Environmental Science

AIMS Environmental Science, 10(5): 628–643.
DOI: 10.3934/environsci.2023035
Received: 14 August 2023
Revised: 14 September 2023
Accepted: 15 October 2023
Published: 24 October 2023

http://www.aimspress.com/journal/environmental

*Research article*

# The Effect of Environmental Albedo on the Energy Use of a Selected House in Amman-Jordan

**Saad S. Alrwashdeh***

Mechanical Engineering Department, Faculty of Engineering, Mutah University, P.O Box 7, Al-Karak 61710 Jordan

*** Correspondence:** Email: saad_r1988@yahoo.com.

**Abstract:** I explore the effect that albedo has on the amount of solar energy collected as well as the effectiveness of various building materials used in Jordan's varied construction industry. Albedo, which is the reflection of incoming radiation by surfaces, is of crucial relevance in minimizing the damage that solar radiation may do to building components like windows. The construction sector in Jordan is a substantial contributor to the overall level of energy consumption in the country because of the wide variety of building types, purposes and technologies found there. The findings of this research show that substances with greater albedo values produce the best results in terms of energy gains. These findings are supported by in-depth albedo value analyses and provide useful insights that may be used to improve building design and construction methods in Jordan, which will eventually lead to increased energy efficiency and sustainability within the construction sector.

**Keywords:** Albedo; building industry; energy; construction medium

## 1. Introduction

The unregulated and unequal distribution of traditional energy sources constitutes a significant development gap for all countries in the world, making energy the most pressing issue of our day. Hence, the interest in two fundamental techniques to provide the energy required for all kinds of living in all countries of the globe, the first of which is the rationalization of energy consumption through the application of the most advanced technological means. Second, focusing on alternative energy sources, which are the optimal answer for meeting the energy needs of countries, such as solar and wind energy [1].

Jordan is one of the least wealthy nations in the world in terms of conventional energy sources because it imports a variety of traditional energy derivatives and depends on its neighbors for at least 90% of its entire energy needs. In order to address the different energy needs of Jordan, interest in supplying innovative, contemporary and sustainable sources of energy evolved here. With Jordan being one of the world's richest nations in renewable energy sources and being one of the sunbelt nations with more than 320 days of sunshine per year at high average solar intensity rates, renewable energy has emerged as one of the most crucial alternatives [2–4]. Jordan has wind speed rates that position wind energy in second place for exploitation and meeting energy needs [5–7]. The sources are not restricted to solar energy alone. It also contains geothermal energy and other sources, which gives Jordan hope that its energy needs will be met. It should be noted that Jordan's strategic plans aim to raise the proportion of renewable energy sources in the country's overall energy requirements, as the percentage of renewable energy sources in those demands has now reached 30% and is steadily rising [8–10].

Jordan's buildings use a lot of solar energy. Solar radiation affects building energy dynamics due to the country's year-round sunlight. Solar radiation interacts with buildings' windows and other surfaces, causing thermal gains and losses that affect heating, cooling and lighting energy needs [11–13]. Jordanian buildings collect a lot of heat via their windows and outside surfaces during the summer. Air conditioning systems must work harder to maintain pleasant indoor temperatures. Solar heat gain can also cause pain, decreased productivity and health hazards for inhabitants. Thus, buildings must have efficient solar radiation mitigation methods. Winter sun radiation can be used for passive heating. Solar heat may be captured and retained by well-positioned windows and surfaces with strong solar absorptance, lowering energy use and saving money [14–16]. Passive solar heating and suitable shading may manage solar radiation entering the structure, optimizing energy efficiency year-round. Building albedo also affects solar radiation. High-albedo surfaces reflect more solar radiation back into the atmosphere, lowering building heat absorption. This reduces interior cooling demand and energy use [17–19]. Light-colored or reflecting roof coatings and exterior finishes can reduce solar radiation's negative effects, saving energy and improving building thermal comfort. Jordan’s buildings need a holistic strategy to optimize energy use. This entails using passive solar designs to take advantage of solar radiation in winter and shade in summer [20–22]. High-albedo building materials optimize energy gain and decrease energy loss. Jordan may reduce its building sector's energy consumption and greenhouse gas emissions by implementing these initiatives and prioritizing energy-efficient building techniques [23–27].

Jordan's energy plan emphasizes renewable energy to improve energy security, reduce greenhouse gas emissions and promote sustainable development [28–30]. Jordan has used renewable energy technology to diversify its energy mix and minimize its dependence on imported energy. Jordan relies heavily on solar electricity. Solar energy generation is possible due to the country's sunny climate [31–33]. The government has promoted solar technology through rooftop photovoltaic (PV) systems and large-scale concentrated solar power (CSP) facilities. These projects address the country's electricity needs, create jobs and improve solar energy technology [34–36].

Jordan's renewable energy landscape includes wind power. The country's deserts and coastlines are ideal for wind power generation. Jordan has wind farms and supporting policies to attract investments and use wind energy [37–39]. This enormous resource can diversify energy sources, reduce greenhouse gas emissions and improve energy security. Jordan is also investigating various renewable energy sources for its energy transformation. Biomass energy from biological waste and agricultural leftovers may provide power and heat. Biomass can replace fossil fuels and solve waste management issues. Geothermal energy, which taps into the Earth's inherent heat reserves, is a clean, stable source of energy that Jordan may use. Jordan's energy industry benefits from renewable energy. Diversifying the energy mix and lowering fossil fuel imports increases energy security [40–42]. This reduces global fuel price and supply disruption vulnerability. Second, adopting renewable energy technology reduces carbon emissions and mitigates climate change. Jordan can help fight climate change by abandoning fossil fuels. Finally, renewable energy initiatives promote technical innovation, job creation and economic prosperity. Local industry, R&D and clean energy exports benefit from renewable energy [43–45].

Jordan's extensive renewable energy strategy and efforts demonstrate its commitment. Energy security, carbon reduction, and sustainable economic growth are the country's goals in harnessing solar, wind, biomass, and geothermal energy. Jordan can lead the area in renewable energy adoption by promoting deployment and enacting supporting legislation [46].

Across the board, Jordan's building industry presents a formidable obstacle when it comes to meeting energy demand, especially in the residential sector, which accounts for 40 percent of the country's overall energy consumption and ranks among the highest in the world [47]. Several factors, including consumption habits, conventional construction processes, the use of non-energy-saving technologies and many more, have contributed to Jordan's rising building sector energy consumption. The use of new and modern technological means to rationalize energy consumption and modern methods of energy production has emerged in recent years, with the most notable relying on energy production through reliance on renewable energy sources such as solar energy systems of various kinds through direct or indirect production, wind energy and others [48].

