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دراسة حول الألواح الكهروضوئية و التصميم الشمسي السلبي ومشاكل استهلاك الطاقة في المباني

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Studying Photovoltaic Panels, Passive Solar Power and Energy Consumption Issues in Buildings

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الملخص:

نظرًا لتزايد عدد سكان العالم وارتفاع مستويات المعيشة، فمن المتوقع أن يستمر قطاع البناء في استهلاك كميات كبيرة من الطاقة. الغرض من هذه الدراسة توضيح الاستخدام الأمثل للطاقة الشمسية، بما في ذلك الطاقة الشمسية الكهروضوئية و التصميم الشمسي السلبي. الفرق التكنولوجي الرئيسي بين الألواح الكهروضوئية والطاقة الشمسية السلبية هو أن الالواح الكهروضوئية تنتج طاقة كهربائية يمكن استخدامها على الفور أو تخزينها في البطاريات أو تغذيتها في شبكة الكهرباء وتستخدم الألواح الشمسية المصنوعة من مواد شبه موصلة لتحويل ضوء الشمس مباشرة إلى كهرباء. ومن ناحية أخرى، تستخدم تكنولوجيا (تصميم) الطاقة الشمسية السلبية هيكل المبنى ومواده لجمع وتخزين وتوزيع الحرارة الشمسية دون الحاجة إلى أنظمة ميكانيكية. أولاً، ستتم مناقشة فوائد وعيوب كلا الطريقتين، إلى جانب المشاكل المحيطة باستهلاك الطاقة في ليبيا، والذي قُدر بـ 15,830 جيجاوات/ساعة في عام 2019. وثانيًا، تهدف إلى دراسة الجوانب المختلفة التي تؤثر على كفاءة الالواح الكهروضوئية وتوفير الابتكارات التقنية (مثل البيروفسكايت والخلايا متعددة الوصلات) التي يمكن أن تعزز أدائها. أخيرًا، تثبت هذه الدراسة أن الألواح الكهروضوئية ذات كفاءة عالية مقارنه بالتصميم الشمسي السلبي بسبب إجمالي الطاقة المجمعة يوميًا كمصدر لإنتاج الكهرباء خاصة في منطقة جنوب شرق ليبيا.

الكلمات الدالة: الالواح الكهروضوئية، التصميم الشمسي السلبي، الطاقة، الاستهلاك ،الكفاءة.

Abstract

Because of the growing global population and rising standards of living, the building sector is expected to continue consuming large amounts of energy. The optimal utilization of solar energy, including photovoltaic and passive solar energy, is the main topic of this study. The main technological difference between photovoltaic (PV) and passive solar energy is that PV energy produces electrical power that can be used instantly, stored in batteries, or fed into the power grid and it uses solar panels made of semiconductor materials to convert sunlight directly into electricity. On the other hand, passive solar energy technology uses a building's structure and materials to gather, store, and distribute solar heat without the need for mechanical systems. Firstly, the benefits and drawbacks of both approaches will be discussed in this study, along with the issues surrounding Libya's energy consumption, which was estimated to be 15,830 gigawatt-hours in 2019. Secondly, it aims to investigate the various aspects that impact photovoltaic (PV) efficiency and provide technical innovations (such as perovskite and multi-junction cells) that can enhance its performance. Finally, this study proves that, photovoltaic panels is useful as a strategic tool because of the total energy gathered daily as a source of electricity production especially in the East South Libya region.

Keywords: Photovoltaic Panels, Passive Solar, Energy, Consumption, Efficiency

1. Introduction:

Solar energy has emerged as one of the most promising and rapidly expanding alternative energy sources today. Its diverse applications include significant energy savings in buildings. Consequently, modern construction frequently employs two primary solar energy strategies to reduce power consumption: photovoltaic (PV) panels and passive solar design. Passive solar design involves architectural principles that optimize a building's energy efficiency by harnessing natural light and heat. In contrast, photovoltaic arrays use solar cells to convert sunlight into electricity. Both strategies have proven effective in saving energy, but they come with distinct pros and cons. Photovoltaic panels provide a direct source of renewable energy for heating and cooling. Despite their benefits, both passive solar and PV systems can be significantly influenced by weather conditions, such as cloud cover and seasonal changes in sunlight. Passive solar systems, on the other hand, are eco-friendly since they use natural resources and do not emit harmful radiation. However, their performance can be highly dependent on the building's design and location.

