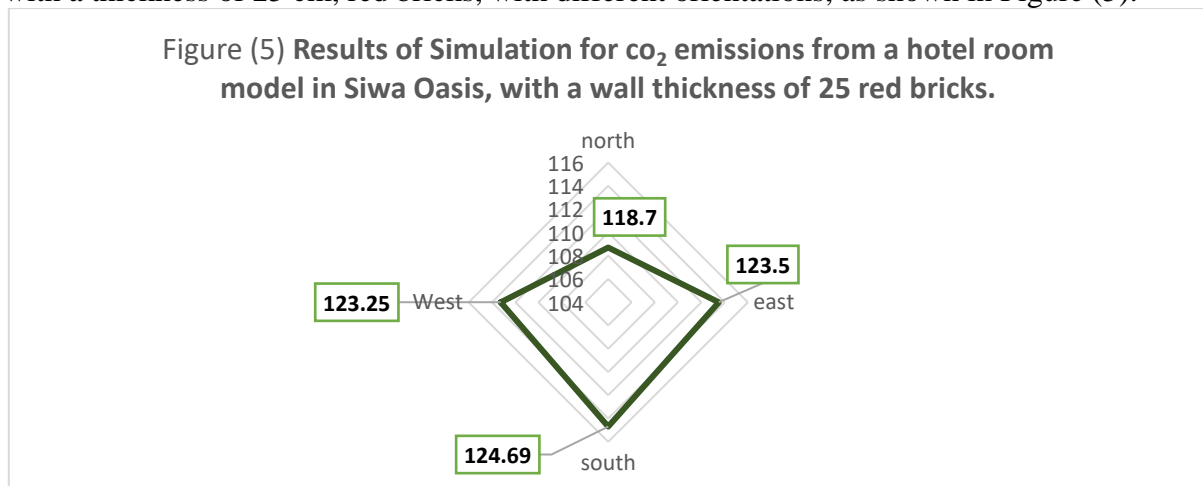


Figure (5) the first case: shows the results of simulation of the rate of co<sub>2</sub> in the case of using the wall is 25 cm thick, red bricks with different orientations for hotel rooms in Siwa Oasis in Egypt

Figure (5) shows that the CO<sub>2</sub> rate varies according to the orientations. The results of simulation showed that the highest CO<sub>2</sub> emission rate for hotel rooms in Siwa Oasis, Egypt, occurs in the south-facing orientation, with a wall thickness of 25 cm of red brick, resulting in an annual CO<sub>2</sub>

emission rate of 124.69 tons per  $m^2$ , which is the highest CO<sub>2</sub> emission rate among hotel rooms in Siwa Oasis. The emission rate decreases in the north-facing orientation, which has the lowest CO<sub>2</sub> emission rate of 118.7 tons per  $m^2$ , indicating a 5.2% decrease in CO<sub>2</sub> emissions compared to the south-facing orientation. The annual CO<sub>2</sub> emission rate for the west-facing orientation is 123.25 tons per  $m^2$ , and the annual CO<sub>2</sub> emission rate for the east-facing orientation is 123.5 tons per  $m^2$

- The second case: the results of simulation for the CO<sub>2</sub> are based on using a thicker wall with a thickness of 40 cm of red bricks, with different orientations, as shown in Figure (6).

