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SUSTAINABILITY OF PRISONS: WATER AND ENERGY CONSUMPTION IN REFORM BUILDING

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Abstract

This study investigates the impact of design and operational standards on energy and water consumption in prison buildings in Saudi Arabia. The research aims to analyze energy efficiency and the controlling factors affecting energy performance within correctional facility infrastructure, focusing on technical standards and human behaviors as influencing variables.

The study highlights those improvements in design elements, such as heating and cooling systems, building envelopes, the use of natural lighting, and renewable energy integration, can significantly enhance energy efficiency. It also emphasizes that building age and surrounding climatic conditions play crucial roles in determining energy consumption efficiency. On the operational side, factors such as user awareness, duration of their stay, and their willingness to contribute to energy efficiency, as well as the users' gender, affect energy consumption effectiveness. The research presents a case study of one of the largest and most recent prison facilities in Saudi Arabia, where water and energy consumption was measured based on official consumption invoices and records. The findings underscore the importance of adhering to appropriate design standards to reduce water and energy consumption and stress the need for comprehensive environmental studies before and during the design phase of prison buildings to achieve sustainability and resource efficiency goals.

Key Word: Sustainability, Rationalization, Prisons, Water, Energy, Reform buildings.

Introduction

The significance of energy is universally recognized for its crucial role in supporting national and societal development. Amidst political crises and economic fluctuations affecting energy prices, enhancing energy efficiency has become an urgent issue globally. According to the European Commission's 2014 report, progress in improving energy efficiency in the building sector within the European Union has been limited (European Commission, 2014). The International Monetary Fund estimates that the global market for improving energy efficiency in the industrial and residential sectors was valued at $360 billion in 2017 (International Monetary Fund, 2017). In Saudi Arabia, energy consumption doubled by 65% from 1990 to 2012, representing 25% of the total oil production during that period (Saudi Energy Efficiency Center, 2012). From 2016 to 2022, energy consumption in the government sector increased by 30% without a significant impact on GDP (Saudi Energy Efficiency Center, 2022).

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Energy consumption in the building and industrial sectors in Saudi Arabia is the highest, accounting for approximately 80% of the total generated energy, with cooling, ventilation, and lighting consuming 80% of this energy (SEEC, 2019). The government sector is one of the largest energy consumers, and efforts are underway to reduce operational costs through various initiatives, including support for companies aiming to minimize waste (Baqasi, 2022).

Correctional facilities, being among the largest security-related architectural components, have high energy and water consumption due to their large number of inmates and the need for thermal comfort, including ventilation, cooling, and lighting (LOWERIRE, 2017). Despite their importance, the secrecy and security nature of these facilities limit the ability to apply design and operational standards aimed at enhancing environmental performance and reducing energy consumption (DRUERE, 2022). This lack of environmental policies to manage energy consumption highlights the need for effective strategies in the design and operation of these large facilities.

Although correctional facilities are large and house many users, they are often designed and operated primarily with security considerations, neglecting energy and water consumption policies. This oversight results in limited progress in improving energy efficiency in these buildings (Christoforidis et al., 2014).

In this context, sustainability has become an integral part of Saudi Arabia's strategic initiatives, with several leading initiatives launched, such as the Green Middle East Initiative and the Saudi Green Initiative, both under the patronage of Crown Prince Mohammed bin Salman. These initiatives reflect the Kingdom’s commitment to resource conservation and reducing water and energy waste. Accordingly, this study focuses on improving water and energy consumption in Saudi correctional facilities through a case study of a correctional building, as part of a series of studies aimed at enhancing the sustainability of these crucial facilities.

