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A PROPOSED DESIGN APPROACH TO SUPPORT SUSTAINABILITY REQUIREMENTS OF THE DESIGN OF NEW MOSQUES AND IN THE EXISTING MOSQUES

CASE STUDIES OF SOME REGIONAL AND INTERNATIONAL MOSQUES AND THEIR REFLECTION ON SUPPORTING SUSTAINABILITY REQUIREMENTS

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Abstract— **The mosque is considered one of the most important religious buildings for Muslims, it is the place of performing religious rituals, It's also playing an important religious and societal role and therefore it has a great importance to the individuals and Muslim society. The design of the mosques carries a number of vocabulary and distinctive architectural elements such as minarets, domes, Mihrab, Minbar and internal courtyard (Sahn). It contains some of the vocabulary associated with some of religious symbols and also, in some cases, some religious and social activities and uses may be joined with the mosque. The research problem is the lack of interest in achieving the sustainability requirements in some mosques, which leads to increase the energy consumption ,increase water consumption, increase the consumption of resources and increasing the operation cost. Achieving sustainability in buildings is an important trend in the current period locally and internationally. Because the mosque is an important building to Muslims, therefore, it is necessary to work towards achieving sustainability in the mosques. The research seeks to establish the concept of sustainable mosques by trying to achieve the principles of sustainability in the design of new mosques and the existing mosques, the research has made a theoretical study followed by an analytical study of a number of case studies of mosques from several countries, the research has studied also some case studies of mosques that were developed to meet some requirements of sustainability. The analytical study included of the most important international experiences to achieve the aspects of sustainability in the design of mosques and in the existing mosques, which led to conclude the latest international solutions and methods in this field, to identify the architectural elements of the mosque that can be utilized for the purposes of sustainability, and to extract the most important aspects, with the utilizing of the latest ideas, to reach the appropriate and applicable solutions to support the sustainability requirements.**

The research aims at providing an approach to support the sustainability requirements in the design of mosques and in the existing mosques. The research has concluded this approach to aid to support achieving sustainability in the design of new mosques, and improving the performance of existing mosques towards sustainability, including the required treatments and solutions, the utilizing of the architectural elements of the mosque to support achieving the sustainability, utilizing of the modern technological developments and the recent international ideas.

***Index Terms*—Sustainable mosques, sustainability, sustainable design, design of mosques, sustainability and mosque design.**

***Research problem*—**The lack of interest in achieving the requirements of sustainability in some mosques, that leads to increase the consumption of energy, resources and water with the increasing of the operating cost**.**

***Research Goal*—**The research aims to provide an approach to support the requirements of sustainability in the design of new mosques, and improve the performance of existing mosques towards sustainability, which includes the latest developments in this field.

***Research Methodology*—**The research is based on a theoretical approach and an analytical approach, whereas the theoretical approach included the principles of sustainability, benefits of sustainability, different applications, the basis and concepts of sustainable design and the solutions that promote of sustainability, it followed by some case studies of mosques in several countries to demonstrate how to apply sustainability requirements at the international and regional levels. The analytical study included the most important elements and basics for sustainability that carried out, to conclude the latest solutions, techniques and ideas that led to

conclude the proposed approach to support achieving sustainability in the design of new mosques and the improvement of the existing mosques performance towards sustainability. The proposed approach included utilizing of the main architectural elements in the mosque, benefiting of many international experiences and solutions in this field, benefiting from latest technological developments, and conserving of energy and resources, in order to support achieving the sustainability requirements.

I. INTRODUCTION

The mosque has a great importance to Muslims, the design of the mosque is associated with some main distinguished elements such as minarets, domes, Mihrab, and mashrabiyas. The main functional spaces in the mosque include the prayer hall, the ablution area, the internal courtyard (Sahn), the required service rooms and it may include other activities. Mosques are located in Arab and Islamic countries and in places where Muslims gather in foreign countries. In line with international trends to meet sustainability in buildings, this requires to achieve sustainability requirements in mosques.

II. SUSTAINABLE DEVELOPMENT

Sustainable development works to achieve a better quality of life. It works to maintain of the natural environment, benefit from natural resources, reduce energy consumption and reduce the consumption of resources and water, thus leads to reduce the operating costs [1].

III. SUSTAINABLE ARCHITECTURE

Sustainable architecture can be defined as the architecture maintains the environment ,respects the available resources, provides users requirements and maintains their health, [2] and it can be defined as innovations and tools that create a healthy environment based on environmental requirements, and the available resources, aims to reduce the negative impact on the environment, to save energy and rationalize the consumption of resources throughout the operation of the building [3].

IV. DESIGN OF SUSTAINABLE BUILDINGS

Sustainable design takes into account the environment, consumes the resources appropriately without over-consume, reduces pollution, provides a healthy environment for users and not to affect the right of future generations to meet their natural resource requirements [4].The main aspects of the design of sustainable buildings include the promotion of positive aspects of the environment with taking all solutions, ideas and treatments, both traditional and innovative, to achieve the principles of sustainable architecture in the design and the implementation of buildings [5].Sustainable design is achieved through an integrated system, which starts from the design stage to the , the construction stage ,then the occupancy stage, as defined by the International Council for Research and Innovation in Building (CIB), the sustainable building system includes the good use of sites, water, energy, resources, improvement of the internal environment and provides a healthy environment [6]. Sustainable design is associated with several elements to be considered:

A. Energy efficiency and use of renewable energy

This element is based on taking into consideration the efficient use of energy in building without over-consume ,the use of solutions and treatments to reduce of energy consumption in building, the use of renewable energies, the local climatic aspects and their impact on design, ,the efficiency of the external building envelope and the efficient thermal insulation of building to reduce to reduce the waste of energy [7]. Renewable energy is the energy generated from inexhaustible natural resources and does not include the consumption of any resources, including the resources from waterfalls, wind power, solar energy, wave movement, geothermal energy and biomass energy [8]. Buildings that benefit from renewable energy utilize the potential of renewable energy to reduce dependence on traditional energies such as electricity and gas to reduce their consumption. Renewable energy is used for heating and for generating electricity through special units that may be on the roofs ,facades or any other part of building [9].

B. Considering the impact of design on the environmental

It's required to take into consideration the conditions of the environments and sites while maintaining of the nature , the utilizing of plants in any site within coordinating with the new project, the conserving of water purity to avoid pollution of water near the site, and the study of the materials used so as not to affect adversely on the environment and does not work on water pollution, it's also required to take into account to avoid of air pollution and to study and rationalize of the amount of energy required to operate the building [10].

C. Rationalizing of materials' consumption and water with working on recycling operations

This is accomplished through the use of materials that can be reused in a future period and the reuse of materials and equipment , it can be accomplished by waste reduction, waste classification and separation of waste according to their type, and recycling of materials [10]. conserving of water is an important element that can be accomplished by reusing and recycling of water, collecting and recycling of rainwater and waste water [11].

D. Improving the quality of internal environmental in buildings

It depends on reducing the amount of organic matter that may result from construction work, preventing germs from growing, providing sufficient fresh air, controlling the organic compounds resulting from the operation of the building, reducing the use of organic compounds and reducing noise resulting from the building, it's also required to not to increase the percentage of carbon dioxide ,not to increase any gases harmful to health, and not to produce of any toxic gases [10].

E. Social aspects

It's based on the provision of community requirements, to take into account the historical, social and cultural values of the society and the buildings [9].

V. THE DIMENSIONS OF SUSTAINABILITY

Sustainability is associated with several dimensions : the environmental dimension, the social dimension, and the economic dimension. The environmental dimension is preserving the functions, characteristics and nature of the environment, preserving the natural resources, working on reusing of materials, minimizing the flow of waste and harmful substances into the environment with treating them harmlessly to the environment, and reducing of the negative effects on human health. The social dimension works to enhance the society's requirements by providing a better environment for users ,safer environment , better quality of life and a more positive impact on society. The economic dimension is the ability to use the available resources and systems to achieve the best possible return ,reduce of the total costs, reduce of operating costs and reduce the cost of materials [7].

