

Assessment of the Implementation of Energy Conservation Opportunities Arising from Energy Audits; A Study of Luxury Hotels in Riyadh, Saudi Arabia

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Abstract: This study analyses the implementation of energy conservation measures in luxury hotels in Riyadh, Saudi Arabia, as recommended by specialised audits. The hospitality sector in Riyadh is facing increasing pressure to provide high-quality and sustainable services while conserving energy. To address this, professional auditing firms conducted comprehensive energy audits across four-star and five-star hotels, identifying a range of Energy Conservation Opportunities (ECOs) across various systems such as lighting, HVAC, and building operations. The data analysis revealed a discrepancy between the identification of energy conservation opportunities (ECOs) and their full-scale adoption, with the implementation rate falling below the desired 100% over three years. The rate of implementation, currently at 35%, indicates the presence of significant yet unexploited opportunities for energy savings and efficiency gains. The limited adoption of ECOs can be attributed to several factors, including the immediate financial burden of upfront costs, the constraints of current policy frameworks, and the lack of awareness and training among hotel staff. The strategic application of the energy-saving measures identified in the audits can result in substantial reductions in carbon emissions and operational costs for these hotels, enhancing energy reliability even amid fluctuating energy prices. Targeted incentives and comprehensive staff training programs should be implemented to improve the adoption rate. This research underscores the importance of systematic follow-through post-audits to capitalise on the latent energy-saving potential within the hospitality industry. The outcomes of this study aim to guide policy development and support initiatives that will facilitate the transformation of energy audit recommendations into actionable results, thereby advancing the energy efficiency front within Saudi Arabia's growing tourism and hospitality sectors.

Keywords: Energy Conservation Opportunities (ECOs); Luxury Hotels in Riyadh Energy Audits; Implementation Rate; Sustainable Hospitality Practices

1. INTRODUCTION

1.1 Background on the Tourism and Energy Conservation in the Hospitality Industry of Riyadh

Within the Kingdom of Saudi Arabia, which holds rich historical and cultural significance, Riyadh, the capital city, is a testament to the nation's progress and modernisation while honouring its past. This study explores the convergence of the thriving tourism industry and sustainable energy practices within the luxury hospitality sector of Riyadh. Saudi Arabia's strategic location at the crossroads of Asia, Africa, and Europe has historically made it a trade, culture, and religion hub. The kingdom's topography is bordered by eight countries as diverse as its surrounding neighbours (Abdulrahman, 2015). Riyadh, the central city of the Najd region, is situated at the heart of the country, both geographically and in terms of its political and social significance (Abdulrahman, 2015; International Business Magazine, 2021). With a population surpassing 30 million, including over a third of non-citizens, Saudi Arabia is a melting pot of cultures brought together by the unifying language of Arabic (Abdulrahman, 2015; General Authority for Statistics, 2017). As a growing urban centre, Riyadh reflects this diversity within its demographic composition and sprawling landscape. Historically reliant on its vast oil reserves, Saudi Arabia has, in recent years, embarked upon a journey to diversify its economy, with tourism emerging as a critical sector (HAIFA, 2023).

This shift is a strategic economic choice and a cultural opening, inviting the world to explore the rich tapestry of Saudi heritage. The tourism industry has rapidly become a significant source of national revenue and employment, with ambitious projections signalling a robust growth trajectory. The Saudi Commission for Tourism and Antiquities (SCTA), established at the turn of the

millennium, leads this transformative agenda, devising policies and frameworks to cultivate and sustain tourism development(HAIFA, 2023). Their efforts have yielded a broad spectrum of tourism products, encompassing religious pilgrimages, explorations of the kingdom's natural landscapes, and rich historical sites. The holy cities of Mecca and Madinah, which are of utmost spiritual significance and attract millions of Muslim pilgrims annually, demonstrate the enduring impact of religious tourism within the kingdom(HAIFA, 2023; Taleb & Sharples, 2011). This pilgrimage, known as Hajj, holds deep spiritual meaning and has significant economic implications for the hospitality industry, particularly in the cities that accommodate these travellers(HAIFA, 2023).

In addition to religious tourism, Saudi Arabia's recognition of its cultural heritage sites by UNESCO further reinforces the nation's status as a guardian of significant cultural landmarks(Abdulrahman, 2015; International Business Magazine, 2021). With Riyadh's influx of religious and cultural tourists, luxury hotels must prioritise sustainability, particularly in energy conservation. Energy audits and implementing conservation opportunities are essential steps in addressing this responsibility while maintaining exceptional service standards in the hospitality sector(Abdulrahman, 2015; Ogola et al., 2023; Vinnie, 2014). This study evaluates the effectiveness of energy-saving practices in luxury hotels, highlighting the critical balance between service excellence and environmental sustainability in the tourism industry. As the hospitality sector is a crucial driver of Saudi Arabia's ambitious tourism expansion, it is imperative to strike this balance to ensure its long-term viability.

1.2 The Hospitality Industry

The hospitality industry, an essential contributor to global economic activity, is navigating a period characterised by a growing emphasis on sustainable practices(Cetron et al., 2020). In the Kingdom of Saudi Arabia (KSA), the luxury hotel sector, which plays a crucial role in the country's thriving tourism industry, is situated at the intersection of prosperity and environmental responsibility(HAIFA, 2023; Legrand et al., 2016). It is widely recognised that energy costs represent a significant portion of hotel operating expenses, second only to staff salaries, making it imperative to adopt energy-efficient measures(HAIFA, 2023). Not only can such actions lead to substantial cost savings, but they also support the environmental and social pillars of sustainability.

In the KSA, energy resources have historically underpinned the country's economic growth(Abdulrahman, 2015; HAIFA, 2023; Krarti, 2019). The government's subsidy regime has enabled the country to maintain low energy prices, contributing to the nation's development(Abdulrahman, 2015). However, this approach has also fostered a culture of high energy consumption, with energy usage per capita exceeding that of other countries at similar levels of development. As a result, the KSA faces the pressing challenge of meeting an increasing energy demand driven by rapid economic and social growth.

Saudi Arabia's per-capita electricity consumption, at 6417 kWh in 2004, was comparable to that of Spain but has shown a dramatic increase from the 1990 figure of 3754 kWh(Abdulrahman, 2015). When this consumption is gauged against the GDP per unit of energy used, KSA's efficiency appears lacklustre, especially compared to Spain's far more efficient energy use(Abdulrahman, 2015; HAIFA, 2023). This inefficiency is rooted in the historically low cost of domestic energy, resulting in unchecked consumption. Compounded by high rates of population growth and the rapid expansion of the economy, the electricity demand has soared. In Saudi Arabia, electricity consumption increases substantially during the summer months, with residential, commercial and industrial customers accounting for most of the high summer load. Although the daily peak period occurs between 1 PM and 5 PM, loads exceeding 95% of the annual peak load only last for 0.3% of the year's total hours; therefore, they are costly to serve(Abdulrahman, 2015).

Projections indicate that an additional 35 GW of generating capacity will be required by 2023, with substantial investment implications(Kingdom of Saudi Arabia, 2016). These factors have heightened awareness of the finite nature of fossil fuel resources and the need for conservation and efficient energy management(Alyahya & Irfan, 2016; Kingdom of Saudi Arabia, 2016). To address these challenges, the Energy Efficiency Programme was established to promote energy efficiency and conservation measures across all sectors of Saudi society, including the commercial sector. This program seeks not only to curtail energy demand but also to slow the rate of increase(Alyahya & Irfan, 2016; Kingdom of Saudi Arabia, 2016). Since its inception, the program has played a critical role in incorporating energy efficiency into the national narrative and paving the way for future initiatives. It has identified obstacles to energy efficiency and proposed strategies to overcome them, setting the stage for the kingdom's sustainable use of energy resources.

The present study evaluates the practical application of Energy Conservation Opportunities (ECOs) identified through Energy Audits in Riyadh's luxury hotels(HAIFA, 2023; Hamele, 2001; Sumaila et al., 2015). These audits are crucial, empowering hotel executives to make informed decisions that optimise energy usage, reduce environmental impact, and enhance financial viability. The study aims to assist luxury hotel stakeholders in developing strategies that maximise efficiency with minimal resources, aligning with the broader goals of Saudi Arabia's Vision 2030 for economic diversification and sustainability(Kingdom of Saudi Arabia, 2016).



Figure 1. Map of the Middle East featuring Saudi Arabia (Nations Online Project 2023).