2. Methodology

This study used a literature review methodology. Theoretically, it analyzes available data in a certain field and weighs the advantages and disadvantages of installing PV panels and passive solar energy in homes. It presents the factors and displays the panels efficiency calculations.

Moreover, it analyses some factors that make passive solar energy less effective in saving energy.

.3Literature Review

3.1 advantages of Photovoltaic Panels Use

The installation of photovoltaic panels in a building has several advantages. First of all, PV panels are easily included into new construction designs, such as skyscrapers, to offset the costs of the roof and façade. They can also be added to existing structures or erected as a distinct structure to boost their efficacy in meeting power demands and even generate cash [6]. In addition, its technology has the advantage of being able to provide storable energy, which can be exploited when sunlight is unavailable, such as at night or in times of adverse weather. However, the current technology is still difficult because its necessary storage batteries are large, bulky and expensive [7]. [Using photovoltaic arrays to generate power and heat water instead of fossil fuels can help reduce greenhouse gas emissions. For instance, in Taiwan in 2008, the energy output from photovoltaic panels represented 2.1 million tons of yearly CO_2 emissions reductions and 8.2% of the country's total CO_2 emissions [5]. Consequently, solar panels can be integrated into entire structures to share and store energy output without releasing carbon dioxide and to lower construction costs.

3.2 Disadvantages Of photovoltaic panels

However, there are several drawbacks to solar panels as well, which could limit their application to buildings. The primary drawback of utilizing a photovoltaic technique is that its ability to generate electricity is dependent upon geographic location and local solar data. For instance, a 1 kW solar system in Germany would produce 900–1000 kWh annually if the fixed surfaces of the PV array were slanted at an angle equal to the latitude minus 10°, and up to 1800–2000 kWh annually in arid locations like South Africa or Arizona [1]. The high expense of purchasing the required equipment is another drawback of this energy source. For instance, photovoltaic systems cost 30% to 40% per kWh, which is much higher than the 4% to 5% per kWh cost of oil, coal, or gas [18]. However, The costs of photovoltaic systems are dropping quickly due to advancements in technology and increased production scale [3]. Additionally, one drawback is that the energy output of photovoltaic panels can be significantly reduced by low temperatures, potentially impacting their ability to meet energy demands [9]. In short, the primary disadvantages of utilizing photovoltaic panels include their susceptibility to local weather conditions, high initial costs, and their environmental impact on the climate.

Advantages of Passive Solar Energy 3.3

Initially, passive solar architecture has great promise for cost savings, cozy interiors, and a decrease in emissions that contribute to climate change in residential structures. Firstly, because passive elements like walls, roofs, balconies, and glazed windows last as long as the structure itself, passive solar energy is a financially sensible choice. It has been suggested that passive design can reduce expenses by 25–40% when it comes to the amount of energy required to heat and cool residential buildings [4]. This amounts to a substantial monthly financial savings that could support families during difficult economic times. The effectiveness of passive solar design is more than sufficient in areas with moderate climates, which is another benefit. For instance, 88% of the colder half of the year can be heated by passive solar heating, so that no cooling is needed during the warmer half of the year [15]. This is a result of how buildings are oriented to maximize solar heat . Firstly, because passive elements like walls, roofs, balconies, and glazed windows last as long as the structure itself, passive solar energy is a financially sensible choice. It has been suggested that passive design can reduce expenses by 25–40% when it comes to the amount of energy required to heat and cool residential buildings [4].This amounts to a substantial monthly financial savings that could support families during difficult economic times. The effectiveness of passive solar design is more than sufficient in areas with moderate climates, which is another benefit. For instance, 88% of the colder half of the year can be heated by passive solar heating, so that no cooling is needed during the warmer half of the year [15]. The reason for this is the building's orientation, which effectively harnesses solar heat without the need for mechanical systems [5]. Utilizing passive solar energy is highly beneficial due to its lack of negative environmental impact: It produces no harmful fumes, pollutants, or emissions [17]. This is achieved through the use of traditional architectural elements, resulting in reduced reliance on technologies such as air conditioning and decreased use of fossil fuels for construction energy [8]. Clearly, opting for passive solar energy allows for cost savings and the creation of a comfortable living space without releasing harmful pollution into the atmosphere.