VI. SOME DESIGN TREATMENTS AND SOLUTIONS IN ISLAMIC ARCHITECTURE THAT CAN BE USED TO SUPPORT THE ENVIRONMENTAL DIMENSION OF SUSTAINABILITY:

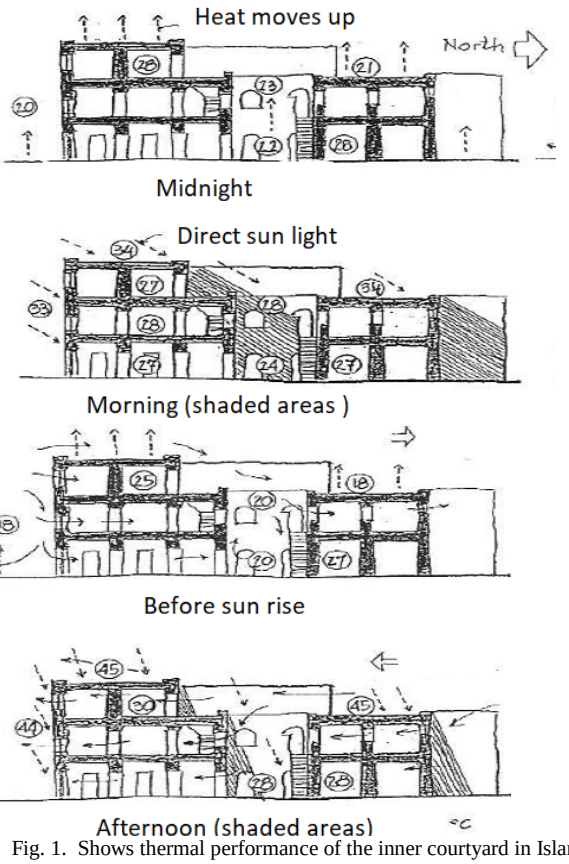

Fig. 1. Shows thermal performance of the inner courtyard in Islamic architecture [12].

Islamic architecture included many treatments that can be used to support the environmental dimension of sustainability requirements, such as the use of building materials that were from the natural local materials that were available in the local environment, the use of internal courtyards that provide natural ventilation and natural lighting , the use of the wind catchers and different types of wind towers to support natural ventilation to the building, the use of vents below the dome for natural ventilation and moving the air and the use of mashrabias to protect the openings from direct solar radiation and to provide the required shades while allowing for the entry of fresh air, and also there's a use of landscape elements such as trees and plants and the use of water fountains in interior spaces [13], as shown in figure (1) and figure (2).

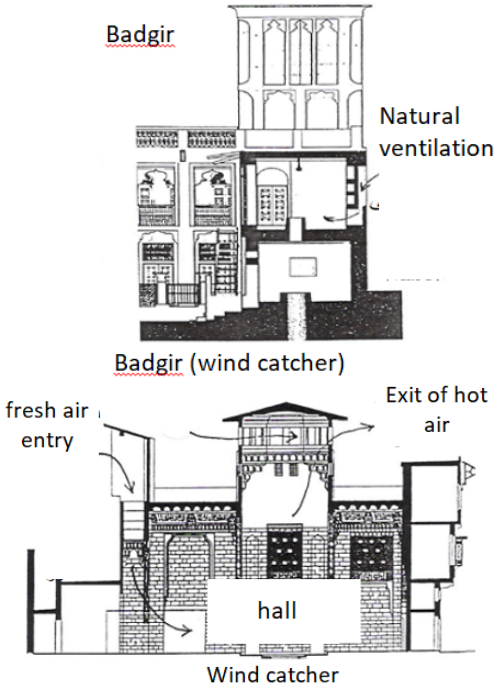

Fig. 2. Shows ventilation through the wind catchers [12].

A. Internal courtyard (Sahn)

The shape and size of the open courtyard (Sahn) are varying according to the location of the mosque due to the different climatic zones. The area of the open courtyard (Sahn) disappears or decreases in some cold countries, and its area changes in hot climatic zones. The area of the open courtyard is large and open in the Arab countries and Iran, while it is smaller in the mosques of Turkey, and in regions of Asia. In rainy regions, it is preferable to cover the most of the internal courtyard while in cold regions there's no presence of the open courtyard , and worshipers pray in the covered prayer hall only [14].

- The open courtyard in mosque (Sahn) and its effect on natural lighting and natural ventilation

  The open courtyard (Sahn) can be utilized as a main source to provide with the required natural lighting and natural ventilation for the prayer hall and other areas in the mosque, by integrating with set of

elements including openings below the dome, windows that covered by mashrabias and the openings that are resulting from the different levels in some parts of the roof [14].

- The effect of the absence of the open courtyard in the design of some new mosques

  The absence of the open courtyard from the design of some new mosques leads to the absence of the function performed by this open courtyard in terms of maintaining of a large amount of shaded areas in the open courtyard, protection of a large amount of solar radiation, allowing good natural ventilation and allowing a large entry of natural light without entering of solar radiation, that lead to the increase of the dependence on artificial ventilation and artificial lighting, and the increase of the energy consumption [15].

B. The use of double-layer domes

Double domes have been used in some historical mosques. They are based on a vacuum between the two layers that works as a thermal insulator. The outer dome is exposed to outer weather while the internal dome is a part of the internal space. In addition to that, the height of the internal dome is less than the height of the exterior dome to be suitable for the internal space, Imam mosque in Isfahan is an example of the multilayered domes [16].

Fig. 3. Shows double layer bulbous dome of the Imam Mosque, Isfahan [16].

C. Mashrabias

The mashrabias were used to allow natural daylight to entry while protecting against solar radiation when needed, depending on the climate zone of the mosque site. Mashrabias can be used also for the entry of fresh air to achieve the required natural ventilation (Al-Afghani, 2016).

D. Fountains

The use of water elements such as fountains to increase the relative humidity when needed according to climatic zone of the mosque's site [17].

E. The use of the available local materials in the buildings

VII. International and Regional Case Studies

A. Khalifa Al Tajer Mosque in Dubai:

The mosque ,as shown in figure (4) ,was implemented in 2014 in Dubai, United Arab Emirates, where the mosque was designed to use recycled materials, reduce of energy consumption, reduce carbon emissions, reduce of water consumption, recycle water and take into account the sustainability requirement The mosque has awarded the LEED Silver Certificate for green buildings, and it's considered an environmental friendly building [18].

Fig. 4. Shows Khalifa Al Tajer Mosque, Dubai[18].

- Generation of electricity from renewable energy resources:

Some applications were used to generate electricity from renewable energies in the mosque, as show in figure (5). Special columns are equipped by solar panels and special batteries were used to provide the mosque with the required electrical energy. Solar heaters were used on the roof of the mosque to heat the needed water for ablution . Energy- efficient lighting units (LED) are used in the mosque, as shown in figure (6), with an automatic lighting control system to control the required time for lighting which is during prayer times, to reduce energy consumption [18].

Fig. 5.Shows the use of solar panels to generate electricity [18].

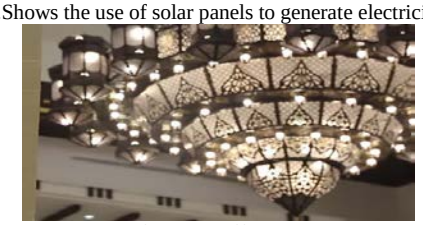

Fig. 6. Shows the use of energy- efficient lighting units (LED) in Khalifa Al Tajer Mosque [18].

