International Journal of Energy Production and Management
Vol. 8, No. 2, June, 2023, pp. 115-122
Journal homepage: http://iieta.org/journals/ijepm

Towards a Sustainable Design: Integrating Spatial Planning with Energy Planning When Designing a University Campus

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https://doi.org/10.18280/ijepm.080208

Received: 22 March 2023
Accepted: 15 May 2023

Keywords:
spatial planning, energy planning, sustainable planning, spatial dimensions, social sustainability, developing countries, Jordan

ABSTRACT

Spatial planning and energy planning are two crucial topics related to each other, as both subjects have environmental, social, and economic benefits. Worldwide, few researchers have studied the integration of spatial planning with energy planning, however, in Jordan, this subject remained unexplored. This study aims to assess the sustainable planning practices that are implemented in small-scale projects, it explores the spatial issues that planners should consider to increase the integration of energy technologies into the planning process. A mixed methods approach is employed in data collection and analyses to enhance the accuracy and creditability of the findings. The spatial dimensions of energy planning which include analyzing the project's master plan, evaluating the urban structure, and calculating energy production are used to assess the existing situation of Zarqa University in Jordan. Numerical and data analyses, site analyses, and field observations are conducted to achieve the research aim. Zarqa University was selected because it is the first Jordanian university that implements energy planning strategies when designing its campus. The study findings confirm the importance of integrating these two disciplines which contribute to achieving effective planning policies, it recommends replicating those strategies in other small projects to enhance their level of sustainability.

1. INTRODUCTION

The huge development of urban infrastructure during the last decades has increased energy demand and greenhouse gas emissions [1], it also increased the transformation of the built environment and the pollution of the natural environment [2]. Decision-makers highlighted the need to anchor energy transition and climate protection as a vital public duty across sectors, including spatial planning [3]. However, the connection between spatial planning and energy planning is undeveloped [4]; each discipline is perceived from a different perspective and used separately to solve the city's problem. Therefore, it is recommended to integrate spatial planning with energy planning and benefit from the experience of the developed countries. Such disciplines, which are now technically independent, must combine into an organic structure to identify efficient and sustainable approaches for implementation, following a holistic approach in which engineering, climate, planning, and landscaping merge and form a progressively more integrated vision [5].

Spatial planning is essential to enhancing the quality of life and endorsing sustainable development. It focuses on "the problem of coordination or integration of the spatial dimension of sectoral policies through a territorially-based strategy" [1, 6]. Spatial planning manipulates the strains and conflicts amongst strategies, for instance, the contradictions among environmental, social, and economic systems [7, 8]. The primary role of spatial planning is to propose comprehensive uses of land and an inclusive integration among them, to balance the development requirement while protecting the current resources and environmental, social, and economic goals [8]. Furthermore, spatial planning systems focus on the techniques and strategies applied by the public sector and the private organizations that influence the distribution of natural and cultural resources in a specific region [9]. The aims of spatial planning vary from nation to nation; however, most recognize spatial planning as a method to set out long and medium-term goals and policies [2]. In the United Kingdom, for instance, the government recognizes spatial planning in a comprehensive way that overcomes traditional land-use planning; and integrates policies, strategies, and programs that impact the nature of places [10].

Spatial planning is built on organizing specific areas, whether these areas are on large scales like cities or small scales like firms and universities. The importance of spatial planning, according to Cullingworth and Nadin [6], comes in many environmental, economic, and social sectors. Environmentally, it promotes the proper use of land and building infrastructure. Economically, it offers more confidence and steadiness for investment, classifying land and confirming that land for development is well placed. Socially, spatial planning considers the need of local communities, increases accessibility, and supports the provision of local amenities.

Similarly, the benefits of energy planning come in diverse environmental, social, and economic fields, but it has been seen from a different perspective, as it focuses on the local impact and the spatial distribution of costs [11]. Energy planning ought to present the consequences of economic development and population growth; it also supports using natural energy resources to generate power that fulfils human needs [12], such as solar energy by using solar panels or wind energy by using air turbines. However, new challenges that have affected infrastructure systems, as well as spatial planning, are linked to the use of renewable resources [2].