Concept of Sustainability

The concept of sustainability lacks a universally agreed-upon definition; however, four principal characteristics are commonly associated with various definitions:

1. **Temporal Scope**: Sustainability is often regarded as a phenomenon extending across generations, with the timeframe for sustainability typically ranging from 25 to 50 years (Al-Ghamdi, 2007).
2. **Multilevel Framework**: Sustainability functions at multiple levels—global, regional, and local—addressing diverse contexts and scales of implementation (Al-Ghamdi, 2007).
3. **Multidimensional Aspects**: Sustainability encompasses three primary domains: economic, environmental, and social. These dimensions collectively highlight the holistic nature of sustainability and its importance across different sectors (Al-Ghamdi, 2007).
4. **International Debate**: Sustainability is a subject of ongoing international discourse, with substantial focus on its various dimensions and levels of application (Al-Ghamdi, 2007).

The significance of sustainability has gained considerable global attention, particularly in recent years. The Brundtland Report, titled "Our Common Future" and published by the World Commission on Environment and Development (WCED) in 1987, emphasized this focus by integrating economic, social, and environmental needs into a unified definition. The report defined sustainable development

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as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). Sustainability is fundamentally based on three pillars:

- **Environmental Pillar**: This pillar emphasizes the conservation of nature, including waste reduction and pollution control, while leveraging waste through recycling and resource recovery.
- **Economic Pillar**: It focuses on reducing costs through enhanced efficiency, minimizing energy use, and utilizing available natural resources.
- **Social Pillar**: This aspect addresses providing comfort and safety, preserving cultural identity and heritage, promoting social equity, and fostering community cohesion (Hilal et al., 2014; Ahmed et al., 2020).

The interaction with both natural and built environments infuses buildings with vitality and aligns them with the needs of their users. Natural systems, characterized by closed-loop processes such as food and energy cycles, operate without depleting resources. Sustainable design aims to understand and mitigate the environmental impacts of design by evaluating site conditions, energy use, material choices, design energy efficiency, construction methods, and identifying potential negative impacts. This involves using sustainable materials and low-toxicity products and incorporating recyclable materials and tools (Freed et al., 2019).

The integration of design environments and supportive processes necessitates collaboration among various disciplines involved in the design process. Sustainable buildings should be incorporated from the initial stages of decision-making, involving users, local communities, and neighboring areas in the process (Al-Khazmi & Aqeel, 2019).

Moreover, sustainable design must consider user characteristics and the nature of the built environment, taking into account the needs of the population, cultural backgrounds, and traditions. Sustainable architecture integrates aesthetic, environmental, social, political, and ethical values, employing user expectations and technological advancements to inform a design process that is appropriate for its context (Al-Mashad, 2011).

Sustainability in the Kingdom of Saudi Arabia

In 2016, Saudi Arabia launched its Vision 2030, establishing 2030 as the target year for a long-term strategic vision aimed at providing an infrastructure that supports economic, social, and environmental development. This vision underscores the importance of sustainability and architecture as two interrelated domains that address environmental, economic, and social concerns. The strategic objectives of 2030 Vision place significant emphasis on enhancing urban landscapes and improving quality of life in cities, as highlighted by the Quality-of-Life Program (2020). This program underscores the critical role of the built environment and its impact on various aspects of quality of life. The program aims to position three Saudi cities among the top 100 cities globally in terms of quality of life. Addressing the challenges of making buildings sustainable is fundamental in tackling contemporary issues such as climate change and natural disasters, which cannot be confined to physical boundaries alone. These challenges must be integrated with economic and social dimensions, demonstrating the importance of applying sustainability principles to modern buildings both in design and construction,

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http://magellanes.com/

as well as retrofitting existing buildings to meet sustainability requirements.
The Sustainable Development Goals (SDGs) have been integrated into 2030 Vision, establishing sustainability standards and indicators as key benchmarks for evaluating the performance of governmental and non-governmental entities in Saudi Arabia. This approach aligns with international sustainability agreements and global standards that the Kingdom adheres to, including the Paris Agreement on climate change and the United Nations Framework Convention on Climate Change. These agreements aim to combat the effects of climate change. 2030 Vision is built on three main pillars: a vibrant society (social), a thriving economy (economic), and an ambitious nation (environmental). This clearly reflects that the vision is grounded in the principles of sustainability and its core components (Towards Sustainable Development in Saudi Arabia, 2018).

