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Utilization of Engineering Management Principles in the Adoption of Solar Energy in Iraq

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Abstract

This article explores the application of engineering management principles to overcome energy challenges in developing countries, focusing on Iraq's energy sector. It examines the current situation, challenges, and potential of solar energy in Iraq. The article introduces the topic, reviews relevant literature, and discusses the evolution of Iraq's electricity sector. It highlights challenges and proposes solar energy as a solution. The study evaluates the state of solar energy in Iraq, emphasizing its contextual suitability and potential impact. The research methodology, data analysis, and key findings are outlined, ensuring rigor and validity. The role of engineering management principles in adopting solar energy is explored. The conclusion summarizes research outcomes, offering recommendations for policymakers, stakeholders, and researchers to enhance solar energy benefits in Iraq.

Keywords: Energy Sector; Engineering Management Principles; Solar, Challenges; Adoption; Iraq.

1. INTRODUCTION

This article delves into Iraq's persistent energy challenges, examining the potential of solar energy adoption and how engineering management principles can be instrumental in this transformation. Challenges include war-induced infrastructure damage, overreliance on fossil fuels, and issues like illegal grid trespassing. The article posits that solar energy, with Iraq's abundant sunlight, can revolutionize the energy landscape, bolster economic stability, and align with global environmental goals. The study aims to provide a comprehensive overview of Iraq's energy sector, highlight the advantages of solar power, employ user-based data analysis, and propose a roadmap for solar energy adoption using engineering management principles.

On a global scale, there's an urgent push towards renewable energy sources, particularly solar, as emphasized by international organizations and agreements. The literature review traces the historical evolution of global electric power generation, underscoring the increasing significance of renewable energy [21]. According to Vijayan et al. (2023), engineering management practices play an important role in solar energy projects in developing countries. The adoption and application of engineering management principles in the context of these countries needs to be carefully examined, considering their unique characteristics and challenges. It emphasizes the vital importance of

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effectively utilizing engineering management principles for the successful execution and management of solar energy initiatives in such environments [22]. The article puts forth a hypothesis suggesting a robust link between engineering management principles and increased solar energy adoption in Iraq, leading to enhanced living standards and environmental sustainability. The methodology employs a multi-method approach, combining a thorough literature review with a case study in Iraq, incorporating a questionnaire. The research framework involves a comprehensive examination of literature, engagement with end users and experts, and statistical analysis of collected data. Acknowledging limitations such as geopolitical instability, infrastructural constraints, economic challenges, and cultural factors, the study proposes a holistic and multidisciplinary approach to overcome.

In conclusion, the article aspires not only to explore possibilities but to drive a transformative shift by advocating for the responsible adoption of eco-friendly energy sources in Iraq, with a specific focus on solar energy and the strategic application of engineering management principles.

1.1 *Electricity Sector In Iraq*

Iraq's electricity sector faces challenges due to a demand-supply gap, chronic underinvestment, and aging infrastructure. Political instability, corruption, and military conflicts have further strained the sector. Despite these issues, Iraq is taking steps to rehabilitate infrastructure, diversify energy sources, and attract foreign investment. The government's efforts aim to improve reliability, support economic growth, and position Iraq as a key player in the regional energy landscape [10].

In Iraq, electricity consumption is divided across sectors, with the residential category being the largest consumer. The rise in population and urbanization has increased household connections to the grid, leading to a surge in reliance on electricity for daily needs [20]. However, this concentration in the residential sector strains the national power grid, causing frequent shortages and impacting residents' access to essential services. Iraq heavily depends on fossil fuels for electricity, contributing to environmental issues and financial burdens [18]. To address these challenges, Iraq is actively pursuing strategies, including diversifying energy sources, promoting energy efficiency, and investing in renewable projects, aiming to enhance reliability, reduce environmental impact and ensure.

