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Research Paper

The Ways of Integration the Solar Panels in Contemporary Shopping Centers, Oman.

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-Abstract:
The Below study is concentrating on the different ways of integrating the solar panels in the contemporary shopping centers and showing theirs advantages. Moreover, determining the kinds of solar panels which are most suitable and applicable in the shopping centers. In addition, giving the importance of installing photovoltaic in the buildings. Summarizing the methods applied in the research, firstly, five cases study were done and applied on the shopping centers, Secondly, designed for the way of combing solar panel with the shopping centers, by the using Revit 2020 software, so that to suggest some useful and helpful solutions and recommendations on how to integrate the solar panels in the building: elevations, walls, roofs, parking canopy and cantilevers. The study had resulted into that most of the shopping centers are using the solar panels at the building roofs and parking canopy, while only few centers are using the solar panels in their exterior walls, in addition to the results obtained is that the energy consumption have been decreased drastically by those building which use solar panels at the roofs. The solar panels was not limited only for the building elements, but it was combined successfully with breakers and shading systems. The use of solar panels has been developed and combined with heritage elements such as domes and Mashrabiyas. To conclude, on the integration of the solar panels study, it is providing one of the new practices which is more useful and supportive globally which can be highly recommended for the shopping centers, as well as, it is playing a major role in reducing the electricity bills, identifying one of the source of a renewable energy, explaining how to design the buildings elevation, exterior walls, roofs, cantilever and parking canopy and the heritage elements with solar panels.

Keywords: *Solar panel - Contemporary shopping centers - Ways of installing Solar panels*

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I. Introduction:

Solar energy is a plentiful, reliable and sustainable source of energy and is also the cleanest form of energy known to human because it is pollution-free and leads to the reduction of a country's carbon emissions. For much of their energy consumption needs, commercial buildings (offices and malls) rely on electricity, and energy consumption in shopping centers is even higher, making them better suited for solar panel construction. With the increase in economic construction in Oman and the rise in people's living standards, the energy demand crisis and environmental deterioration are rising.

The biggest energy users in cities are shopping malls: they run for 12 hours a day or more, are typically completely air-conditioned and have a lot of lighting even during the day. They are excellent candidates for solar electricity, with ample rooftop space in both the mall buildings and in parking areas.

Previous research was limited to the study of the complementary relationship in integrating solar panels into residential buildings, but this research will address the study of different ways to integrate solar panels into commercial buildings, which are contemporary shopping centers in Oman [1] The purpose of conducting this research is to focus on the different ways on integration solar panels in contemporary shopping centers and determine the types of solar panels suitable in shopping center with focusing in the importance of installing photovoltaic in the building.

II. Materials and Methods:

This point deals with detailed information about solar panels, such as the concept and benefits of solar panels, in addition to their types and dimensions. Their types will be presented in various forms.

2.1: Definitions of solar panel:

Solar panels (also referred to as "photovoltaic panels") are devices used to transform light from the sun, which consists of particles of energy or "photons," into electricity that can be used to supply electricity.There are three basic components of a solar panel system: a solar panel, an inverter and a solar gate. Solar panels absorb and convert the sunlight hitting your roof into electricity. This electricity is converted by a solar reflector connected to your solar panels into renewable energy that will feed the lights and appliances in the building. [2]

2. 1.1: Benefits of Solar Energy:

The sun gives energy about an hour to the world, which for one year will satisfy global energy needs. There is no question that the sun is a strong source of energy, and considering the failure to capture a fraction of that energy, it will make a significant difference to the world by harnessing this energy by adding solar panels. Solar panels, however, have faced a great deal of backlash for being costly on a wide scale, but solar panels have now proved to be very beneficial not only to the climate, but also to the economy.

Green Match has identified the main advantages and disadvantages of solar energy in the following points: [3]

2.1.1.1: The Solar Energy's Advantages :

a) Renewable Energy Source:

When it comes to the benefits of solar energy, the most significant thing is that the solar energy is one of the renewable energy sources which can be connected and joined in various areas around the globe as well as it is commonly available in all the places and in every single day of our lives.

b): Reduces Electricity Bills:

Electricity consumption is our day to day mandatory source where we can't live without. Since that the electricity will be dependent on the solar system, as a result it will meet people's energy needs on daily basis with reduced amount to be paid of the electricity bills.in addition to that , there will be a possibility of getting the payments for the surplus energy which can be exported back to the grid by the smart export guarantee (SEG).

c) Diverse Applications:

For the various purposes, the solar energy can be easily used in Photovoltaic or heat which is known as solar thermal. Moreover, solar power can be used to generate the electrical power in several areas without the need of accessing the energy grid. Can be used to distill water in the places with limited supplies of clean water and to power space satellites.

d) Low Maintenance Costs:

Basically, the system of solar energy does not require lots of maintenance, the only useful practice is to keep the system clean by applying periodic cleaning and polishing once a month. Relaying on specialized cleaning companies which can provide cleaning services with prices between £25-£ 35. Most reliable manufacturers of solar panels are offering warranties between 20-25 Years.

e) Technology Development:

Technology is continuously improving and developing in the solar power industries. Inventions in quantum physics and nanotechnology could rise the solar panel efficiency and double or even triple the electrical inputs of the solar power system .

2.1.1.2:Disadvantages of Solar Energy:

a) Cost: there is a very high upfront cost for purchasing the solar system. This is including the payment for the installation of solar panels, batteries, wiring, inverters. However, there is a fixed evolution of solar technologies, so it is safe to say that the prices may fall down in the future.

b) Weather-Dependent: if it is possible to capture the solar energy on miserable and rainy days, the solar system's performance will be declining. Solar panels are depending on the sunlight when we need to capture efficiency of the solar energy. On the other hand, For cloudy and rainy days, it will have a noticeable effect on the energy system. As well as, it is a must to take into consideration that during the night, solar energy can not be gathered.

d) Solar Energy Storage Is Expensive: It is better to use the solar energy right away. Or this can be stored in big batteries. Used in off the grid solar panels, batteries can be charged during the day so that the electricity is utilized at night time.

e) Uses a Lot of Space: as people want to gather as much sunshine as possible , more energy people need to generate, so more solar panels people may require. It takes lots spaces for solar PV panels and the roofs are not big enough to accommodate the amount of solar.

f) Associated with Pollution: while there is less emission to the system of solar energy compared to other forms of energy, pollution can be connected and associated with the solar energy. Gases can be released correlated with the transport and construction of the solar

2.1.2: Solar panel Dimensions: the performance of the panel can basically measured and accounted by ranking the power divided by the total panel areas. The cell surface area can by increased by larger panels that which use large cells,which improves the total performance. Figure 1 shows the different dimensions of solar panels and their effect on its energy power.[4]

- **Common Solar panel sizes:**
- 60 cell panel (120 HC) : Approx width 0.98m x length 1.65m
- 72 cell panel (144 HC) : Approx width 1.0m x length 2.0m
- 96/104 cell panel: Approx width 1.05m x length 1.60m
- **New*** 66 cell panel (132 HC) - Approx width 1.0m x length 1.80m
- **New*** 78 cell format (158 HC): Approx width 1.3m x length 2.2m