Classification of Prisons in Saudi Arabia and Their Development Stages

As a modern and developing nation, Saudi Arabia is committed to implementing regulations and policies that ensure the rights of all individuals residing within its borders. These regulations are designed to adapt to current needs and future plans of the state. Accordingly, the importance of establishing prison facilities that effectively serve the purpose of detaining offenders or those posing a threat to community security is paramount. These facilities are tailored to meet the Kingdom's needs, potential inmate numbers, and the programs to be offered. This approach can be summarized through the following stages:

Stage 1: Foundation and Initial Classification: The Kingdom of Saudi Arabia, established with concerted efforts to maintain security and stability in the Arabian Peninsula, initially managed inmate custody within facilities attached to police departments before 1369 AH (1999 AD). The formal establishment of prisons began in 1369 AH, following Royal Decree No. 3594 dated 29/3/1369 AH, which led to the creation of a General Prison Authority. This decree classified prisons into four main categories: Central or Remand Prisons, Juvenile Prisons, Women's Prisons, and General Prisons. Key focuses of this system included: Classification of prisoners, Provision of healthcare for prisoners, and Internal penalties for prisoners.

Stage 2: Organizational and Operational Improvements: This phase saw the organization of inmate admission procedures and the establishment of operational and training standards. In 1385 AH (1965 AD), a temporary prison regulation was issued by the Minister of Interior, detailing the responsibilities of the receiving authorities (1997 AD). Prisons during this period typically consisted of two-story buildings: the ground floor included common areas, while the upper floor housed inmate sleeping quarters and restrooms.

Stage 3: Modern Classification and System Development: In 1398 AH (1978 AD), the prison and detention system were formalized by Ministerial Decision No. M/31. The General Directorate of Prisons in Saudi Arabia classified prisons into the following categories:

1. General Prisons: For male detainees.
2. Reformatories: Categorized into four classes (A, B, C, D) for male and female convicts.
3. Women's Prisons: For both convicted and detained females.

Inmates in these facilities are classified into eight categories based on the nature of their offenses,

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http://magellanes.com/

considering the inmate's age (Prison and Detention System, 1427 AH).
This classification and development framework ensures that prison facilities in Saudi Arabia are effectively designed to meet the needs of different inmate categories while maintaining the security and efficiency of the correctional system.

Research Methodology

To achieve the study's objectives, a descriptive-analytical methodology will be employed. This approach will focus on the principles and concepts of sustainability and the criteria used for evaluating government projects. The study will utilize sustainability criteria specifically related to energy and water conservation as evaluation tools for reform facility buildings. The primary goal is to assess the environmental performance of these buildings, with a particular focus on reform facilities in the Makkah region. The analysis will generate insights and recommendations for enhancing future prison projects and improving existing prison buildings. A model will be developed to measure the extent to which current prison buildings meet sustainability standards, evaluating their performance based on key factors influencing non-renewable energy consumption and associated costs. This model will also assess its impact on optimizing expenditure and reducing government costs.
The study will involve a detailed examination of water and electricity consumption records and bills from the facility. It will apply the consumption standards set by the National Water Company and the Saudi Electricity Company for individual use in the Makkah region.

Description of the Case Study Facility

The reform facility is situated on an area exceeding 1.5 square kilometers. It has been selected for the following reasons:
1. Latest Approved Model: It is the most recent model approved by the General Directorate of Prisons for Class (A) reform facilities. See Figure 1.
2. Capacity and Expansion Potential: It is the largest facility in terms of inmate capacity, accommodating both male and female inmates, with potential for future expansion.
3. Design Standards: The facility is designed according to the standards recommended by the American Correctional Association (ACA). It has a built-up area of 180,000 square meters, accommodating over 7,000 inmates with future expansion capability up to 10,000 inmates. The facility is classified as a Class (A) reform facility. The Ministry of Interior has constructed four similar Class (A) facilities in Riyadh, Jeddah, Taif, and Dammam.
The project, with a budget of 5.2 billion Saudi Riyals, commenced on August 21, 2010, and the facility began operations in 2015. The Ministry of Interior's implementation of these four Class (A) reform facilities across different Saudi regions aligns with the kingdom's goal of meeting behavioral rehabilitation objectives for inmates. The application of sustainability standards to this project will be examined, given its significant investment and role in advancing correctional infrastructure in Saudi Arabia.