Iraq's' electricity sector faces numerous challenges:

a. *Supply Demand Imbalance:* Meeting the increasing electricity demand is a critical challenge due to population growth, urbanization, and industrial expansion, causing a surge in consumption.

b. *Infrastructure Deficiencies:* Decades of conflict, neglect, and underinvestment have deteriorated Iraq’s electricity infrastructure, leading to reduced efficiency and substantial power losses, impacting healthcare, education, and economic activities.

c. *Political Instability and Security Concerns:* Frequent government changes, disputes, and security issues hinder long-term planning and discourage investment. Attacks on infrastructure disrupt electricity supply, affecting essential services and deterring foreign investment [9].

d. *Corruption and Mismanagement:* Corruption diverts funds from infrastructure development, leading to an overburdened power grid. Mismanagement affects project quality, causing frequent outages, straining essential services, and diverting resources from vital public services and infrastructure.

e. *Lack of Investment:* Despite international support, a significant funding gap hinders modernization and expansion efforts. Security concerns and bureaucratic complexities deter private sector investment, leaving Iraq with outdated infrastructure and frequent power disruptions.

f. *Environmental Concerns:* Heavy reliance on fossil fuels contributes to environmental degradation, air pollution, and climate change impacts. Iraq's commitment to cleaner energy sources is hampered by current sector composition [7].

g. Regulatory and Governance Issues: Inefficient regulatory frameworks and governance mechanisms create uncertainty and impede modernization efforts. Inefficient pricing methods and subsidies strain public finances, and widespread illegal electricity network use results in substantial state revenue loss.

h. Regional and International Dynamics: Dependence on neighbouring nations for electricity due to limited domestic resources, coupled with geopolitical complexities, leads to energy insecurity, disrupting daily life and economic planning. Iraq needs to diversify energy sources, invest in infrastructure, and engage diplomatically for stable energy relations [2].

1.2 Solar Energy In Iraq

1.2.1 Overview on Iraq's Solar Electricity Capacity

Iraq, with its abundant sunshine, is strategically positioned for solar power harnessing, particularly in the southern and western regions with high solar irradiance levels. The government has initiated various solar projects, including a 750 MW plant in Al-Samawah and a 300 MW project in Al-Dibdibah, aiming to diversify the energy mix, reduce emissions, and decrease reliance on fossil fuels [13]. However, challenges such as political instability, security concerns, infrastructure investments, and regulatory frameworks must be addressed for successful solar sector development. Despite obstacles, Iraq aims for 30% of national demand to be met by renewables, including solar, by 2030 [10].

1.2.2 Potentials of Solar Energy in Iraq

Iraq boasts significant potential for solar energy due to its strategic location, abundant sunshine, and distinctive country attributes:

1.2.2.1 Abundant Solar Irradiance

Situated in the Sun Belt region, Iraq enjoys exceptional solar energy potential, particularly during its long, hot summers. The region experiences consistent sunlight, clear skies, and intense solar radiation, creating an optimal environment for efficient solar power systems. With high solar insolation and extended daylight hours, Iraq is well-positioned for substantial electricity generation from solar sources [2].

1.2.2.2 Optimal Land Availability

Iraq's' extensive flatlands in the southern and western regions provide ideal conditions for large-scale solar energy projects. These flat areas offer ample space for solar panel installations, contributing to meeting the country's growing electricity demands. The desert landscapes minimize land-use conflicts, facilitating the deployment of solar installations without significant disruptions. The flat terrain ensures uninterrupted sunlight exposure, maximizing energy production and supporting energy security and sustainability objectives [2].

1.2.2.3 Low Precipitation

Iraq's' climate, characterized by low annual precipitation levels and minimal cloud cover, enhances its solar energy potential. Clouds can impede solar panel performance by scattering and blocking sunlight, resulting in inconsistent energy generation. However, Iraq's arid regions with clear skies experience fewer obstacles between the sun and solar panels, ensuring optimal sunlight absorption and a more predictable energy generation pattern. This reliability benefits both energy consumers and providers [2].