The landscape surrounding the structures is one of the tools that plays a crucial role in the process of harnessing the sun's natural energy. The extent of a building's connection with natural energy can be determined by observing the location of the building's centre. There are a variety of designs surrounding the structures, including green and desert cover, among others. It should be mentioned that the degree of energy absorption, reflection and access to structures plays a crucial role in determining the amount of energy required by buildings for cooling and heating reasons in particular. Prior calculations were based on the examination of a fundamental factor known as Albedo, which entailed examining the effect of the medium on the calculation of energy values.

Our main objectives of this research are to examine the effects of albedo on the quantity of solar energy gathered and to evaluate the performance of various building materials in Jordan's diversified construction sector. Both of these purposes will be accomplished via the use of this text. In the context of limiting the possible damage caused by solar radiation to building components, notably windows, albedo, which measures the reflection of incoming radiation by surfaces, is recognized as a significant aspect in mitigating the risk. Our purpose of this study is to determine whether or not materials with higher albedo values are more successful in terms of energy gains. This is important since the construction industry plays a large part in Jordan's overall energy consumption due to the country's different building types and technologies. These findings, which are backed by extensive analyses of albedo value, provide useful insights that may be used to improve building design and construction methods in Jordan, eventually leading to increased energy efficiency and sustainability within the construction industry.

## 2. Geographical and meteorological data

With 320 sunny days, a very long number of radiation hours and a very high radiation intensity, Jordan is one of the world's greatest nations in abundance in solar energy and is considered one of the most urbanized countries with access to renewable energy sources. Jordan's capital, Amman, is located at 36° north latitude and 32° east longitude. In figure 1, there is a visual depiction of how many hours of sunlight reach the city of Amman, Jordan [49].

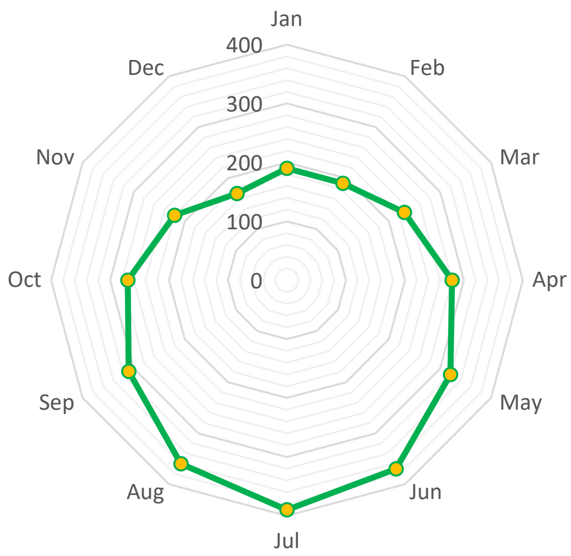
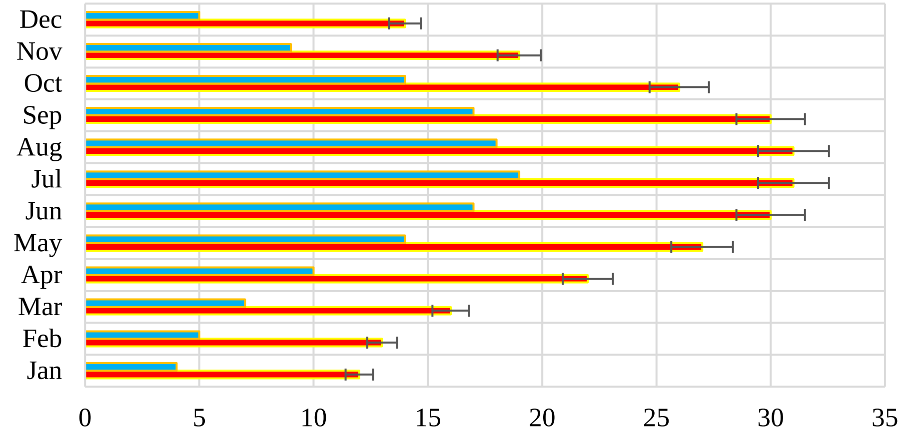



**Figure 1.** sunshine hours in Amman-Jordan around the year.

Figure 2 shows year-round temperature changes in Jordan's bustling capital, Amman. This chart shows the city's maximum and minimum temperatures per the year. This graphic accurately depicts Amman's seasonal temperature range. July, August and September are the city's hottest months. These months represent the height of summer due to brilliant sunshine and warm, dry weather. Rising temperatures affect agriculture, energy use and public health. A diverse climate emerges in January, February and December in Amman. The coldest months have lower temperatures. Amman's winters may be cold, with occasional rain and precipitation, especially at higher elevations. The cooler temperatures in Amman affect everything from clothes to heating needs.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Low | 4 | 5 | 7 | 10 | 14 | 17 | 19 | 18 | 17 | 14 | 9 | 5 |
| High | 12 | 13 | 16 | 22 | 27 | 30 | 31 | 31 | 30 | 26 | 19 | 14 |

Temperature °C

Low High

**Figure 2.** Average Max and Min temperature at Amman-Jordan around the year.

## 3. Solar calculations

In Amman, the average yearly solar radiation is between 1400 and 2300 kWh/m$^2$, with daily averages ranging from 4 to 8 kWh/m$^2$. As a result, solar power is Jordan's best bet for meeting its energy demands in the future. Considering the amount of sunlight that Jordan receives. The southern part of Jordan has a solar radiation rate of 6–7 kWh/m$^2$, the eastern region 5.5–6 kWh/m$^2$, the central region 4.5–5.55 kWh/m$^2$ and the northern and western regions below 4.5 kWh/m$^2$.

