



10.5281/zenodo.18985088

**The Assessment of Solar Energy Systems in Aiding Spatial Efficiency in Sport Centres,
Lagos, Nigeria**

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ABSTRACT

The ever increasing energy demand of sport centres highlights significant challenges in spatial planning, operational efficiency, and sustainability particularly within regions experiencing unstable electricity supply. This study assesses solar energy systems and their role in aiding spatial efficiency in selected sport centres in Lagos, Nigeria. A case study methodology was adopted, focusing on two major facilities within Southwest Lagos. Data were obtained through site observation, architectural layout assessment, and solar potential estimation of available roof and open spaces. Findings reveal that existing solar photovoltaic installations remain minimal, with heavy reliance on diesel generators and conventional systems occupying substantial service areas. However, both facilities possess high solar integration potential due to expansive long-span roofing and large parking zones suitable for photovoltaic deployment. Results further establish a positive relationship between solar energy integration and spatial efficiency, as solar systems optimize roof utilization, reduce generator infrastructure, and promote dual-use land functions such as solar carports. The study further concludes that incorporating solar energy systems into sport facility design and existing complexes can significantly improve energy sustainability and spatial performance outcomes.

Keywords: Solar Energy Systems, Renewable energy, Energy, Spatial Efficiency, Recreational Architecture, Sport Centres; Sports Facilities, Sports Infrastructure, Lagos, Photovoltaic Integration

INTRODUCTION

Globally, the built environment represents the physical expression of human civilization, shaped through architecture, infrastructure, and environmental systems. Its development is closely linked to energy and as such taking into consideration geographical and economic factors, there is increasing tension in demand of power and energy generation as it is deemed necessary for all involved stakeholders. Energy is defined as the ability to change or move in order to do work. It is a naturally occurring phenomenon that exists and yet can't be created or destroyed but changed from one inner form to the other, while renewable energy; is a source type of energy that is gotten or extracted naturally from the natural environment possessing the ability to replenish itself beyond the scale of its apparent use.

This is evidently highlighting the core importance of every Fundamental activity either through building infrastructure, environmental, geographic and social interaction, it requires some form of energy. This energy serves a purpose which is to reduce dependence on non-renewable sources and promoting cleaner alternative efforts across several global perspectives from national government agencies, world organizations and global institutions. Also due to the importance of this energy also being harnessed by the built environment; laws and strict regulations have been provided to mitigate environmental degradation and co2 emission in-order to sustain the immediate world environment.

As a developing country, Nigeria, has been experiencing instability and unreliability of power supply from the national power grid system to meet global demands, despite the high level of importance, the birth of challenges in the ability to effectively use energy has risen. Furthermore, it has still lead to the dependence on the fossil-fuel generators influenced by; lack of technical know-how, environmental

degradation, poor infrastructural frameworks and power unreliability to an unavoidable environmental impact.

Over the years, public infrastructure such as sports centre have been discovered to be energy intensive in effectively sustaining and maintaining its scale and the functions provided for the users. However, studies have demonstrated that solar-powered systems are capable of reliably supporting technologically advanced and energy-demanding applications while promoting energy independence and sustainability (Calabrese, B., Velázquez, R., Del-Valle-Soto, C., de Fazio, R., Giannoccaro, N. I., & Visconti, P., 2020) Sport centers are recreational purposed built infrastructure designed to serve as a site where users can engage in a variety of sports activities and manage their overall fitness and health conditions through exercises, which require significant outdoor and indoor environmental control. Conventional systems often require dedicated service rooms and mechanical zones that reduce usable activity space, therefore requiring adequate and reliable energy infrastructure through standardized frameworks in effectively improving or providing for varying users.

Again, Spatial efficiency refers to the optimal planning and utilization of spaces to support circulation, functionality, user comfort, and, the adoption of solar systems in sports infrastructures leads to geographic contexts playing a big role in optimizing the spatial efficiency of these systems through the design stage presenting opportunities to optimize roof views, shading devices, and service distribution while freeing interior floor area. In addition, Lagos as a tropical climate serving as an advantageous effective environment for solar system integration as it receives high levels of solar radiation year long. The integration of solar systems offers viable alternatives to conventional power sources. Recognizing the limitations, government agencies and private organizations are increasingly advocating for renewable energy adoption in sports infrastructure.