Capitalizing on these factors, Iraq has a unique opportunity to transition towards a sustainable and resilient energy future, diminishing reliance on fossil fuels, mitigating environmental impact, and fostering economic development. Successful implementation necessitates supportive policies, substantial infrastructure investments, capacity building, and collaborative efforts among stakeholders [12]. With a comprehensive strategy, Iraq can fully unlock the potential of solar power, paving the way for a sustainable and resilient energy future.

1.2.3 Potentials of Solar Power in Addressing Iraq's Electricity Challenges

The myriad challenges facing Iraq's electricity sector, a comprehensive strategy is imperative. This must encompass infrastructure rehabilitation, energy diversification, policy reforms, good governance, regional cooperation, and climate change adaptation. Successfully addressing these issues promises enhanced energy security, improved citizen well-being, and sustainable socio-economic development. The main challenges faced are also outlined in Figure 1.

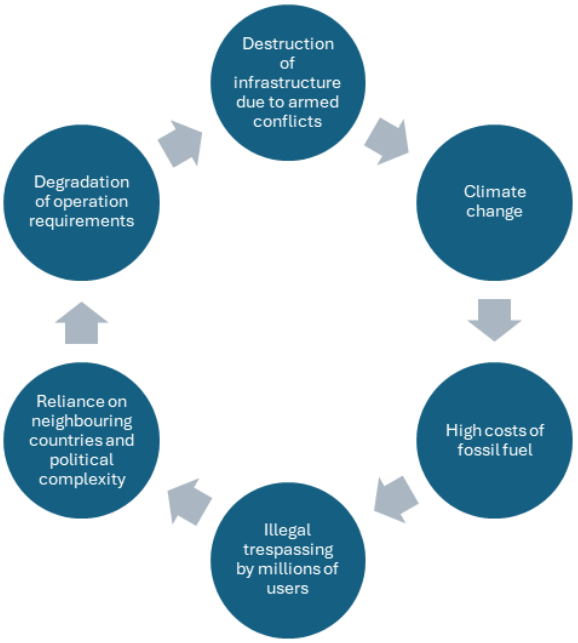

Figure 1. Key Challenges Analyzed [1].

It is imperative to consider that a successful implementation hinges on establishing a robust framework encompassing supportive policies, substantial investments in research and development, enhanced capacity building initiatives, and fostering collaborative partnerships among stakeholders [1]. With a comprehensive and multifaceted strategy in place, Iraq can confidently stride towards a sustainable, secure, and resilient energy future, contributing to a globally responsible and eco-conscious tomorrow.

2. METHODOLOGY

The term "multi-method study" refers to a study where many distinct research methodologies are employed to address related questions effectively. “Different paradigms each focus attention on different aspects of the situation, and so multimethod research is necessary to deal effectively with the full richness of the real world” [14].

To uphold ethical and scientific standards while conducting rigorous research and producing dependable results, a systematic approach was employed. This approach included meticulous questionnaire design, effective web-based distribution, a combination of secondary and primary data collection methods, and an extensive data analysis phase [16]. The focus was on addressing the intricate challenges associated with the transition to renewable energy in Iraq.

The research process followed can be explained in the below three key phases:

Phase #1: Questionnaire Design:

The 15-questions questionnaire was thoughtfully designed to be easy-to-understand, non-suggestive to any certain opinions, topic-relevant yet comprehensive enough to gather credible information on respondents' personal information, educational backgrounds, habits of electricity consumption, and attitude and positions on solar energy.

Phase #2: Questionnaire Finalization and Data Collection:

During the data collection phase, A pilot testing involving individuals with data expertise was conducted to improve the questionnaire quality. Before the 150 questionnaires were distributed, resulting in 123 valid responses. The adopted approach was a web-based dissemination for ease of access, minimal time and effort, customization, data verification, real-time analysis, cost-efficiency, and environmental friendliness.