2.0 Literature Review

2.1 Basic Information on Energy Audits

An energy audit comprehensively assesses energy consumption patterns across various residential, commercial, institutional, and industrial sectors to identify potential efficiency improvements and cost savings (Ogola et al., 2023). This process can range from simple walk-through surveys that provide immediate, low-cost recommendations to more detailed audits that thoroughly analyse systems to quantify savings opportunities through retrofits or upgrades (Ogola et al., 2023). Saudi Arabia's energy audit initiative has heightened corporate awareness of the concept's benefits and highlighted its potential through proof-of-concept implementations (HAIFA, 2023; Ogola et al., 2023). Initial governmental, commercial, and industrial facility audits have revealed 10-35% potential savings through HVAC optimisation, lighting retrofits, and insulation (HAIFA, 2023; International Business Magazine, 2021). More comprehensive audits of industrial plants and large commercial establishments have shown the potential to reduce consumption by up to 20% nationwide versus current levels through capital improvements adequately financed (HAIFA, 2023; International Business Magazine, 2021). The most intensive audits of boiler and steam systems, coupled with training programs on efficiency best practices, have yielded 5-10% savings (International Business Magazine, 2021; Ogola et al., 2023). Overall, the exercise has demonstrated the importance of energy auditing as a pivotal first step in any successful energy management and efficiency strategy. The data and insights from these audits continue to inform national policies and planning.

2.2 Steps for an Energy Audit

Conducting an energy audit in Saudi Arabia's luxury hotel sector is a systematic and rigorous approach to identifying pathways to enhance energy efficiency, minimise waste, and optimise cost savings. The following delineates the critical steps involved in executing a comprehensive energy audit within this context.

- I. **Desktop Studies and Preliminary Analysis:** Energy audits commence with a meticulous review of existing consumption data and financial documents. This desktop study is instrumental in pinpointing patterns of waste and escalating costs. Auditors assess a spectrum of parameters, including kilowatt-hours (kWh) of electricity, volumes of fuels such as heavy fuel oil (HFO) and liquefied petroleum gas (LPG), water usage measured in cubic meters, and overall energy expenditures. This stage sets the foundation for a targeted on-site assessment (Boharb et al., 2016; Kaddari et al., 2018; Ogola et al., 2023).
- II. **On-site Walk-through Assessment:** The next phase involves the auditor physically inspecting the hotel property to spot immediate energy-saving opportunities. This walk-through validates the desktop findings and observes the operational

dynamics that might influence energy consumption(Chisale & Mangani, 2021a).

- III. **Comprehensive Auditing with Specialized Equipment:** Advanced energy audits are executed using specialised tools that provide real-time data on energy consumption. Equipment such as thermal imagers, power meters, and flow meters are employed to accurately assess system components' performance. Using energy auditing software may uncover inefficiencies, such as steam or compressed air leaks, which can significantly impact energy expenditure(Boharb et al., 2016; HAIFA, 2023; Kaddari et al., 2018).
- IV. **Comprehensive Data Analysis and Engineering Finance Evaluation:** Following data collection, a thorough analysis is conducted to identify energy-saving opportunities. This step involves the application of engineering finance methods to evaluate the potential project's costs, the payback period, and the anticipated return on investment (ROI). Developing investment strategies with favourable ROIs and short payback periods is essential to ensure financial viability and appeal(Krarti, 2019; Nagy et al., 2015).
- V. **Performance Contracting and ESCO Involvement:** In Saudi Arabia, Energy Service Companies (ESCOs) are crucial in facilitating energy efficiency upgrades by offering performance contracting. Under this arrangement, the ESCO invests in necessary improvements at no upfront cost to the hotel, and the subsequent energy savings are used to repay the investment over time. This financial model is particularly attractive to facilities that lack the capital or expertise to undertake energy conservation measures independently(Krarti, 2019; Nagy et al., 2015; Santiago, 2021).
- VI. **Business Advisory Seminars and Capacity Building:** Business advisory seminars complement the audit process by offering essential knowledge and skill sets to emerging ESCOs. These seminars cover various topics, including contractual and legal aspects, business development, and international partnerships. Practical guidance is provided on overcoming market entry barriers, identifying energy efficiency opportunities, and capitalising commercially(HAIFA, 2023; Santiago, 2021).
- VII. **Market Development and Support:** The energy efficiency market in Saudi Arabia, with an estimated value of SR 1.2 billion annually for the commercial, governmental, and industrial sectors, presents substantial opportunities(Cetron et al., 2020; Kingdom of Saudi Arabia, 2016). Despite only a few ESCOs, the demand for energy conservation is significant, with potential savings of up to 35%. Market development efforts and government support can catalyse the growth of this nascent industry, ultimately contributing to the national goals of energy sustainability and economic diversification. Each step of the energy audit is critical for the transition towards more sustainable energy management in Saudi Arabia's luxury hotels(Eskerod et al., 2019; HAIFA, 2023).

By methodically applying these steps, the hotel sector can significantly reduce energy consumption, support environmental goals, and maintain economic efficiency in alignment with the kingdom's broader strategic objectives.

2.3 Audit Instruments and Equipment

An energy audit mandates using specialised tools and equipment to cater to a facility's unique energy consumption profiles and potential savings avenues(Ogola et al., 2023). The necessary instruments and their corresponding measurements are systematically listed in Table 1, providing auditors with a comprehensive toolkit for thorough analysis. Among the crucial tools is the power and quality analyser, an indispensable device for measuring parameters such as power factor, voltage, and current(Chisale & Mangani, 2021a, 2021b; Ogola et al., 2023). These measurements are essential for gaining a detailed understanding of energy usage and quality within the audited premises. The toolkit encompasses basic instruments, such as thermometers for temperature readings and advanced technological solutions designed to identify leaks in steam or compressed air systems(Chisale & Mangani, 2021b; Ogola et al., 2023).

Every instrument plays a vital role in mapping energy flows and identifying inefficiencies, allowing auditors to formulate targeted recommendations for energy conservation measures. The toolkit's comprehensiveness reflects the audit's depth, ranging from superficial inspections to intricate energy consumption patterns and inefficiencies analyses.

2.4 Demographic Information on 5-Star and 4-Star Hotels

The luxury hospitality landscape in Riyadh is exemplified by a selection of distinguished 5-star and 4-star hotels, each providing guests with a unique blend of comfort, elegance, and exemplary service. For this research titled *Assessment of the Implementation of Energy Conservation Opportunities Arising from Energy Audits: A Study of Luxury Hotels in Riyadh, Saudi Arabia*, we focused on a sample of these establishments to evaluate their energy conservation measures post-audit.

5-Star Hotels:

- I. Jareed Hotel Riyadh: This hotel embodies luxury and state-of-the-art amenities, setting the benchmark for luxurious stays in Riyadh.
- II. Movenpick Hotel and Residences Riyadh: With its Swiss heritage, this hotel combines modernity and tradition, catering to leisure and business travellers.
- III. Radisson Blu Hotel Riyadh Qurtuba: A part of a renowned international chain, this hotel stands out for its distinctive design and commitment to sustainability.
- IV. DoubleTree by Hilton Riyadh Financial District Hotel & Suites: This hotel promises a blend of comfort and innovation at the heart of Riyadh's financial hub.
- V. Vittori Palace Hotel and Residences: The Vittori Palace offers a royal experience, combining luxury with cultural elegance.

4-Star Hotels:

- I. Cantonal Hotel by Warwick, Al Olaya: Located in the vibrant Al Olaya district, this hotel is known for its exceptional service and strategic location.
- II. Vivian Park El Raeid Hotel: This establishment is a testament to contemporary architecture and offers a serene environment for its guests.
- III. Privere Hotel Suites, Al Rawabi: Nestled in Al Rawabi, this hotel is a sanctuary of relaxation focused on personalised services.
- IV. Mira Business Hotel: Catering primarily to business travellers, this hotel is acclaimed for its professional atmosphere and modern facilities.
- V. Joudyan Olaya Riyadh: Offering a blend of tradition and modernity, this hotel provides a hospitable retreat in the heart of Riyadh.

Each of these hotels operates under the guidance of a general manager who oversees the hotel's administrative and operational functions. The hotel management structure is bolstered by department heads who lead their respective divisions with a dedication to guest satisfaction and operational efficiency(HAIFA, 2023; Ogola et al., 2023; Santiago, 2021). The departments integral to hotel operations include:

- Engineering Department: Vital for maintaining the hotel's infrastructure and implementing energy conservation measures.
- Housekeeping Department: Ensures the cleanliness and comfort of the hotel's accommodations and public areas.
- Food Production and Beverage Department: Delivers exquisite culinary experiences and oversees beverage services.
- Front Office Department: The face of the hotel, managing guest services and experiences from arrival to departure.
- Admin and Finance Department: Manages the hotel's finances, human resources, and administrative tasks.
- Sales and Marketing Department: Drives the hotel's revenue through strategic marketing and sales initiatives.
- ICT Department: Supports the hotel's technology infrastructure, ensuring seamless operations and guest services.
- Security Department: Ensures guests, staff, and property safety and security.