**Table 1.** Symbol and full version in the manuscript.

| Symbol | Full Version |
|---|---|
| $\delta$ | Solar declination angle |
| $\omega_s$ | Sunset hour angle |
| $\varphi$ | Latitude |
| $H_o$ | Daily extraterrestrial radiation on horizontal surface |
| $\overline{H}$ | Monthly average solar radiation on a horizontal surface |
| $\overline{K_T}$ | Monthly average clearness index |
| $\omega_s'$ | Sunset hour angle of a tilted surface |
| $\beta$ | Tilt Angle |
| $\overline{H_{bT}}$ | Average daily beam radiation on the tilted surface |
| $\overline{H_b}$ | Average daily beam radiation on a horizontal surface |
| $\overline{H_d}$ | Ratio of the diffuse component to the total monthly average radiation |
| $\overline{H_T}$ | Monthly mean solar radiation on a tilted surface |
| $\rho$ | Albedo Ground Reflection |

The parameters listed below must be determined in order to have a true understanding of the solar energy's potential benefits [29, 30].

$$\delta = 23.45 \sin\left(2\pi\frac{284+n}{365}\right) \quad (1)$$

$$\omega_s = \cos^{-1}(-\tan\varphi\ \tan\delta) \quad (2)$$

$$H_o = \frac{86400 \times G_{sc}}{\pi \times 10^6}.\left[1 + 0.033\cos\left(\frac{360n}{365}\right)\right].\left(\cos\varphi\cos\delta\sin\omega_s + \frac{2\pi\omega_s}{360}\sin\varphi\sin\delta\right) \quad (3)$$

$$\overline{H} = \overline{K_T} \times \overline{H_o} \quad (4)$$

$$\omega_s' = \min_{\omega_s}\begin{pmatrix}\cos^{-1}(-\tan\varphi\ \tan\delta)\\ \cos^{-1}(-\tan(\varphi-\beta)\ \tan\delta)\end{pmatrix} \quad (5)$$

$$\overline{R_b} = \frac{\cos(\varphi-\beta)\cos\delta\sin\omega_s' + (\pi/180)\omega_s'\sin(\varphi-\beta)\sin\delta}{\cos\varphi\cos\delta\sin\omega_s' + (\pi/180)\omega_s'\sin\varphi\ \sin\delta} \quad (6)$$

$$\overline{H_d} = (\,0.8 + 0.006\,(\omega_s - 90) - [0.5 + 0.0045(\omega_s - 90)]\cos[\,115\overline{K_T} - 103]\,) \times \overline{H} \quad (7)$$

$$\overline{H_T} = \overline{H}\left(1 - \frac{\overline{H_d}}{\overline{H}}\right)\overline{R_b} + \overline{H_d}\left(\frac{1+\cos\beta}{2}\right) + \overline{H}\,\rho\left(\frac{1-\cos\beta}{2}\right) \quad (8)$$

## 4. Results and discussion

The configuration of the research building, which is found in Amman, Jordan, is shown in Figure 3, which provides a thorough picture of the facility's layout. This architectural context will serve as the canvas upon which the significant influence of albedo on a variety of features, including the building's facade, roof, windows and several other components, will be painstakingly researched and evaluated. This architectural setting also acts as the canvas upon which this study is conducted. The research venture sets out on its scientific trip with a concentrated case study that is carried out on the tenth of December. This day is known for its notoriety as being the most difficult day of the year. The selection of this particular date is appropriate given its characteristics, which include having the greatest possible amount of daylight hours and the most potent kind of solar radiation. This case study serves as an important beginning point, providing essential insights into the direct consequences that albedo has. In spite of this, given the significance of having a complete comprehension of the yearly dynamics, the research has broadened its focus to encompass an exhaustive inquiry that spans the entirety of the year.

This exhaustive examination requires the careful collecting of data, such as measurements of solar radiation, fluctuations in surface temperature and patterns of energy consumption, in order to offer an in-depth view of how Albedo behaves during the course of a full year. In addition, the analysis takes into account seasonal shifts, taking into account how the albedo affects energy efficiency and comfort within the structure throughout various climatic circumstances, such as Jordan's sweltering summers and freezing winters. I aim to contribute not only to the specific context of Jordan's built environment but also to a broader understanding of how albedo can be harnessed as a valuable tool in enhancing energy efficiency and sustainability in various global settings. This will be accomplished by delving into a variety of aspects over a prolonged period of time.