Phase #3: Data Processing:

Data analysis stands as a pivotal phase in the research journey, playing a crucial role in translating collected data into meaningful insights. This integral step encompasses both qualitative and quantitative findings, serving as a linchpin in the comprehensive research process by bridging the gap between theoretical concepts and practical application. The resulting outcome not only furnishes well-grounded conclusions but also offers valuable insights. Moreover, the process places emphasis on acknowledging the complexity of the transition to renewable energy by considering a multitude of perspectives and opinions.

2.1 Unveiling Perspectives on Renewable Energy Adoption

The planned areas of investigation through the survey commence by emphasizing the collective responsibility of individuals in preserving the environment. Subsequently, it underscores the increasing significance of adopting alternative, clean, and renewable energy sources over fossil fuel systems. The transition is posited to contribute to enhancing the quality of life for future generations, mitigating the degradation of human habitats, and preserving the natural environment. The survey queries individuals about the environmental impact of incorporating energy-saving practices into their daily routines. Additionally, it draws attention to the economic and environmental superiority of technologies facilitating energy conservation [8]. While emphasizing the potential contribution of insulating household surfaces to environmental amelioration, the survey scrutinizes the extent of efforts by government bodies, support organizations, and the private sector in raising awareness regarding the benefits of clean energy utilization. Participants are prompted to express their opinion on the most suitable renewable energy source for investment in Iraq and whether governmental support, particularly in subsidizing the costs of renewable energy technologies, would incentivize citizens to adopt them. The questionnaire also delves into the participants' perspectives on the adequacy of governmental, support agencies', and the private sector's initiatives in promoting the benefits of utilizing alternative clean and renewable energy sources. Moreover, respondents are asked to consider the financial feasibility of long-term investments in installing renewable energy sources, particularly solar energy,

thereby providing a comprehensive exploration of attitudes and considerations regarding sustainable energy practices in Iraq.

3. Results Generation

The empirical data gathered was analysed using SPSS 22. The analysis aimed to gauge energy users' habits and perceptions regarding solar energy in Iraq, contributing to the overarching research topic. SPSS is a widely recognized and extensively employed statistical software that provides a comprehensive platform for data management and statistical analysis [4]. Descriptive statistics were employed to summarize and present the key features of the dataset, offering insights into the central tendencies and variability of the collected data. With 150 respondents following a diverse and inclusive selection criterion, the questionnaire captured insights from individuals of varied ages, sexes, education levels, employment statuses, and electric power user relationships. Notably, the high response rate of 82%, with 123 participants, underscores the research's significance and the effectiveness of the data collection approach. The scrutinized data allowing for meaningful findings, pattern identification, and informed conclusions. This marks a crucial point in the research journey, transitioning from data collection to actionable insights, with the robust participation rate bolstering the credibility and reliability of the research. Key Statistical Indicators included the Repose Ratio, Reliability, Likert Scale, Respondents Backgrounds, Standard Deviation, Mean Value, Variance, and Rank Correlation.

$$\text{Response ratio} = \frac{123}{150} * 100 = 82\% \quad (1)$$

3.1 Reliability Test

The reliability coefficient, also known as Cronbach's Alpha, can be calculated using statistical tools like SPSS [11]. Ranging from 0 to 1, a higher value indicates greater reliability in the survey tools and items. In this research, Cronbach's Alpha is 0.806, signifying strong reliability and reasonably high internal consistency. Notably, a reliability coefficient of 0.70 or above is considered satisfactory.

Table 1. Questionnaire Reliability Statistics

Reliability Statistics	
Cronbach’s Alpha	No. of Items
0.806	12

3.2 Employment Status

A total of 123 valid responses were obtained for the survey. The participants' employment status distribution is as Figure 2: 22% were students, 37.4% were employed, 26% were self-employed or freelancers, 4.1% were retired, and 10.6% were homemakers. The largest demographic group consists of employed individuals, constituting 37.4% of the total respondents. Following closely, the second-largest group comprises self-employed individuals and freelancers, accounting for 26%, while students represent the third-largest group with a percentage of 22. The proportion of retired participants is 4.1%, whereas homemakers constitute 10.6% of the total responses. Cumulative percentages represent the total proportion of participants within each category.