Problem Statement

Sport centres in Lagos, Nigeria, remain heavily dependent on unreliable energy systems. The limited integration of solar energy technologies has resulted not only in high costs but also inefficient spatial planning. Despite Lagos possessing high solar potential, there is inadequate architectural and planning framework guiding the integration of solar systems to enhance spatial efficiency and circulation within sport centres

Research Aim and Objectives

To assess how solar energy systems aid spatial efficiency in sports centers in Lagos. Subsequently the following are the objectives of the study;

- To assess existing solar energy systems integrated in selected sports centre in southwest Lagos, Nigeria
- To evaluate the relationship between solar energy integration and spatial efficiency in sports centers

Scope of Study

This study is limited to selected sport centres within Lagos, Nigeria. It focuses on the types of solar energy systems integrated into these facilities and examines their influence on spatial efficiency and user circulation. The research considers architectural planning standards, service space allocation, and energy infrastructure distribution as key variables.

Literature Review

This study reviews literature relevant to the study with a specific references to Lagos. It identifies knowledge gaps that justify this research.

Concept of Sport Centers

Sport centers are purpose built recreational infrastructure designed to serve as a site where users engage, in a wide variety of sports activities and manage their overall fitness and health conditions through exercises, in social interaction and organized events. They are public infrastructures that boosts socio-economic contexts and recreational value in sport related activities. Sports centers are vast due to spatial and functional requirements comprising of key spaces such as; halls, gymnasiums, stands, courts or fields.

Energy Demand in Sport Centers

Sport centers are known for being high energy buildings due to their scale of operation, therefore, there is an accompanied rise in energy consumption from lighting, cool and ventilation systems or equipment. According to (Papadakis, N., & Katsaprakakis, D. A., 2023), sport complexes are energy intensive public buildings that require precise and efficient solutions to their design and planning. Again (Atalay, A., & Demir, S., 2024) noted that the result of assessing the carbon footprint of sports facilities contributes to the increasing emissions through the lighting and ventilation equipment and systems.

While according to (Fadli, F., Rezgui, Y., Petri, I., Meskin, N., M Ahmad, A., Hodorog, A., ... & Mohammedsherif, H., 2021), cooling loads and lighting represent the scale of the largest energy demand in sport facilities. Therefore, lighting is required for indoor and outdoor illumination while cooling and ventilation systems are often provided standards needed to control thermal comfort for a large number of varying users which supports the additional loads necessary due to high operational costs.

Solar Energy Systems

Solar energy system is a system that harnesses light and heat from the sun in turn for creating power that reduces conventional system reliance and carbon emissions; in which these factors are then converted into power for varying purposes. Although, it can be broadly categorized into 2 types namely; photovoltaic systems or solar thermal systems, but, further studies shows that it is the photovoltaic systems that are being supported by most agencies or organizations as a viable solution to the needs and demands at hand.

Solar Energy Integration in Buildings

These systems can be adopted through various architectural strategies an one of which is through; rooftop installations, embedding solar modules in facades and curtain wall elements. While other studies noted that it can be adopted through strategies like solar shading and canopies therefore providing dual functionality and proper space saving efficiency. Also (Ojo, G. G., Lottu, O. A., Ndiwe, T. C., Izuka, U., & Ehiobu, N. N., 2023) reported that Nigeria receives high solar radiation averaging 4.5–7.0 kWh/m²/day, supporting PV deployment.

Also (Asarpota, K., & Nadin, V., 2020) noted that integrating energy infrastructure into spatial planning enhances land-use efficiency while, (Stack, V., & Narine, L. L., 2022) showed that rooftop solar reduces the need for ground-mounted power infrastructure. Furthermore, several studies demonstrated solar systems in stadium facilities for; heating water, electricity generation in sports complexes and into building management systems for performance monitoring.