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Water Consumption Data Analysis

Quantitative data were collected through formal channels established by the General Directorate of Prisons. The researcher engaged with the Institutional Excellence Management to secure the necessary approvals. The collected data included Monthly water consumption rates, Monthly water consumption costs in Saudi Riyals, and Inmate numbers, obtained from the Operations Department, for the duration of the study.

The study period for water consumption analysis extended over 17 months, from May 2020 to September 2021. Prior to this period, the facility was not connected to the public water network managed by the National Water Company. Instead, water was supplied by contractors via tankers.

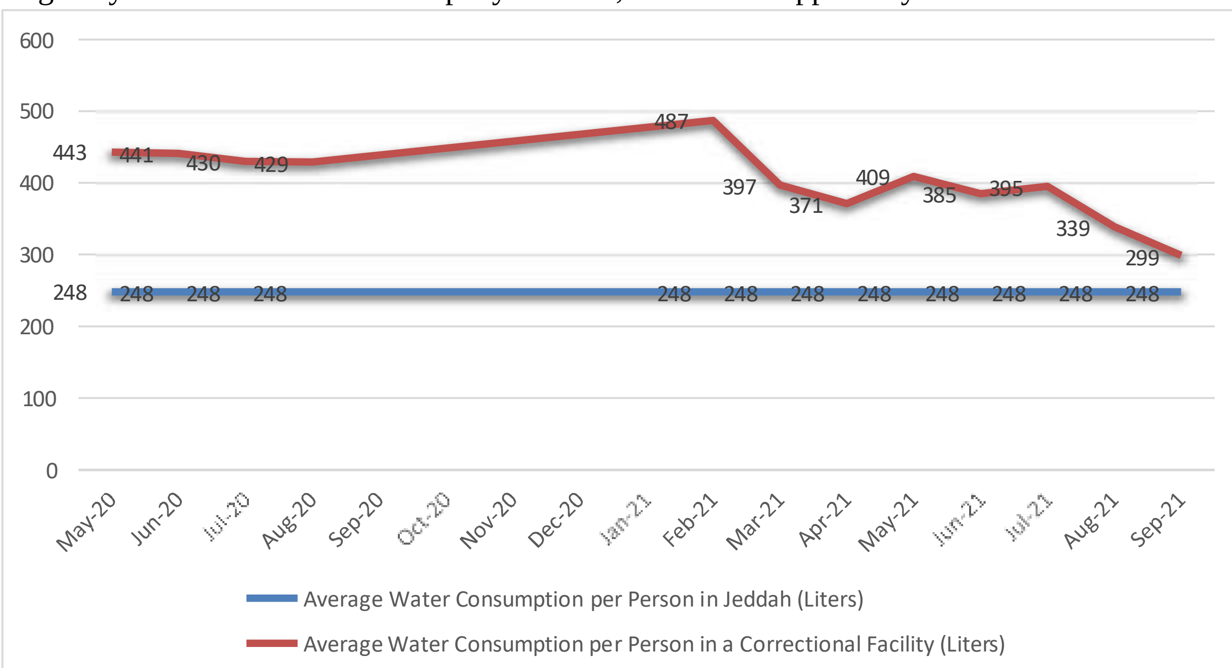

Figure 1.Water Consumption in a Correctional Facility (Liters) During the Study Period Compared to the Average Consumption in Jeddah.