HC = half-cut cells

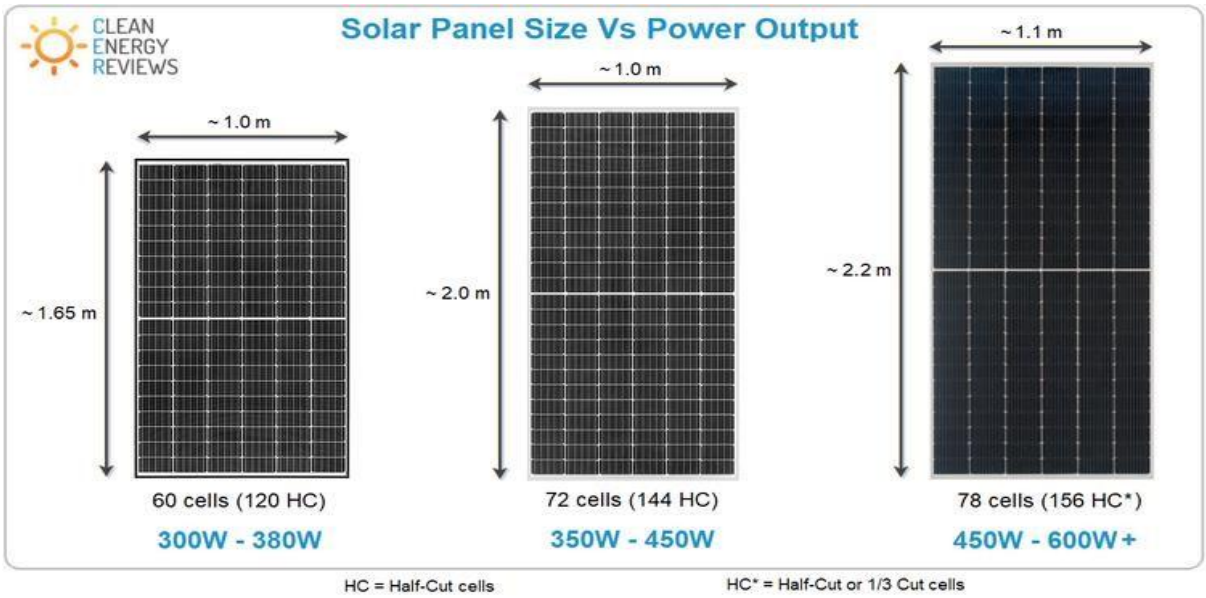


Figure (1): Dimensions of solar panels [4].

In the past, because of advancements in solar cell technology, most improvements in panel power came from performance gains.

Although that is partially a catalyst behind the huge panel wattage leap, the key reason is the creation of modern larger cell sizes along with a greater number of cells per panel. The new panels are physically much broader in scale thanks to these new cell formats and configurations. In general, large panels are ideally suited for solar farms or industrial projects on a utility scale. Figure (1) shows the dimensions of solar panel [4].

Two key sizes have historically been available for solar panels: the standard 60 cell panel format (approximately 1.65 m high x 1 m wide) used for residential rooftops, and the larger 72 cell commercial panel format (approximately 2 m high x 1 m wide). Then half-cut cell panels appeared at almost the same height, but at 120 cells and 144 cells with twice the volume of half-sized cells. In addition to the standard sizes, there are a few premium producers such as Sun Power and Panasonic that generate unique 96 and 104 cell panels.as shown in figure 2

The industry-standard panel size was built around the 156 mm x 156 mm or 6-inch square cell shape for most of the last decade. The emerging new panel sizes are up to 2.3 m long and 1.1 m tall and have a much wider surface area for panels (and cells). Compared to the standard 2 m x 1 m 72-cell plates, this is an improvement of close to 20 percent.[44]

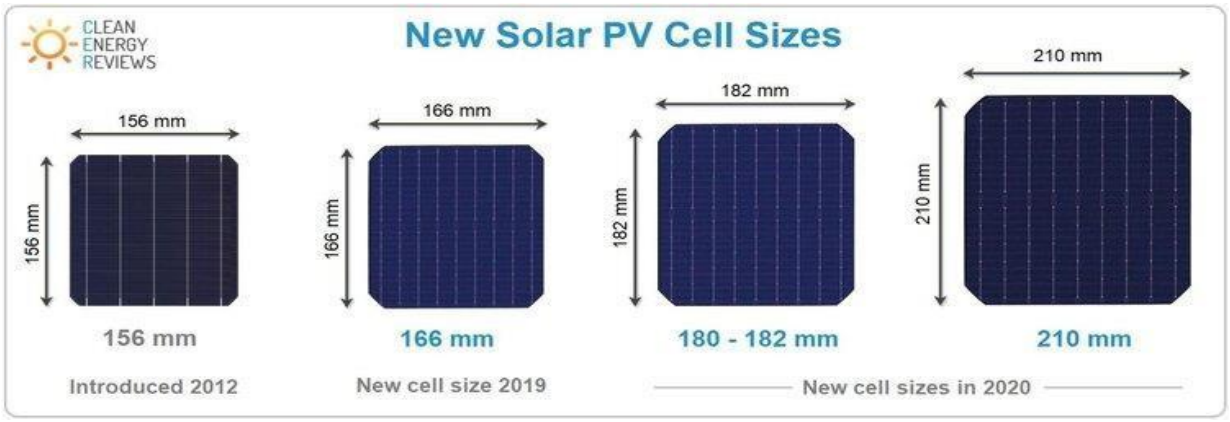


Figure (2): The Measurements of the New Solar Cells [44]

2. 1.3: Types of solar panels:

The biggest distinction between solar panels is the purity or arrangement of silicon, the more accurate the arrangement of the particles of silicon, the more sunlight is turned into energy by the solar panels. Depending on the needs of the plant, there are five key types of solar cells and the strongest kind as show in figure 3. The more effective the panels are, the more costly they are. The solar panel forms are split as follows**:[5]**

2.1.3.1: Monocrystalline Photovoltaic Solar Panel: Monocrystalline solar cells are the most powerful way to turn energy from the sun into electricity. Often, they are the priciest solar panels currently available. As they can generate more electricity, they consume less space than other cells.