This demographic overview provides a foundation for understanding the operational context within which the energy audits were conducted and the subsequent implementation of conservation strategies in these prominent hotels in Riyadh.

Table 1: Comprehensive Equipment List for Energy Audits(Abdulrahman, 2015; Lai, 2016; Ogola et al., 2023)

Category	Equipment	Measurement Output/Application
Electrical Analysis	Power and Quality Analyser/Logger-Single Phase	Power Factor, Voltage, Current, kW, Electricity Consumption, Harmonics, Waveforms
	Power and Quality Analyser/Logger-3 Phase	Power Factor, Voltage, Current, kW, Electricity Consumption, Harmonics, Waveforms
Combustion Analysis	Combustion Analyser	Efficiency of hot water generators, steam boilers, fossil fuel burning machines
Illumination	Lux Meter	Light intensity
Safety	Safety Equipment	Ensuring auditor safety during energy audits
Thermal Analysis	Infrared Thermometer	Temperatures in offices & worker areas; temperature of operating equipment
Electrical Diagnostics	Voltmeter/Multimeter/Clamp-Meter	Operating Voltages, Currents in Conductors
	Wattmeter/Power Factor Meter	Power consumption and power factor of individual motors and inductive devices
Ventilation Analysis	Airflow Measurement Devices	Airflow from heating, air conditioning, or ventilation ducts
Infiltration Testing	Smoke Generator	Air infiltration and leakage detection around doors, windows, ducts,
Combustion Efficiency	Fuel Efficiency Monitor	Combustion efficiency
Water Analysis	Flow Water Flow Meter (non-contact)	Water Flowrate in piping systems
Dimensional Analysis	Laser Distance Meter	Dimensions of walls, ceilings, windows, and distances between equipment in the plant room

2.5 Energy Management Systems in the Hotel Industry in Riyadh

Energy Management Systems (EMS) symbolise the convergence of technology and strategy in pursuing energy optimisation within the hospitality sector (Ogola et al., 2023). These systems coordinate the operational dynamics of energy-consuming equipment, such as boilers, chillers, and HVAC (Heating, Ventilation, and Air Conditioning) systems, regulating their function in response to fluctuating demand. In the environment of five-star hotels, the predominant energy-consuming infrastructures encompass HVAC systems, hot water production mechanisms, lighting, electrical and elevator systems, and culinary equipment (International Business Magazine, 2021).

The hospitality industry's dependence on electricity is diverse and extensive, encompassing applications such as air conditioning, heating, illumination, ventilation, gastronomic operations, electrical systems, and hot water generation. Energy expenses represent approximately 3% to 6% of operational costs. Fossil fuels, namely gas, coal, and petroleum, are the primary contributors to greenhouse gas emissions (Abdulrahman, 2015; Lai, 2015). Consequently, the reduction of energy consumption is inherently linked to the removal of these emissions. Of note, HVAC systems in hotels are responsible for approximately half of the total energy utilisation. Furthermore, the water consumption metrics in these establishments indicate a requirement of 380 to 760 litres of potable water per guestroom daily (Bohdanowicz & Martinac, 2007; Tsoutsos et al., 2018).

Energy audits within the hotel industry typically focus on areas and systems such as lighting, electricity distribution, air conditioning, refrigeration units, boilers, steam systems, and LPG usage (Ogola et al., 2023; Tsoutsos et al., 2018). The greening of the hotel industry, a movement gaining momentum since the International Hotels Environmental Initiative (IHEI) of 1993, seeks to diminish the environmental footprint of hotels by curtailing energy and water usage, minimising reliance on non-durable goods, and reducing emissions into the biosphere (Alshakhshir & Howell, 2021; Cetron et al., 2020). This paradigm shift towards sustainability is encapsulated in the concept of 'green hotels,' which are characterised by their adherence to environmentally sustainable practices and principles, including the conservation of resources and minimisation of waste and emissions, thereby preserving the environment, and enhancing operational efficiency and cost-effectiveness (Bohdanowicz & Martinac, 2007; Meschede et al., 2017).

Environmental stewardship in the hotel sector is exemplified through the implementation of Environmental Management Systems (EMS), which outline a hotel's ecological objectives, responsibilities, and policies, along with provisions for auditing the efficacy of these systems in achieving set environmental goals (Bohdanowicz & Martinac, 2007; Sozer, 2010; Taleb & Sharples, 2011). It is important to note that the level of EMS implementation varies across the industry, reflecting varying degrees of ecological commitment. Hoteliers are vital in monitoring energy consumption, implementing conservation strategies, and reducing atmospheric pollutants (Ogola et al., 2023; Taleb & Sharples, 2011). Effective waste management, recycling, and procurement policies prioritising reduced environmental impact and promoting social, ecological, and local economic sustainability are crucial in mitigating environmental degradation. Despite the limited consumer demand for green hotels, there is a discernible trend towards increasing environmental consciousness. Marketing a hotel as environmentally conscientious can significantly enhance its competitive edge, distinguishing it within its locale and attracting a clientele that values sustainability, as suggested by Krarti (2019).

2.6 Post Audit Analysis Giving Energy Conservation Opportunities (ECOs)

Post-audit analysis represents a crucial phase where the auditor's expertise is demonstrated by identifying and evaluating high-impact Energy Conservation Opportunities (ECOs) unique to the hotel under assessment (Krarti, 2019; Ogola et al., 2023). This stage requires a comprehensive analysis of granular energy usage data and demand profiles to identify efficiency gaps across lighting, HVAC, building envelope, operations, and maintenance (Abdulrahman, 2015; Ogola et al., 2023). The auditor draws upon their technical knowledge of hotel facilities and energy-efficient technologies to develop customised ECOs that offer maximum savings potential (Ogola et al., 2023; Santiago, 2021).

The proposed solutions must align with the hotel's distinctive functional dynamics and service standards. For example, outdoor lighting may be minimised except along key perimeter areas and entrances to maintain the prestigious aesthetics expected of luxury hotels. Cooling setpoints are optimised to balance guest comfort with efficiency (Abdulrahman, 2015; Lai, 2016; Ogola et al., 2023). The auditor considers upfront costs, expected returns, ease of implementation, and potential disruption to operations when proposing ECOs (Ogola et al., 2023). Technical considerations include right-sizing of HVAC equipment, zoning of lighting controls, and integration of variable speed drives. Feasible payback horizons and Return on Investment (ROI) metrics guide ECO selection suited for the hotel's business outlook (International Business Magazine, 2021; Ogola et al., 2023).

A strategic audit goes beyond identifying general ECOs to customising solutions that unlock maximum savings while maintaining guest experience (Krarti, 2019; Ogola et al., 2023). The final recommendations represent the auditor's culmination of technical expertise, domain knowledge, and financial acumen. When translated into action, they can significantly enhance the hotel's sustainability and energy security.

2.7 ECO Cost-Effectiveness

The evaluation of ECO cost-effectiveness is a multi-dimensional process. While the Simple Payback Period (SPP) provides a straightforward metric for assessing the time frame for cost recovery, it is imperative to consider the time value of money for a comprehensive analysis (HAIFA, 2023; Ogola et al., 2023). Advanced methods such as Net Present Value (NPV) and Internal Rate of Return (IRR) offer a more nuanced understanding of an ECO's financial performance over time. These methods account for the

discounting of future cash flows, providing a present-day valuation of long-term savings. Such economic assessments are crucial for making informed decisions on ECO implementation, ensuring that the selected measures are environmentally beneficial and economically sound(Ogola et al., 2023; Santiago, 2021).

2.8 Hotel Sustainability

Sustainability has evolved from a passing trend to a fundamental business principle within the hotel industry. This shift in perspective encompasses environmental responsibility, economic viability, and social accountability. In the context of luxury hotels in Riyadh, sustainability is of utmost importance and requires a tailored approach that resonates with the region's unique cultural and environmental landscape. Implementing green building protocols, sustainable procurement strategies, and utilising renewable energy sources are crucial (Ogola et al., 2023). Such initiatives enhance the hotel's reputation and cater to the growing number of environmentally conscious travellers, aligning with the overall objectives of reducing carbon footprints and preserving natural resources(Ogola et al., 2023).