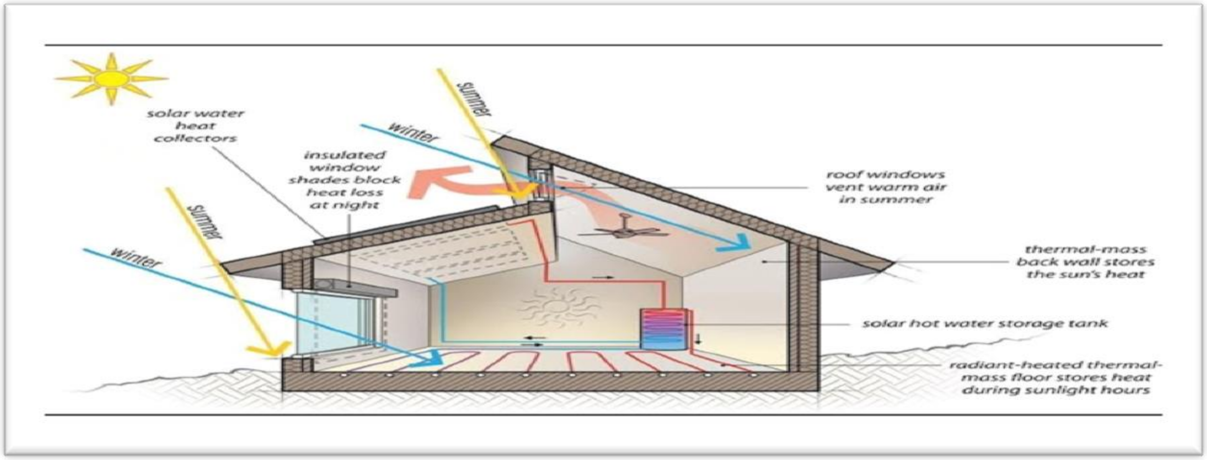

Figure (1) Passive Solar Architecture [21]

3.4 Disadvantages of Passive Solar Energy

The usage of passive solar energy in residential buildings may be limited by several drawbacks. One such drawback is its lack of reliability, as its effectiveness is dependent on the climate type. For instance, in colder regions, a passive solar design may only fulfill 7%–50% of power demands during the colder months [18]. Despite its limited effectiveness in cold weather for part of the year, passive solar energy can be complemented by active technologies like Photovoltaic panels to fulfil the building's complete energy requirements [5]. Another disadvantage is that passive solar energy is not easily applied to large and compact buildings, such as large office buildings or skyscrapers because of building shading and closed windows, which are characteristics of most tall buildings. However, passive solar design can be implemented successfully in these cases if buildings can be oriented relative to the sun and windows also can be opened for natural ventilation [6]. Finally, Passive solar techniques are often challenging to implement in older buildings due to the fact that they typically need to be integrated into the building design from the start, which can prolong the design process and raise costs. Nevertheless, building sustainability experts have emphasized that crucial decisions regarding sustainability can be made during the initial design phase by the building designer [14]. It is clear that this goal is best achieved in new constructions, which typically results in a 3% to 5% increase in construction costs [12]. However, many proponents of passive solar systems argue that building codes and regulations should be changed to promote passive solar energy[6]. Briefly, the limited effectiveness of passive solar design in cold climate zones and the practical challenges associated with older, larger buildings have been the primary limitations of passive solar design [13].