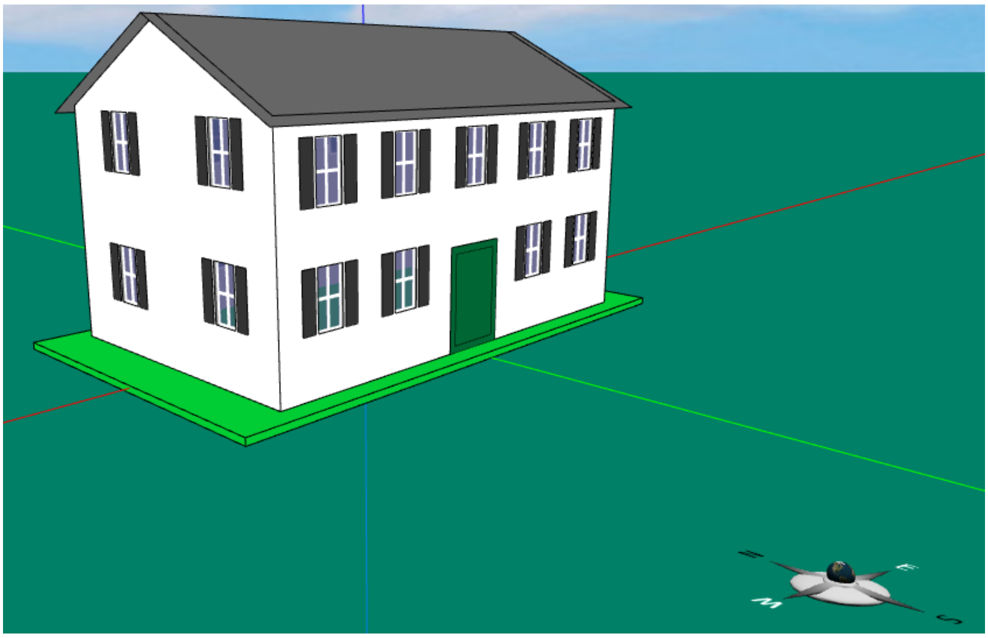


**Figure 3.** Plan of the study house in Amman-Jordan.

Figure 4 provides an in-depth overview of the first stage of our inquiry, with a particular emphasis on the most important characteristic of the soil medium, which was given a value of 0.17 for its albedo. This essential piece of data will serve as the basis for our following investigations, which will provide light on the ways in which the natural environment interacts with the constructed structure. The inquiry is taken to a deeper level in Figure 4A, where a thermal diagram of the structure is shown for your perusal. This graphic provides a visual depiction of how the heat is handled and dispersed throughout the building. It demonstrates the dynamic interplay that occurs between the many thermal components of the building and reveals the paths by which heat is transmitted, stored and discharged inside the structure. Figure 4B, on the other hand, zeroes down on a particular facet of the thermal performance of the building. Specifically, it examines the amount of heat gain that is associated with the windows of the structure in a number of different orientations. By dissecting these gains, I am able to acquire significant information about how the structure reacts to external environmental elements like as sunshine and fluctuations in the surrounding temperature. This information is essential for maximizing the building's potential in terms of both energy efficiency and comfort. The diagrams in Figures 4C and 4D provide a more in-depth look at the complexities of energy transfer inside the structure. The rate of energy acquisition from the four walls of the house is investigated in Figure 4C, taking into account the orientations of the walls in relation to the cardinal directions. Because of this research, I have a better understanding of how the structure interacts with its environment, either taking in or giving out energy depending on what is required to keep its thermal equilibrium. As I proceed with the examination, Figure 4D directs our attention to the rate of energy acquisition that occurs within the structure's lower floor and its higher ceiling. These regions are extremely important to the overall thermal performance of the building, which in turn affects both the level of comfort and the amount of energy used. Having an understanding of the energy dynamics at play here can lead to the development of novel design and construction solutions that improve both the building's long-term viability and the health of its occupants. Expanding on this analysis allows me to go further into other topics, such as investigating the implications of these discoveries for the construction of energy-efficient buildings, the environmental effect of varying albedo levels and the possible uses of this research in the fight against climate change. In addition, I may talk about the procedures that were carried out throughout the data gathering and analysis, which would provide light on the level of scientific rigor that underpinned our investigation. With the help of this multidimensional approach, I am able to extract a lot of knowledge from Figure 4 and the data that is linked with it, so paving the way for a built environment that is more sustainable and resilient.

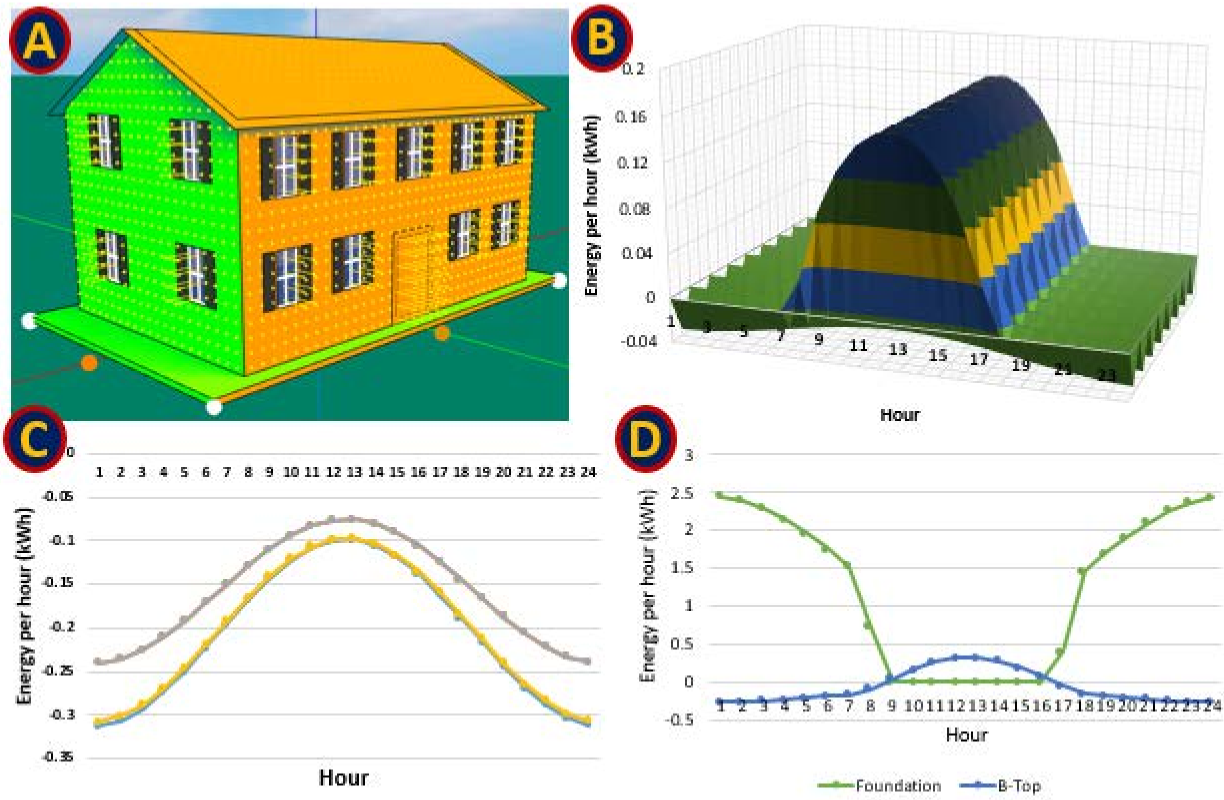



**Figure 4.** The energy rate diagram (A), the windows energy gain(B), the wall energy gain (C) and the foundation and roof of the building energy gain (D).

Figure 4 shows that the value of heat gain due to albedo is highest in the foundation, followed by the windows, and then the remainder of the home components. This is considered a correct result because the direct contact between the albedo and the foundation is as large as possible due to the physical relationship that links the effect of the albedo with the reflection of the rays into the house and the ability of the reflection to reflect the greatest possible value of the rays falling on the level, thereby assisting the house and its components under study to absorb the greatest amount of energy reflected on it.

The instance of a concreate medium with an albedo value of 0.55 is seen in Figure 5. The thermal diagram of the structure is depicted in Figure 5A. Figure 5B displays the values of heat gain from various orientations of the building's windows. Figure 5 C and D represent the rate of energy gain from the four walls of the residence in the four cardinal directions, as well as the rate of energy gain in the floor and upper ceiling of the building.