The tourism sector in Saudi Arabia, deeply rooted in the nation's historical significance as a religious epicentre, has evolved into a substantial economic force. As the second-largest source of revenue after the petroleum industry, tourism generates approximately US\$13.8 billion annually and is the kingdom's third-largest employer(Abdulrahman, 2015; Zell et al., 2015). The trajectory of tourist influx has shown a steady increase, rising from 755 million in 2004 to 1135 million in 2014, with projections indicating potential revenues from international travel and tourism reaching US\$63.7 billion by 2019(ECRA, 2006). Predominantly driven by religious pilgrimages, the hospitality landscape, particularly in Mecca and Al Madinah, has expanded to accommodate this influx. As the capital, Riyadh offers diverse hospitality establishments, totalling 67 hotels, including 16 five-star and 13 four-star hotels. This stratification caters to a broad spectrum of visitors, with four-star hotels achieving the highest occupancy rate of 65.5% in 2011, indicating a preference that eclipses that of one and two-star hotels, which stood at 58.9%(Abdulrahman, 2015; HAIFA, 2023). Seasonal fluctuations further characterise the industry, with summer and fall marking peak occupancy periods(Abdulrahman, 2015). The integration of tourism data highlights the significance of sustainable practices within the hotel industry, not only as a reaction to environmental concerns but also as a strategic response to the changing nature of tourism in Saudi Arabia(Abdulrahman, 2015). The synchronisation of sustainability efforts with the cultural and religious significance of the region can stimulate economic development while promoting an ethos of conservation and social responsibility.

2.9 Contemporary Hotel Energy Solutions

The hotel industry is transforming toward energy-efficient operations, driven by the dual imperatives of economic sustainability and environmental responsibility. The deployment of cutting-edge technologies such as smart thermostats, advanced energy management systems, and IoT-enabled monitoring devices is revolutionising how hotels conserve energy while maintaining, if not improving, the quality of guest experiences(Alshakhshir & Howell, 2021; Eskerod et al., 2019). These technological advancements permit substantial reductions in energy consumption and operational costs while elevating guest comfort and convenience through intelligent automation and real-time adjustments. Furthermore, acquiring eco-labels exemplifies a hotel's commitment to environmental conservation, distinguishing it within the highly competitive hospitality market and ensuring compliance with international sustainability standards(Abdulrahman, 2015; Lai, 2016).

Despite the hotel sector's significant contributions to employment and economic growth, it remains one of the most energy-intensive facets of the tourism industry. Accommodation services alone are responsible for a substantial portion of the tourism sector's carbon emissions, contributing to 2% of the global CO₂ emissions attributed to tourism(Krarti, 2019). In Saudi Arabia, the context is particularly nuanced. Despite the nation's Vision 2030 goals, which include reducing fossil fuel subsidies, the country had the third-largest subsidy worldwide in 2019, predominantly favouring oil and fossil-fuel-based electricity production. The availability of inexpensive fossil fuels has historically dampened the impetus for renewable energy investments, as they are often perceived as less economically attractive in comparison(Krarti, 2019).

However, the Saudi Green Initiative (SGI), inaugurated in 2021(Ogola et al., 2023; Taleb & Sharples, 2011), marks a pivotal redirection towards sustainable climate action. With ambitious targets for emissions reduction, afforestation, and protecting terrestrial and marine environments, the SGI is a clarion call for a sustainable future. By 2030, Saudi Arabia aims to derive 50% of its energy from renewable sources. The initiative encompasses strategic programs designed to lower emissions and diversify the energy mix, including developing carbon capture and storage technologies, enhancing energy efficiency through the Saudi Arabia Energy Efficiency Programme, and exploring new, sustainable energy sources(Kingdom of Saudi Arabia, 2016). This paradigm shift is poised to reshape the economic landscape, presenting challenges and opportunities for the hotel industry as it navigates the transition towards greener, more sustainable energy solutions.

2.10 Heating, Ventilating, and Air Conditioning System (HVAC)

In the strategic landscape of Saudi Arabia's Vision 2030, which aims to diversify the economy and reduce reliance on oil, the Heating, Ventilating, and Air Conditioning (HVAC) system emerges as a pivotal element in the hotel energy management sector(International Business Magazine, 2021; Kingdom of Saudi Arabia, 2016). It is a substantial energy consumer, yet it is essential for maintaining guest comfort—a balance achieved through innovative technologies. Variable Refrigerant Flow (VRF)

systems, known for their precise temperature control and energy efficiency, integration of automation and intelligent management, exemplify the advancements that enable real-time adjustments to climatic variations and occupancy. Such proactive measures and the shift to more energy-efficient models are vital in reducing energy consumption and operational costs (Abdulrahman, 2015; International Business Magazine, 2021; Krarti, 2019).

The architectural grandeur of Saudi Arabia, with its towering skyscrapers set against the backdrop of oil-rich deserts and the sacred cities of Mecca and Medina, is complemented by an essential yet often invisible network of HVAC systems (Abdulrahman, 2015; Lai, 2016). These systems are necessary in the harsh climate, ensuring indoor environments remain hospitable. The HVAC market in Saudi Arabia is on a trajectory of growth, expected to burgeon from \$2,476.1 million in 2020 to \$4,821.8 million by 2030, with a CAGR of 8.1% from 2021 to 2030 (Abdulrahman, 2015; Kingdom of Saudi Arabia, 2016; Ogola et al., 2023). This surge is intertwined with the hospitality sector's expansion, fueled by the steady stream of pilgrims and tourists visiting the holy cities, thus escalating the demand for HVAC systems.

The hospitality sector's growth is a testament to the country's cultural and religious magnetism, which draws visitors from around the globe. HVAC systems are indispensable in this sector, providing guests with a controlled and comfortable environment (Abdulrahman, 2015; HAIFA, 2023). With the sector's expansion, the Saudi Arabian HVAC market revenue is forecasted to climb from \$2,709.0 million in 2019 to \$3,197.4 million by 2030, at a 3.2% CAGR between 2020 and 2030 (Abdulrahman, 2015; HAIFA, 2023). The burgeoning hotel industry is exemplified by the recent opening of the largest InterContinental Hotel in Mecca and the ambitious plans of Hilton Worldwide Holdings Inc. and Radisson Hospitality AB to construct new hotels. These developments are a clear indicator of the market's robust growth.

The proliferation of hotels directly results from Saudi Arabia's religious prominence, which annually attracts millions seeking spiritual fulfilment, thereby underscoring the indispensable role of HVAC systems (HAIFA, 2023; International Business Magazine, 2021). This symbiotic relationship between tourism and HVAC infrastructure supports the nation's economic goals. It ensures that visitors' experiences in the 'Land of the Two Holy Mosques' are comfortable, regardless of the external desert climes.

2.11 Change of Practice in Hotel Management and Operation

The hotel management and operation paradigm is undergoing a significant transformation, with a heightened focus on sustainability and energy conservation. Studies by Abdulrahman (2015) and Ogola et al. (2023) identify primary energy consumers as lighting, air conditioning, housekeeping, and cooking. Furthermore, the research highlights the psychological impact of lighting and its role in fostering a sense of security for both hotel personnel and guests. Abdulrahman (2015) advocates scheduling housekeeping activities during daylight hours to capitalise on natural illumination, reducing reliance on artificial lighting and promoting energy efficiency. Housekeepers are also advised to draw back curtains and blinds to infuse guestrooms and public spaces with sunlight while being mindful of energy wastage by avoiding unnecessary use of appliances such as televisions during cleaning. Krarti (2019) contributes to this discourse by identifying a repertoire of energy-saving tactics that are cost-effective and simple to implement. Switching off lights in unoccupied rooms is a fundamental yet impactful method (Krarti, 2019). In areas bathed in abundant natural light, the need for artificial lighting should be critically assessed and adjusted accordingly. The maintenance and calibration of public lighting controls, such as timers and photocells, are essential to ensure they operate at peak efficiency (Krarti, 2019; Nagy et al., 2015). Post-room servicing, the protocol of closing curtains and blinds and switching off lights can significantly curtail energy consumption. Also, dirty lamps and fixtures can diminish lighting efficiency by up to 50% (Krarti, 2019; Nagy et al., 2015).

Hence, regular cleaning of these components is imperative to sustain optimal lighting efficiency. Moreover, reassessing the lighting design to reduce redundancy in over-lit areas and incorporating task-specific lighting can lead to substantial energy savings. Nagy et al. (2015) extend this conversation to the external environment, advocating for the strategic shutdown of outdoor and pool area lighting when not in use, balancing the dual objectives of safety and energy conservation. These evolving hotel management and operation practices reflect a broader industry shift towards sustainable resource use (Cetron et al., 2020; Nagy et al., 2015). By reevaluating and updating operational protocols, hotels can significantly reduce their energy footprint while maintaining, if not enhancing, guest satisfaction and safety (Cetron et al., 2020; Legrand et al., 2016; Vinnie, 2014). This shift is not only a response to environmental imperatives but also aligns with the economic interests of hoteliers, as energy efficiency translates into cost savings and can fortify the hotel's reputation as an environmentally responsible establishment (LeGrand et al., 2016; Vinnie, 2014).