Accordingly, it is essential to integrate energy technologies into the planning process when shaping the future of space. Spatial planning is concerned with the rational arrangement of activities by considering all the standards and conditions regarding human comfort in the design, whether the design is on a large scale or a small scale. However, energy planning mainly concerns creating sustainable land use by applying combined approaches that admire providing energy supplies and consider energy efficiency's importance.

The spatial planning decisions have tangible effects on the energy demand, the mobility connection with surrounding areas, and the site selection with specific slopes and characteristics [11]. For instance, if the project depends on solar energy, the chosen area must be free of clouds, flat land, and have a high sun coefficient; or if the project depends on wind energy, there is an extrusive relation between area height and the energy produced by the air turbines [4]. Existing spatial plans such as local spatial development strategies, local plans, and regional plans could be viable to protect renewable resources by zoning relevant districts, where the major components of the integrated energy and resource plans set the border for spatial planning [11, 13].

Previous studies confirm that spatial planning traditions in developing countries, such as Jordan, are often not well-integrated with the recent development of new technologies in the energy field; the experts in the energy sector, as well as the architects and planners, are facing many problems in properly integrating plants in urban contexts and ecological landscapes [5]. In Jordan and developing countries, it is not obvious to many experts how this integration could be achieved and how it looks. Most architects and planners are unaware of Renewable Energy Systems (RES) and energy planning technologies. Likewise, RES engineers are not conscious of urban planning or landscape architecture [4].

A few successful examples of integrated spatial and energy plans have been implemented in Mediterranean developing countries. One example is the Tunisian Solar Plan, launched in 2009, which aimed to increase the country's share of renewable energy by installing solar photovoltaic (PV) panels on rooftops and developing large-scale solar power plants. It also incorporated spatial planning considerations by detecting suitable locations for renewable energy projects, such as areas with high solar irradiation. As a result, Tunisia has made significant progress in increasing its renewable energy capacity [14].

Another example is the Moroccan Integrated Wind Energy Project, launched in 2010 and aimed to develop 2,000 MW of wind power capacity across five different regions in the country. The project incorporated spatial planning considerations by identifying suitable locations for wind farms and taking into account the potential impacts on local communities and the environment [15].

Similarly, there are various initiatives that support the concept of this integration to fill the gap in higher education programs, such as the ENEPLAN Project-Energy Efficient Process Planning System-which was funded by Erasmus+ and aims at creating interdisciplinary educational approaches to energy planning renewable sources and spatial planning in Mediterranean areas by suggesting alternative learning methods for these courses at the Jordanian universities [5]. The main objective of ENEPLAN is to combine the theoretically detached disciplines to achieve successful and sustainable implementation strategies by following an inclusive approach in which the environment, technology, planning, and landscape move together towards an increasingly integrated vision [16, 17].

Still, the main questions are: How can spatial design strategies be developed to support energy planning? How to explore the main spatial dimensions of energy planning and how to implement them? Based on previous literature and to fill the existing gaps, the following sections will present the research aims, then it will focus on the methods employed in data collection and analysis, after that it will go through the discussion and recommendations, to finalize with the research conclusions.

2. METHODOLOGICAL APPROACH

This research aims at assessing the planning strategies that are implemented in small-scale projects such as universities. It explores the spatial dimensions that should be used by planners to increase the integration of energy technologies into the planning process. These strategies are discussed and assessed from an architectural viewpoint.

Previous studies have been reviewed to define the contemporary meaning of spatial planning and energy planning and to explore the main spatial dimensions of energy planning. These dimensions have been used in assessing the case study of Zarqa University in Jordan. A mixed methods approach has been implemented in data collection and analyses, it is selected to overcome the minuses of using only qualitative or quantitative methods [18]. 85% of the implemented methods are qualitative, while only 15% are quantitative (Figure 1). The research methodology is mainly based on site plan analyses, unstructured observation, and numerical and data analysis.