3.5 Energy consumption situation in Libya

In Libya, the residential sector is thought to be one of the biggest and most significant users of electricity. The sector's share of consumption came to almost 31% of all energy sold in 2010 [12]. This energy is frequently used in homes and by electrical appliances. An estimated 18.35% of the energy used in the industry is consumed by residential air conditioners [12]. This is comparatively significant and comes in second in terms of household usage after lighting. Given that air conditioners are found in the majority of Libyan houses, they are frequently used during the summer. Additionally, it is challenging to program the air conditioners low thermostat settings for automatic operation. Because of this, the compressor must run nonstop, which results in a high rate of energy consumption. Libya's final electrical energy consumption in 2019 was projected to be 15,830 gigawatt-hours, the highest amount since 2014 with 10,890 gigawatt-hours consumed, that year's consumption was the lowest. Overall, the final electricity consumption in Libya increased annually from 2014 to 2019 [22].

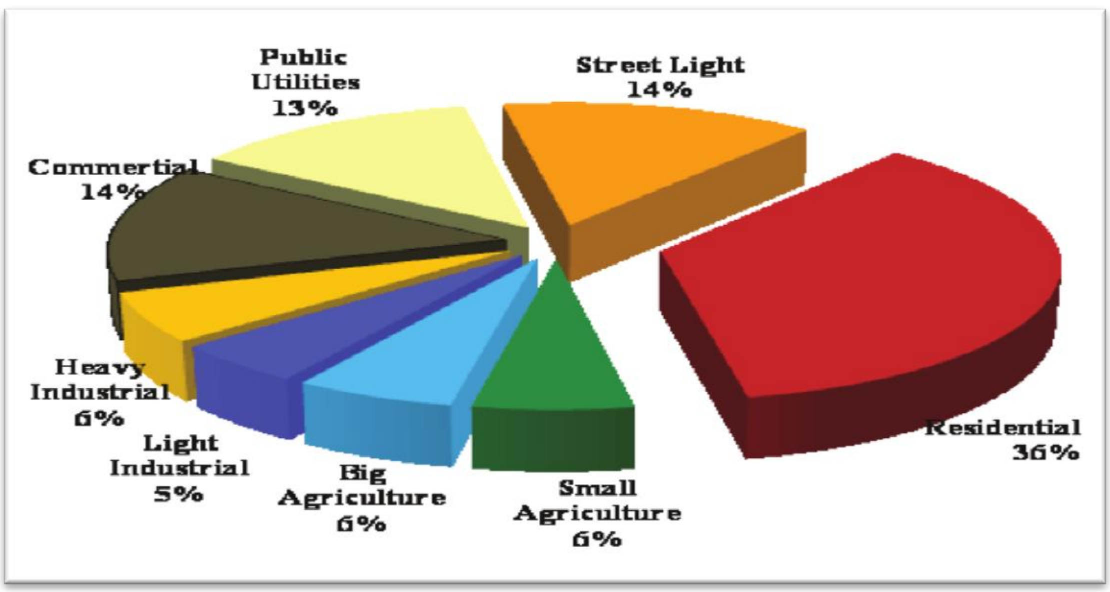

Figure 2: Electricity consumption (2012) [24]

. Results and Discussions 4

Based on the analysis of the pros and cons of photovoltaic panels and passive solar energy, it is clear that photovoltaic arrays are the better source of solar power. The photovoltaic array offers several benefits compared to passive solar energy. Due to the fluctuating weather conditions, photovoltaic panels are advantageous as they allow the captured energy during optimal conditions to be stored for use during unfavorable weather. Passive solar energy cannot accommodate this factor, possibly due to its instantaneous nature [1]. Additionally, the photovoltaic array is highly versatile since it can be installed in a residence without the need to alter the house's design or components. It can be positioned anywhere, allowing the energy to be readily available for use. The orientation of a building is important for passive energy use, taking into account both sunlight and wind [1]. Analysis of building orientation should be done at the design stage before construction, which can be challenging for older houses. As a result, photovoltaic panels are the preferred solar energy option for buildings.

4.1 The efficiency of (PV) panels and passive solar energy

The efficiency of photovoltaic (PV) panels and passive solar energy refers to different concepts in solar energy utilization.

4.1.1 Photovoltaic (PV) Panels:

PV panel efficiency can be defined as is the ratio of the electrical energy output to the solar energy input on the panel. It is expressed as a percentage.