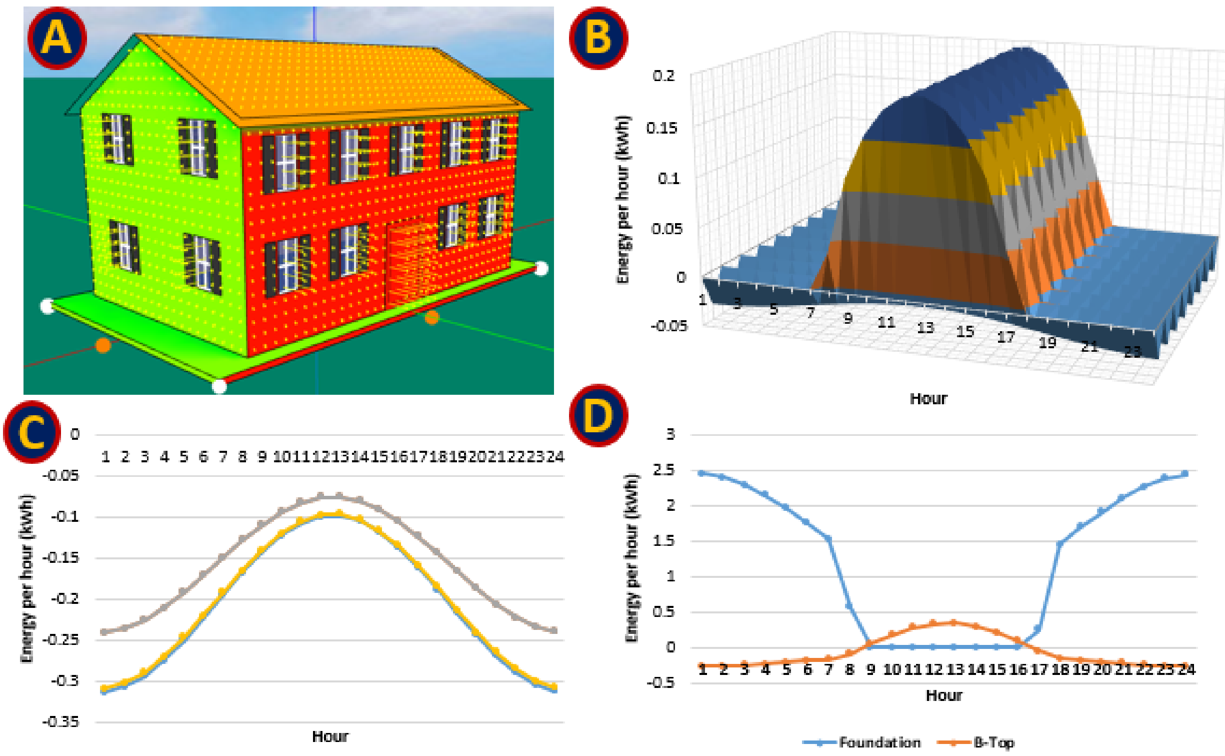



**Figure 5.** The energy rate diagram (A), the windows energy gain(B), the wall energy gain (C) and the foundation and roof of the building energy gain (D).

The value of the energy acquired by the home for the purpose of the research grows as the albedo value rises, as shown in figure 5. By transitioning from a soil medium to a concrete media, the value of the obtained energy increases substantially. Keeping in mind that the biggest value of heat gain was in the house's foundation, followed by the windows, and then the remainder of the house's components, supports the physical connection between the albedo and the surrounding environment.

Figure. 6 depicts an instance of a snow medium with an albedo value of 0.9. Figure 6A illustrates the structure's thermal diagram. Figure 6B illustrates the values of heat gain from different window configurations. Figure 6 C and D depict the rate of energy gain from the residence's four walls in the four cardinal directions, as well as the rate of energy gain from the residence's floor and higher ceiling.

Observations from the findings depicted in figures 4, 5 and 6 indicate that the rate of energy acquisition rises with increasing albedo and lightening of the medium, reaching a maximum at white color.

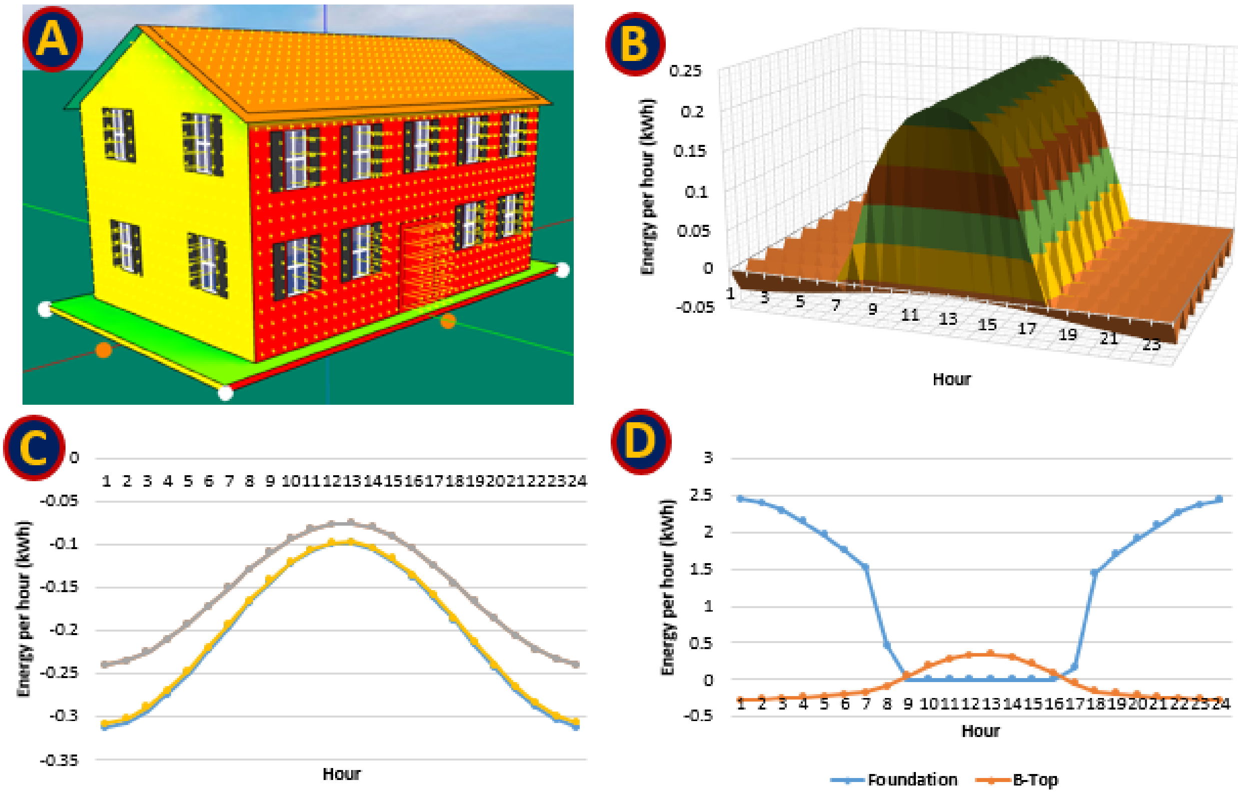



**Figure 6.** The energy rate diagram (A), the windows energy gain(B), the wall energy gain (C) and the foundation and roof of the building energy gain (D).