2.12 Adoption of Renewable Energy Technologies by the Hotel Industry

In the context of the hospitality industry in Saudi Arabia, the adoption of renewable energy technologies is not only a strategic move towards environmental stewardship but also a practical approach to addressing the energy consumption challenges inherent in large public buildings such as hotels (LeGrand et al., 2016; Vinnie, 2014). The energy consumption profile of such establishments is typically dominated by electricity, with a significant portion allocated to heating, ventilation, and air conditioning (HVAC), lighting, and power equipment (LeGrand et al., 2016; Ogola et al., 2023; Vinnie, 2014). Figure 2 elucidates this by showing the Energy consumption distribution characteristics of hotels or large public buildings. Given the high energy consumption density and the considerable potential for energy savings, integrating renewable energy sources presents a compelling case for the hotel industry. Solar photovoltaic (PV) systems, for instance, offer a clean and efficient way to generate electricity directly from sunlight (Abdulrahman, 2015; General Authority for Statistics, 2017; Zell et al., 2015). This technology can be particularly

advantageous in Saudi Arabia, where solar irradiance levels are high (General Authority for Statistics, 2017; Zell et al., 2015). Deploying solar PV panels can reduce greenhouse gas emissions and operational costs associated with energy consumption. Similarly, wind energy can provide a sustainable power source through small wind electric systems, reducing electricity expenses and enhancing energy independence for remote hotel facilities. (General Authority for Statistics, 2017; HAIFA, 2023; Zell et al., 2015)

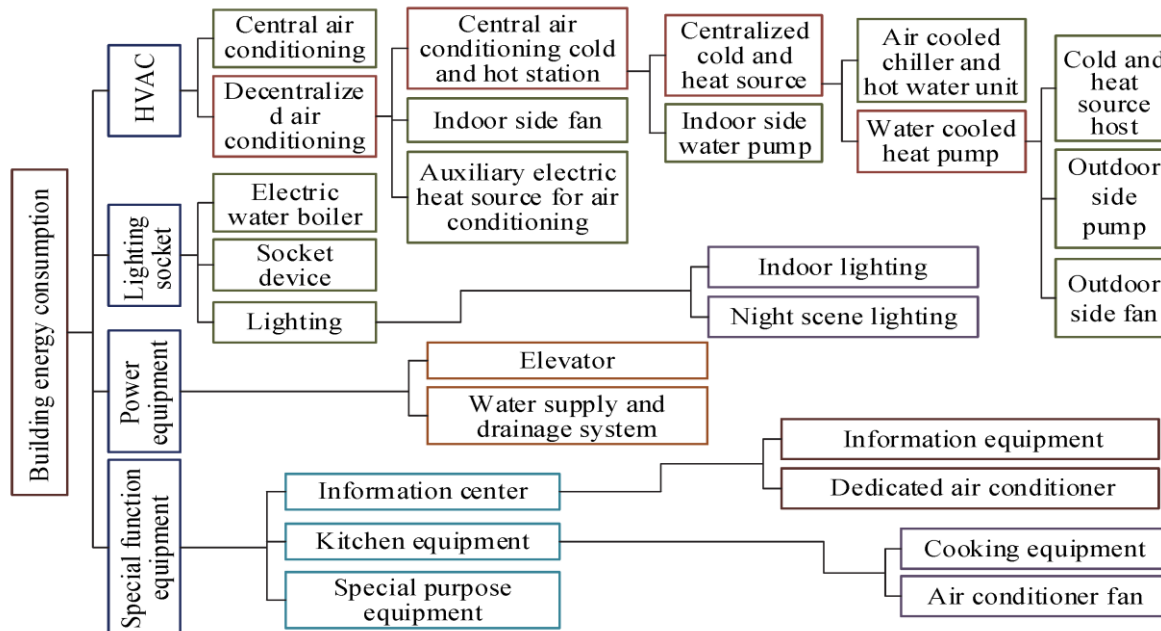


Figure 2: Energy Consumption Distribution Characteristics For Hotels And Large Public Buildings In Saudi Arabia (Ogola et al., 2023)

The implementation of renewable energy technologies, such as micro-hydropower systems, ground source heat pump (GSHP) systems, and integrated cogeneration or combined cooling, heat, and power (CHP) systems, presents a viable solution for the hotel industry in Saudi Arabia (Abdulrahman, 2015; Zell et al., 2015). These technologies have evolved to be clean, safe, efficient, and cost-effective, providing a reliable and sustainable energy source. Wood-burning technologies can utilize wood chips and pellets derived from forestry waste and agricultural by-products to minimize air pollution and energy waste while heating small to medium-sized hotels. Adopting these renewable energy technologies aligns with the national Vision 2030 objectives of reducing carbon footprint and promoting sustainable development (Taleb & Sharples, 2011; Zell et al., 2015). By implementing these innovative approaches, the hotel industry in Saudi Arabia can set a precedent for sustainable operations and energy management while contributing to the country's renewable energy goals.

2.13 Research Gap(s)

The existing literature on environmental management within the hotel industry, specifically in the context of luxury hotels in Riyadh, Saudi Arabia, reveals a notable research gap. Although previous studies have explored the attitudes of hotel managers towards environmental management and the implementation of green practices, there is a lack of research providing precise guidance on fundamental green energy management strategies post-energy audits in five-star hotels. These studies have shown that more significant chain hotels are likelier to adopt environmental management practices than smaller establishments. However, they fail to delineate actionable energy conservation opportunities that align with Energy Audit Requirements and demonstrate cost savings alongside enhanced ecological sustainability.

Moreover, the literature has identified barriers to the implementation of Environmental Management Standards (EMS) in hotels, as discussed by Taleb & Sharples (2011), and the need for region-specific adaptations of standards like LEED, considering the unique geographic and climatic challenges, particularly in the Arab Gulf countries as noted by SASO (2008). As pointed out by ECRA (2006), the scarcity of tourism studies in Saudi Arabia further complicates the issue, indicating a pressing need for research focused on sustainable energy sources within the Saudi hotel industry.

There is an evident need for further investigation into the implementation of energy conservation opportunities (ECOs) resulting from energy audits, as well as the participation of hotel staff in energy management practices, to promote sustainable operations within the hospitality industry in the Middle East, particularly in Saudi Arabia (Taleb & Sharples, 2011). This study aims to address this gap by examining the impact of ECOs on cost savings and environmental sustainability in Riyadh's luxury hotel sector. The findings of this research will contribute to the existing body of knowledge on sustainable practices in the hospitality industry within

the region.

2.14 Problem Design

Luxury hotels in Riyadh consume substantial energy due to climate, architectural factors, and service demands. Studies show building envelopes, including windows and doors, account for about 50% of a hotel's energy use. While large-scale retrofits may not be feasible, optimisations like reflective glazing can significantly reduce external heat gain and cooling loads. However, implementing such tailored measures suggested by energy audits remains suboptimal. This study examines why adopting recommended energy conservation opportunities (ECOs) is constrained and proposes improvements to enhance sustainability. Given the high energy intensity, the hospitality sector is a prime candidate for efficiency gains. However, myriad structural and operational barriers exist, from thermal design limitations to staff behaviours. By investigating the nuances around audit implementation in Riyadh's luxury hotels, this research can uncover leverage points to accelerate ECO adoption. The context-specific insights will inform policies and resource allocations needed to translate audits into practice. This will strengthen environmental sustainability and energy security for a sector vital to Saudi Arabia's future. The focus is now explicitly on investigating "why" and "how" to improve audit implementation, framed as a problem definition. The rationale highlights the sector's intensity and untapped potential.

3. METHODOLOGY

3.1 Data Collection

This study utilises a mixed methods approach, incorporating both quantitative and qualitative techniques, to comprehensively analyse hotel energy performance. Quantitative data was gathered through energy audit reports, ECO assessments, utility bills, and digital questionnaires, while qualitative data was collected through interviews with staff across various departments. The study employed a random sample of 10 luxury hotels in Riyadh, selected from a list of 67 provided by the Saudi Commission for Tourism and Antiquities. This sample ensures that the findings represent the city's luxury hospitality segment. The mixed techniques employed in this study provide analytical rigour and narrative richness, enabling a holistic investigation into the implementation gaps of energy audits. The segment on sampling provides relevant details without excessive enumeration of individual properties. The study highlights the importance of triangulating quantitative consumption statistics, ECO reports, and staff perspectives to understand hotel energy performance comprehensively. The results of this study demonstrate the value of using a mixed methods approach to support a holistic analysis of hotel energy management.