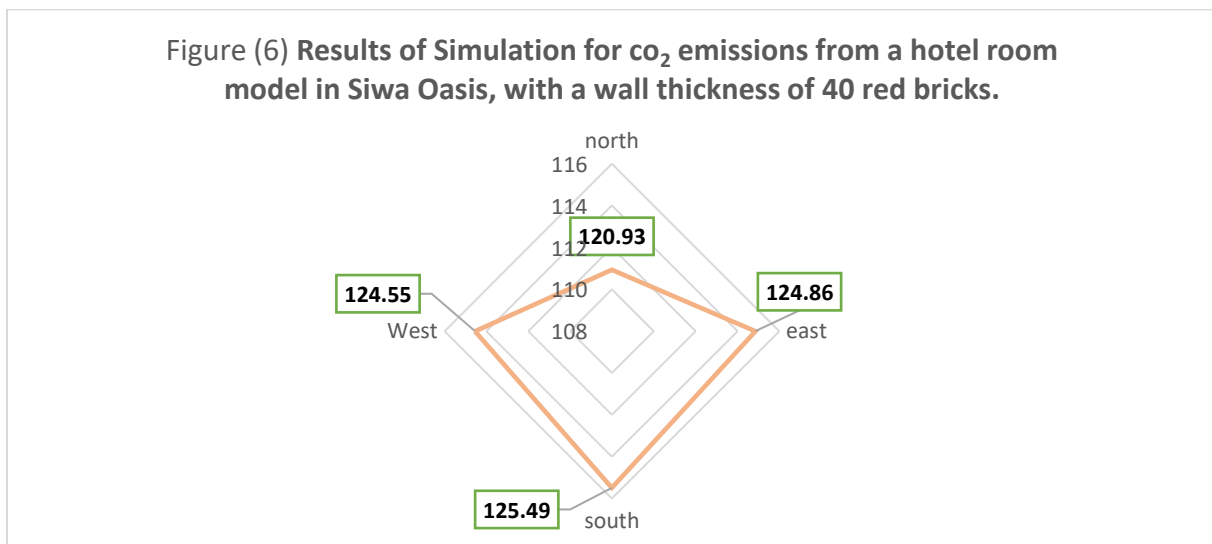


Figure (6) the second case: shows the results of CO<sub>2</sub> in case of using the model. The wall is 40 cm thick, red bricks with different orientations for hotel rooms in Siwa Oasis in Egypt.

Figure (6), shows that the CO<sub>2</sub> emission rate varies with different orientations in the second case. The results of simulation showed that the highest CO<sub>2</sub> rate for the hotel rooms in Siwa Oasis, Egypt, occurs in the south-facing direction, with a wall thickness of 40 cm of red bricks, resulting in an annual CO<sub>2</sub> rate of 125.49 tons per  $m^2$ . This is the highest CO<sub>2</sub> emission rate among the hotel rooms in Siwa Oasis. The emission rate decreases in the north-facing direction, which has the lowest CO<sub>2</sub> emission rate of 120.93 tons per  $m^2$ , indicating a 4% reduction in CO<sub>2</sub> emissions compared to the south-facing direction. The west-facing direction has an annual CO<sub>2</sub> emission rate of 124.55 tons per  $m^2$ , and the east-facing direction has an annual CO<sub>2</sub> emission rate of 124.86 tons per  $m^2$ .

. The third case: results of simulation for CO<sub>2</sub> in the case of using a wall model with a thickness of 25 cm cement bricks with different orientations, as shown in Figure (7):