2.1.3.2: Polycrystalline Photovoltaic Solar Panel Polycrystalline solar panels are now the most popular alternative in residential installations. They are made up of numerous silicon cells that are glued together and then recrystallized.

2.1.3.3: Amorphous Silicon Photovoltaic Solar Panel: Amorphous silicon the least costly and least effective solar panels are solar panels. By inserting a thin film of amorphous (no crystalline) silicon on a large option of surfaces, these panels may be fabricated. This panels may be lightweight and flexible, which is why solar panels are generally called "Thin Film".

2.1.3.4: Hybrid Silicon Photovoltaic Solar Panel: The use of both monocrystalline solar cells and amorphous solar cells to generate optimum performance is the hybrid silicon solar panel. These panels have better performance ratings than other solar panels, and mono or poly-crystalline panels are far more costly. They are best suited to nations with more sunny climates.

2.1. 3.5: Building Integrated Photovoltaic (BIPV): Roofs, facades, walls and even windows can be integrated with solar shingles, solar tiles, slates and others. In standard households, BIPV is way too pricey to build.

2.2. Shopping Centers:

Shopping malls are common aspects of everyday life around the world, but their roots can be traced to a particular time and place, unlike many other shopping formats.

2.2.1: Definition of Shopping Center:

A shopping center is characterized as an aggregate of businesses and businesses providing services, planned, built and run as a whole, located within a given territory and providing vehicle parking within that territory[6]. At the pre-design phase, according to the requirements for the industrial, architectural and design elements of the overall design of the shopping center, the architectural features of the shopping centers in the largest city are created.

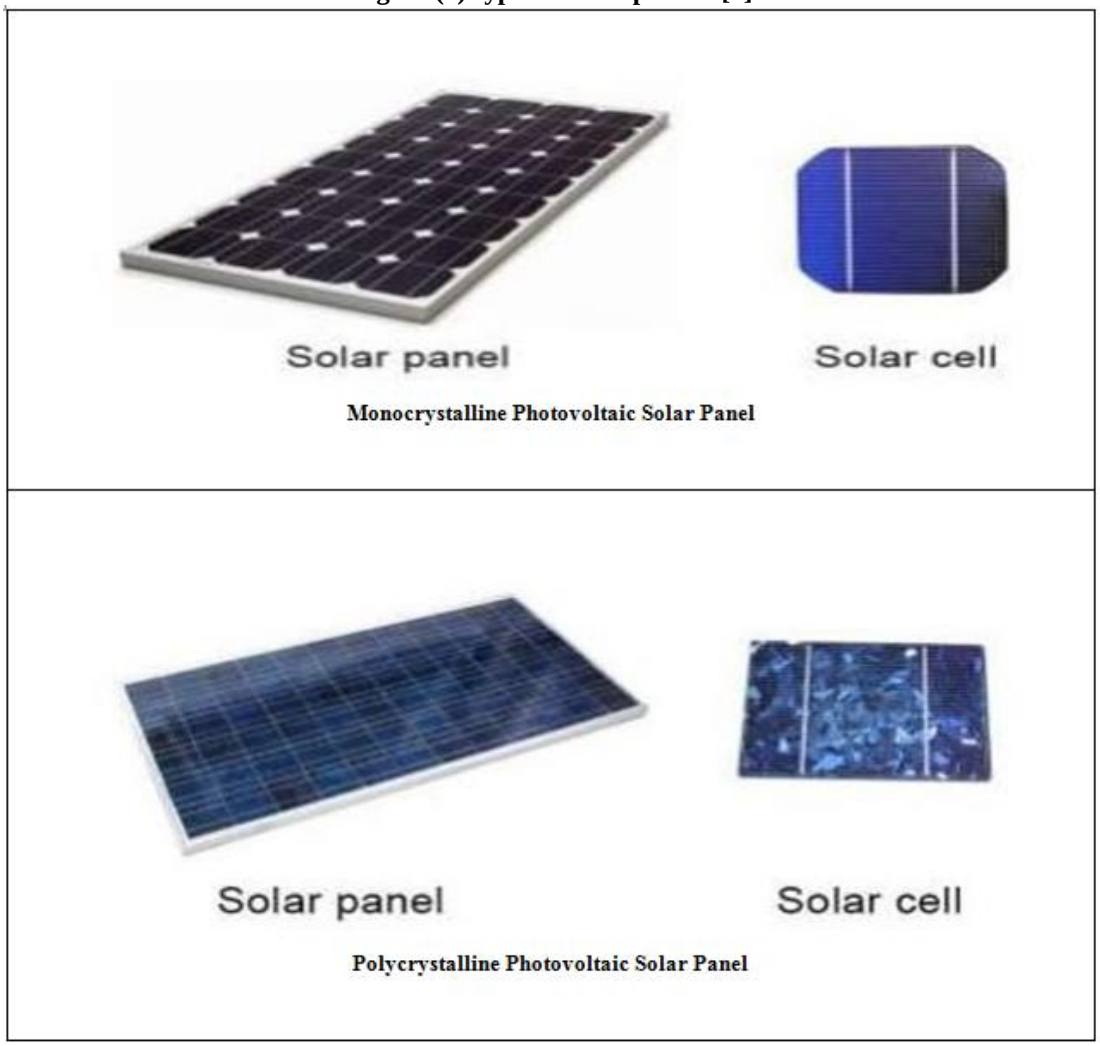
2.2.2: The smart shopping center:

The use of smart technologies in shopping malls is variable and appropriate for all shopping malls where shopping mall management wishes to have specific and mandated technical needs, such as protection, energy management and conservation, as well as priorities for entertainment and business, customer monitoring and acquisition of marketing data.

2.3: Why solar panels important for shopping centers:

Shopping malls are big city energy consumers: they run for 12 hours a day or more, are normally completely air-conditioned, and provide a lot of lighting even during the day. With ample rooftop space, they are perfect candidates for solar power in both mall buildings and parking areas. However, there are certain drawbacks to the use of solar electricity, which should also be regarded as follows:[7]

Figure (3)Types of solar panels: [5]



2.3.1:Energy security: During load-shedding, rooftop solar plants can deliver electricity, ensuring critical loads still work Not all solar plant configurations can deliver power during load-shedding.

2.3.2:Cost-effective: Rooftop solar power at Rs. 18 / kWh (or more) has a leveling cost of Rs. 4.5-5 / kWh (or less), slightly lower than diesel power cost. Solar could also be cheaper than EB fuel, depending on your tariff. In comparison, unlike diesel and EB fuel, the electricity cost is now set for the next 25 years, which continues to rise.

2.3.3:Reliable: There are no moving parts in a solar power plant, providing reliable power for 25 years.

2. 3.4: Flexible configurations: As long as the frame can withstand the weight of the panels, solar panels can be mounted on all kinds of roofs, like covered parking areas. They are also very versatile, with rooftop plants varying from less than 1 kW to more than 1 MW of power. [7]

2.4. Ways of integration solar panels in shopping centers:

The application in shopping centers of solar energy and building integration technologies has three major aspects: solar thermal technology, solar photovoltaic technology, solar optical technology, and is primarily focused on Roofs, cantilever,exterior walls, parking canopy and façade:

2.4.1: Combined with the roof:

When installed on a sloping roof, solar cells can be integrated into the roof like a roof hatch or flat on the roof, as show in figure (4), and integrate with the construction to increase the beauty of the building. When installing on the flat roof, the flat solar collector can act as the roof cover or insulation layer and also avoid the repeated investment and reduce the cost.

There are many ways to benefit from solar energy, due to its low construction cost and other cost saving advantages, rooftop solar panels are popular these days. Essential for installing a solar system on the roof. To harvest solar energy, rooftop solar panels can be effectively installed on the roofs of commercial buildings.

However, in order to install solar panels on the roof, you must ensure the condition of the surface on which the solar panels will be installed and prepare for installation.

Figure (4) Solar Panel Combined with the roof

2.4.2: Combined with the cantilever:
Solar cantilever are one of emerging ways that organizations are improving their facilities. A steel structure was designed with solar panel to cantilever off the main roof as show in figure (4), where the modules are fitted to create a light canopy over the walkway around the building and in the main entrance of building. Roof cantilever generates more power than it uses with a giant solar array forming an oversized roof.

Figure (4) Solar Panel Combined with cantilever structure

2.4.3: Combined with parking canopy: Thanks to photovoltaic solar panels that are built directly into its construction, a solar parking canopy often generates electricity. Canopies come in varying configurations and dimensions. Single-column (one support column, each other parking spot), two-column (two support columns, each other parking spot), and louvered (a shuttered panel style) are various styles, as shows in figure 5. Commercial canopy designs, resembling garages with open sides, can handle several vehicle rows.Solar canopies are dual-purpose; they shield vehicles from the weather and provide your organization with solar and green energy savings. The energy generated during the day can be used to power the equipment, technology, and environmental systems of your plant.[8]