Typical Efficiency: Modern commercial PV generally achieve efficiencies between 15% and 22%, indicating that they can convert 15-22% of the sunlight they receive into electricity .

Factors Affecting Efficiency:

- Material quality
- Temperature,
- Angle of installation
- Shading

4.1.2 Passive Solar Energy efficiency:

It is harder to quantify as it include the use of building design to capture, store, and distribute solar energy as heat without mechanical systems. Efficiency in this context is more about the effectiveness of design strategies in reducing the need for additional heating or cooling. Design Strategies: Orientation of the building, window placement, insulation, thermal mass (materials that store heat), and shading.

Factors Affecting Efficiency: Climate, building materials, design and layout of the building, and user behaviour.

In summary, PV panel efficiency is a specific measurable value representing how well a panel converts sunlight into electricity. In contrast, passive solar energy efficiency refers to the effectiveness of design strategies to harness solar energy for heating and lighting, which is more qualitative and context-dependent.

4.2 Factors That Make It Harder for a Building to Use Passive Solar Energy to Save Energy

Because there is no battery to store the energy generated by passive solar technology, it is not possible to use it to provide services or store it for use in an emergency. Moreover, it is utilized for individual homes. In any case, the photovoltaic exhibit enjoys the benefit that the caught energy can without much of a stretch be shared by various individuals. In other words, if photovoltaic panels are installed on their own structure, they can use as many houses as possible by capturing as much sunlight as possible. Additionally, the system's energy can be utilized to run machinery. For instance, in medical clinics, when there is no power from the principal network line, photovoltaic can be utilized. This makes it unnecessary to look for fuel to run a generator. In addition, as outlined above, photovoltaic can easily be shared by more than one individual. This makes it conceivable to sell such energy, which can be a kind of revenue. The Photovoltaic boards are likewise convenient. One can without much of a stretch convey its boards and put up a framework anyplace together to gather the sun's energy. This makes it exceptionally helpful and demonstrates the way that it tends to be effectively rented to produce pay. However, passive solar energy cannot be transported. In short, photovoltaic array technology is superior to passive solar energy in terms of harnessing the sun's energy for emergency power needs.

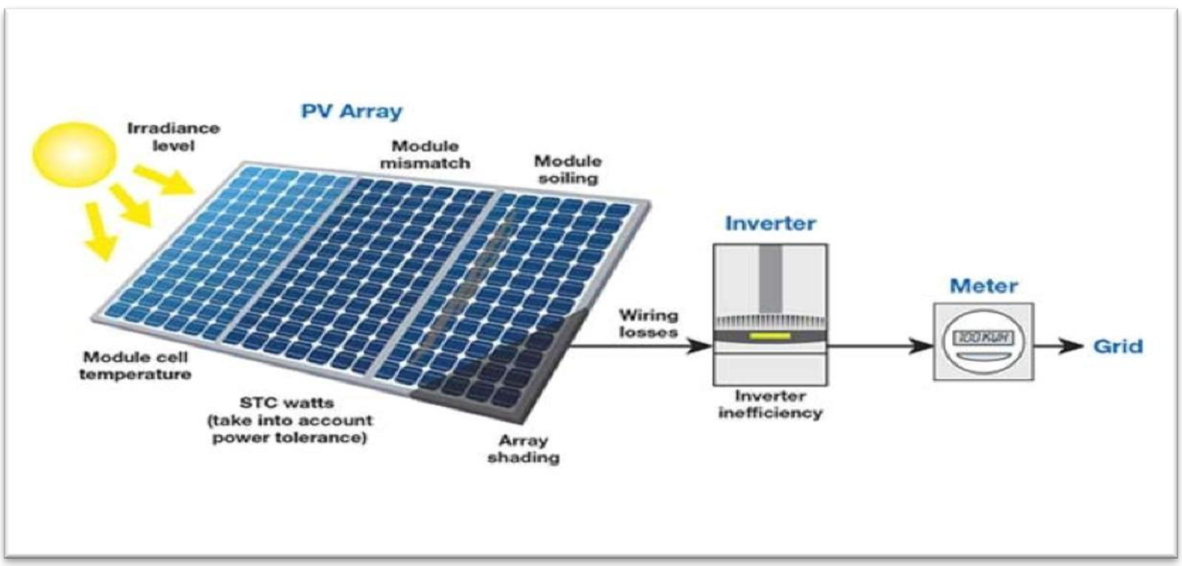

Figure 3 : A solar panel generates power from sunlight [22]

4.3 PV Panels Efficiency Calculation

To determine the efficiency of photovoltaic panels, one might do the following five steps:

Step 1: Determine the maximum power capacity of the module.