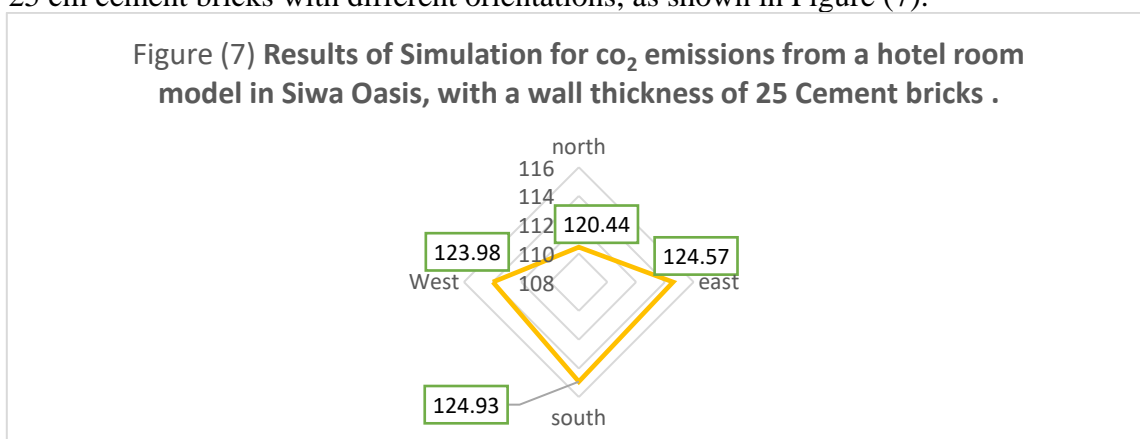


Figure (7) the third case: shows the results of simulation of the rate of  $\text{CO}_2$  emissions. The wall is 25 cm thick, cement bricks with different orientations for hotel rooms in Siwa Oasis in Egypt.

Through the analysis of Figure (7), it is evident that ( $\text{CO}_2$ ) emission rate varies with different orientations in the third case. The results of simulation showed that the highest  $\text{CO}_2$  emission rate for the hotel rooms in Siwa Oasis, Egypt, occurs in the south-facing direction, with walls of 25 cm thickness made of cement bricks, resulting in an annual  $\text{CO}_2$  emission rate of 124.93 tons per  $\text{m}^2$ . This is the highest  $\text{CO}_2$  emission rate among the hotel rooms in Siwa Oasis. The emission rate decreases in the north-facing direction, which has the lowest  $\text{CO}_2$  emission rate of 120.44 tons per  $\text{m}^2$ , indicating a 4% reduction in  $\text{CO}_2$  emissions compared to the south-facing direction. The west-facing direction has an annual  $\text{CO}_2$  emission rate of 123.98 tons per  $\text{m}^2$ , and the east-facing direction has an annual  $\text{CO}_2$  emission rate of 124.57 tons per  $\text{m}^2$ .

Fourth case: Results of simulation for the rate of  $\text{CO}_2$  emissions with a 40 cm thick wall made of cement bricks with different orientation, as shown in Figure (8):