Figure (1) illustrates the water consumption rates of inmates in the correctional facility. Five months were excluded due to a malfunction in the water meter during the period from September 2020 to January 2021, as reported by the technical staff responsible for water supply to the facility. The data reveal that the highest per capita water consumption occurred in February 2020, with an average of 487 liters per person. The lowest consumption period was in September 2021, with an average of 299 liters per person. The average consumption during the study period, for an average of 3,014 inmates, was 407 liters per person per day. This figure exceeds the general average water consumption per individual in Jeddah.

Interpretation of Water Consumption Results in a Correctional Facility

The Pearson correlation test revealed a statistically significant relationship between the number of inmates and the quantity of water consumption, with a p-value less than 0.05, specifically 0.00,

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indicating a perfect positive correlation with a Pearson coefficient of (1).
The study shows that the per capita water consumption in the correctional facility is more than one and a half times higher than the average per capita consumption in Jeddah. To ensure the accuracy of these results, the researcher reviewed the data to check for any errors in recording and entry, in collaboration with the specialists responsible for water supply at the site. Additionally, the researcher verified that there were no leaks in the water network at the facility. The responsible authority confirmed that routine inspections of the water supply network are conducted, and several samples were taken from different points for water quality testing by the National Water Company and the health authorities in Jeddah.
The researcher attributes the higher water consumption to the fact that inmates, unlike residents in private homes who can leave their residences, are continuously residing within the facility and can only leave after completing their sentences. Moreover, continuous cleaning and sanitization processes at the facility require substantial water usage to maintain the general health of the inmates and reduce the incidence of diseases and infections among them. Errors in the billing data were ruled out after reviewing them with the specialists responsible for water supply, and the possibility of leaks was also dismissed based on the authority's reports.

Analysis of Electricity Consumption Data in a Reformative Building:

Following the same procedures used for collecting data on water consumption, the electricity consumption was studied through an analysis of electricity bills. The study period spanned 22 Gregorian months, from January 2019 to November 2021, covering the longest possible timeframe to provide a clear picture of the site. The data is illustrated in the following figure (2,3,4). The highest rate of electricity consumption per person occurred during the summer months, particularly between June 2019 and August 2019, with a consumption rate of 8471 kWh per person per month. The lowest period of electricity consumption was from March to May, with a consumption rate of 2081 kWh per person per month.

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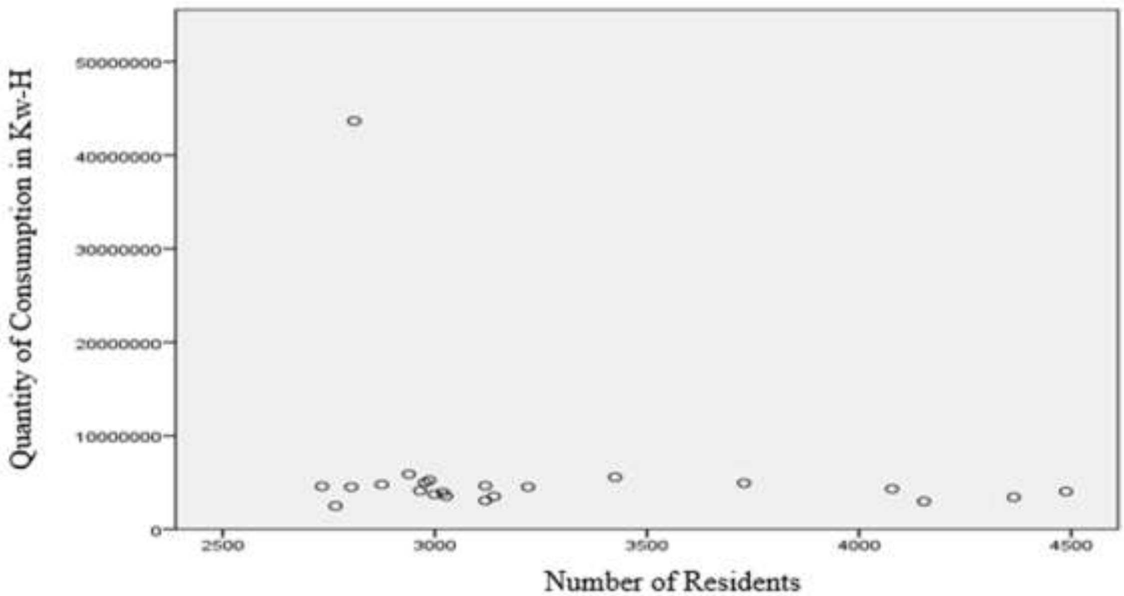