- The use of Smart Systems:

Lighting sensors were used to use the minimum operating time of artificial light and to rely on the maximum amount of natural lighting throughout the mosque and accessories to reduce the consumption of electrical energy, with the use of special smart systems for air conditioning units to reduce the consumption. The use of these systems is saving 30% of the electricity consumption [19].

- The use of solar energy to heat the water:

The mosque is equipped with solar heaters, which rely on solar energy to heat water instead of using electricity to reduce the electricity consumption [20].

- High quality of thermal insulation works:

The thermal insulation works for the mosque are achieved with high quality for the walls and ceiling to reduce the thermal transmission from outdoor to indoor or vice versa, which reduces the burden on the air conditioning system, and also the openings are equipped with double glass with special treatment, to reduce thermal transmission through glass[19].

- Air conditioning system that saves energy consumption:

The mosque includes an advanced system for automatic control of cooling systems to save energy consumption. This system controls the cooling devices according to the need, according to prayer times, and according to the number of worshippers in order to save energy consumption. The air conditioning systems reduce the use of gases that negatively affect the ozone layer, as well as increasing the purification of internal air [18].

- The use of recycled water to reducing of water consumption:

The water consumption in the mosque has been reduced during ablutions. Special water taps have been used to suit with the consumption of water which works to reduce the speed of water flow during ablution with providing only with the suitable amount of water, and also, some processes are doing to the ablution water after use like filtration, treatment and recycling processes to reuse the water in irrigation and in toilets flush systems, these methods reduced water consumption by 40% [19].

B. Cambridge mosque in UK

Fig. 7. Shows prayer area in Cambridge mosque, [21].

Fig. 8 . Shows Cambridge mosque,[21].

The mosque has been designed to be environmentally friendly and has many solutions for sustainability. It contains a prayer hall for 1000 worshippers for men and women, a garden, underground parking lots and bicycle parking spaces, the mosque can be reached on foot or by means of mass transportation as the mosque is close to a public transportation. The project includes a community services area includes a showroom and a meeting room for community service, the mosque is shown in figure (7) and figure (8), [21].

- Maximum use of natural lighting:

The main prayer hall depends on the natural lighting derived from the units in the roof and from the glazing units in front facade of the mosque to offer natural lighting throughout the day as much as possible for reducing the use of artificial lighting, as shown in figure (9), [22].

Fig. 9. shows the use of natural light through the units in the roof [23].

- The use of planting:

The mosque was built with a garden on its roof that works to purify the air and increase the thermal insulation of the roof. A new garden was also created adjacent to the mosque which serves the surrounding community with the presence of plants and cypress trees surround the mosque and the entrance area as shown in figure (10), [23].

Fig. (10) shows the use of planting at the entrance and the roof of the mosque with creating of a garden adjacent to the mosque to serve the surrounding community [23].

- The use of local materials:

The local building materials were used in the mosque. The local bricks were used in the walls and local wood was used in the interior space in forming the interior columns and decorative units to meet the requirements of sustainable design [23].

- The use of low energy consumption lighting units:

The Cambridge mosque utilizes renewable energy capabilities, while indoor lighting are (LED) lighting units which used when needed , these lighting units consume lower electricity than other lighting units to save the energy consumption as well as they are distributed throughout the mosque [24].

- Generating electricity from Renewable Energy Sources:

Energy is obtained from renewable energy sources such as solar panels located on the roof of the mosque

to generate the electricity needed to the mosque, the produced energy is used in cooling ,heating, lighting and to support the energy requirements in the mosque, with the presence of lighting control systems to reduce the consumption. Air source heat pumps are installed for heating systems , which is using renewable energy in this operation, to reduce energy consumption in heating, water heaters that use solar energy are installed on the roof of the mosque to provide with hot water for ablution when needed, as shown in figure (11), [24].

Fig.11. Shows the solar panels and solar heaters on the roof of Cambridge mosque [25].

- Water conservation and recycling:

The mosque works to preserve the water, it recycles the ablution water, with the presence of a system for collecting and recycling of rainwater [26].

C. Mesheirab mosque in Doha

Fig. 12. Shows Mesheireb mosque [27].

The Mesheireb mosque is located in Doha, Qatar, which was opened in 2016. The Mesheireb Mosque won the Abdullatif Al Fozan Prize in 2017, which is awarded to the outstanding mosque in the Arabian Gulf, in terms of design and achieving the sustainability requirements. This prize concerns about the emergence of the mosque as a distinctive architectural element and its solutions to the climatic requirements and the concepts of sustainability, the award began in 2014. The mosque area is about 1,400 square meters and can accommodate about 600 worshipers, as shown in figure(12), [27].

- The use of Renewable energy:

Fig. 13. Shows the solar panels on the mosque's roof [27].

There're solar panels on the roof of the mosque to generate electricity from solar energy as a use of renewable energy, that reduces the consumption from traditional electricity sources which reduces the running costs, as shown in figure (13), [27].

- Maximum use of natural daylight in prayer hall

The design of the mosque's prayer room is based on the use of natural lighting, which passes through special decorative units that allow the natural lighting to enter to the prayer hall without allowing the solar radiation, which eliminates the use of artificial lighting during the day and reduces the consumption of traditional electric power, as shown in figure (14), [28].

Fig. 14. Shows the entry of natural daylight to prayer hall[28].

- The use of decorative units on openings and facades:

Fig. 15. Shows decorative units on the mosque's openings[28].

The decorative units were used on external openings to protect against solar radiation, while allowing natural daylight to enter throughout the day, as shown in figure (15),and also white color was used on the external façades which have a few number of openings, the design was also based on the use of the inner courtyard of the mosque for natural lighting [28].

- The presence of an internal courtyard:

The mosque has an open courtyard surrounded by green plants and a shaded aisle to protect worshipers from solar radiation, with the presence of a water fountain. This open courtyard provides a suitable shades throughout the day and some environmental treatments [28].

- The use of plants to purify the air and provide shades:

The mosque contains a number of trees and bushes which provide shades, purify of air from carbon dioxide (Co2) and give an aesthetic appearance to users [28].

D. Case studies of some existing mosques that developed towards sustainability requirements:

- Development of Badriya Jumaa mosque in India:

Fig. 16. Shows Badrya Juma mosque [29].

Badriya Juma mosque has been built for 80 years in India and currently it has developed to match with sustainability requirements. Natural cooling and ventilation of the prayer hall was carried out through the ventilation holes in the minaret which is directed towards the desired orientation of the wind to achieve the natural ventilation to the mosque, where the minaret with a height of 70 feet is used as a wind catcher. GRC units were used on facades and openings as decorative units with holes to protect from solar radiation while allowing air and natural light to reach to prayer hall as in figure (16), [29]. The mosque takes into account the methods to reduce consumption, recycling and reuse of materials and generation of renewable energy. The solar panels are installed to generate electricity. The mosque now is producing its full energy through renewable energies like solar and wind energy, which is considered a zero energy building. The generated energy is greater than the mosque needs, so the mosque will supply the electrical power network of the city with this extra energy. Recycling methods , recycled material and local materials were used in the development of the mosque, as well as water consumption was reduced by reusing and recycling of water, and also using of low flow valves [30].

- Development of Jamek mosque in Kampung Baru, Kuala lumpur, Malaysia

Fig. 17. Shows Jamek Mosque in Kampung ,Kuala lumpur, Malaysia[31].