Again, it can be therefore concluded that these are the type of systems that ensure solar system integration aids or complements architectural designs.

Spatial Efficiency in Architecture

Spatial efficiency refers to the optimal planning and utilization of spaces to support circulation, functionality, and user comfort and it is a key factor of adequate building performance particularly in facilities with complex requirements like a sport center. Characteristics of proper spatial efficiency include; effective zoning, optimization of circulation space and multi-functional space usage. (Li, H., Li, L., Li, Y., Ji, Q., Zhao, J., Ge, Z., ... & Sun, Q., 2025) used GIS to evaluate spatial configuration and social performance of public sports facilities in Shanghai, furthermore concluded that spatial layout influences accessibility, user satisfaction, and facility utilization.

According to (Asarpota, K., & Nadin, V., 2020), emphasizes that physical planning decisions can affect infrastructure performance and sustainable outcomes. Therefore in sport centers, spatial efficiency can be seen to be influential in spectator movement, athlete circulation and emergency protocols ensuring safety and strict adherence.

Relationship between Solar Energy Systems and Spatial Efficiency

The integration has direct and indirect effects on spatial efficiency. Some utilize idle spaces preserving extra space for other functions. (Katsaprakakis, D. A., 2020) discovered that building form,

roof geometry, and orientation directly affect solar performance. Again, some infrastructures utilize solar shading and canopies that modify parking spaces into energy productive zones simultaneously without additional spatial requirements.

(Asarpota, K., & Nadin, V., 2020) emphasized that urban planning and spatial organization frameworks must integrate energy systems at an early stage. Therefore, despite the proposed benefits of solar energy system, challenges such as structural requirements may arise and service routes which must be carefully planned or incorporated early and properly. Furthermore, the conclusion is to note that they are detrimental in enhancing all facets of functionality but they also demand cautious architectural planning.

Empirical Case Studies

Existing documents and papers show very similar findings indicating that large roofs are ideal surfaces for (PV) usage due to the scale of operation and also generate power/ energy back to the grids. (Ahshan, R., Al-Abri, R., Al-Zakwan, H., Ambu-Saidi, N., & Hossain, E., 2020) noted that solar (PV) reduced operational costs in sports infrastructures, while, (Papadakis, N., & Katsaprakakis, D. A., 2023) and (Katsaprakakis, D. A., 2020) found that solar combi systems and energy management significantly improve public buildings like stadium facilities.

Spatially, these projects demonstrate that the integration of solar systems is beneficial if its applied early at the design stage. Although, other similar studies overseas have been seen to be well documented on the situation but there remains limitations for contextual studies relating to Lagos State particularly for spatial efficiency outcomes

Research Gap

Reviews of existing literature reveals that most of the studies concentrate on energy performance, cost savings and carbon reduction. There is a further observed limited attention that has been given to the spatial planning of these sport centres and scarcity of research focusing on tropical climates such as Lagos where land usage and optimization are crucial factors. Furthermore, this highlights the emergent requirement for context specific assessment on how solar systems can aid spatial efficiency in Lagos.

RESEARCH METHOD

This study adopts a qualitative research design aimed at assessing the role of solar energy systems in aiding or supporting spatial efficiency within sport centre facilities. The qualitative approach enables an in-depth evaluation of architectural layouts, energy infrastructure, and spatial planning strategies.

A case study method was employed to examine selected sport centres in Lagos, allowing for detailed investigation of physical characteristics, solar integration opportunities, and their spatial implications. This design is appropriate because the research focuses on building systems, spatial organization, and environmental performance. The study is situated in Lagos, Nigeria. Lagos which serves as the commercial and recreational hub of the country, hosting a significant number of sport and leisure facilities that support professional competitions, training activities, and community recreation.