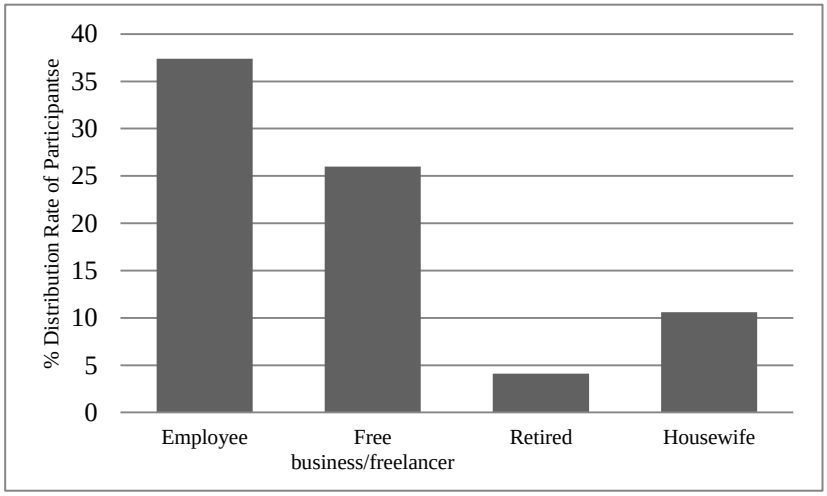

Figure 2. Respondents Employment Status.

3.3 Respondents Educational Levels

The distribution of participants' educational levels is as Figure 3: 48.8% of respondents hold a bachelor's degree (BSC), constituting the largest educational category. Following closely, participants with a master's degree (MSC) make up the second-largest group with a percentage of 13.0. Those with a Doctorate (PHD) represent 9.8% of the respondents. Individuals with diplomas constitute another significant group, comprising 14.6% of the total respondents. Additionally, participants who graduated from high school account for 13.8% of the distribution. Overall, there is a diverse participation in terms of educational backgrounds among the respondents who completed the survey. This distribution aligns with the typical pattern of academic qualifications.

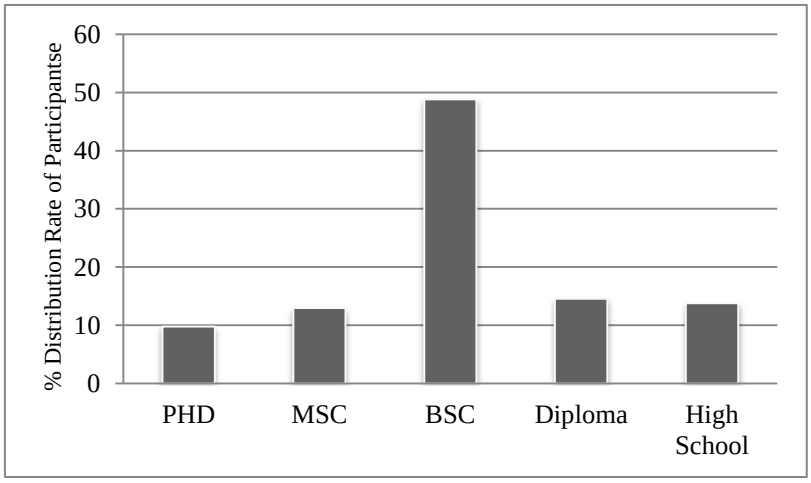

Figure 3. Respondents Educational Level.

3.4 Mean Value

The mean, within the context of mathematical and statistical analysis, denotes the average value derived from a given set of numerical data. Calculation of the mean involves various methods, with the most prevalent being the arithmetic mean. This method entails the summation of all individual values within the dataset, followed by division by the total number of observations [15]. In the specific context of our questionnaire items, mean values

were computed for each item, reflecting the respondents' collective evaluation of the presented statements. These mean values ranged from 4.32 to 3.53, showcasing the spectrum of responses and the degree of agreement or disagreement among the participants. The variability in mean values across different questionnaire items provides insights into the nuances of perceptions or attitudes towards the aspects under investigation, contributing to a more comprehensive understanding of the dataset.