The mosque, in figure(17),was built in several phases, the most recent of which was in 1955, the mosque is currently being developed taking into consideration the requirements of sustainability as the following:

a) **Water conservation:** The development included taking into account the collection of rainwater in special tanks and recycling inside the mosque to be used for ablutions, toilets, and cleaning works inside and outside the mosque, the development also used special water taps to reduce water consumption during ablution and added some squat toilets because they consume less water.

b) **Reducing energy consumption:** The development included the use of minimal electricity consumption, the use of (LED) lighting and the use of environmentally friendly fans which save energy in moving the air inside the mosque.

c) **Generation of electricity from renewable energy:** The development included the installation of solar panels on the roof of the mosque to generate electricity from solar energy to be used in the mosque, to reduce the use of normal electricity.

d) **Natural lighting:** The use of natural lighting has been modified to reach to maximum possible use throughout the day to reduce dependence on artificial lighting.

e) **Providing places of prayer in open areas to reduce the need for energy for lighting and ventilation:** The development included the provision of prayer places in outdoor shaded areas so there is no need to consume more energy in air ventilation and in lighting during the day.

f) **Social awareness:** The development included the mosque to be a place to educate Muslims to live in a sustainable manner and not to waste the resources.

g) **Economic return from recycling operations:** The development included a place in the mosque where recycling operations are done, there're financial return of these operations to the workers in the mosque [31].

- Development of Sultan Bulfara Al Kobaisi Mosque in UAE

Fig. (18) Shows Sultan Bulfara Al Kobaisi Mosque [32].

The development of Sultan Bulfa Al Kobaisi mosque in UAE, as in figure (18), included the change of the used lighting units to less power consumption lamps like (LED) lighting. A study carried out on the mosque found that the traditional lamps that was used in the mosque not only consumed more electric power, but also generated a large amount of heat, which increased the burden on the air conditioners. The development included the recycling of water from ablution after filtration and reused in irrigation and cleaning of toilets. The development also included the use of solar energy to generate electricity and the use of biodegradable materials. [32].

VIII. Elements that aid to support the principles of sustainability in the design of mosques:

Through the study and by analyzing a number of case studies, it is clear that there are several elements which enable to achieve of sustainability in mosques as the following:

A. Utilization of innovative masses formation that meet some of climatic requirements

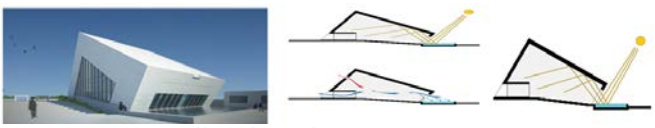

Fig. 19. Shows the effect of mass formation in natural lighting and natural ventilation [33].

One of the ideas for the design of a mosque in Turkey shows the effect of the innovative mass formation in achieving the requirements of ventilation and natural lighting, which supports the climatic requirements, as show in figure (19), [33].

B. Underground mosques

Underground mosques works to protect the building from undesired external climatic factors, while allowing natural lighting and natural ventilation and enhance the sustainability requirements. For example, the Sancaklar mosque, in Istanbul, Turkey, which is underground mosque was built in 2012. The stairs are arranged to lead the user down to the entrance of mosque, consistent with the surrounding landscape, to give a harmony with the environment, the design allows of natural lighting for the prayer hall. This design is based on the function of the mosque [34].

C. Generating of electricity from renewable energy:

Fig. 20. Shows the use of photovoltaic solar panels on the roof of Ambar mosque in India, [35].

Solar panels were used to generate some of the electrical energy required by the mosque for lighting, air conditioning and water heating. These solar panels are added on the mosque's facades or on the mosque's roofs [36], like Ambar mosque in India, as shown in figure (20), [35].

D. Producing of electrical energy from the movement of worshippers:

Fig. 21. Shows a mosque in Bursa that generates electricity from worshippers movement [37].

A mosque in Bursa in Turkey is designed to produce electrical energy from the movement of worshippers through the pressure of the worshippers on the ground during the prostration that by special units to generate electricity, in addition to that the mosque can produce of electricity through the solar panels located on the roof of the mosque, (Glick Aerinngazghi), the architect of the mosque, believes that this mosque will be considered a model in the design of the mosques,as shown in figure(21), [37].

E. Zero energy mosques:

The Astana Mosque in Kazakhstan, as shown in figure (22), is a zero-energy mosque. It was opened in 2018. Its capacity can reach to1000 worshippers, the dome diameter is 26 meters and the minaret height reaches to 43.5 meters. The mosque produces all its required energy from renewable energy sources, that by the solar panels. The generated energy is more than three times the energy needed by the mosque, so the mosque supplies the city with the energy that exceeds than its needs [38].

Fig. 22. Shows Astana mosque [38].

F. Utilizing of the mosque as an element of supplying the city and the surrounding society with the excess energy

The emergence of some mosques that generate electricity from renewable energy such as solar energy and wind power, in some cases mosques produce all their required energy from renewable energies, and in other cases the production of energy is more than the required energy for mosque, that makes the mosque to supply the surrounding city with the excess energy [29]. In that case the mosque becomes one of the sources of providing the electricity to the city and the surrounding community, as in Badriya Juma mosque in India and Astana Mosque in Kazakhstan [38].

G. Utilizing of domes to aid supporting sustainability requirements

- Smart dome and its adaptation with the climate and energy generation system

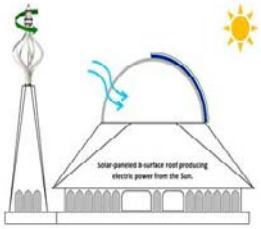

Fig. 23.Shows smart dome

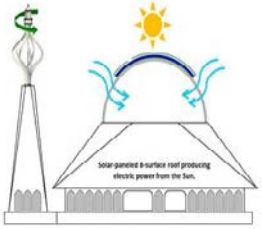

Fig. 24. Shows smart dome

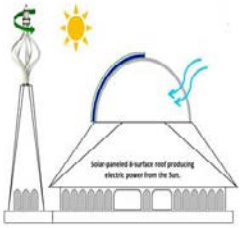

Fig. 25.Shows smart dome

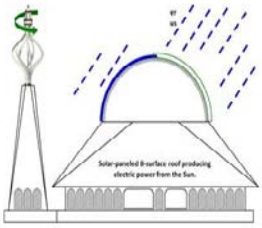

Fig. 26. Shows smart dome

The smart dome is used in the mosque of Al-Biruni school in Batu in Malaysia. The system is integrated with the required climatic treatments, solar power generation on the sides of the dome and wind power at the top of the minaret. The system consists of a dome with two mobile parts, solar panel units and a movable part above minaret. The movable part is rotating by the wind power that drives the turbines to work and generate electricity. The dome consists of two movable parts which move automatically

by an intelligent system that according to the movement of the sun, the daylight hours and the times of rain. The system can close the dome or open a part of it and moves the solar panels to the optimum position that to provide natural ventilation, natural lighting for the prayer hall and to protect from direct solar radiation when needed, with the generation of electricity by the solar panels. The system can handle several different climatic conditions as following:

In case of sunny times with strong winds in the morning, as shown in figure(23), the solar panels are moved to close the place that is facing the sun, this position makes solar panels to face the sun radiation to generate electricity from solar energy and opens the other side of the dome which is away from sun radiation in order to allow air to enter to the prayer hall, also solar panels units are fixed on the flat surfaces of the slanted roof below the dome [39]. In case of sunny times with high winds in afternoon, as shown in figure(24), the solar panels are moved to close the place that facing the sun which is in the upper area of the dome, that making solar panels facing the sun and generating electricity efficiently, that position also enables to open of the side of the dome that is far from the sun radiation to allow the fresh air to access to prayer hall, with the presence of solar panels on flat surfaces of roof to generate electricity while the rotation of the upper part of minaret generates electricity from wind power. In the case of sunny times with high winds in afternoon, as shown in figure(25), The solar panels are moved to close the place that facing the sun which in the upper area of the dome, with the opening of the side of the dome that away from the sun radiation to allow of fresh air, with generating electricity from solar panels. In the rainy times, as shown in figure(26), the moving part closes the dome completely to protect against rain whereas the wind power will be the only source to generate electricity by the unit above the minaret [39].