Figure (5) Solar Panel Combined with Parking Canopy

2.4.4: Combined with the exterior wall: Solar walls are a technology used to heat a building passively. One solution to achieving energy-efficient building architecture is solar walls. These walls integrate external architecture with internal equipment to heat and ventilate enclosed spaces by using solar energy. This walls can be placed on modern buildings or can be retrofitted. To provide an air channel between the two walls, collector panels are installed. To allow the exchanging of warmed air, an air channel is present between these two walls.As the additional solar wall protects the real external wall of the building from freezing weather, solar walls will also make a building colder in the winter.[89]. Figure 5 shows the Schematic diagram of the solar collector combined with the exterior wall

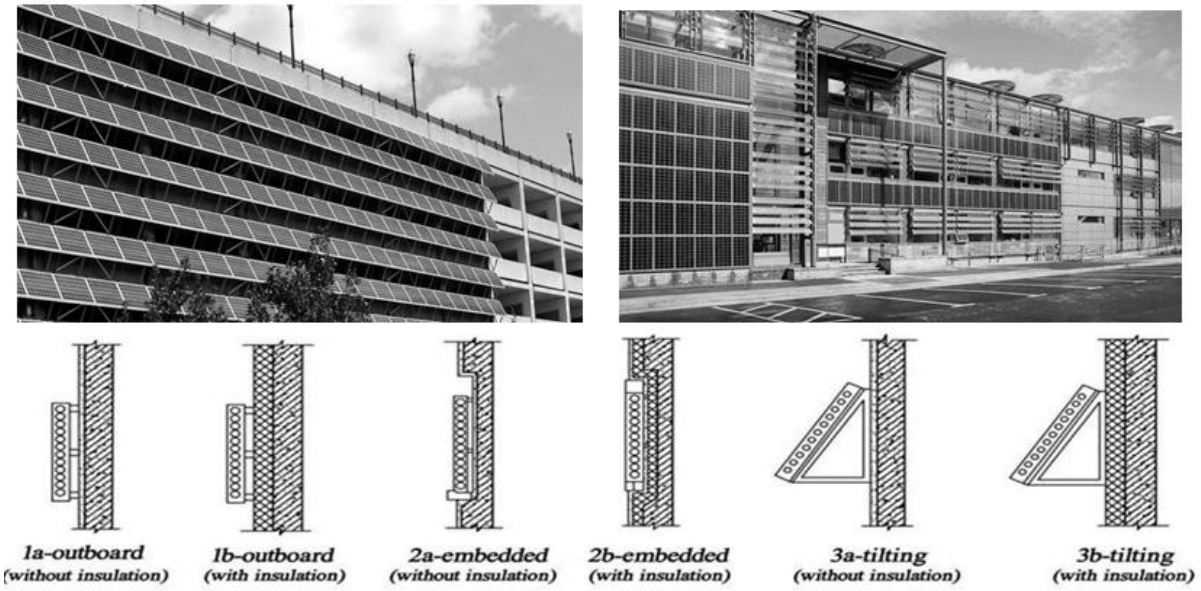


Figure (6) solar collector combined with t he exterior wall

2. 4.5: Combined with the façade:

Sun rays are transformed into electricity by a solar facade device and most facades can be used for solar cladding. Facade-facing green energy systems will be installed and built into the facade. Solar facade systems ensure that photovoltaics are harmoniously incorporated into building facades. For green power, solar facades.[10]]

Figure (7) solar collector combined with façade

2.5.Contemporary Shopping Centers Examples:

Taking case studies for many shopping centers around the world helps to know ways to integrate solar panels in commercial buildings and their importance in design. **Table (1)** shows the comparative points for Contemporary Shopping Centers Examples around the world.

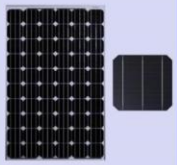
Project name	California shopping mall	The Grove Mall	The Sunshine Plaza	The Constantia Village center	Robinson's Mall
Project image					
Location	California, USA	Namibia	Melbourne's west	Constantia, South Africa	Philippines
Year	2012	2018	1998	2015	2001
Number of solar panel	15,000	8600	4175	2628	58,000
Solar combined methods	Combined with Roof parking canopy &	Combined with Roof	Combined with Roof parking canopy &	Combined with Roof	Combined with Roof parking canopy &
Types of Solar panel used	Monocrystalline 	Monocrystalline 	Polycrystalline 	Polycrystalline 	Polycrystalline 
Energy consumption reduction	30%	20%	45%	20%	35%
Max generation capacity	(MW) 4	KW 60	625KWP	814kwp	kwp 15,940