Figure 7 presents a detailed overview of the energy gain that occurs within the structure, with a particular emphasis on the impact that varying albedo values have on the energy gain that occurs via the building's windows. In Figure 7A, the energy gain potential of the windows under a particular set of circumstances is seen, with the albedo of the soil medium set at 0.17. This illustration provides insightful details into the ways in which windows contribute to energy gain, drawing attention to the role of windows in the overall thermal efficiency of the structure. The situation depicted in Figure 7B, in which the albedo of the surrounding concrete medium is 0.55, brings our attention to this new setting. In this section, I investigate the changes in heat gain from the windows as a result of the different climatic circumstances, with a particular focus on the dynamic link that exists between albedo values and the acquisition of energy. The investigation is continued in Figure 7C, which focuses on a snow-covered medium with an albedo of 0.9. This part of our investigation expands previously presented findings. Because of this scenario, I have a better understanding of how the pace at which energy is acquired via the windows is affected by the various environmental circumstances. The fluctuating albedo values are a reflection of the conditions that exist in the actual world and highlight how important it is to take into consideration elements like these when designing buildings and managing energy. A discernible pattern may be seen developing when one looks more closely at Figure 7. The amount of heat gained through the windows proportionally increases whenever the albedo value is increased. The relevance of albedo as a significant factor of energy dynamics within the building envelope is highlighted by this connection, which highlights its importance. This highlights the need to make deliberate decisions about the construction materials and settings surrounding the structure in order to maximize energy efficiency. Additionally, the impact that the direction has on the amount of heat gained is made clear. The rate of heat uptake via the building's windows is greatest when those windows are located on the building's southern façade. Their prolonged exposure to the brightly refracted sunlight is likely to blame for the occurrence of this phenomena. After that, the windows on the western and eastern sides of the building follow suit, but at a little slower rate than the windows on the southern side of the structure. On the other hand, the rates of heat acquisition are largest for the windows that are located on the northern face. Because this side of the building is exposed to the least amount of direct and indirect solar energy, it has to rely more heavily on other aspects, such as the albedo of its surroundings, in order to achieve the same level of heat uptake as the other sides of the building. This has led to the observed result. Figure 7 demonstrates the complex relationship that exists between the albedo values of a structure, the orientation of its windows and the amount of energy gain that the building experiences. These findings have important repercussions for architects, engineers and regulators who are attempting to design and operate energy-efficient buildings that successfully adapt to a wide variety of environmental circumstances.

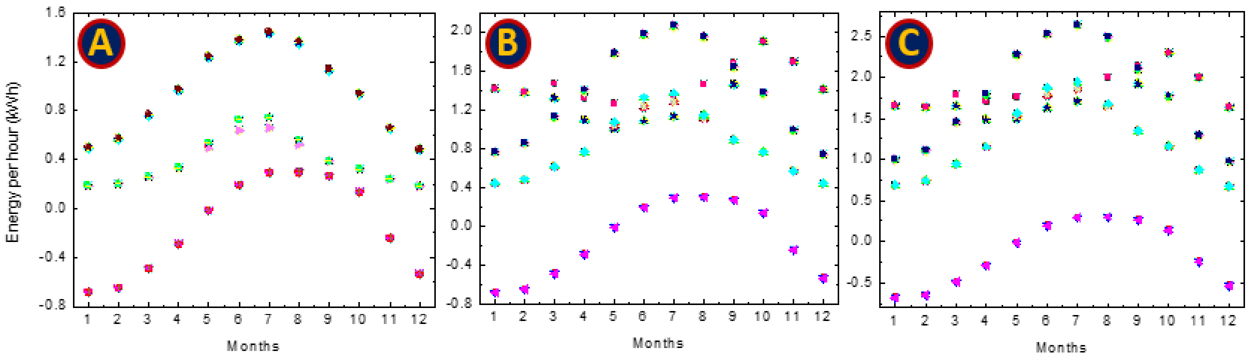



**Figure 7.** energy gain from the windows of the building at albedo values of 0.17 (A), 0.55 (B) and 0.9 (C).

Based on the findings of the current study as well as those of the earlier research, it can be deduced that the rate of heat gain in any house is affected by the nature of the medium on which it is built. This effect is caused by the value of the albedo, which rises in the direction of lighter colors because lighter colors reflect more of the incident rays that strike the medium. The influence of the albedo was investigated in this study using three distinct media: Earthy, concrete and snowy media, each of which had an albedo value of 0.17, 0.55 and 0.9, respectively. As a result, the value of the heat gain for the snow albedo should be as high as possible, followed by the value of the heat gain for the concrete medium, and then finally the value of the heat gains for the soil medium. It should be noted that the heat gain rates increase with the increase in the increase in the amount of the albedo. It is also possible to extract the effect of the direction of the windows on the value of heat gain, so that it is noted that the windows located on the southern facade of the house have the highest value of heat gain, followed by the windows on the eastern and western facades, and the least windows on the northern facade due to the lack of solar radiation falling on them. This is because the windows on the southern facade of the house receive the most sunlight throughout the year. The solar potential that is able to reach the building for a soil medium is 996 kWh, whereas the solar potential for concrete is 1277 kWh, and the solar potential for snow is 1532 kWh. This study is important because it paves the way for researchers to start qualitative studies on the impact of the surrounding environments on buildings on the quantities of energy needed for buildings in a clear development of building technology and the study of the interaction between the components of buildings and the surrounding environments. This opens the horizons for researchers to start qualitative studies on the impact of the surrounding environments on buildings on the quantities of energy needed for buildings.

## 5. Conclusions

The outcome of the research demonstrates that the albedo of the surroundings surrounding buildings has a significant influence in determining the pace at which heat is gained inside the structures. It is evident, based on previous research as well as the findings of this inquiry, that the albedo value, which is closely related with the color and reflecting qualities of a surface, has a significant impact on the thermal performance of a structure. These findings were obtained through this analysis.

In this study, I focused on three separate environmental media: Earthy, concrete, and snowy, with albedo values of 0.17, 0.55 and 0.9 for each one, respectively. Through the use of this selection, I was able to identify a direct connection between albedo and heat gain. It is noteworthy that the rate of heat uptake within the building rose in proportion to the albedo levels. Because of their greater reflectivity, lighter-colored surfaces absorbed less solar energy, which led to a lower rate of heat gain. On the other hand, darker surfaces absorbed more energy, which resulted in a higher rate of heat gain.