- Utilizing of dome to support natural daylight and natural ventilation:

Fig. 27. Shows the movable dome in Alnabawi mosque [40].

The emergence of utilizing mosque domes to provide natural lighting and natural air ventilation with protection from solar radiation in hot and humid climate, hot and dry climate and very hot climate. As movable domes in Alnabwi mosque , where there is a possibility of moving the domes for opening of a part of ceiling or closing it automatically, according to the need, the requirements of natural light and according to the changes in air temperature. These domes are made of lightweight materials, as in figure (27), [40]. In Sheikh Zayed mosque in Abu Dhabi, domes are covered with decorative elements that allow the entry of natural light while preventing of the direct solar radiation, as shown in figure (28), [41].

Fig.28. Shows indirect natural light at Sheikh Zayed mosque in Abu Dhabi [41].

- Solar panel dome

Fig. 29. Shows Solar panel dome in Kosovo mosque [42].

The dome is covered by solar panels in a mosque in Kosovo in a way that allows natural ventilation to enter to prayer hall with preventing of direct solar radiation which is creating a good ventilation for the internal spaces. The layers of solar panels generate the required electricity for the mosque and control the amount of light that can pass to the internal spaces as shown in figure(29), [42].

- Multi layers' domes

Fig. 30. Shows double layers dome in Goktepe mosque [43].

Goktepe Mosque in Turkmenistan has double layers dome the outer layer of the dome covered with colored mosaics and the interior layer is used as decorative element which is covered by Islamic motifs. A space between the two layers is used as thermal insulation to protect from the outdoor weather as shown in figure (30), [43].

- A glass dome with shading louvers

The use of glass domes that covering the prayer hall with external horizontal louvers and a number of vertical elements with the covering of upper part of the dome to prevent of solar radiation and to allow of natural light to illuminate the main prayer hall without allowing of solar radiation, as in Ali Sami Pasha mosque in Ankara ,as shown in figure (31), [44].

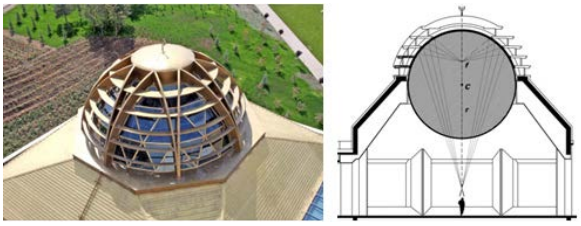

Fig. 31. Shows glass dome with shading louvers in Ali Sami Paşha mosque in Turkey [45].

H. Utilizing of minarets to aid supporting the sustainability requirements

- Using of minarets to put the electric power turbines.

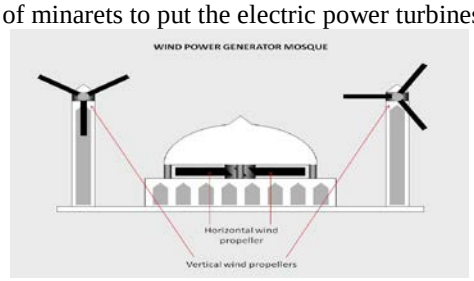

Fig.32. Shows the use of wind turbines on the minarets and below the dome in the Al-Hussein mosque in Malaysia [46].

In Al-Hussain mosque in Kuala Perlis in Malaysia, the minarets was used to put the turbines to generate electricity from the wind .In addition to that, there are other smaller turbines are added in a horizontal row below the dome in order to generate electricity also from wind power , as shown in figure (32), [46]. Power turbines were added on the minarets of Norderstedt mosque and Cologne mosque in Germany, where they are considered the first mosques in the world that use energy turbines in such this way. About 30% of the required electricity are generated by wind turbines in these mosques [47].

I. Utilizing of minaret to support ventilation and air movement in the mosque

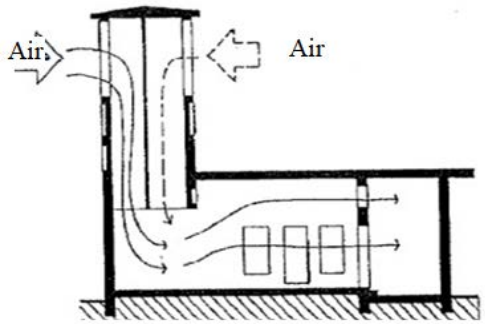

Fig. 33. shows the use of the minaret in air ventilation and the refresh of air inside the mosque [48].

The minarets can be used such as wind catchers with taking into account the orientation of the upper opening of the minaret to be directed to the desired wind direction to insert the fresh air into the prayer hall, while working to find an outlet for air from another place, and this requires a specific design location between the minaret and the prayer hall. This process supports the air movement in prayer hall and natural ventilation. In some cases, the work of the minaret is integrated as a wind tower with the openings in the dome, with taking into account the preferred orientation for the wind and the climatic zone of the location of the mosque, as shown in figure (33), [48]. In some other mosques, as in Rahmaniya mosque in Skaka, Saudi Arabia, the wind towers and air intake were used for natural ventilation in a developed manner. The results of the measurements showed that the temperature decreased by 14.5 ° C as a result of using of these solutions, the results also proved the importance of these treatments in supporting of methods to reduce the energy consumption in mosques [15].

J. Utilizing of the intelligent electronic systems for aiding to support sustainability

Al-Sabtain Mosque in Ras Al-Khaimah in UAE, has been equipped with intelligent systems to reduce energy consumption. Intelligent systems have been used to control the air conditioning systems, which makes the air conditioning system work according to the number of worshippers in the mosque only, to conserve the energy consumption. With the addition of smart systems for the doors, which open and close by special sensors to maintain the indoor air temperature to reduce the burden on air conditioners, and use of smart systems to run lighting according to need only, which reduces energy consumption [49]. There's use of intelligent systems to rationalize the used water consumption in ablution to reduce excessive water consumption, with the presence of intelligent systems to control the toilets flush system according to need to conserve water, and also these smart systems controls recycling and reusing of the used water in ablution [50].

K. Utilizing of the potentials and treatments of exterior facades to aid supporting sustainability

Fig. 34. Shows Islamic calligraphy in exterior facades of Al-Irsyad Mosque in Indonesia [51].

In Al-Irsyad Mosque in Indonesia, which has not a dome in its design, the external façades were designed with some architectural treatments, which include religious calligraphy and contain some holes. These holes allow the outside fresh air to access naturally to the interior spaces of the main prayer hall, By this way, the need for air conditioners in the mosque has been dispensed. These holes also allow the entry of natural light into the prayer hall without glare and without entry of solar radiation as shown in figure (34), [51].

In some other mosques, there's a use of decorative formations and mashrabiya to protect against the direct solar radiation to the external facades and openings, while allowing natural

light. Architectural treatments can encouraging the entry of solar radiation or protecting according to the climatic requirements and climatic zone of the location of the mosque. Figure (35) shows Assyafaah mosque in Singapore which awarded AGH KHAN prize in architecture in 2007, one of the main elements that enables the mosque to receive the prize is the formations of the external facades, which enables the natural ventilation with protection from direct solar radiation [52].

L. Maximum use of natural daylight

Providing of natural lighting is an important aspect of reducing the relying on artificial lighting and therefore reducing the electricity consumption. It also gives a good psychological impression to the worshippers. It is preferable to provide the natural lighting of the prayer hall throughout the day through double-glazed windows or through roof with taking into account the entry of natural lighting with preventing of direct sun radiation that according to the climatic zone of the location of the mosque.

M. Utilizing of the open courtyard of the mosque (Sahn) for natural lighting and natural ventilation

The open courtyard of the mosque (Sahn) is used to provide the required amount of indirect natural lighting throughout the day to the adjacent spaces to open courtyard, as it is also used for the natural ventilation of the prayer hall of the mosque, where it provides an appropriate amount of shades, that makes the air temperature inside the courtyard is less than the external temperature.