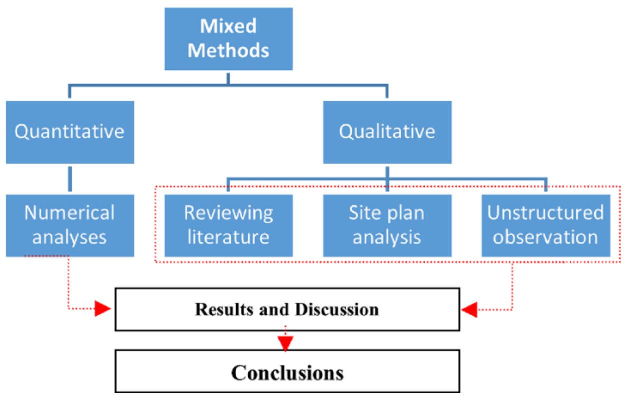


Figure 1. Methodological approach

(1) Site analysis aims at comprehending the spatial organization of energy systems and gives valuable insight into how spatial planning could be integrated with energy planning. Zarqa University's master plan has been assessed based on the critical spatial dimensions of energy planning implemented by planning professionals which are: Master planning and zoning, green infrastructure, and energy production to explore the pluses and minuses of the campus design. This includes the organization of the built environment, distribution of buildings,

the form of outdoor spaces, and accessibility to the site.

(2) Unstructured observation aims at recording the behavior of students and staff at the university campus to explore the impact of spatial organization on their behavior. Unstructured observation is conducted at Zarqa University from 1st January 2022 to 1st July 2022. The target group's behavior is collected by taking photos and drawing sketches to recognize where they sit, stand, and the types of their activities, and their duration. The outcome of the unstructured observation is represented in maps that show the main results obtained.

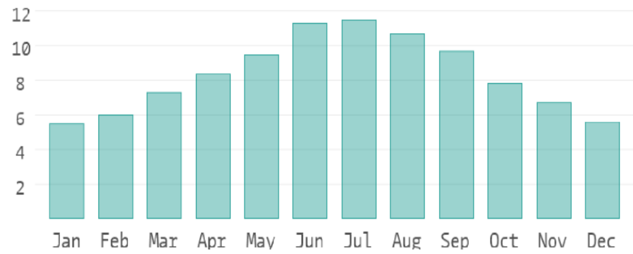
(3) Numerical and data analysis: This method aims at reviewing the literature, gathering data, and analyzing numbers to achieve the research's goal. The author collaborates with the Zarqa Energy Research Center-ZERC in analyzing the required data, figures, and numbers, however, the average value of energy production and the saved budget were calculated by ZERC. The outcomes have been summarized by the author and presented in tables and charts to be read easily.

3. RESULTS AND DISCUSSION

3.1 The case study of Zarqa University

Az-Zarqa City, known as the "Zarqa," situated in the Zarqa River basin (Figure 2). The city is located 24 km northeast of Amman, the capital of Jordan; latitude and longitude coordinate 36.0941795, 32.0608187. Zarqa has a cold semi-arid climate; the average temperature is about 17.4℃, the average rainfall is about 182 mm annually [19], and the number of sunshine hours reaches 12 hours per day in July, which is considered the sunniest month in Zarqa (Figure 3) [20]. All climate diagrams in this research result from the collected data of the official weather station in Zarqa at a height of 683 m above sea level. All data correspond to the average monthly values of the last 20 years.

Figure 2. Zarqa location in the northeast of Jordan



(Source: World data info 2022)

Figure 3. Hours of sunshine per day

The Zarqa University (ZU) was established in 1994 at a strategic location in Zarqa City, it has a relatively small campus area compared to other Jordanian universities. The area of the ZU campus is approximately 86 acres, it is considered small compared to the University of Jordan 300 acres, and Jordan University of Science and Technology 2718 acres. ZU campus is well-equipped with modern facilities and amenities to support its academic programs and student life. Zarqa University is selected as a case study because it is the first private university that uses solar panels to produce energy, and it integrates energy technology throughout the campus. Reviewing the previous studies clarifies that the critical dimensions for integrating energy technologies into the planning process are: master planning and zoning, urban structure, and energy production [21-23]. These dimension ns are used to assess the current situation of the outdoor spaces at Zarqa University, and explore the pluses and minuses of the design:

(1) Master planning and zoning: Master planning is essential in delivering energy solutions because of the necessity to supply power to current and prospective development. Likewise, zoning is crucial to preserve spatial planning and recognize preferred locations for diverse uses, and assist in minimizing contradiction and maximizing synergies.