Step 2: Measure the module's dimensions (the solar panel's length and width).

Step 3: Determine the solar module's power per unit area.

Step 4: Ascertain the STC solar irradiance value

Step 5: Calculate the efficiency of solar panels

given that a solar cell is a semiconductor. Thus, it forms the basis of semiconductor equations. Five non-linear differential equations exist. These equations have been analytically solved with the appropriate boundary condition.

These calculations required:

1- The light generated current density for three part of cell (emitter, base and depletion region)

$$J_E\,(\lambda) = \frac{q\,\alpha\phi_0\,(1-R)L_p}{\left(\alpha L_p\right)^2 - 1} \quad x$$

$$\left[-\alpha\,L_p\,e^{-\alpha w_e} + \frac{S_e + \frac{L_P}{D_P} + \beta L_P - e^{-\alpha w_e}\left(S_e\,\frac{L_p}{D_P}\,cosh\frac{w_e}{L_P} + sinh\frac{w_e}{L_P}\right)}{cosh\frac{w_p}{L_P} + S_e\,\frac{L_P}{D_P}\,sinh\frac{w_e}{L_P}}\right] \qquad (1)$$

$$J_B\,(\lambda) = \frac{q\,\alpha\phi_0{}'\,(1-r)L_n}{(\alpha L_n)^2 - 1} \quad x$$

$$\left[-\alpha\,L_n - \frac{S_h + \frac{L_n}{D_n} + cosh\frac{w_b}{L_n} - e^{-\alpha w_b} sinh\frac{w_b}{L_n} + \alpha L_n\,e^{-\alpha w_b}}{cosh\frac{w_b}{L_n} + S_b\,\frac{L_n}{D_n}\,sinh\frac{w_b}{L_n}}\right] \qquad (2)$$

$$I_{SCR}\,(\lambda) = qF(1-R)Exp(-\alpha xj)\left((1-\exp\left(-\alpha w_p\right)\right) \qquad (3)$$

2-Dark current density in emitter and base

$$J_{darkE} = q\frac{n_i^2\;D_P}{N_D L_P}\left[\frac{S_e\quad \frac{L_P}{D_P}cosh\frac{L_P}{D_P}sinh\frac{w_e}{L_P}}{S_e\quad \frac{L_P}{D_P}sinh\frac{w_P}{L_P}cosh\frac{w_e}{L_P}}\right]\left[e^{\frac{V}{Vi}} - 1\right] \quad (4)$$

$$J_{darkB} = q\frac{n_i^2\;D_n}{N_A L_n}\left[\frac{S_h\quad \frac{L_n}{D_n}cosh\frac{L_b}{D_n}sinh\frac{w_b}{L_n}}{S_e\quad \frac{L_P}{D_P}sinh\frac{w_P}{L_P}cosh\frac{w_b}{L_n}}\right]\left[e^{\frac{V}{VT}} - 1\right] \quad (5)$$

3−Total current density

$$J = J_L - J_{dark} \quad (6)$$

4−internal quantum efficiency (IQE)

$$IQE = \frac{J_L}{q\, \emptyset_0 (1-R)} \quad (7)$$

5− internal spectral response (ISR)

$$ISR = \frac{J_L}{F(1-R)} \quad (8\ )$$

5. Recommendations for Libya's usage of PV panels

Certainly, using photovoltaic (PV) panels in East − South Libya, where the climate is hot and sunny, is an excellent way to harness solar energy. There are some suggestions to maximize the efficiency and effectiveness of PV panels in such regions:

1. Optimal Orientation and Tilt:

Orientation: Position the PV panels to face true south to capture the maximum amount of sunlight throughout the year.