3.2 Instrument for Data Analysis

The target respondents were executives, managers, and owners of luxury hotels in Riyadh, as decision-makers are best placed to provide insights. Hotels were randomly selected from a government list 67 the Saudi Commission of Tourism & Antiquities provided. Data collection involved self-administered questionnaires consisting primarily of closed-ended questions on a 5-point Likert agreement scale. The survey instrument was developed based on established literature on hotel sustainability. The study utilises two primary data sources - hotel energy audit reports and digital questionnaires for hotel staff across departments.

Comprehensive energy audits conducted by contractors at sampled four and 5-star hotels in Riyadh provided quantitative data on energy usage breakdowns, recommended Energy Conservation Opportunities (ECOs), and implementation status of identified ECOs. Analysis of audit reports offered insights into the rate of and barriers around ECO adoption. Additionally, online questionnaires disseminated to hoteliers across departments, including engineering, housekeeping, and front office, assessed staff awareness, involvement, and perspectives on hotel energy management practices. Responses highlighted potential gaps or opportunities related to staff behaviours and training to bolster energy efficiency. The energy audit reports provide technical analytics on efficiency opportunities and implementation, while the staff surveys add crucial qualitative context around awareness, capacity, and organisational support for conservation initiatives. This instrumentation enables a well-rounded assessment of the impediments and enablers for hotels in Riyadh to translate identified ECOs from audits into action - a vital objective of this research. The mixed data equips stakeholders with evidence-based improvements.

3.3 Research Questions

Research Question 1: What is the degree of awareness and understanding of energy audits and conservation measures among hotel managers in Riyadh?

- *Assessment Method:* A survey employing a 5-point Likert-type scale (1: Very Unaware, 5: Very Aware) will gauge the familiarity of hotel managers with the concepts and practices of energy audits and conservation strategies. The distribution of responses will offer insight into the level of awareness within the industry.

Research Question 2: What is the extent of implementation of energy conservation measures identified by energy audits in luxury hotels in Riyadh?

- *Assessment Method:* The survey will ask managers to rate the extent of implementation of recommended energy

conservation measures using a 5-point Likert-type scale (1: Not Implemented, 5: Fully Implemented). This will quantify the adoption rate of energy-saving practices post-audit.

Research Question 3: Which energy conservation opportunities (ECOs) have been most effectively realised and acted upon following energy audits in hotels in Riyadh?

- *Assessment Method:* The frequency and effectiveness of implemented ECOs will be evaluated through a series of questions, each using a 5-point Likert-type scale (1: Not Effective, 5: Highly Effective) to determine the perceived impact of each ECO.

Research Question 4: What are the perceived facilitators and barriers to implementing energy conservation measures post-energy audits in Riyadh's luxury hotels?

- *Assessment Method:* Participants will rate various potential facilitators and barriers on a 5-point Likert-type scale (1: Strongly Inhibit, 5: Strongly Facilitate). This will identify the most significant factors influencing the implementation of energy-saving measures.

Research Question 5: Are there discernible patterns in implementing energy conservation measures related to specific characteristics of luxury hotels in Riyadh?

- *Assessment Method:* Correlational analysis will be conducted between hotel characteristics (age, ownership, star rating) and the implementation of energy conservation measures, with each characteristic rated on its perceived influence using a 5-point Likert-type scale (1: No Influence, 5: High Influence).

4. RESULTS

4.1 Background of Findings

The survey results underscored that most 4-star and 5-star luxury hotels in Riyadh actively pursue energy efficiency through systematic energy audits. As detailed in Table 2, 90% of the surveyed hotels have conducted some form of energy audit, which is instrumental in pinpointing energy conservation opportunities (ECOs). A mere 10% of the hotels have not yet initiated energy audit processes.

The survey targeted a select group of luxury hotels, yielding a 73% response rate, which speaks to the sector's commitment to energy management. The respondents spanned various hotel departments, providing a holistic view of the energy conservation efforts. Notably, the Sales & Marketing and Engineering departments engaged significantly in energy management and sustainability practices. This trend aligns with the increasing preference of corporate clients for hotels that demonstrate environmental stewardship. The Engineering department, in particular, is crucial in managing utilities and implementing sophisticated Energy Management Systems (EMS). The participation of hotel staff from diverse departments, as depicted in Figure 3, reflects the collaborative approach to energy management within the hospitality sector.

Table 2: Types of Energy Audits Conducted by Luxury Hotels in Riyadh

Hotel Classification	In-House Energy Audit	Investment-Grade Energy Audit	No Audit Conducted	Total
5-Star Hotels	3 (60%)	1 (20%)	1 (20%)	5 (100%)
4-Star Hotels	2 (40%)	2 (40%)	1 (20%)	5 (100%)
Total	5 (50%)	3 (30%)	2 (20%)	10 (100%)

Number of Respondents by Departmental Category

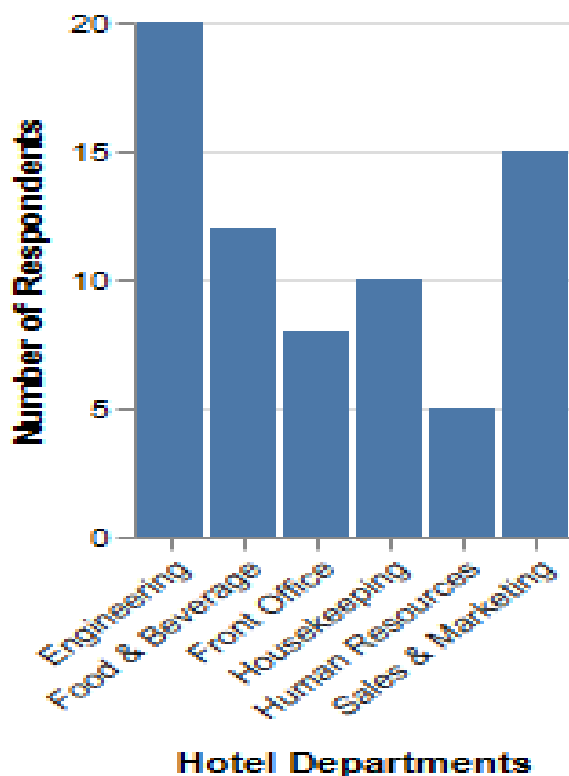


Figure 3: Number of respondents by departmental category (obtained from data analysis)

Table 3: 5-Star Hotels in Riyadh: Departmental and Gender Distribution of Respondents

Department	Female Respondents	Male Respondents	Total	Percentage F	Percentage M
Engineering & ICT	2	13	15	13.3%	86.7%
Housekeeping	12	3	15	80%	20%
Food & Beverage	6	9	15	40%	60%
Front Desk	8	7	15	53.3%	46.7%
Sales & Marketing	5	10	15	33.3%	66.7%
Admin & Security	4	11	15	26.7%	73.3%
Finance	3	12	15	20%	80%

Table 4: 4-Star Hotels in Riyadh: Departmental and Gender Distribution of Respondents

Department	Female Respondents	Male Respondents	Total	Percentage F	Percentage M
Engineering & ICT	1	9	10	10%	90%
Housekeeping	7	3	10	70%	30%
Food & Beverage	4	6	10	40%	60%
Front Desk	5	5	10	50%	50%
Sales & Marketing	3	7	10	30%	70%
Admin & Security	2	8	10	20%	80%
Finance	2	8	10	20%	80%