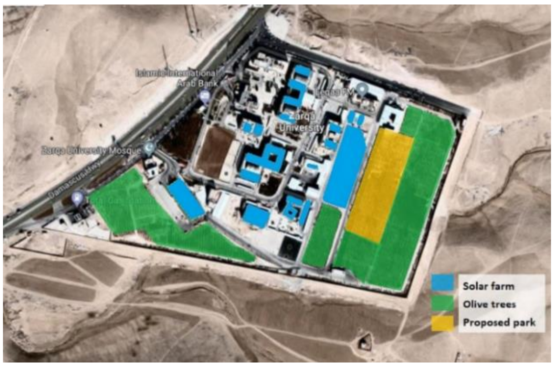
Previous studies have identified master planning and zoning as critical dimensions for integrating energy technologies in various contexts [24-26]. Research in urban planning highlighted the importance of master planning and zoning to enable the integration of renewable energy technologies such as solar panels and wind turbines into the built environment. Similarly, studies in the energy sector have emphasized the role of master planning and zoning in facilitating the deployment of energy storage systems, smart grids, and other advanced energy technologies. These studies emphasize the importance of master planning and zoning in integrating energy technologies into local communities.

Analyzing the master plan of ZU campus confirms that it has a strategic opportunity for future expansion and development. The buildings are mainly located in the northwest corner and are surrounded by open areas that allow for the university's future expansion (Figure 4). This open area is a valuable tool for fully integrating climate change adaptation and justification objectives into the site. Furthermore, Figure 5 shows that the spatial arrangement of the campus supports the energy integration within the landscape, as the central part is used as a solar farm; this farm consists of 8890 solar panels distributed on lands, buildings' roofs, canopies; this farm produces about 660,597 Kwh per year as will be shown later in this research [27]. Moreover, the areas surrounding the buildings are planted with olive trees that have economic value besides their environmental benefits.

Moreover, there are a lot of green spaces open to students and staff; these spaces are well designed and planted with suitable plants, which are known as the xeriscaping plants, as these florae do not need much water; however, these florae do not provide shades for sitting areas or walkways (Figure 6).

(Source: Arial view edited by the author 2021)

Figure 4. The buildings' location at the northwest corner supports the future expansion of the university



(Source: Arial view edited by the author 2021)

Figure 5. The spatial arrangement of the energy features

(Source: The author, 2022)

Figure 6. The xeriscaping plants at the campus do not provide shades for sitting areas or walkways

There is a proposed smart park that will be designed on the eastern side for students and staff; this park will be an eco-energy-friendly area that contains gathering spaces, a bicycle path, walking trails, shaded areas, outdoor sports, and other facilities. It is called smart because it will apply the "Green infrastructure" concept in several spaces. However, the proposed location of the smart park will cause the placement of olive trees, which minimizes the green area and harms the natural environment.

(2) Green infrastructure: Integrating spatial planning with energy planning can also be achieved by applying the green infrastructure approach, which symbolizes a comprehensive strategy that offers a model for development and planning [28]. A green infrastructure approach guides planning beyond simply applying the modern technique of thoughts and practices. It comprises a revolution in how spatial planning systems are organized and perceived by specialists [29].

Green infrastructure refers to a network of natural and semi-natural areas, such as parks, green roofs, and wetlands that provide a range of environmental, economic, and social benefits. When incorporated into spatial and energy planning, green infrastructure help to mitigate the impacts of climate change, reduce energy consumption, and enhance the resilience of urban areas. Previous studies highlight the potential of green infrastructure in enhancing energy efficiency, reducing energy demand, and promoting sustainability. They suggest various ways to use green infrastructure in integrating spatial planning with energy planning, according to them, incorporating green infrastructure into the design and construction of buildings helps to reduce energy consumption and emissions. Green roofs provide insulation and reduce the need for heating and cooling, while solar panels generate renewable energy [30-32].