N. Utilizing of sunshades elements for providing shaded areas in outdoor spaces

Shading is an important element for the mosques that are located in hot and humid climate, hot and dry climate and very hot climate. Suitable shading can be provided by the form and mass of the building, as well as using of lightweight sunshades that provide outdoor shaded spaces to be used in prayer when weather conditions allow. Where these spaces do not need artificial lighting systems or air conditioning systems, which reduces relying on artificial lighting and air conditioning systems, these sunshades can be opened or closed according to need, such as in the sunshades of Alnabawi Mosque in Medina, which are opened by the day and closed after sunset. They are also used to protect worshippers from rain when needed [53]. In Al-Quds mosque in Iran, some units were used to shade the outdoor spaces. These units are derived from heritage and Islamic elements. These outdoor spaces are used in the activities offered by the mosque and in religious and ceremonies events, as shown in figure (36), [54].

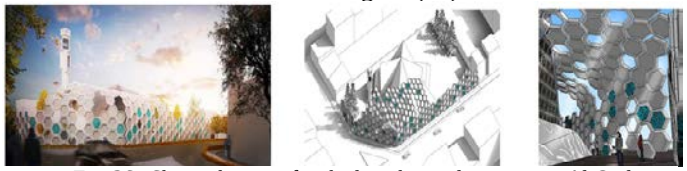

Fig. 36 . Shows the units for shading the outdoor areas in Al-Qods mosque in Iran [54].

O. Reducing the consumption of artificial lighting to the minimum

The consumption of artificial lighting is reduced by increasing the reliance on natural daylight and by relying on the (LED) lighting units. In some mosques, there's a use of transmitting concrete in facades which increases the use of natural lighting through the day and reduces the consumption of artificial lighting like Al -Aziz Mosque in Abu Dhabi in United Arab Emirates which its facades are made from transmitting concrete. Transmitting concrete enables natural daylight to enter to the prayer hall during the day, and also the use of artificial light for outdoor areas is reduced at night because the transmitting concrete facades enable to illuminate the outdoor areas through the facades, as shown in figure (37), [55].

Fig.37. Shows transmitting concrete in façade of Al Aziz mosque in Abu Dhabi [55].

P. Water conservation:

The conservation of water in ablution is considered an important element that must be considered to achieve sustainability in the mosques. The water conservation in the mosque can be achieved by the following elements:

- *Changing the type of water flow valves:*
  Abu Dhabi Distribution Company conducted a study of mosques in Dubai. The study proved that if water flow valves and taps were changed in ablution units in mosques by special new taps , this would lead to a decrease of 40% of the used water in ablutions in mosques. The new taps work on making the flow of water of 4-6 liters per minute ,with a stop period of 15 seconds for each tap , to reduce the waste of water, this amount of water is sufficient for the ablution for one person, while old taps give 10 liters of water per minute with non-stop water flow , the study proved that these valves will save water about 1.75 billion liters per year in UAE [56].
- *Using of environmentally friendly devices to reduce water consumption during ablutions:*
  A certain type of device is used to reduce the consumption of water during ablution, where this device determines the amount of water needed for ablution, and reduces the used water to 1.2 liters , such as the device that invented by Masdar scientific city [57]. And also through the Auto Wudu Washer, which contains sensors to give the only required amount of water for ablution, which reduces the amount of water in ablution from 10 liters in normal conditions to 1.3 liters by using this device, as shown in figure (38), [58].

Fig. 38. Shows Auto Wudu Ablution system, which saves water consumption [58].

- *Reuse of ablution water:*

  The process of reuse of ablution water is carried out by assembling it in special tanks, and then performing purification, filtration and treatment processes, the ablution water is recycled for reused in latrines and irrigation of plants, and trees in the mosque [59].

- *Recycle of sewage water of mosques:*

  The recycling and treatment of sewage water at Sheikha Sabika mosque in Kuwait, was carried out by using an environment-friendly purification device. All harmful materials are disposed to be suitable to irrigate the plants in the mosque. Treatment device can be placed above or underground surface [60].

- *The mosque is connected with a water desalination plant or water treatment unit:*

  One of the latest idea that has recently emerged to preserve water is to connect between the establishment of the mosque with a desalination plant or water treatment unit, whether for desalinating the seawater or treating the collected rainwater, where the required water for the mosque is provided from the output of the desalinating plant or treatment unit. This method also can recycle the water resulting from ablution, that for supporting sustainability in preservation of water. For example, the construction of Al-Muhajirin mosque in Indonesia was based on the establishment of a desalination unit which desalinates of collected rainwater. The required water for ablution in the mosque can be provided through this unit, with the use of the rest of the output water to supply to the surrounding community [61]. In Ibeki mosque in Gaza, the mosque is connected to a desalination plant to provide with the required water for ablution. The unit produces about 150,000 liters of drinking water per day. The surplus water is used in supplying the surrounding area of the mosque with the required water [62].

Q. Utilizing of mosque's roof for aiding to support the sustainability requirements:

The mosques roofs can be used to help achieving the requirements of sustainability. The mosques roofs are exposed to solar radiation throughout the day, the following solutions can be used for roofs:

- *Planting of mosque's roof:* Through the planting of green gardens on the mosque roof to increase the thermal insulation of the roof, [63], such as the use of roof garden in Cyberjaya mosque in Malaysia and, Sancaklar mosque in Turkey.
- *Solar panels on the mosque's roof:* Solar panels that generate electricity can be placed on the mosque's roof to protect the roof from the sun radiation throughout the day, in case of there's a need for protection against solar radiation, as in some climatic zones [36].

R. Using plants for purification of air

Plants are used in the inner courtyards and around the mosque to provide appropriate shades, reduce pollution, reduce CO2 and create a healthier environment, as in Cambridge mosque in UK [23].

S. Community Participation

Community participation is an important element in achieving sustainability. It includes community cooperation with the mosque, where the mosque provides religious, educational and cultural services to the community, the community participates in protecting the mosque building, reducing pollution, conserving resources and fulfilling the requirements of sustainability in the mosque. One of the ways that North America's green mosques are included is to create an outdoor garden that is used to grow plants, vegetables and fruit that can be used to feed the surrounding community, thereby educating the surrounding community on the basis of participation and sustainability [64]. The community participation is clearly visible in the Djenne Mosque in Mali, which is built of mud. Every year after the end of the rainy season, the residents repair the external facades of the mosque by mud. This process is a regular and permanent maintenance of the mosque by the local community to maintain the mosque ad they inherit this process through generations [65].

T. Increasing the awareness of the sustainability practices to Imams, worshippers and mosque users

Increasing the awareness of the sustainability by teaching the users, employees and Imam of the mosque of the importance of sustainability, its link to Islamic religion, the practices that achieve sustainability, ways to reduce energy and water conservation, and ways to conserve of the resources [66].

U. The use of biodegradable substances

Biodegradable materials, substances and bags are used to avoid negative impacts on the environment. This has been appeared in the recent trends in United Arab Emirates [67], as in Sultan Bulfara Al Kobaysi mosque in Zayed city, Abu Dhabi [32].

IX. SOME SOLUTIONS TO IMPROVE THE PERFORMANCE OF THE EXISTING MOSQUES TOWARDS SUSTAINABILITY

The development of the existing mosques in Virginia in USA has focused on achieving the sustainability of the mosques by educating Muslims about the methods of

sustainability and life without exaggeration, planting trees in the mosques to purify the air, reducing water consumption, changing lights to LED lighting, increasing the thermal insulation of the external facades of the mosques ,starting recycling process of materials, waste and water, and installing solar panels to generate electricity from renewable energy to reduce the consumption of traditional electricity. These procedures reduced carbon emissions by 13% and reduced energy consumption by 21% in mosques that according to Khalid Ikbal, director of ADAMS Islamic Center, who is working for the development of mosques in Virginia. [68].