3.5 Standard Deviation

The standard deviation serves as a metric for quantifying the extent of dispersion or variability within a dataset concerning its mean. It is derived by taking the square root of the variance. The standard deviation offers valuable insights into the degree of deviation of individual data points from the dataset's average, providing a measure of the data's overall spread [19]. In the context of comparing datasets or examining the consistency within a dataset, understanding the dispersion of values around the mean becomes crucial. The standard deviation allows for the assessment of the typical distance between individual data points and the mean, thereby indicating the overall stability or variability of the dataset [3]. For the specific questionnaire items under consideration, the computed standard deviation values ranged from 0.739 to 1.188. These values signify the degree of deviation of individual responses from the mean for each respective questionnaire item. A higher standard deviation suggests greater variability among responses, while a lower standard deviation indicates a more clustered distribution around the mean. These standard deviation values contribute to a nuanced understanding of the spread and distribution of responses, aiding in the interpretation of the dataset's reliability and consistency."

3.6 Rank Correlation

Rank correlation is a statistical approach assessing relationships between rankings of ordinal variables, which lack precise numerical values. This method, crucial in fields like social sciences and economics, helps measure agreement or disagreement between different sets of rankings [5]. It is particularly valuable for understanding relationships in data where the order of items holds significance.

Table 2. Statical Analysis of Questionnaire Items

Question No.	Mean	Standard Error of Mean	Standard Deviation	Variance	Rank
1	4	0.084	0.932	0.869	7th
2	4.07	0.087	0.96	0.921	5th
3	3.76	0.107	1.188	1.411	14th
4	3.81	0.092	1.019	1.039	13th
5	3.81	0.084	0.926	0.858	12th
6	4.06	0.085	0.943	0.89	6th
7	3.95	0.077	0.857	0.735	8th
8	3.9	0.083	0.918	0.843	10th
9	3.94	0.072	0.803	0.644	9th
10	4.2	0.077	0.859	0.737	2nd
11	3.53	0.067	0.739	0.546	15th
12	4.15	0.075	0.827	0.683	3d
13	4.32	0.075	0.833	0.694	1st
14	3.84	0.081	0.9	0.809	11th
15	4.14	0.076	0.843	0.71	4th

Table 2 presents the mean values and corresponding ranks for various questionnaire items, offering insights into the participants' perceptions regarding renewable energy adoption in Iraq. (Rank 1)"It is important that government

agencies increase the construction of renewable energy facilities to generate electric power" received the highest mean value of 4.32, securing the first rank. This indicates a strong consensus among respondents regarding the significance of governmental initiatives in expanding renewable energy infrastructure. (Rank 2)"In your personal opinion, please select the most appropriate source of renewable energy for investment in Iraq?" obtained a mean value of 4.20, ranking second. This underscores the participants' considerations on the optimal choice for renewable energy investment, providing valuable insights for policymakers and investors. (Rank 3) "Contribution from government agencies to subsidize the costs of renewable energy technologies will encourage citizens to use them" received a mean value of 4.15, securing the third rank. This suggests a positive perception of the role of financial incentives in promoting renewable technology adoption among citizens. (Rank 4) "In the long term, investing in installing renewable energy sources (solar) is more financially feasible" garnered a mean value of 4.14, positioning it in the fourth rank. This implies a general acknowledgment of the long-term financial viability associated with solar energy investments. (Rank 5) "Recently, it has been evident that it is getting increasingly important to adopt alternative clean and renewable energy sources instead of fossil-fuel systems" achieved a mean value of 4.07, ranking fifth. This reflects the growing awareness among participants regarding the imperative shift towards cleaner energy alternatives. (Rank 6) "Using energy-saving LED lights and home appliances is a better option in both economic and environmental aspects" attained a mean value of 4.06, securing the sixth rank. Participants generally acknowledge the dual benefits of economic savings and environmental impact associated with energy-efficient technologies. The analysis continues similarly for the remaining items, with mean values decreasing gradually. Overall, the rankings provide a clear hierarchy of priorities and preferences among respondents, offering valuable insights into public attitudes towards renewable energy adoption in Iraq. These findings can guide policymakers, energy planners, and stakeholders in formulating effective strategies for sustainable energy transitions.