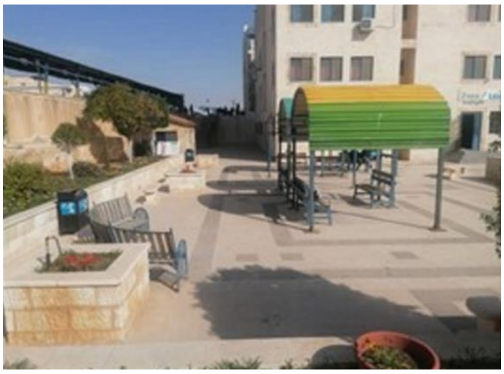
Green infrastructure can be used to support the development of renewable energy systems, such as wind and solar farms. By locating these systems in areas that are compatible with natural ecosystems, they can minimize negative environmental impacts while contributing to a sustainable energy supply. Likewise, integrating green infrastructure into urban planning can create green corridors that help in maintaining biodiversity, reducing the urban heat island effect, and providing opportunities for outdoor recreation.

Analyzing the campus design confirms that it minimizes heat island effects by offering open areas and plantations that promote urban cooling. Analyzing the master plan shows that there are a lot of green open spaces that are opened to students and staff; these spaces include water fountains that are distributed all around the campus to cool the hot weather of the semi-arid zone (Figure 7) [33]. These open spaces are furnished with durable furniture manufactured at the university factory, and canopies and shading constructions are also distributed within the landscape. These design solutions support the space's environment and social sustainability and enhance the "Green infrastructure" approach.

(Source: ZU 2018)

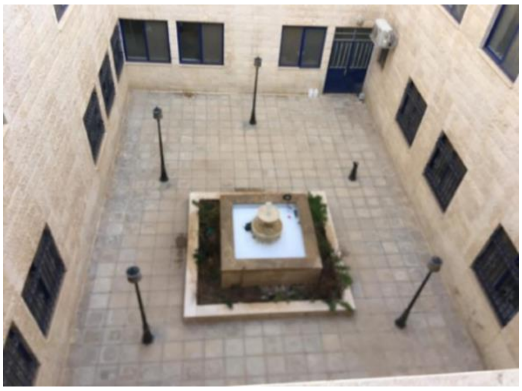
Figure 7. The campus design minimizes heat island effects and promotes urban cooling

In contrast, observing the student behavior confirms that some areas on campus still lack shading structures, pergolas, and benches to encourage students and staff to come, sit, and talk; this harms the social sustainability of the place. The lack of benches leads the students to sit on the walls' parapets or stand on the sidewalks; likewise, the lack of shading elements that protect the users from the direct sun in summer and the rain in winter leads them to sit inside the buildings. In some areas, the shading structure is fixed in the wrong direction and thus cannot protect the student from the direct sun during the day (Figure 8). Furthermore, the site observation shows that the buildings have central courtyards with water fountains at their center; however, many of these courtyards are not accessible for students and staff, and they are physically segregated, and the water features are seen only from the windows. Moreover, the courtyards are not planted or furnished, which negatively affects the design (Figure 9). Therefore, it is advised to redesign these courts by adding benches to encourage students and staff to come, sit, and communicate, planting some shrubs that are visually pleasant and environmentally friendly. The proposed design will increase urban cooling and enhance social sustainability; Figure 10 shows a proposed design for the courtyard that may enhance social and environmental sustainability.



(Source: The author 2022)

Figure 8. Shading structures cannot protect the student from the direct sun during the day



(Source: The author 2022)

Figure 9. The current situation for the courtyards

(Source: The author 2022)

Figure 10. The proposed design for the courtyards

(3) Energy production: Spatial planning plays a critical role in shaping energy production and distribution. The location, size, and type of energy infrastructure are determined by spatial planning, which also affects the accessibility and affordability of energy for consumers. For example, the location of wind turbines, solar farms, and power plants are all determined by spatial planning regulations. Effective spatial planning can help to minimize the negative impacts of energy production on the environment, such as reducing air and water pollution, while also promoting the use of renewable energy sources. Spatial planning can also help to ensure that energy infrastructure is located in areas with adequate natural resources and infrastructure, reducing the costs associated with energy production and distribution. On the other hand, poor spatial planning can lead to negative impacts on the environment and public health. Furthermore, inadequate planning may result in inefficient energy distribution, leading to higher costs for consumers and environmental degradation. Therefore, spatial planning is an essential aspect of energy production that requires careful consideration and planning. Proper spatial planning can help ensure that energy infrastructure is located in areas where it will have the least impact on the environment and public health, while also promoting the use of renewable energy sources and reducing the costs of energy production and distribution.