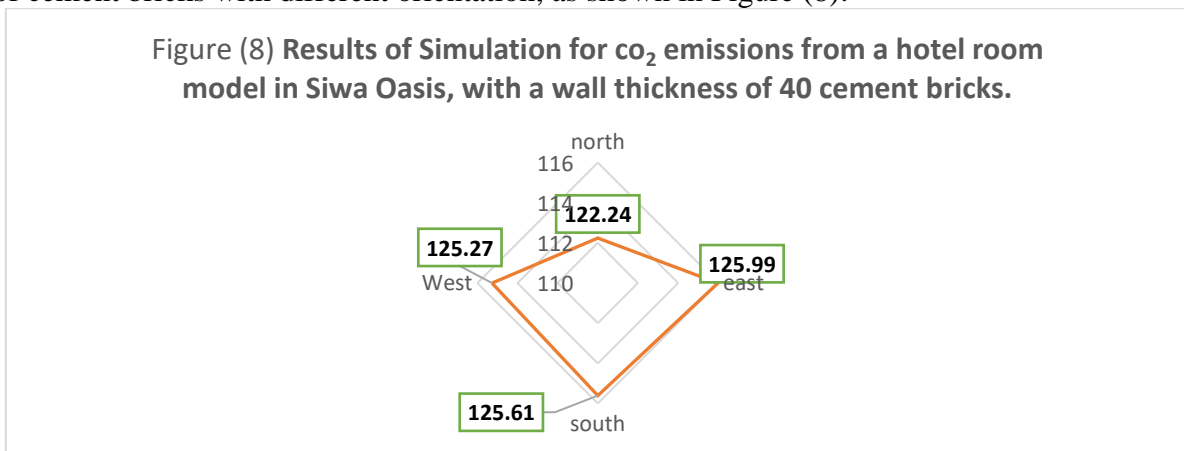


Figure (8) the fourth case: shows the results of simulation for  $\text{CO}_2$  emissions. The wall is 40 cm thick, cement bricks with different orientations for hotel rooms in Siwa Oasis in Egypt. Through the analysis of Figure (8), it is evident that  $\text{CO}_2$  emission rate varies with different orientations in the fourth case. The results of simulation showed that the highest  $\text{CO}_2$  emission rate for the hotel rooms in Siwa Oasis, Egypt, occurs in the south-facing direction, with walls of 40 cm thickness made of cement bricks, resulting in an annual  $\text{CO}_2$  emission rate of 125.61 tons per  $\text{m}^2$ . This is the highest  $\text{CO}_2$  emission rate among the hotel rooms in Siwa Oasis. The emission rate decreases in the north-facing direction, which has the lowest  $\text{CO}_2$  emission rate of 122.24 tons per  $\text{m}^2$ , indicating a 3% reduction in  $\text{CO}_2$  emissions compared to the south-facing direction. The west-facing direction has an annual  $\text{CO}_2$  emission rate of 125.27 tons per  $\text{m}^2$ , and the east-facing direction has an annual  $\text{CO}_2$  emission rate of 125.99 tons per  $\text{m}^2$ .

Fifth case: Results of simulation for the rate of  $\text{CO}_2$  emissions in the case of using a 25 cm thick limestone wall model with different orientation in the case of a 3 mm single transparent glass (as shown in Figure (9)):

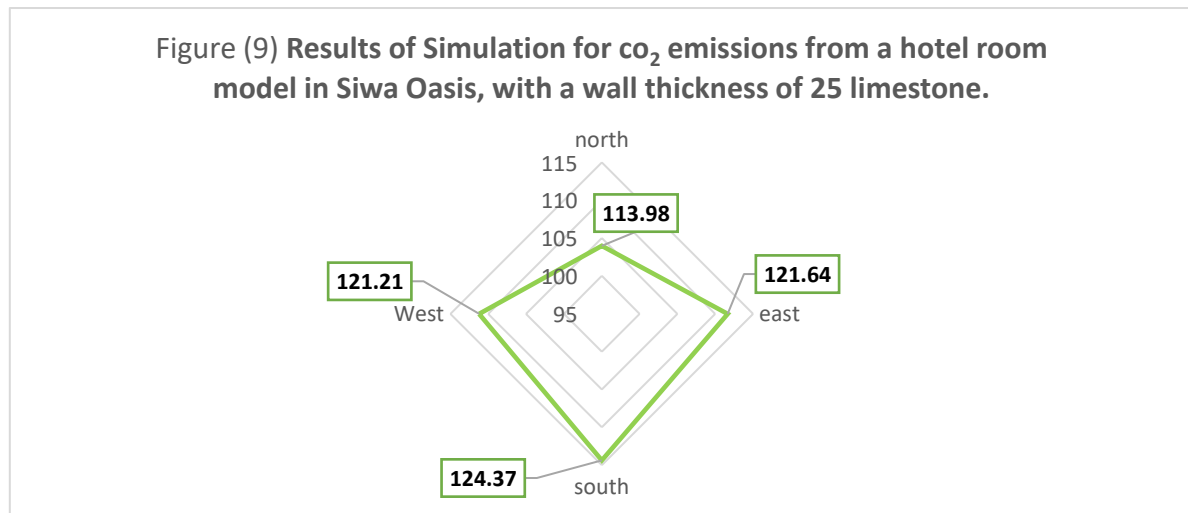


Figure (9) the fifth case: shows the results of simulation for CO<sub>2</sub> emissions. The wall is 25 cm thick, limestone with different orientations for hotel rooms in Siwa Oasis in Egypt.

Through the analysis of Figure (9), it is evident that CO<sub>2</sub> emission rate varies with different orientations in the fifth case. The results of simulation showed that the highest CO<sub>2</sub> emission rate for the hotel rooms in Siwa Oasis, Egypt, occurs in the south-facing direction, with walls of 25 cm thickness made of limestone, resulting in an annual CO<sub>2</sub> emission rate of 124.37 tons per m<sup>2</sup>. This is the highest CO<sub>2</sub> emission rate among the hotel rooms in Siwa Oasis. The emission rate decreases in the north-facing direction, which has the lowest CO<sub>2</sub> emission rate of 113.98 tons per m<sup>2</sup>, indicating a 10% reduction in CO<sub>2</sub> emissions compared to the south-facing direction. The west-facing direction has an annual CO<sub>2</sub> emission rate of 121.21 tons per m<sup>2</sup>, and the east-facing direction has an annual CO<sub>2</sub> emission rate of 121.64 tons per m<sup>2</sup>.