Figure 2. Electricity Consumption by Residents of a Reformative Building in Kilowatt-Hours

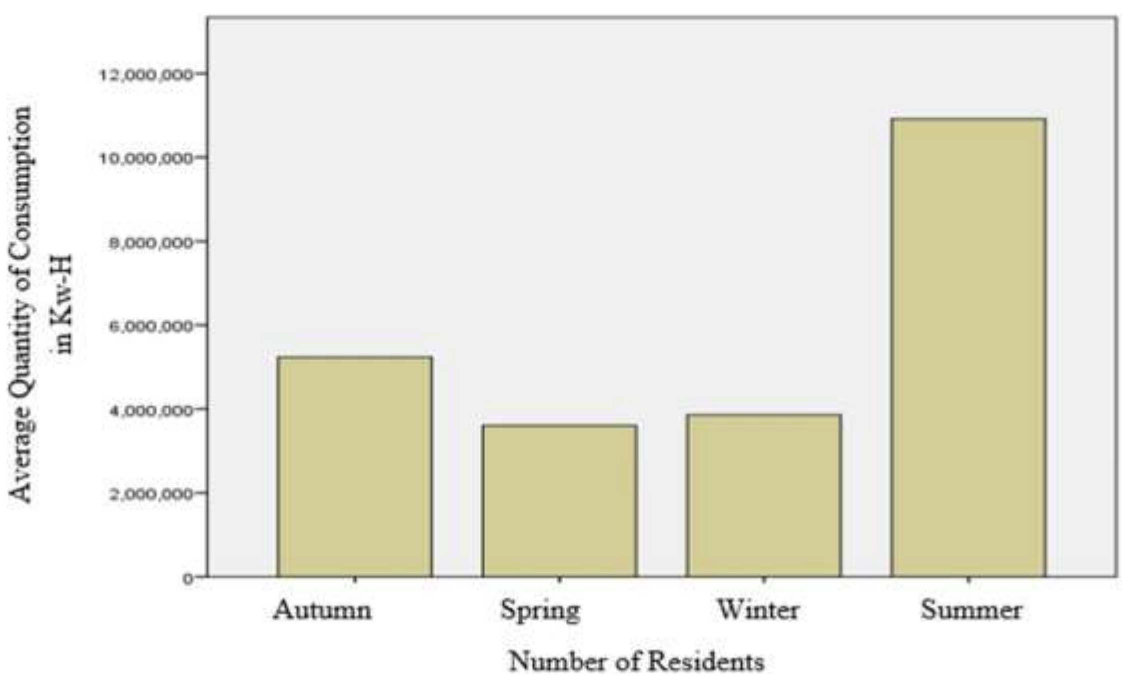

Figure 3. Electricity Consumption in a Reformative Building Across Different Seasons Compared to Consumption Levels