Tilt Angle: adjust the tilt angle of the panels based on the latitude of your location. In Libya (approximately 25° to 33° north latitude), a tilt angle equal to the latitude or slightly less can maximize solar absorption.

2. Cooling Mechanisms:

Natural Ventilation: ensure there is sufficient air circulation around the panels to help dissipate heat. elevated Mounting: Mount panels a few inches above the roof or ground to allow air to flow beneath them, which helps in cooling.

3. Dust and Maintenance:

Regular Cleaning: dust accumulation can significantly reduce the efficiency of PV panels. Schedule regular cleaning, especially after dust storms.

Self−cleaning coatings: consider panels with hydrophobic or self−cleaning coatings to reduce the frequency of manual cleaning.

4. High−Temperature Tolerance:

Choose High−Temperature Tolerant Panels: select PV panels that are specifically designed to perform well at higher temperatures. Some modern panels have lower temperature coefficients, meaning their efficiency decreases less with rising temperatures.

5. Energy Storage: energy can be stored by using the following system:

Battery Systems: Integrate battery storage systems to store excess energy generated during the day for use at night or during cloudy periods.

Hybrid Systems: consider hybrid systems that combine PV panels with other renewable energy sources or backup generators to ensure a stable power supply.

6. Solar Tracking Systems:

Single-Axis or Dual-Axis Trackers: if budget allows, use solar tracking systems that follow the sun's path to increase energy capture by up to 25-35% compared to fixed systems.

7. Grid Connection and Inverters:

efficient Inverters: use high-efficiency inverters to convert the DC power generated by the panels to AC power with minimal losses.

Grid-Tied Systems: If possible, connect to the local grid to sell excess electricity generated during peak times.

8. Government Incentives and Regulations:

Explore Incentives: investigate any local, national, or international incentives, subsidies, or grants for renewable energy projects in Libya. Compliance with Regulations: Ensure your installation complies with local building codes, safety standards, and grid-connection regulations.

9. Shading and Placement:

Avoid Shading: Ensure there are no obstructions (like trees or buildings) that could cast shadows on the panels, reducing their efficiency. Strategic Placement: Place panels in areas with the least shading throughout the day. Implementing these suggestions will help optimize the performance and longevity of PV panels in the hot and sunny climate of East and South Libya.

6. Conclusion

It is evident that there are many benefits and drawbacks to both passive solar energy and photovoltaic panels. Nonetheless, the preferred method of using solar energy in all structures is the photovoltaic array. Its energy storage capacity, which allows for future use, may potentially have financial advantages. It reduces carbon dioxide emissions and is versatile. It might, however, be more costly and useful in some climates than others. The primary advantages of passive solar energy are its affordability, the fact that it requires no special equipment, its 24/7 use, and its ability to shield the environment from damaging pollutants. However, its drawbacks include reliance on wind and building orientation, as well as the possibility that not all of its components will fit inside.