- Sixth case: Results of simulation for the rate of CO<sub>2</sub> emissions with a 40 cm thick limestone wall with different orientation, as shown in Figure (10):

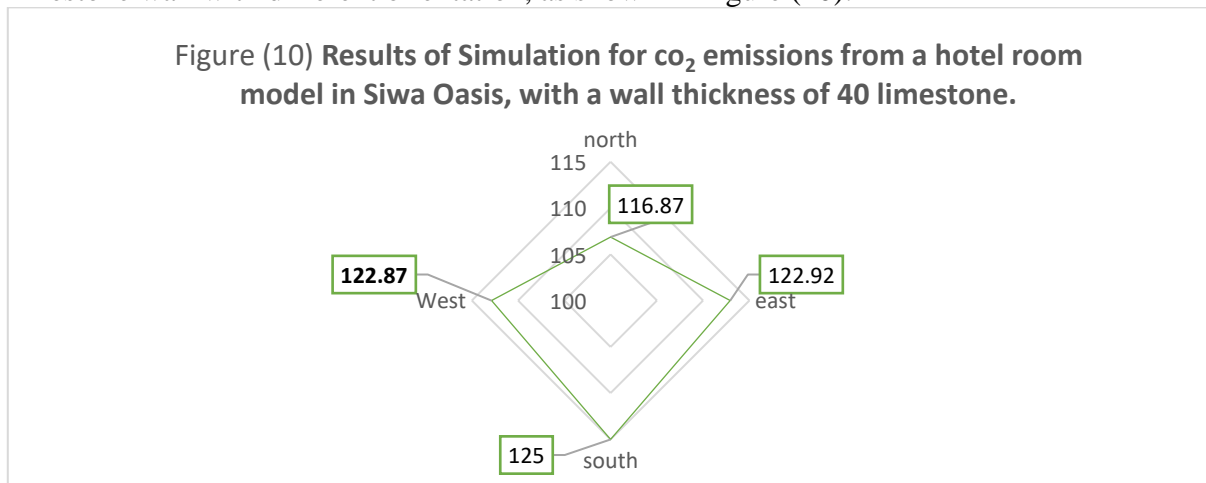


Figure (10) the sixth case: shows the results of for CO<sub>2</sub> emissions. The wall is 40 cm thick, limestone with different orientations for hotel rooms in Siwa Oasis in Egypt.

Through the analysis of Figure (10) in the sixth case, it is evident that CO<sub>2</sub> emission rate varies with different orientations. The results of simulation showed that the highest CO<sub>2</sub> emission rate for the hotel rooms in Siwa Oasis, Egypt, occurs in the south-facing direction, with walls of 40 cm thickness made of limestone, resulting in an annual CO<sub>2</sub> emission rate of 125 tons per m<sup>2</sup>. This is the highest CO<sub>2</sub> emission rate among the hotel rooms in Siwa Oasis. The emission rate decreases in the north-facing direction, which has the lowest CO<sub>2</sub> emission

rate of 116.87 tons per m<sup>2</sup>, indicating a 7.6% reduction in CO<sub>2</sub> emissions compared to the south-facing direction. The west-facing direction has an annual CO<sub>2</sub> emission rate of 122.87 tons per m<sup>2</sup>, and the east-facing direction has an annual CO<sub>2</sub> emission rate of 122.92 tons per m<sup>2</sup>.