(Source: Arial view edited by the author)

Figure 11. The distribution of photovoltaic panels

(Source: ZERC 2017)

Figure 12. Various locations for solar panels at the campus

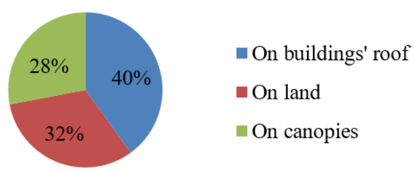


Figure 13. The percentage of photovoltaic panels according to their location

The data and numerical analysis confirm that the campus design maximizes the renewable energy potential by focusing on energy production to achieve the integrated scheme given by spatial planning. Renewable energy at Zarqa University, known as the Zarqa solar farm [29], can be considered a successful project for electric power generation where the generated energy reaches 2 MW. The project was established in 2016 on an area of 19 km^2; it includes 7560 photovoltaic panels (250 watts of nominal power per panel). These panels are distributed on buildings' roofs, canopies, and vacant lands (Figure 11, Figure 12, and Figure 13). Analyzing the location of these panels confirms that their distribution and fixation angle were studied very well to benefit from the sun for the longest time during the day.

In 2016, the Zarqa solar farm generated monthly an average of 242,000 Kwh, with an annual production of 2,806,238.55 Kwh; the system saved in the first year of installation approximately 717,424.87 JD; in addition to the balance of 246799 KWh stored in the electricity company at the end of this year, equivalent to 29,615.88 JD. The system costs 2,594,000 JD; therefore, the payback period is three and a half years [21], which is reasonable for such a project. In 2018, about 1330 solar panels were added to the original farm. Accordingly, the total number of panels was 8890, the project capacity increased to 2.3 MW, and the annual production increased to 3,660,597.1 Kwh, with an average of 239,000 Kwh [27]. Table 1 shows the average monthly and average annual production of the Zarqa solar farm from 2016 to 2019.

The numerical analysis confirms that the annual energy production increased by about 854,358 Kwh from 2016 to 2019 and remained almost the same till 2022 as the number of solar panels and the hours of sunshine per day do not change.

Given the 12 hours of sunshine per day in July, which is considered the sunniest month in Zarqa, while January is the shortest with only 6 hours of sunshine per day, this automatically affects the monthly energy production as shown in Table 1, as the average production in July reaches 363,630.30 Kwh in 2019, while in January never exceed 211,482.8 Kwh throughout the last years.

Table 1. The average value of energy production

Monthly Kwh production /year	Monthly Kwh production /2016	Monthly Kwh production/ 2017	Monthly Kwh productio n/2018	Monthly Kwh production /2019
Jan.	171,613.1	187,477.6	166,045.3	211,482.8
Feb.	224,222.7	217,719.5	176,273.9	236257
Mar.	259,836.9	246,301.6	268,944.2	298696.7
Apr.	277,355.7	290,822	272763.5	326356.1
May.	305,291.6	320,104.5	279,899	384,642.3
Jun.	368,293.8	307,201.5	306,403.5	363,630.30
Jul.	319,973.3	304,892.6	308,805.6	393381.9
Aug.	270,397.4	Maintenance	271,129.3	360128.4
Sep.	175,125.0	Maintenance	264,360	307,647.0
Oct.	220,287.9	Maintenance	223,080	283,988.0
Nov.	192,542.8	Maintenance	169848.1	267708.8
Dec.	162,817.3	Maintenance	157419.3	226677.8
Annual production	2,806,238.5	1,874,519.3	2,864,972	3,660,597.1

(Source: ZERC 2017 and ZERC 2021- Data combined by the author)

Additionally, to support renewable energy sources and propose various energy developments, the University established the Zarqa Energy Research Centre (ZERC) at the campus. ZERC provides safe and reasonable access to sustainable energy, which is considered one of the critical challenges in Jordan and the Middle East. The Centre hosts regional-leading researchers who see this challenge as an opportunity to help future generations and university students conduct their research [34]. This Centre helps to achieve the University's energy-friendly campus goals.