Fig. 39. Shows Glasgow Central Mosque in Galsgo,UK [69].

The development of Glasgow Central Mosque in UK, as shown in figure (39), has been based on improving the thermal efficiency of the main dome of the prayer hall by performing heat insulation operations for this dome. This reduces heat loss and reduces the burden on air conditioning. And also the development depends on using (LED) lighting, encouraging the community to live in ways that save energy and reducing consumption [69]. In Amman city in Jordan, many procedures had made to develop mosques towards sustainability requirements and reduce carbon emissions. Solar panels were added to the mosques which made some of these mosques became able to provide all their electricity needs from renewable solar energy. The lamps had changed to be energy saving lighting (LED), rain water had collected and reused in irrigation and in toilets [70].

X. Main elements that support the proposed approach for supporting sustainability requirements in mosques

a). Utilizing of the main architectural elements of the mosque like minarets, domes, roofs , facades, mashrabias and internal courtyard in a way to serve sustainability requirements.

b) Taking advantage of international and regional experiences in achieving sustainability in mosques.

c) Utilization of latest technologies, intelligent systems and scientific development in order to achieve the sustainability requirements.

d) Taking advantage of some procedures, the most appropriate systems and design methods that can be applicable to achieve sustainability in mosques.

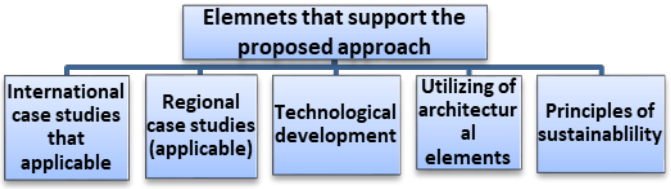

Fig. 40. Shows Elements that support the proposed approach

XI. The different international solutions to aid supporting sustainability in mosques

The different international solutions to support sustainability in mosques are in the next table:

Table 1. Shows the summary of the different international solutions in mosques and their impact on supporting the sustainability requirements

The solutions	The effect of this solution	Aspects of supporting sustainability
The use of local materials		Environmental
The use of decorative units on openings and facades	Increasing the shades	Environmental
Multi layers' domes	Increasing the thermal insulation.	Environmental
A glass dome with shading louvers	Providing of natural lighting.	Environmental
The presence of an internal open courtyard of the mosque (Sahn)	Providing of natural lighting & natural ventilation.	Environmental
The use of smart dome	Providing of natural lighting & natural ventilation.	Environmental
innovative masses formation that meet some of climatic requirements	Environmental solutions	Environmental
Underground mosques	Environmental solution	Environmental
Utilizing of dome to support natural daylight and natural ventilation	Providing of natural lighting & natural ventilation.	Environmental
Utilizing of minaret to support ventilation and air movement	Providing of natural ventilation	Environmental
the treatments of exterior facades to protect from sun	Providing of Shades	Environmental
Planting of mosque's roof	Increasing the thermal insulation	Environmental
High quality of thermal insulation works	Increasing the thermal insulation	Environmental
Producing of electricity from the movement of worshippers	For generating of the electricity	Conserving of energy
Maximum use of natural lighting	For decreeing of the energy consumption	Conserving of energy

The solutions	The effect of this solution	Aspects of supporting sustainability
The use of low energy consumption lighting units	For decreeing of the energy consumption	Conserving of energy
Smart dome	For generating of electricity	Conserving of energy
Solar panel dome	For generating of electricity	Conserving of energy
Reducing the consumption of artificial lighting	For decreeing of the energy consumption	Conserving of energy
Solar panels on the mosque's roof	To generate electricity from renewable energy	Conserving of energy
Wind turbines on minarets	To generate electricity from renewable energy	Conserving of energy
The use of Smart Systems	To generate electricity from renewable energy	Conserving of energy
The use of solar energy in heating	To reduce the energy consumption	Conserving of energy
Air conditioning with energy saving systems	To reduce the energy consumption	Conserving of energy
Utilizing of the mosque as an element of supplying the city and the surrounding society with the excess energy	Generation of energy and supporting the surrounding society	
Planting of mosque's roof	For purification of air to increase quality of air	Improving of indoor environment
Using plants for purification of air	Quality of air	Improving of indoor environment
Increasing the awareness of the sustainability practices to users	Society participation	Social participation
The use of biodegradable substances	Reducing the waste in environment	Reducing the waste
The use of recycled water	For reducing of water consumption	Conserve of water
Changing the type of water flow valves	For reducing of water consumption	Conserve of water
Using of environmentally friendly devices in ablutions	Reducing the consumption of water	Conserve of water
Reuse of ablution water	Reducing the water consumption	Conserve of water
Recycle of sewage water	Reducing the water consumption	Conserve of water
The mosque is connected with a water desalination plant		Conserve of water

XII. A PROPOSED DESIGN APPROACH TO SUPPORT SUSTAINABILITY REQUIREMENTS IN THE NEW MOSQUES AND IMPROVING OF EXISTING MOSQUES PERFORMANCE.

A. Developing the use of architectural elements

Developing and Utilizing of the main architectural elements of the mosque to aid supporting sustainability requirements:

- **Utilizing of mass formation (In the case of the design of new mosques, unless there is a possibility to achieve in the existing mosques).**
  Selecting the appropriate mass formation that allows for the required architectural treatments, according to the climatic zone.
- **Utilizing of minarets to aid supporting sustainability (In the case of the design of new mosques, unless there is a possibility to achieve in the existing mosques).**
  a) Utilizing of the minarets as wind catchers, to enhance the natural ventilation and the movement of air inside the prayer hall.
  b) Utilizing of minarets for fixing of the wind power turbines to generate electricity from wind power.
- **Utilizing of domes (In the case of the design of new mosques, unless there is a possibility to achieve in the existing mosques).**
  a)The use of the dome, which has moving parts that allowing to provide with the required natural lighting, and natural ventilation to the prayer hall.
  b) Utilizing the openings in the dome with other elements inside the mosque such as the minarets for enhancing the natural ventilation inside the prayer hall.
  c) The use of movable domes to enhance natural ventilation according to the climatic zone of the site of the mosque.
  d) The use of multi-layer domes to enhance the thermal insulation.
  e) The use of domes with solar panels for generating energy.

- **Utilizing of mashrabias and decorative elements in openings**
  a) The use of mashrabias and decorative elements on external openings for protection from sun when this is required, that's depending on the climatic zone of the mosque site.
  b) The use of the small holes in mashrabias for enhancing natural ventilation and movement of the air inside the prayer hall through the exit of hot air from the upper openings of the prayer room through domes, minarets and roof, and the entry of fresh air from the holes in mashrabias,

that's depending on the climate zone of the site of the mosque.

- **Utilizing of facades (In the case of the design of new mosques, unless there is a possibility to achieve in the existing mosques).**
  a) Utilizing of facades for the protection of direct sunlight, or for enhancing the entry of sun, according to the climate zone of the location of the mosque.

- **Utilizing of roofs.**
  a) Utilizing of roofs for protection from sunlight, according to the climatic zone of the location of the mosque.

B. Utilizing of technological development to aid supporting the sustainability requirements within the mosque

- **Renewable energy**

a)Generation of electricity from renewable energy, whether from solar panels on roofs and facades or by using wind turbines to generate electricity from the wind power , that's according to the geographical location of the mosque.

b) Utilizing the movement of worshipers in generation of electricity.

- **Conserve of energy**

a) The use of smart systems to decrease the energy consumption in lighting and air conditioning systems.