- Seventh case: Results of simulation for the rate of CO<sub>2</sub> emissions in the case of using the 25 cm thick kerchief wall model with different orientation, as shown in Figure (11):

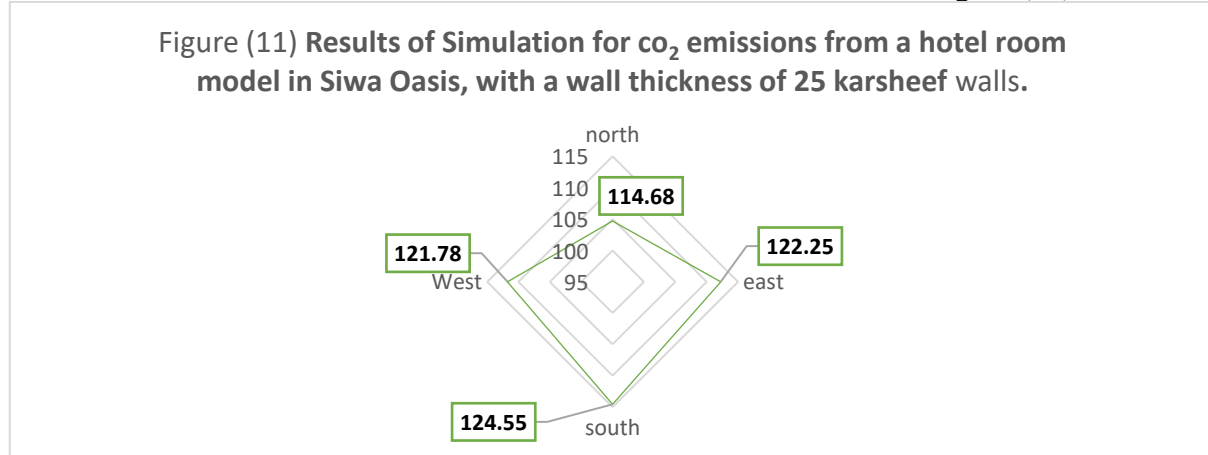


Figure (11) the seventh case: shows the results of simulation for CO<sub>2</sub> emissions. The wall is 25 cm thick, kerchief with different orientations for hotel rooms in Siwa Oasis in Egypt.

Through the analysis of Figure (11) in the seventh case, it is evident that CO<sub>2</sub> emission rate varies with different orientations. The results of simulation showed that the highest CO<sub>2</sub> emission rate for the hotel rooms in Siwa Oasis, Egypt, occurs in the south-facing direction, with walls of 25 cm thickness made of kerchief, resulting in an annual CO<sub>2</sub> emission rate of 124.55 tons per m<sup>2</sup>. This is the highest CO<sub>2</sub> emission rate among the hotel rooms in Siwa Oasis. The emission rate decreases in the north-facing direction, which has the lowest CO<sub>2</sub> emission rate of 114.68 tons per m<sup>2</sup>, indicating a 6.4% reduction in CO<sub>2</sub> emissions compared to the south-facing direction. The west-facing direction has an annual CO<sub>2</sub> emission rate of 121.78 tons per m<sup>2</sup>, and the east-facing direction has an annual CO<sub>2</sub> emission rate of 122.25 tons per m<sup>2</sup>.

- Eighth case: Results of simulation for the rate of CO<sub>2</sub> emissions in the case of using the 40 cm thick kerchief wall model with different orientation, as shown in Figure (12):