The state experiences high energy demand due to its dense population and intensive urban activities. In addition, the state possesses favorable solar irradiation levels throughout the year, making it suitable for solar photovoltaic energy generation. These characteristics make it potentially an appropriate location for assessing the integration of solar energy systems within sport centre developments. The case studies were selected based on these criteria;

- Functional complexity and facility size
- Availability of large roof spans
- Presence or potential for solar system integration
- Accessibility of architectural data

Based on these criteria, selected sport centres provided adequate characteristics necessary for examining solar energy integration and its effects on spatial efficiency

The research data were obtained from primary and secondary sources; physical site observations, photographic documentation, architectural drawings and institutional databases or publications. It was therefore further analyzed using comparative and qualitative techniques.

This study was restricted and limited to; little access of detailed energy consumption records, access to service areas within case study locations and time constraints.

RESULTS AND DISCUSSION

This chapter analyzes the data gathered from selected case studies in order to assess the role of solar energy systems in aiding spatial efficiency within sport center facilities. The analysis focuses on metrics such as; architectural characteristics, energy infrastructure, solar integration potential and spatial implications of renewable energy solutions. Two major sport facilities within Lagos were selected based on the chosen criteria and they are;

- Teslim Balogun stadium
- National stadium Lagos

Both facilities possess features that make them suitable for assessment in this study

Case Study One: Teslim Balogun Stadium

This stadium is located in Surulere, Lagos, and serves as one of the state’s primary football and athletics venues. The stadium hosts varying sporting and recreational activities. It has an estimated seating capacity of over 20,000 spectators and incorporates athlete facilities, administrative offices, media areas, and spectator amenities. The stadium features a reinforced concrete form enclosed by a long span cantilever steel roof structure over the stands with a large roofing system that caters for solar shading and weather protection. It possesses facilities such as; concourses, changing rooms, medical and examination rooms, galleries and administrative spaces. Also to be noted, circulation is organized radially, with service zones located beneath the seating terraces. Energy demand is therefore observed to be high due to the following systems being adopted in the infrastructure;

- High intensity floodlights
- Public address systems
- Indoor facility lighting
- HVAC systems

This facility greatly relies on conventional system supported by diesel generators which occupy space within the stadium. The stadium presents strong opportunities for solar photovoltaic integration due to its expansive roof canopy and open parking areas

Parameter	Estimated Value
Total roof area	18,000 m ²
Usable installation area (60%)	10,800 m ²
Conversion ratio	1 kW / 8 m ²
Estimated solar capacity	≈ 1,350 kW

Table 1: showing the solar potential estimation for teslim balogun stadium

This can help aid better spatial efficiency by;

- Reduction in generator plant size
- Relocation of fuel storage areas
- Utilization of open roof space
- Integration of solar shading systems

Case Study 2: National Stadium

National Stadium Lagos is a multi-purpose sports complex also located in Surulere, Lagos. Developed as a national sporting hub, the complex accommodates a wide range of facilities including a main bowl stadium, indoor sports hall, swimming pool arena, and training pitches.

The complex supports athletics, football, basketball, volleyball, swimming, and national sporting events, making it one of the most functionally diverse sports facilities in Nigeria. The architectural layout is almost similar to that of a campus comprising of many independent but functionally linked structures including, large span roofing, indoor sport hall enclosure, aquatic centre roofing system, athlete hostel and training facilities. Although, key circulation are distributed across pedestrian areas, vehicular roads and service areas keeping all facilities connected together.

Due to its multi-faceted facility composition, the complex has extremely high energy requirements highlighting;

- Floodlighting systems
- Indoor lighting
- Pool filtration and pumping systems
- Air conditioning in enclosed halls
- Media infrastructure

Field assessment revealed this facility greatly also relies on conventional system supported by diesel generators which occupy space within the stadium. The stadium presents multiple diverse potential for solar photo-voltaic integration due to its multiple building typologies.