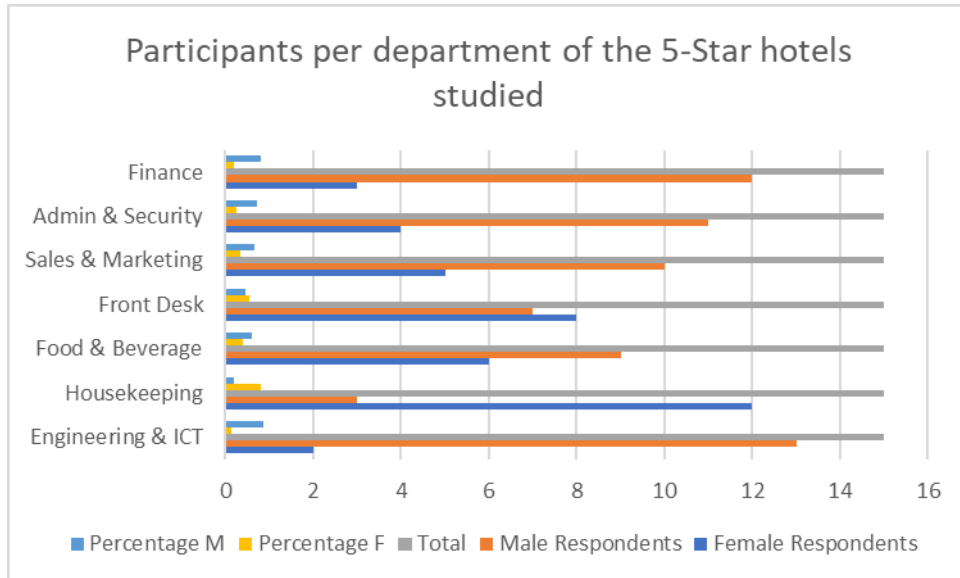


Figure 4: Participants Per Department Of The 5-Star Hotels Studied

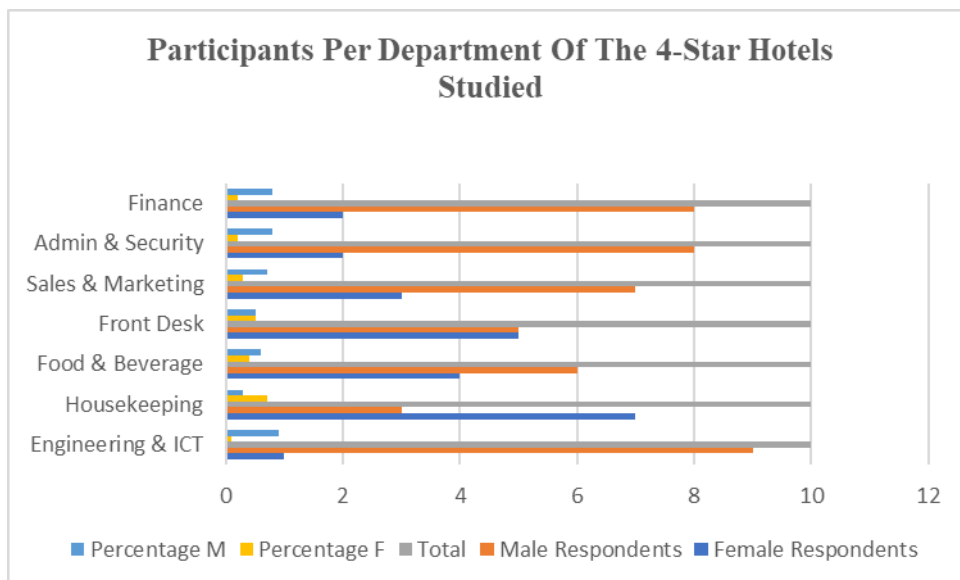


Figure 4: Participants Per Department Of The 4-Star Hotels Studied

Table 5: Data From The Energy Audits And Assessments The 5-Star Hotels

Energy Conservation Opportunity (ECO)	Jareed Hotel	Movenpick Hotel	Radisson Blu	DoubleTree by Hilton	Vittori Palace
Energy saving bulbs	9500 kWh	3000 kWh	12500 kWh	8700 kWh	2900 kWh
Energy-efficient appliances	11000 kWh	9200 kWh	2600 kWh	11500 kWh	9600 kWh
Training programs	2100 kWh	11300 kWh	9800 kWh	2200 kWh	11700 kWh
Engages guests in green practices	9600 kWh	2800 kWh	12300 kWh	8900 kWh	2700 kWh
Recycling copy/print paper	11800 kWh	9100 kWh	2300 kWh	11900 kWh	9500 kWh
Environmental Committee	Yes	No	Yes	No	Yes
Digital thermostats	2300 kWh	11400 kWh	9700 kWh	2400 kWh	11800 kWh

The comprehensive survey results among luxury hotels in Riyadh indicate a proactive approach to energy conservation. Most 4-star and 5-star establishments have undertaken energy audits to identify and implement Energy Conservation Opportunities (ECOs). This data is presented in Table 2, which shows that 90% of the surveyed hotels have engaged in energy audits. This commitment to energy management is further demonstrated by the response rate of 73% from the targeted luxury hotels. The survey covered a broad range of hotel departments, providing a comprehensive perspective on the adopted energy conservation measures. The findings reveal that the Sales & Marketing and Engineering departments are particularly active in energy management initiatives. This indicates a growing trend where sustainability credentials are increasingly influencing corporate clients' choice of hotels. The Engineering department plays a pivotal role in this domain, overseeing utility management and the deployment of advanced Energy Management Systems (EMS).

The survey results in the tables indicate that many Energy Conservation Opportunities (ECOs) are being implemented across the hospitality industry. For example, 5-star hotels such as Jareed Hotel and Radisson Blu have demonstrated significant kWh savings by adopting energy-efficient appliances and lighting, ranging from 2,900 kWh to 12,500 kWh. These savings were achieved through training programs and guests' engagement in green practices, highlighting the hotels' comprehensive approach to energy conservation.

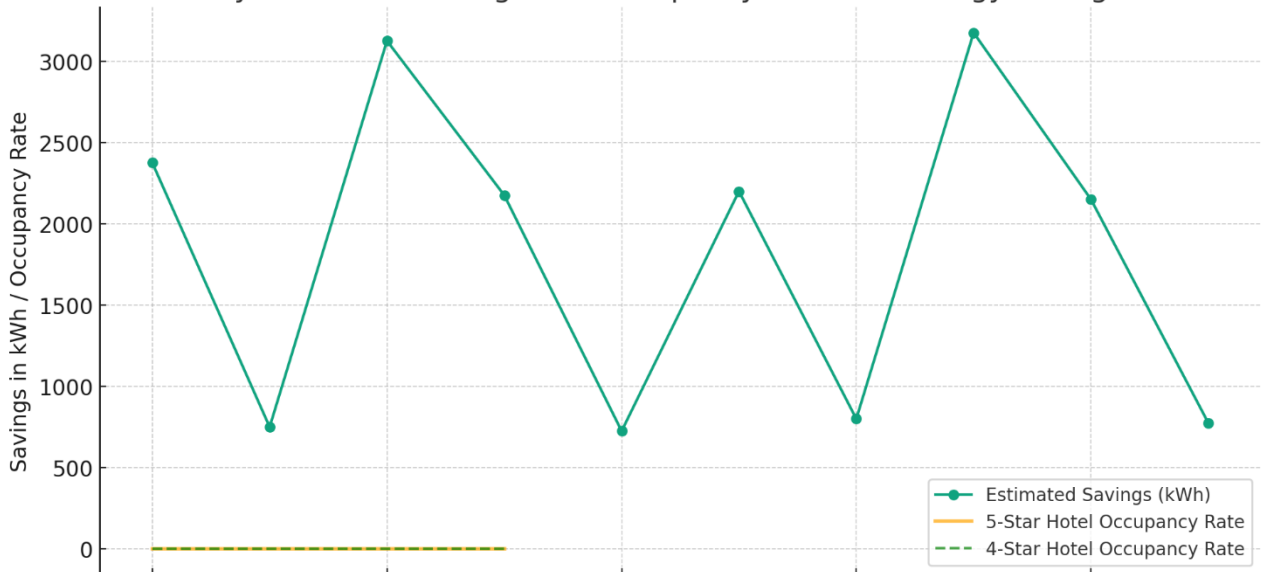
Similarly, 4-star hotels such as Cantonal Hotel and Mira Business Hotel have reported substantial energy savings by implementing digital thermostats and energy-efficient lighting, resulting in savings between 2,200 and 12,700 kWh. The participation of environmental committees within these hotels also varies, providing further insight into the varying levels of formalised commitment to environmental management. The distribution of the involvement across departments, shown in Figure 3, underscores the interdisciplinary nature of energy management efforts in the hospitality industry. It is clear that energy conservation is not confined to a single department but is a collective endeavour that involves various aspects of hotel operations. The survey results demonstrate that the hospitality industry is aware of the importance of energy efficiency and is actively taking steps to improve it. The energy audits serve as a foundational activity, guiding hotels in implementing ECOs that lead to significant energy and cost savings while contributing to the broader goal of environmental sustainability.