In addition, the results of the research demonstrated that the orientation of windows has a major impact on the patterns of heat gain. The windows that were located on the building's southern façade continuously displayed the maximum heat gain, followed by the windows that were located on the building's eastern and western facades. Windows located on the northern façade of the building, on the other hand, showed the least amount of heat gain since they received the least amount of direct sunshine. This directional mismatch is caused by the constant exposure that the southern façade receives to sunshine throughout the year. As a result, the southern facade is the most solar-intensive component of the structure.

This research, in its core, provides a key insight into the delicate interplay that exists between the architecture of buildings, environmental conditions and energy dynamics. It acts as a basic stepping stone for the progression of building technology and it urges the incorporation of sustainable design concepts that make use of albedo concerns in order to maximize energy efficiency. This study paves the way for more qualitative investigations into the larger interaction between buildings and their surrounds by identifying the substantial influence that surrounding environments have on buildings. This, in turn, contributes to the creation of a built environment that is more environmentally friendly and efficient in its use of energy.

## Use of AI tools declaration

The author declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

## Conflict of interest

The author declare no conflict of interest.

## References


1. Ren X, Li J, He F, et al. (2023) Impact of climate policy uncertainty on traditional energy and green markets: Evidence from time-varying granger tests. *Renew Sust Energ Rev* 173: 113058. https://doi.org/10.1016/j.rser.2022.113058
2. Abdel-Fattah A, Hamdan S, Ayadi O, et al. (2022) Energy efficiency and thermal insulation code violations for residential buildings in Jordan and the role of social advocacy campaigns. *Energ Sustain Dev* 71: 419–432. https://doi.org/10.1016/j.esd.2022.10.013
3. Qadourah J A (2022) Energy and economic potential for photovoltaic systems installed on the rooftop of apartment buildings in Jordan. *Results Eng* 16: 100642. https://doi.org/10.1016/j.rineng.2022.100642
4. Abu Qadourah J, AL-Falahat A M, Alrwashdeh S S (2022) Alrwashdeh, Assessment of solar photovoltaics potential installation into multi-family building's envelope in Amman, Jordan. *Cogent Eng* 9 https://doi.org/10.1080/23311916.2022.2082059
5. Alrwashdeh S S (2019) Investigation of Wind Energy Production at Different Sites in Jordan Using the Site Effectiveness Method. *Energ Eng J Assoc Energ Eng* 116: 47–59. https://doi.org/10.1080/01998595.2019.12043338
6. Alrwashdeh S S, Alsaraireh F M (2018) Wind energy production assessment at different sites in Jordan using probability distribution functions. *ARPN J Eng Appl Sci* 13: 8163–8172.
7. Juaidi A, Abdallah R, Ayadi O, et al. (2022) Chapter 7 - Wind energy in Jordan and Palestine: current status and future perspectives, in Renewable Energy Production and Distribution, M. Jeguirim, Editor. Academic Press. 229–269. https://doi.org/10.1016/B978-0-323-91892-3.00006-6
8. Abu-Rumman G, Khdair A I, Khdair S I (2020) Current status and future investment potential in renewable energy in Jordan: An overview. *Heliyon* 6: e03346. https://doi.org/10.1016/j.heliyon.2020.e03346
9. Al Afif R, Ayed Y, Maaitah O N (2023) Feasibility and optimal sizing analysis of hybrid renewable energy systems: A case study of Al-Karak, Jordan. *Renew Energy* https://doi.org/10.1016/j.renene.2022.12.109
10. Alawin A A, Rahmeh T A, Jaber J O, et al. (2016) Renewable energy education in engineering schools in Jordan: Existing courses and level of awareness of senior students. *Renew Sust Energ Rev* 65: 308–318. https://doi.org/10.1016/j.rser.2016.07.003

11. Alawneh R, Ghazali F, Ali H, et al. (2019) A Novel framework for integrating United Nations Sustainable Development Goals into sustainable non-residential building assessment and management in Jordan. *Sustain Cities Soc* 49: 101612. https://doi.org/10.1016/j.scs.2019.101612
12. Albatayneh A, Hindiyeh M, AlAmawi R (2022) Potential of renewable energy in water-energy-food nexus in Jordan. *Energ Nexus* 7: 100140. https://doi.org/10.1016/j.nexus.2022.100140
13. Qadourah J A, Alrwashdeh S (2022) ECONOMIC FEASIBILITY OF HEATING SOURCE CONVERSION OF THE SWIMMING POOLS. *J Appl Eng Sci* 20: 230–238. https://doi.org/10.5937/jaes0-34474
14. Al-Falahat A M, Kardjilov N, Khanh T V, et al. (2019) Energy-selective neutron imaging by exploiting wavelength gradients of double crystal monochromators—Simulations and experiments. Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 943. https://doi.org/10.1016/j.nima.2019.162477
15. Ala'a M, Qadourah J A, Alrwashdeh S S, et al. (2022) Energy performance and economics assessments of a photovoltaic-heat pump system. *Results Eng* 13. https://doi.org/10.1016/j.rineng.2021.100324
16. Ali H, Hashlamun R (2019) Envelope retrofitting strategies for public school buildings in Jordan. *J Buiild Eng* 25: 100819. https://doi.org/10.1016/j.jobe.2019.100819
17. Alkhalidi A, Alqarra K, Abdelkareem M A, et al. (2022) Renewable energy curtailment practices in Jordan and proposed solutions. *Int J Thermofluids* 16: 100196. https://doi.org/10.1016/j.ijft.2022.100196
18. Almomani E, Hammad E A, AlQutob R, et al. (2022) Capacity Building for Health Technology Assessment in Jordan: Institutionalization and Its Use in Pricing and Reimbursement Decisions. *Value Health Reg Iss* 32: 47–53. https://doi.org/10.1016/j.vhri.2022.07.006
19. Alrwashdeh S S (2017) Determining the optimum tilt solar angle of a PV applications at different sites in Jordan. *J Eng Appl Sci* 12: 9295–9303.
20. Alrwashdeh S S (2018)Predicting of energy production of solar tower based on the study of the cosine efficiency and the field layout of heliostats. *Int J Mech Eng Technol* 9: 250–257.
21. Alrwashdeh S S (2018) Investigation of the energy output from PV racks based on using different tracking systems in Amman-Jordan. *Int J Mech Eng Technol* 9: 687–694.
22. Alrwashdeh S S (2018) Comparison among solar panel arrays production with a different operating temperatures in Amman-Jordan. *Int J Mech Eng Technol* 9: 420–429.
23. Bartmiński P, Siłuch M (2022) Mapping the albedo of the active surface at different stages of the growing season using data from various sources. *Remote Sens Appl Soc Environ* 28: 100818. https://doi.org/10.1016/j.rsase.2022.100818
24. Cierniewski J, Ceglarek J (2023) Influence of arable land location incorporating its roughness on blue-sky albedo variation. J Quantit Spectrosc Radiat Transf 296: 108440. https://doi.org/10.1016/j.jqsrt.2022.108440
25. Du J, Zhou H, Jacinthe P A, et al. (2023) Retrieval of lake water surface albedo from Sentinel-2 remote sensing imagery. *J Hydrol* 617: 128904. https://doi.org/10.1016/j.jhydrol.2022.128904