3.7 Harmonizing Public Preferences with Engineering Management in Iraq's Sustainable Energy Transition

The outcomes of the survey not only underscore the public sentiment towards renewable energy adoption in Iraq but also provide a nuanced understanding of the factors influencing the preferences and priorities of the populace [6]. As governmental and societal interest increasingly converges toward embracing cleaner and sustainable energy alternatives, the integration of engineering management principles becomes pivotal in navigating the complexities of Iraq's energy transition. The survey's emphasis on the role of government agencies, financial incentives, and long-term feasibility aligns seamlessly with the overarching objective of effectively implementing engineering management strategies [17]. In steering the energy landscape towards greater reliance on renewable sources, engineering management principles offer a structured approach to address challenges, optimize resource allocation, and ensure the successful integration of solar energy and other sustainable solutions. As this transition unfolds, the insights gleaned from the survey stand poised to inform evidence-based decisions, facilitating a harmonized constructive collaboration between public aspirations and strategic engineering management in realizing Iraq's sustainable energy future.

3.8 Utilizing Engineering Management Principles in Iraq’s Energy Transition

Engineering management is a multifaceted and expansive field with a wide range of principles and practices that can be approached and categorized in many ways, each shedding light on various aspects of the field. Seven key principles of engineering management were identified to support drawing a pathway for Iraq’s energy sector transition towards solar source in Table 3.

Table 3. Engineering Management Principles and Solar Energy Transition in Iraq

Engineering Management Principle	How To Utilize It
Integration of Engineering and Management	• Strategic Alignment: Develop a clear solar energy strategy that aligns with broader energy goals. • Cross-Functional Collaboration: Form interdisciplinary teams for comprehensive problem-solving. • Effective Communication: Establish robust channels for feedback and reporting to ensure seamless coordination.
Project Management	• Project Planning: Define clear objectives, scopes, and deliverables for solar power initiatives. • Resource Allocation: Efficiently allocate skilled personnel, equipment, and materials to maximize productivity. • Monitoring and Evaluation: Implement Key Performance Indicators for tracking project progress and ensuring quality.
Total Quality Management (TQM)	• Defining Quality Standards: Specify rigorous standards for adherence to solar components. • Quality Assurance: Enforce stringent quality control measures for procurement and installation. • Process Improvement: Implement continuous improvement processes and prioritize ongoing training initiatives.
Risk Management	• Risk Identification: Conduct thorough risk assessments to identify potential threats. • Risk Mitigation: Develop comprehensive strategies for identified risks, including diversification. • Risk Monitoring: Continuously monitor risks and reassess their potential impact to proactively manage challenges.
Cost Management	• Cost Estimation: Develop precise cost estimates, considering all aspects of the project. • Budget Allocation: Allocate financial resources judiciously, ensuring long-term financial sustainability. • Cost Control: Implement effective mechanisms to prevent cost overruns and optimize expenses.
Innovation and Technology Management	• Technology Assessment: Continuously assess emerging solar technologies to stay ahead. • Research and Development: Invest in Research and Development for adapting technologies to local conditions. • Pilot Projects: Implement pilot projects to test new technologies in real-world conditions and inform decision-making.
Ethics and Sustainability	• Environmental Impact Assessment: Conduct thorough assessments to mitigate any adverse effects. • Social Engagement: Involve local communities in the planning process to ensure equitable benefits.
Transparency and Accountability	• Maintain transparency in project financing, procurement, and operations. • Compliance with Regulations: Adhere rigorously to local and international regulations throughout the entire project lifecycle.