Table (1): Contemporary Shopping Centers Examples

2.6: Solutions and suggestions: In the previous point of the studies, we see that most of the shopping centers incorporate solar panels in the roofs , elevation car parks, so looking at this, a design has been made for a shopping center that contains solar panels with different designs on the facades, roofs, external walls, and heritage elements such as domes. As shown in Figure (8):

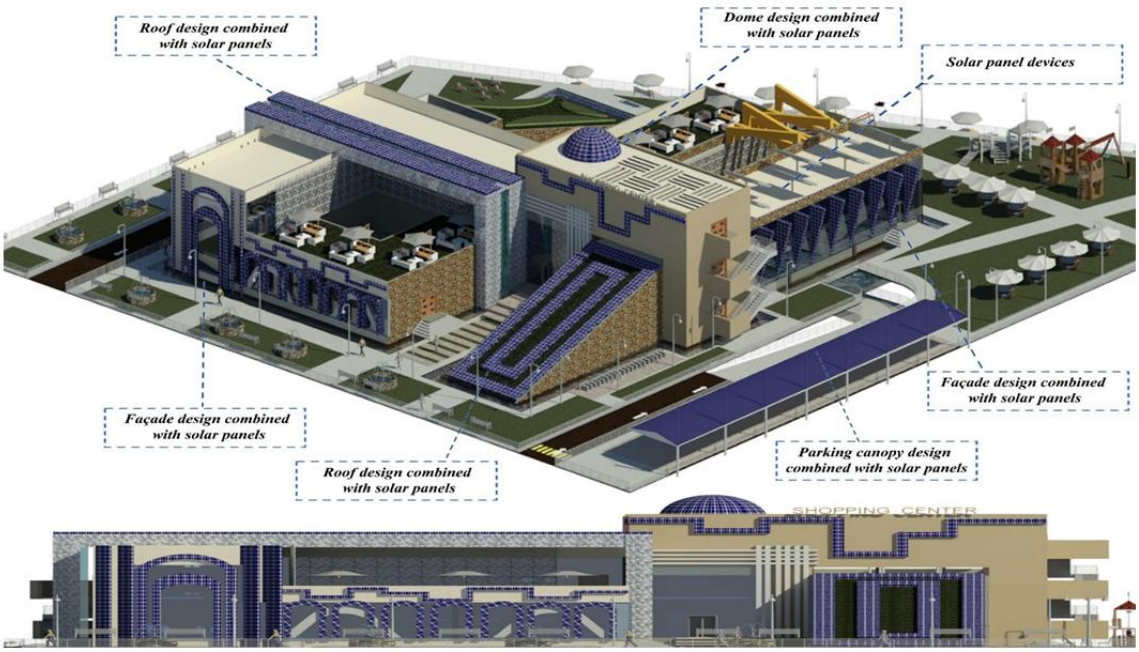


Figure (8) Design shopping center with solar panels

III. Results:

After conducting case studies for selected shopping centers and analyzing the ways of integrating solar panels in the design of facades, roofs exterior walls, cantilever and parking canopy for contemporary shopping centers, In the case study that we have chosen, there are buildings that used solar panels combined with roofs ,elevation and parking canopy, **Table 2** shows the solar combined methods in selected case studies:

Solar combined methods	Roof	Cantilever	wall	Facade	Parking
	5	N.A	2	2	3

Table (1): Solar Combined

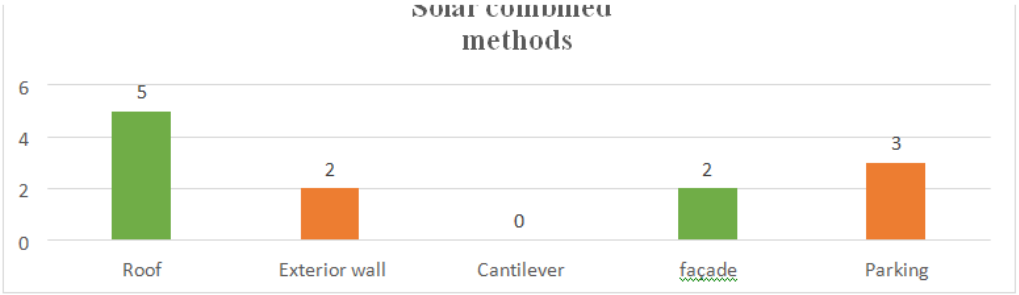


FIG 9 Solar Panel Combined Methods

Exterior

- We found two types of roof combined solar panel :

1. **Flat roofs** have the advantage of receiving solar rays with ease of installation and maintenance, so we see that most shopping malls mentioned in **Table (1)** integrated solar panels on flat roofs.
2. **Tilted roofs** are a model for installing solar panels, as they can be installed and combined easily, and photovoltaic surfaces are one of the most popular interesting applications as the design which shows in figure (8).