The solar farm at Zarqa University in Jordan provides a range of environmental benefits. One of the primary advantages of solar energy is the reduction of greenhouse gas emissions, helping to improve air quality and protect public health. Moreover, the solar farm requires very little water to operate unlike traditional power plants, which use large amounts of water to cool their systems, solar panels generate electricity without the need for water. This helps conserve scarce water resources, which are often in short supply in arid regions like Jordan. In addition, the installation of the solar farm at Zarqa University did not require any land clearing, as they are distributed on rooftops and canopies, making it a much more sustainable and environmentally friendly option compared to other energy sources. Traditional energy sources often require large amounts of land to be cleared for infrastructure, which can disrupt natural habitats and wildlife.

4. CONCLUSION

This study revises the planning strategies that are implemented at small-scale projects to identify the best practices for integrating energy technologies into the planning process. It finds that there are a few successful examples of integrated spatial and energy plans in Mediterranean developing countries such as the Tunisian Solar Plan, and the Moroccan Integrated Wind Energy Project. These projects integrate energy technologies into the planning process by applying the following strategies, which are:

1. Master planning and zoning to recognize the preferred locations
2. Using green infrastructure when designing open areas to maximize urban cooling
3. Increasing the energy production to achieve the integrated scheme given by spatial planning.

These strategies are used to assess the outdoor spaces at Zarqa University. A site analysis followed by field observation, numerical analyses, and data analyses were conducted to fulfill the research aims and explore the minuses and plusses of the campus design.

The study confirms that energy planning and spatial planning cannot be detached and should be integrated to achieve sustainable planning. Therefore, urban planners should work with energy planners throughout all design stages. Moreover, the study identifies the main spatial dimensions of energy planning that are proposed.

Analyzing the university master plan shows alternative passive and active sources of energy that enhance the project's sustainability such as the solar farm, the green open spaces, the water features, the shading structures, and the plantation. The analysis also highlights the importance of green infrastructure, suggesting required supplementations, repairs, and technology upgrades. Although the design has some minuses that should be resolved, it could be taken as a referencing model for the other universities in Jordan and surrounding countries. Therefore, the study recommends replicating the planning strategies in other projects in Jordan, not only universities, which would contribute to achieving sustainable social and environmental goals.

The study confirms the need to spread awareness about the importance of integrating energy planning with spatial planning for future generations, this can be achieved by applying projects in higher education similar to ENEPLAN which was funded by Erasmus+.

The study also confirms that spatial issues and energy planning should be comprehensively perceived, as separation and partial analysis lead to incomplete solutions. The study finds that by incorporating energy efficiency and renewable energy technologies into spatial planning, local governments can promote sustainable development, support clean energy technology, conserve water resources, reduce energy consumption, reduce greenhouse gas emissions, reduce the urban heat island effect, and maintain biodiversity.

5. LIMITATIONS

Although this study is essential for realizing how spatial planning can be integrated with energy planning, it had some limitations. First, the study mainly focuses on the spatial consideration more than the energy ones, and the case study was assessed from an architectural viewpoint as the background of the author is architecture and urban design. Second, the study focuses only on one university due to limitations in resources and time, this university was selected because it is the first university in Jordan that integrates the spatial issues of energy planning when designing its campus. Third, the methodology section does not provide a detailed explanation of the numerical analysis and how the collected data were analyzed to calculate the average value of energy production and the saved budget because these data are mainly based on the numbers collected by ZERC and the author only analyzes and summarizes these data. In spite of these limitations, the findings of this study will help in exploring the major strategies that should be used when integrating spatial planning with energy planning in small projects.

ACKNOWLEDGMENT

This research is funded by the deanship of research at Zarqa University in Jordan.

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