References

1. N. Armaroli, , V. Balzani, "Energy for a Sustainable World: From the Oil Age to a Sun-powered Future. Weinheim, Germany : Wiley-VCH c2011, 2010.
2. Baños, R., Manzano-Agugliaro, F., Montoya, F. G., Gil, C., Alcayde, A., & Gómez, J. (2011). Optimization methods applied to renewable and sustainable energy: A review. Renewable and Sustainable Energy Reviews, 15(4), 1753-1766.
3. Hoffman, A. J. (2000). Competitive Environmental Strategy: A Guide to the Changing Business Landscape. Washington, D.C : Island Press.
4. Kruzner, K., Cox, K., Machmer, B., & Klotz, L. (2013). Trends in observable passive solar design strategies for existing homes in the U.S. Energy Policy (0). doi :
5. http://dx.doi.org/10.1016/j.enpol.2012.10.071
6. Lam, J. C., Yang, L., & Liu, J. (2006). Development of passive design zones in China using bioclimatic approach. Energy Conversion and Management, 47(6), 746-762. doi: http://dx.doi.org/10.1016/j.enconman.2005.05.025
7. MacKinney, M. L., Schoch, R. M., Yonavjak, L., & Zell, S. (2012). Environmental Science: Systems and Solutions. Burlington MA: Jones and Bartlett LEARNING.
8. Morrissey, J., Moore, T., & Horne, R. E. (2011). Affordable passive solar design in a temperate climate: An experiment in residential building orientation. Renewable Energy, 36(2), 568-577. doi: http://dx.doi.org/10.1016/j.renene.2010.08.01
9. Shane, J. (2012). Positioning Your Library for Solar (and Financial) Gain. Improving Energy Efficiency, Lighting, and Ventilation with Primarily Passive Techniques. The Journal of Academic Librarianship, 38(2), 115-12. doi :http://dx.doi.org/10.1016/j.acalib.2012.01.004
10. Sassi, P. (2012). Strategies for Sustainable Architecture. Retrieved from http://CURTIN.eblib.com.au/patron/ FullRecord .
11. C.-D Yue, & G.-R Huang,.. An evaluation of domestic solar energy, 2011.
12. G. Seeling-Hochmuth, "A combined optimisation concept for the design and operation strategy of hybrid-PV energy systems", Solar Energy, Vol. 61, (1997) 77-87.
13. G. Notton, V. Lazarov, L. Stoyanov, "Optimal sizing of a grid-connected PV system for various PV module technologies and inclinations, inverter efficiency characteristics and locations". Renewable Energy, Vol. 35 (2010) No. 2, 541-554
14. S. El-Hefnawi, "Photovoltaic diesel-generator hybrid power system sizing". Renewable Energy, Vol. 13 (1998), 33 - 40. [20] M.

15. Ashari, C. Nayar, “An optimum dispatch strategy using set points for a photovoltaic (PV)–diesel battery hybrid power system”. Solar Energy, Vol. 66 (1999), 1- 9.
16. H. Hussein, G. Ahmad, H. El-Ghetany, “Performance evaluation of photovoltaic modules at different tilt angles and orientations”. Energy Conversion and Management, Vol. 45, 2441–2452, 2004.
17. H. Elminir, A. Ghitas, F. El-Hussainy, R. Hamid, M. Beheary, K. Abdel-Moneim, “Optimum solar flat-plate collector slope: case study for Helwan, Egypt”. Energy Conversion and Management, Vol. 47 , 624–637, 2006.
18. B. Grein,. Nordell, & A. M. Almathnani.. UTES Potential for Space Heating and Cooling in Libya. In The Tenth International Conference on Thermal Energy Storage. May 31 – June 2, 2006.
19. A. Taher, N. Abdalla, S. Jaber, W . Shahin. Report on analysis of the political, socio-economic and climatic conditions in the Mediterranean countries. Amman – Jordan: National Energy Research Center; 2009
20. S. Jaber, S. Ajib, “Optimum, technical and energy efficiency design of residential building in Mediterranean region”. Energy and Buildings, Vol. 43 No. 8, 1829-1834, 2011.
21. A. Campoccia, L. Dusonchet, E. Telaretti, G. Zizzo, “Comparative analysis of different supporting measures for the production of electrical energy by solar PV and Wind systems: Four representative European cases”. Solar Energy, Vol. 83 ,No. 3, 287-297, 2009
22. B. Hammad, S. Rababeh, M. Al-Abed, A. Al-Ghandoor, “Performance Study of On-Grid Thin-Film Photovoltaic Solar Station as a [22]. Pilot Project for Architectural Use”. Jordan Journal of Mechanical and Industrial Engineering, Vol. 7 No. 1, 1-9, 2013.
23. https://www.statista.com/statistics/1235181/final-consumption-of-electricity-in-libya/
24. A. Almabrouk and S. Abulifa, "The Technology of Renewable Energy and Its Role in Achieving Sustainable Development," International Journal of Electrical Engineering and Sustainability (IJEES), vol. 1, no. 2, pp. 1-9, 2023.
25. Ibrahim. H. Tawil and Khairy R. Agha, ‘Possibilities of domestic solar water heating in improving energy demand management in libya (in Arabic)’, journal of solar energy and sustainable development , JSESD, vol. 6, no. 1, 2017.