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http://magellanes.com/

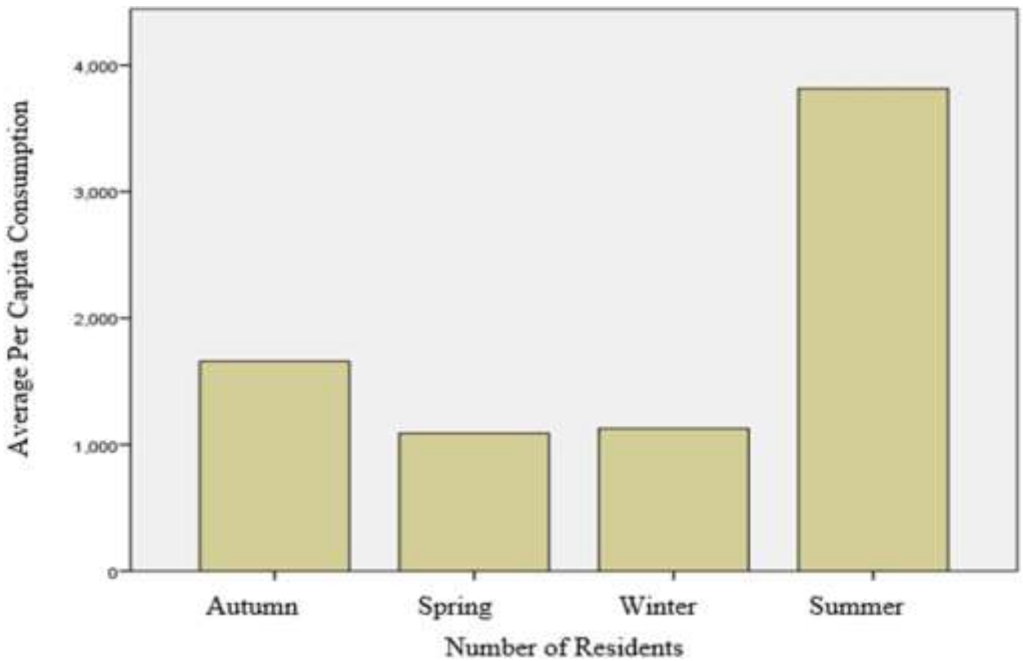

Figure 4.Electricity Consumption in a Reformative Building Across the Seasons Compared to Per Capita Consumption in Each Season

Interpretation of Electricity Consumption Results in a Reformative Building

The analysis of the Pearson correlation coefficient between the number of residents and the quantity of electricity consumption showed no statistical significance, as the P Value was greater than 0.05, specifically 0.48.

The study of per capita electricity consumption at the site and its correlation with the number of residents revealed that there is no statistically significant relationship between electricity consumption rates and the number of residents. This is due to the fact that the consumption rate is nearly constant. However, there is a significant relationship between electricity consumption rates and the seasons. In summer, the consumption rate peaks, as it involves higher energy use associated with cooling and air conditioning systems, which are linked to maintaining indoor temperatures at 23°C, according to site specialists.

Conclusion

The analysis reveals that water consumption rates are correlated with the number of residents, with the average water consumption per resident being higher than the average in Jeddah, reaching 248 liters per person per day. This is 239 liters per day above the general consumption average in Jeddah. In contrast, there is no correlation between the number of residents and electricity consumption. The increase in electricity consumption is linked to the operation of cooling systems, with peak consumption occurring in the summer months. Therefore, it can be concluded that current government prison buildings need to adopt specific sustainability standards to help reduce water and energy consumption. The water consumption rate is 1.5 times higher than the general average, and electricity consumption is not

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http://magellanes.com/

correlated with the number of residents.

Recommendations

- To address high water consumption, implement effective water-saving measures and adopt advanced cleaning technologies like automatic sensors and UV disinfection.
- Reduce building surfaces and resident space to meet design standards, minimizing areas requiring cleaning and water use.
- Incorporate environmental studies into the design phase to optimize building orientation and window sizes, reducing thermal loss and improving energy efficiency.
- Integrate sustainability principles into the design of security facilities, especially prisons, to achieve energy and water savings.
- Develop advanced security monitoring systems with modern motion sensors to cut down on lighting waste.
- Establish specific sustainability criteria for government prison buildings to align with security needs while reducing resource, water, and energy waste.
- Promote a sustainability culture among security personnel by providing resources and training for engineers, architects, and experts, leading to effective and efficient facility management.

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