C. Water conservation in ablution, with reuse and recycling processes

- The use of devices and valves that can control the consumption of water, and reduce the excessive consumption of water during the process of ablution.
- Recycling the water resulting from the ablution process by assembling in special tanks and performing the processes of filtrating and purifying to be ready for reusing in toilets flush systems, urinals and in irrigation of plants and trees.
- Collecting and recycling of condensed water result from the cooling systems.
- Collecting and recycling of rainwater, if that's applicable.

D. Energy conservation

- Utilizing of smart control systems to save energy
- Maximum use of natural lighting

  To support the maximum entry of natural lighting through the facades and mosque roof with the presence of the necessary treatments to protect from direct solar radiation, according to the requirements of the climatic zone for the site of the mosque.

- **The use of solar energy in heating and for heating water**

  The use of solar heaters to heat the required water when needed, and the use of solar energy in the heating when needed that depending on the climate zone of the site of the mosque.

- **Minimum use of artificial lighting with the use of energy-saving lighting units**

  Energy-saving lighting units are used inside the mosque (LED), which are less energy consumption.

- **Mechanical cooling system**

  The use of advanced automatic control systems for mechanical and variable cooling systems according to the number of worshipers and to prayer times, that lead to reduce the energy consumption.

- **The efficient thermal insulation**

  Performing proper thermal insulation work for all facades and roofs, and also using double glazing for all glazing surfaces.

E. Utilizing of plants and soft landscape elements to serve sustainability requirements

The use of trees and plants to serve the requirements of sustainability to achieve the required shades for outdoor areas, as long as it's required, and also to reduce the carbon dioxide, with taking into account the climate zone of the site of the mosque.

F. Water features (in dry climatic zones)

The use of water features such as fountains by using recycled water to serve the requirements of sustainability and to increase the relative humidity in the air as long as it's required, according to the climate zone of the site of the mosque.

G. Taking into account for the presence of inner courtyard (Sahn) in the mosque (in the case of the design of new mosques, unless there is a possibility in the existing mosques.

Taking into consideration the presence of an inner courtyard (Sahn) in the mosque to be utilized in natural lighting and natural ventilation.

H. Taking into account the climate and environmental requirements of the site

Taking into account the climatic requirements according to the location of the mosque.

I. The use of biodegradable materials

The use of biodegradable materials in the construction of the building, in the operating materials and in the materials used frequently.

J. Developing the awareness of sustainability to the community and users

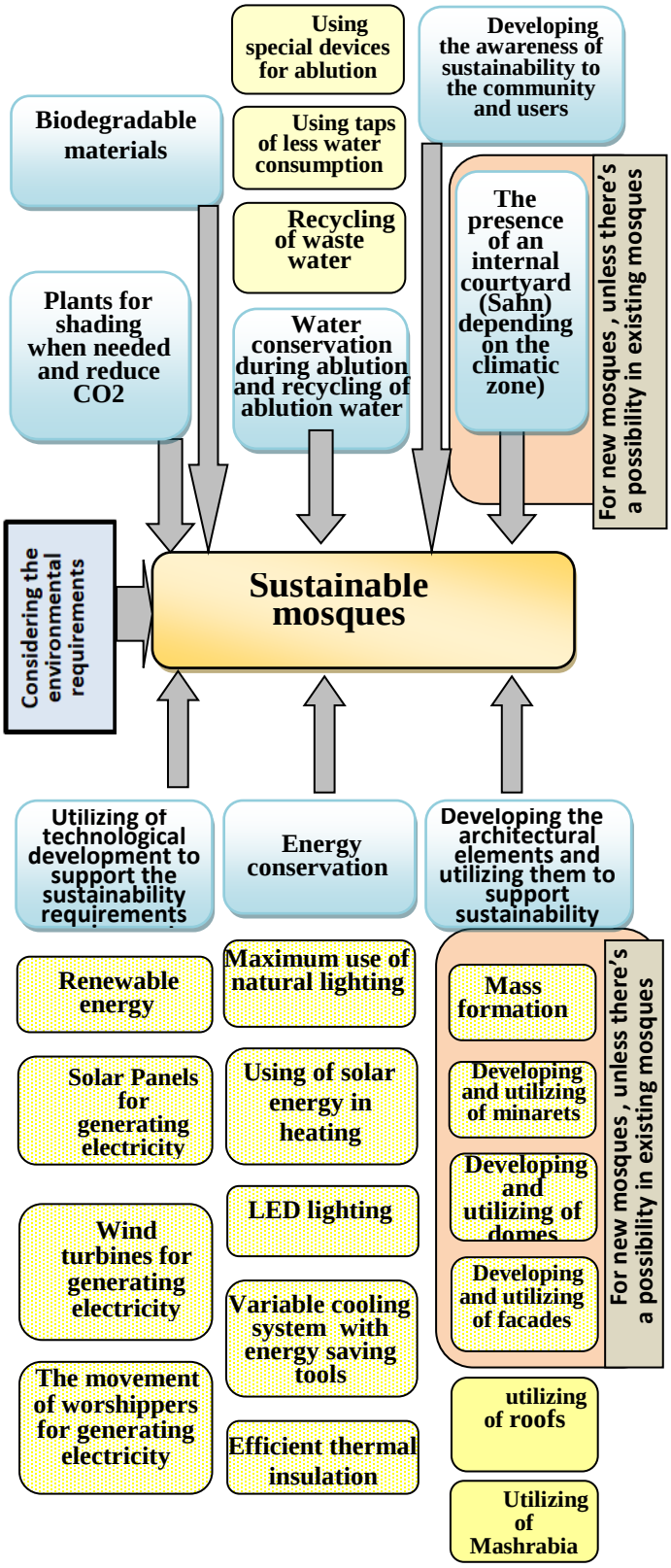

Fig. 41. Shows the proposed approach to aid supporting the requirements of sustainability in the design of new mosques and to improve the performance of the existing mosques towards sustainability

XIII. Conclusion

- The research concluded an approach to enhance supporting the requirements of sustainability in the design of mosques, and improve the performance of the existing mosques towards sustainability.
- The research concluded a method for utilizing the main architectural elements of the mosque to support the requirements of sustainability.
- The research extracted the latest architectural solutions drawn on the international, regional and local experiences that enhance supporting the sustainability requirements for the new mosques design and improve the performance of existing mosques towards sustainability.
- The research concluded that the elements that enhance supporting the sustainability requirements in the design of mosques are:
  a) Utilizing of the architectural elements in the mosque to support the requirements of sustainability such as domes, minarets, marshrabias, facades and internal courtyard (Sahn). It includes also the creating of some especial masses and forms that meet some climatic requirements, with the possibility of building underground mosques as one of the climatic solutions. Minarets can be utilized as wind towers, to enable natural ventilation to the prayer hall with fixing the wind turbines on the higher part of minarets for generating electrical power. Domes can be utilized as smart domes for the purposes of natural lighting ,natural ventilation and fixation of solar panels while facades, internal courtyard and mashrabias can be utilized for the purposes of natural lighting and natural ventilation and also to be utilized to serve some purposes of sustainability.
  b) Conserving of energy and reducing the energy consumption by maximizing use of the natural day light , the use of intelligent systems to save energy consumed in lighting and cooling systems, the use of less energy consumption lighting units , the use of solar energy for heating and heating when needed and the use of efficient thermal insulation required for the roofs and walls.
  c) Generation of energy from renewable resources by installing of solar panels on the roofs and facades of the mosque to generate electricity from solar radiation, and installing of wind turbines to generate electricity from wind power, and also generating electricity from the movement of worshipers to by using special devices.
  d) Utilizing of the technological development to support the requirements of sustainability by using the smart control systems for lighting and mechanical cooling to save energy.

e) The use of new devices and electronic systems to reduce the water consumption during ablution, as well as recycle and reuse the ablution water.
f) Developing the awareness of the sustainability methods of users and worshipers with taking into account the site's specific climatic requirements.
g) The using of biodegradable materials with the use of landscape elements to aid supporting the sustainability requirements.

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