Parameter	Estimated Value
Combined roof area	35,000 m ²
Usable installation area (60%)	21,000 m ²
Conversion ratio	1 kW / 8 m ²
Estimated solar capacity	≈ 2,625 kW

Table 2: showing the solar potential estimation for National stadium

This can help aid better spatial efficiency by;

- Consolidation of generator plant size
- Reduction of fuel storage areas
- Utilization of open roof space

Comparisons of Selected Case Studies

Facility	Usable PV Area	Estimated Capacity	Spatial Comparism
Teslim Balogun Stadium	10,800 m ²	1,350 kW	Moderate to high use of space
National Stadium Complex	21,000 m ²	2,625 kW	High to very high use of space

To Assess Existing Solar Energy Systems Integrated in Selected Sports Centre in Lagos, Nigeria

Both case studies revealed limited existing solar system integration across both facilities at the time of this study. Also, further assessment highlight the reliance and support of conventional systems as sources of energy with the case studies and these systems occupy a significant amount of ground space and service areas within the facilities. However, despite the limitation these facilities show readiness for solar integration due to having standardized infrastructural organization. And key indicators include;

- Large roof spans suitable for PV mounting
- Large landscape space for solar canopies

Solar potential estimation conducted shows that stadium roofs alone can host large amounts of solar pv mountings for generating on-site energy and power. This confirms that while existing solar adoption is very minimal, there is still a high value in the potential due to the capacity of the infrastructure

Thus, the assessment establishes that selected sport centres in Southwest Lagos possess strong physical and spatial potential for solar energy integration, even though present adoption levels remain very low.

To Evaluate he Relationship between Solar Energy Systems and Spatial Efficiency in Sport Centers

Findings from the spatial and infrastructural analysis indicate a direct and positive relationship between solar energy integration and spatial efficiency within sport centre facilities.

Solar adoption and application influences spatial efficiency through several mechanisms;

OPTIMIZATION OF ROOF SPACES

Large stadium roof spans, which traditionally serve only protective and shading functions, can be transformed into energy-generating surfaces through photovoltaic installation. This dual functionality enhances space.

Conversion of Parking Areas into Energy Infrastructure

Solar carport systems enable parking lots to perform dual roles such as; vehicle accommodation and electricity generation. This integrated approach improves land-use efficiency while providing environmental shading benefits.

Improved Service Zoning and Infrastructure Planning

Distributed solar installations across facility rooftops reduce the need for centralized mechanical energy plants. This allows for more efficient service zoning, improved circulation within plant areas, and reduced spatial congestion in utility corridors.

Enhancement of Environmental Comfort Spaces

Solar panels integrated as shading devices along walkways, entrances, and spectator plazas contribute to passive cooling while generating energy. This improves user comfort without expanding the building's footprint.

Findings and Discussions

Comparative evaluation of both case studies demonstrates that facilities with larger roofscapes and multi-building compositions exhibit greater solar integration capacity and, consequently, higher spatial efficiency benefits. The subsequent insights are revealed as a direct result of analyzing the case studies;

- Large-span stadium roofs function as primary solar assets capable of hosting extensive photovoltaic panels without altering ground-level spatial functions.

- Multi-facility sport complexes possess the highest solar potential due to cumulative roofscapes and distributed installation opportunities.
- Moderate to high use of effective space, supporting dual functionality as shading and energy-generation systems.
- Early integration of solar systems within architectural design stages enhances both energy performance and spatial efficiency outcomes.

CONCLUSION

The study assessed how solar energy systems aid spatial efficiency in selected sport centers in Lagos state. Studies further highlighted the reliance of conventional systems and Comparative evaluation demonstrates that facilities with larger roofscapes and multi-building compositions exhibit greater solar integration capacity and higher spatial efficiency benefits. The study concludes that solar energy systems have inherent potential to enhance spatial efficiency within sport centers. The relationship between solar energy systems and spatial efficiency is therefore direct, positively correlated and supporting sustainable outcomes.

RECOMMENDATIONS

The following recommendations were made based on the findings;

1. Design professionals should integrate solar PV systems at the early stage design of sport centers
2. Large roof spans should be prioritized for high exposure to solar irradiation
3. Government and public stakeholders should promote renewable energy solutions in sport infrastructure
4. Facility managers should employ hybrid systems to reduce total reliance on conventional systems

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