- There is an increasing need to pay attention to the design of breakers and shading systems as a result of the increased use of large window sculptors in shopping malls today. Photoelectric breakers are one of the most sustainable formations that can be used to shade façades and block the sun while at the same time producing electricity.
- The use of solar panels has evolved and reached its incorporation into heritage elements such as domes and Mashrabiyas, in addition to its use in designing facades and external walls, which led to an increase in interest in solar panels as a source that provides electricity production and gives an aesthetic value in commercial buildings.

Energy consumption reduction	California shopping mall	The Grove Mall	The Sunshine Plaza	The Constantia Village center	Robinson's Mall
	30%	20%	45%	20%	35%

Table (3): Energy consumption reduction

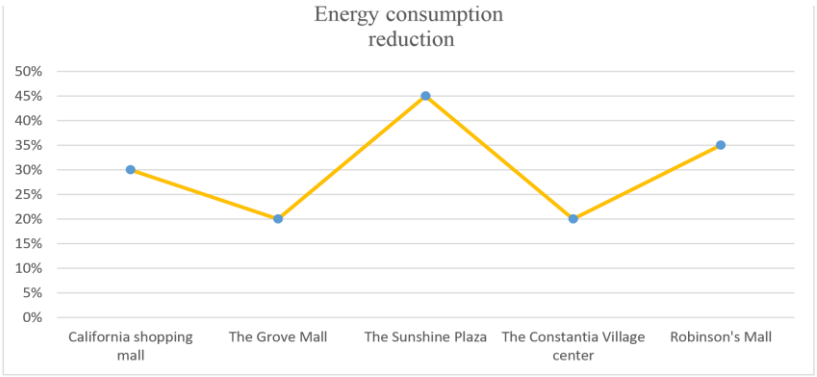


Figure (10) Energy consumption reduction

Max generation capacity	California shopping mall	The Grove Mall	The Sunshine Plaza	The Constantia Village center	Robinson's Mall
	40	60	625	814	15,940

Table (4): Max generation capacity

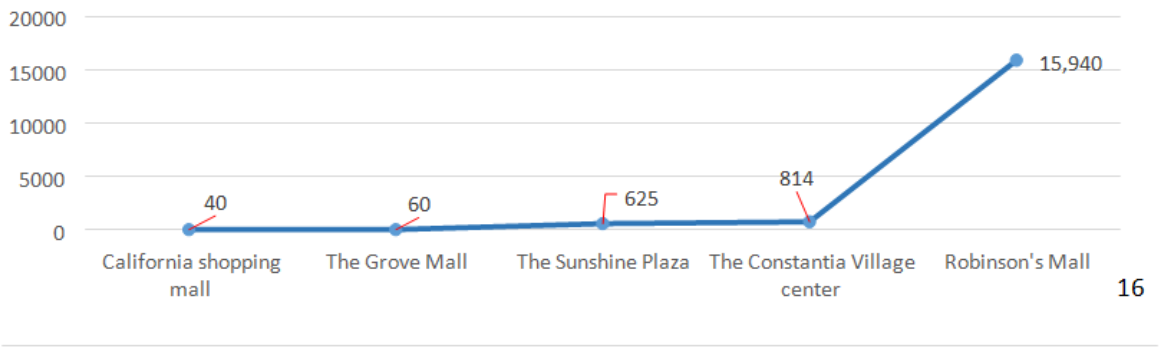


Figure (11 Max generation capacity

IV. Conclusion

This research is based on the ways of integrating the solar panels in contemporary shopping center, as well as the research is clarifying the importance of integrating the solar panels in the buildings including different types of solar panels with their various properties. The advantages and features of solar panel integration project in the shopping centers are , to renew the old practice to most modern one, reducing the bills of the electrical consumption, identifying how to design the buildings elevation, exterior walls, roofs, cantilever and parking canopy and the heritage elements with solar panels. This research is resulting into that most of the shopping centers are integrating the solar panels through their building roofs, in addition to that , this integration can be used in the parking canopy. Rarely, the integration of the solar panels with the building elevation can be applied. I recommend the integration of solar panels in the facades, the cantilever and the external walls to benefit more as shown in the design in table (1).

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