In the conducted study several constraints and limitations were encountered and should be acknowledged for comprehensive understanding. Firstly, the research was conducted within a specified timeframe, limiting the scope and depth of data collection and analysis. Additionally, language constraint was present as the study relied solely on Arabic and English sources, potentially excluding valuable insights from other linguistic perspectives. Furthermore, the sampling method employed may introduce selection bias due to the overrepresentation of readily accessible or willing participants, thus limiting the generalizability of the findings to the broader population of energy users in Iraq. These constraints should be considered when interpreting the results and implications of the study, providing a nuanced understanding of its contributions and potentials for future research endeavours.

4. CONCLUSION AND RECOMMENDATIONS

Underscores a global shift towards solar energy, supported by regulated entities engaged in research and advocacy. Solar power's advantages, including cleanliness, renewable nature, and economic appeal, are universally recognized. In Iraq's context, abundant sunlight, economic benefits, and environmental advantages make solar energy a pertinent choice. The majority of surveyed respondents in Iraq endorse transitioning to solar power, favour energy conservation, and expect government leadership in solar initiatives. Engineering management principles, covering integration, project management, cost management, risk management, quality management, innovation and technology management, and ethics and sustainability, form a robust framework for successful energy transition.

In driving the transition towards increased reliance on solar energy in Iraq, each of the following stakeholders plays a crucial role, contributing uniquely to the success and sustainability of this transformative initiative. Government of Iraq is at the forefront of solar energy integration, responsible for developing a regulatory framework, establishing financial mechanisms, and allocating resources for national grid development. Concurrently, investments in research and development are crucial for enhancing solar technologies and ensuring long-term viability. Private Sector is crucial for developing and operating solar projects, investing in construction and maintenance. Collaboration with international firms is essential for technology transfer and expertise. Private entities engage with local communities to ensure social and environmental alignment, and public-private partnerships are explored for expanding solar capacity and enhancing investment opportunities, promoting sustainable energy growth. International Community, including entities like the United Nations, governments, and non-governmental organizations, supports Iraq's solar energy transition through financial aid and grants, facilitating infrastructure development and knowledge exchange. Collaboration with global research centres promotes mutual benefits and technological advancements. Participation in regional energy initiatives, particularly cross-border sharing of solar power, enhances regional energy security and sustainability.

Collaboration with Neighbouring Countries enhances local and regional energy security. Exploring cross-border energy trade agreements allows efficient use of surplus solar power for regional energy needs. Sharing best practices in solar energy integration fosters regional knowledge exchange. Establishing joint research and development programs promotes solar technology advancements, benefiting the entire region. A regional consortium for renewable energy fosters collaborative efforts to address energy challenges. Research and Academic Institutions lead innovation and education in renewable energy, conducting research for advanced solar technology, providing specialized education and training, collaborating internationally for knowledge exchange, and offering data-driven insights for evidence-based decision-making. Citizens' active involvement is crucial for the success of solar projects in Iraq. Their participation in energy conservation and community-based solar projects fosters a sense of ownership and sustainability. Advocating for sustainable energy policies and promoting solar power adoption further drives awareness and support for solar energy in Iraq.

The roadmap for the adoption of solar energy in Iraq presents a structured approach that emphasizes collaboration and sustainability over a defined period. It begins with Phase 1 focusing on establishing the necessary regulatory framework, infrastructure, and initial investments from both the government and private sector. Phase 2 sees the scaling up of solar energy projects, with increased support from the government and continued engagement with international partners. Phase 3 aims at achieving energy security and sustainability through further expansion of solar capacity, regional collaborations, and integration into the national grid. Finally, Phase 4 emphasizes the long-term sustainability and community involvement, highlighting the importance of stable regulatory environments, innovation, citizen participation, and advocacy for sustainable energy practices. Overall, the roadmap provides a comprehensive strategy for Iraq's transition to solar energy; It asserts the potential for a sustainable energy future while acknowledging the complexities involved.

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Declaration of Competing Interest

There is no conflict of interest in this study.

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