Table 6: Data From The Energy Audits And Assessments The 4-Star Hotels

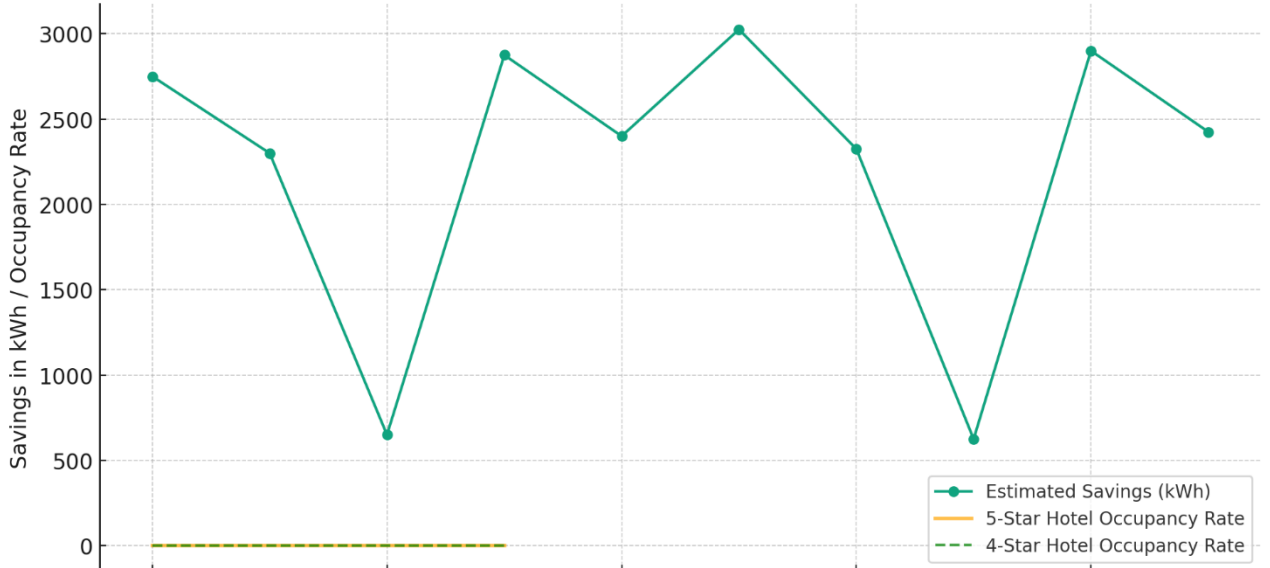
Energy Conservation Opportunity (ECO)	Cantonal Hotel	Vivian Park	Private Suites	Mira Business Hotel	Joudyan Olaya
Energy saving bulbs	8800 kWh	3200 kWh	12700 kWh	8600 kWh	3100 kWh
Energy-efficient appliances	12100 kWh	9300 kWh	2500 kWh	11600 kWh	9700 kWh
Training programs	2000 kWh	11500 kWh	9900 kWh	2100 kWh	11600 kWh
Engages guests in green practices	9700 kWh	2900 kWh	12400 kWh	9000 kWh	2800 kWh
Recycling copy/print paper	11700 kWh	9200 kWh	2400 kWh	12000 kWh	9400 kWh

Environmental Committee	No	Yes	No	Yes	No
Digital thermostats	2200 kWh	11200 kWh	9600 kWh	2300 kWh	11500 kWh

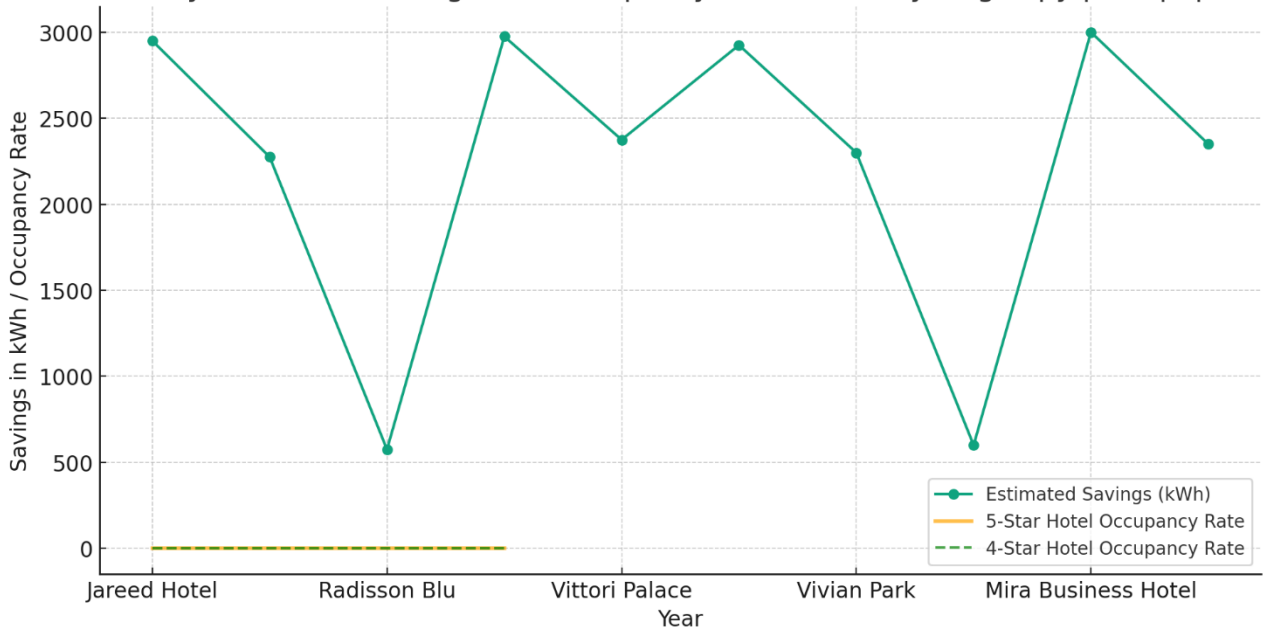
Yearly Estimated Savings and Occupancy Rates for Energy saving bulbs



Yearly Estimated Savings and Occupancy Rates for Energy efficient appliances



Yearly Estimated Savings and Occupancy Rates for Recycling copy/print paper



The chart in Figure 5 shows the yearly estimated savings in kWh for the selected Energy Conservation Opportunities (ECOs)—"Energy saving bulbs," "Energy efficient appliances," and Recycling copy/print paper—along with the constant occupancy rates for both 5-star and 4-star hotels from 2019 to 2022.

In each subplot:

- The line with markers represents the estimated savings in kWh for each ECO, assuming the savings are distributed evenly over the four years.
- The dashed orange line indicates the assumed constant occupancy rate for 5-star hotels at 70%.
- The dashed green line indicates the assumed constant occupancy rate for 4-star hotels at 60%.

5. CONCLUSION

The comprehensive survey conducted among the luxury hotels in Riyadh reveals a proactive stance towards energy efficiency and sustainability. An overwhelming majority, accounting for 90% of both 4-star and 5-star hotels, have engaged in energy audits to identify and implement Energy Conservation Opportunities (ECOs), as evidenced in Table 2. This initiative underscores the sector's commitment to energy management, as reflected by the substantial 73% response rate from the targeted luxury hotels. The survey spanned diverse departments, offering a holistic view of the energy conservation efforts underway. Notably, the Sales & Marketing and Engineering departments have emerged as critical players in driving energy management initiatives, aligning with the growing preference of corporate clients for environmentally responsible accommodations. The Engineering department, in particular, is instrumental in managing utilities and implementing sophisticated Energy Management Systems (EMS).

The survey results, detailed in the tables, showcase the implementation of a wide array of ECOs within the industry. For instance, 5-star hotels like Jareed Hotel and Radisson Blu have realised substantial kWh savings, ranging from 2,900 kWh to 12,500 kWh, by adopting energy-efficient appliances and lighting. These achievements testify to the efficacy of training programs and guest engagement in green practices. Similarly, 4-star hotels such as Cantonal Hotel and Mira Business Hotel have reported significant energy savings, from 2,200 kWh to 12,700 kWh, using digital thermostats and energy-saving lighting solutions. The involvement of environmental committees varies among these hotels, indicating differing levels of formal commitment to environmental management. The interdisciplinary participation in energy management, as depicted in Figure 3, illustrates that energy conservation is a collective endeavour integral to various operational facets of hotel management.

The energy audits serve as a critical tool for guiding hotels in implementing ECOs and pave the way for substantial energy and cost savings, contributing to the overarching objective of environmental sustainability. However, the audit reports reviewed during this study indicate that individual ECOs have not been fully appraised. There is a need for a thorough evaluation of these ECOs, including an analysis of projected savings, payback periods, and internal rates of return. Future work should aim to fully assess these opportunities, discussing the risks associated with their implementation and proposing mitigation strategies for each identified risk. Such an appraisal is crucial to inform energy stakeholders, including financial institutions, about potential investment and lending opportunities, facilitating informed decision-making and promoting the adoption of ECOs across the hospitality sector. This study serves as a clarion call for a concerted effort to transform energy audit recommendations into actionable results, fostering a paradigm shift towards energy efficiency and sustainability in Saudi Arabia's thriving tourism and hospitality industry.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

Author Contributions

Conceptualisation, Reem Alwarejeh and Abubakar Ibrahim Suleiman.; Methodology, Reem Alwarejeh and Abubakar Ibrahim Suleiman; writing—original draft preparation, Reem Alwarejeh and Abubakar Ibrahim Suleiman and Michael Obenten.

All authors have read and agreed to the published version of the manuscript.

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