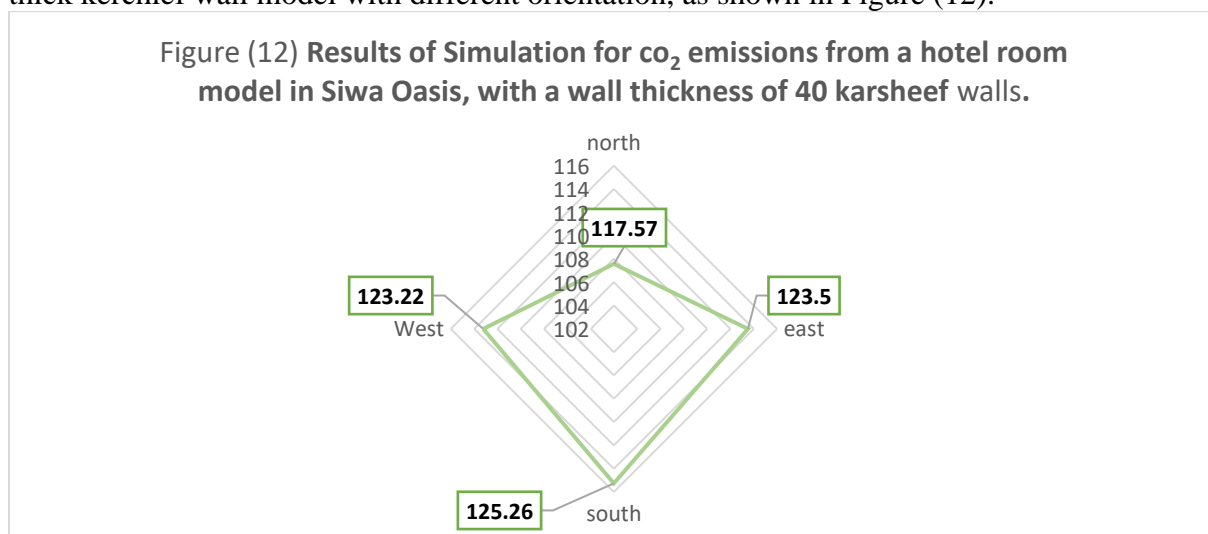


Figure (12) the eighth case: shows the results of simulation for CO<sub>2</sub> emissions. The wall is 40 cm thick, kerchief with different orientations for hotel rooms in Siwa Oasis in Egypt.

Through the analysis of Figure (12) in the eighth case, it is evident that CO<sub>2</sub> emission rate varies with different orientations. The results of simulation showed that the highest CO<sub>2</sub> emission rate for the hotel rooms in Siwa Oasis, Egypt, occurs in the south-facing direction, with walls of 40 cm thickness made of kerchief, resulting in an annual CO<sub>2</sub> emission rate of 125.26 tons per m<sup>2</sup>. This is the highest CO<sub>2</sub> emission rate among the hotel rooms in Siwa Oasis. The emission rate decreases in the north-facing direction, which has the lowest CO<sub>2</sub> emission rate of 117.57 tons per m<sup>2</sup>, indicating a 6.6% reduction in CO<sub>2</sub> emissions compared to the south-facing direction. The west-facing direction has an annual CO<sub>2</sub> emission rate of 123.22 tons per m<sup>2</sup>, and the east-facing direction has an annual CO<sub>2</sub> emission rate of 123.5 tons per m<sup>2</sup>.

### 13- Recommendations:

- Sustainable design is a powerful tool for achieving sustainability in the hotel sector and reducing the carbon footprint of urban areas. This can be achieved through the combined efforts of governments, the private sector and civil society to encourage and implement sustainable design principles throughout the hotel life cycle.
- Sustainable hotels are an integrated system at the economic, social and environmental levels. Their importance and the need to enhance them and meet their requirements must be identified. They require cooperation to achieve optimal exploitation that benefits local residents and the local community and provides economic value and benefits. Policies must be developed to reduce the carbon footprint that is developed by environmentally friendly buildings, as they include a set of systems, laws and regulations that help reduce carbon emissions and achieve indoor air quality.
- Determine the standards, requirements and environmental considerations for sustainable hotels and work to generalize them to tourist facilities in Egypt.
- Apply the Egyptian Green Building Code, the Green Pyramid, to hotel buildings to reduce carbon emissions and encourage the application and use of local materials in building sustainable hotels in Egypt.
- The use of local materials, especially kerchief, helps reduce the emission rate of carbon dioxide.
- Encouraging investment in green hotels: Providing financial incentives to investors who establish sustainable hotels.
- Developing codes and specifications: Developing building codes and specifications that promote the application of sustainable design principles in hotels.
- Raising awareness: Organizing awareness campaigns on the importance of sustainable design in the hotel sector.
- Supporting research and development: Supporting research and development in the field of sustainable hotel design.

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