26. Lin X, Wu S, Chen B, et al. (2022) Estimating 10-m land surface albedo from Sentinel-2 satellite observations using a direct estimation approach with Google Earth Engine. *ISPRS J Photogramm Remote Sens* 194: 1–20. https://doi.org/10.1016/j.isprsjprs.2022.09.016
27. Xiao Y, Ke C Q, Shen X, et al. (2023) What drives the decrease of glacier surface albedo in High Mountain Asia in the past two decades? *Sci Total Environ* 863: 160945. https://doi.org/10.1016/j.scitotenv.2022.160945
28. Alrwashdeh S S (2018) Energy production evaluation from a linear fresnel reflectors arrays with different array orientation. *Inter J Engin Res Technol* 11: 1811–1819.
29. Alrwashdeh S S (2018) Assessment of the energy production from PV racks based on using different solar canopy form factors in Amman-Jordan. *Inter J Engin Res Technol* 11: 1595–1603.
30. Alrwashdeh S.S (2018) The effect of solar tower height on its energy output at Ma'an-Jordan. *AIMS Energ*. 6: 959–966. https://doi.org/10.3934/energy.2018.6.959
31. Alrwashdeh S S (2018) Assessment of photovoltaic energy production at different locations in Jordan. *Int J Renew Energ Res* 8: 797–804.
32. Alrwashdeh S S (2019) An energy production evaluation from PV arrays with different inter-row distances. *Int J Mech Prod Eng Res Develop* 9: 1–10.
33. Alrwashdeh S S (2019) Energy production assessment of solar tower based on the study of the mirror shadowing and blocking effects. *Univers J Mech Eng* 7: 71–76. ttps://doi.org/10.13189/ujme.2019.070205
34. Jin Y, Liu K, Xiong L, et al. (2022) A non-traditional variant nonlinear energy sink for vibration suppression and energy harvesting. *Mech Syst Signal Process* 181: 109479. https://doi.org/10.1016/j.ymssp.2022.109479
35. Kiwan S, Al-Gharibeh E (2020) Jordan toward a 100% renewable electricity system. *Ren Energ* 147: 423–436. https://doi.org/10.1016/j.renene.2019.09.004
36. Ma'bdeh S N, Ali H H, Rabab'ah I O (2022) Sustainable assessment of using green roofs in hot-arid areas – Residential buildings in Jordan. *J Buiild Eng* 45: 103559. https://doi.org/10.1016/j.jobe.2021.103559
37. Alrwashdeh S S (2021) Investigation of the energy output from PV panels based on using different orientation systems in Amman-Jordan. *Case Stud Therm Eng* 28. https://doi.org/10.1016/j.csite.2021.101580
38. Alrwashdeh S S (2021) Investigation of the energy output from PV panels based on using different orientation systems in Amman-Jordancorlowast. *Case Stud Therm Eng* 28: 101580. https://doi.org/10.1016/j.csite.2021.101580
39. Alrwashdeh S S (2022) INVESTIGATION OF THE ENERGY OUTPUT OF PARABOLIC TROUGH RACKS BASED ON USING DIFFERENT RHOMBOID LAYOUT. *ARPN J J Eng Appl Sci* 17: 578–586.
40. Alrwashdeh S S, Ammari H (2019) Life cycle cost analysis of two different refrigeration systems powered by solar energy. *Case Stud Therm Eng* 16. https://doi.org/10.1016/j.csite.2019.100559
41. Alrwashdeh S S, Ammari H, Jweihan Y S, et al. (2022) Refurbishment of Existing Building toward a Surplus Energy Building in Jordan. *Open Const Build Technol J* 16 https://doi.org/10.2174/18748368-v16-e2208150

42. Alrwashdeh S S, Qadourah J A, Al-Falahat A M (2022) Investigation of the Effect of Roof Color on the Energy Use of a Selected House in Amman, Jordan. *Front Mech Eng* 8. https://doi.org/10.3389/fmech.2022.897170
43. Alsarayreh A A, Al-Obaidi M A, Alrwashdeh S S, et al. (2022) Enhancement of energy saving of reverse osmosis system via incorporating a photovoltaic system, in Computer Aided Chemical Engineering. 697–702. https://doi.org/10.1016/B978-0-323-95879-0.50117-X
44. Altarawneh O R, Alsarayreh A A, Ala'a M, et al (2022) Energy and exergy analyses for a combined cycle power plant in Jordan. *Case Stud Therm Eng* 31. https://doi.org/10.1016/j.csite.2022.101852
45. Pastor R, Tobarra L, Robles-Gómez A, et al. (2020) Renewable energy remote online laboratories in Jordan universities: Tools for training students in Jordan. *Renew Energ* 149: 749–759. https://doi.org/10.1016/j.renene.2019.12.100
46. Chenoweth J, Al-Masri R A (2021) The impact of adopting a water-energy nexus approach in Jordan on transboundary management. *Environ Sci Policy* 118: 49–55. https://doi.org/10.1016/j.envsci.2021.01.006
47. Murtadha T K, dil Hussein A A, Alalwany A A H, et al. (2022)Improving the cooling performance of photovoltaic panels by using two passes circulation of titanium dioxide nanofluid. *Case Stud Therm Eng*. 36. https://doi.org/10.1016/j.csite.2022.102191
48. Schuetze B, Hussein H (2023) The geopolitical economy of an undermined energy transition: The case of Jordan. *Energ Policy* 180: 113655. https://doi.org/10.1016/j.enpol.2023.113655
49. Alrwashdeh S S (2022) Energy sources assessment in Jordan. *Results Eng* 13. https://doi.org/10.1016/j.rineng.2021.100329