T.C.
ISTANBUL GEDİK UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

UTILIZATION OF ENGINEERING MANAGEMENT PRINCIPLES IN THE ADOPTION OF SOLAR ENERGY IN IRAQ

MASTER'S THESIS

Ahmed Kamil Ahmed ALBO HAMED

Engineering Management Department

Engineering Management Master in English Program

OCTOBER 2023
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Bu çalışma 06.10 2023 tarihinde aşağıdaki jüri tarafından Engineering Management Department, Engineering Management (Tezli Yüksek Lisans) Programı Yüksek Lisans Tezi olarak kabul edilmiştir.

TEZ JÜRİSİ

Dr. Öğr. Üyesi Tuğbay Burçin GÜMÜŞ
Danışman
İstanbul Gedik Üniversitesi

Doç. Dr. Redvan GHASEMLOUNIA
Üye (İmza)
İstanbul Gedik Üniversitesi

Prof. Dr. Gözde ULUTAGAY
Üye (İmza)
Ege Üniversitesi

DECLARATION

I, Ahmed Albo HAMED, hereby certify that this thesis entitled "Utilization of Engineering Management Principles in the Adoption of Solar Energy in Iraq" is my original thesis for the award of Master's Degree in Engineering Management at the Faculty of Engineering Management. I further certify that this thesis or any part thereof has not been submitted and presented for any other degree or research thesis at any other university or institution.

Ahmed Albo HAMED

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First and foremost, I express my profound gratitude to the Almighty God, whose blessings have guided and sustained me on this remarkable journey. His strength, wisdom, and support have been the cornerstones of my achievements, and for that, I am truly thankful.

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I also wish to convey my deep appreciation to my friends and colleagues, whose companionship and invaluable insights have transformed this academic pursuit into an enriching and enjoyable experience. Your contributions played a pivotal role in shaping the direction of my research and expanding my intellectual horizons.

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FOREWORD

It is with great pleasure and a profound sense of accomplishment that I introduce this master's thesis, titled "Utilization of Engineering Management Principles in the Adoption of Solar Energy in Iraq." This work represents the culmination of extensive research, dedication, and a deep commitment to addressing one of the most critical challenges of our time: the transition to sustainable and renewable energy sources.

The adoption of solar energy in Iraq is not merely an academic pursuit; it is a matter of paramount importance with far-reaching implications for the nation's energy security, economic development, and environmental stewardship. Against a backdrop of global climate change concerns and the imperative to reduce reliance on finite fossil fuel resources, this thesis endeavors to shed light on a path forward.

In this endeavor, the author has delved into the rich and multifaceted domain of engineering management, drawing upon its principles, strategies, and best practices. Through meticulous research and analysis, the thesis explores how these principles can be harnessed as a guiding framework for the successful integration of solar energy into Iraq's energy landscape.

The journey that unfolds within these pages traverses a diverse array of topics, from the historical evolution of engineering management to the practical applications of solar energy in Iraq. It touches upon the collaborative efforts of governments, private sector entities, academic institutions, and citizens in realizing a sustainable energy future for the nation.

This thesis is a testament to the author's unwavering commitment to academic excellence and their passion for contributing to solutions that transcend the academic realm and hold the potential to drive real-world change. It is a reminder that research is not an isolated pursuit but a collective endeavor, one that requires the collaboration of minds and the synergy of ideas.

As you embark on this academic journey through the pages of "Utilization of Engineering Management Principles in the Adoption of Solar Energy in Iraq," I invite you to consider the broader implications of the work presented here. It is a testament to the power of human innovation and collaboration in addressing the most pressing challenges of our time.

May this thesis serve as both an inspiration and a practical guide for those who seek to bring about positive change in our world, one that is characterized by sustainable energy practices, environmental responsibility, and a brighter future for all.

October 2023 Ahmed Albo HAMED

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ABBREVIATIONS

DNI : Direct Normal Irradiance
EBR : Experimental Breeder Reactor
EU : European Union
FiTs : Feed-in Tariffs
GW : Gigawatts
IPCC : Intergovernmental Panel on Climate Change
IREA : International Renewable Energy Agency
MW : Megawatts
TQM : Total Quality Management
UNFCCC : United Nations Framework Convention on Climate Change

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UTILIZATION OF ENGINEERING MANAGEMENT PRINCIPLES IN THE ADOPTION OF SOLAR ENERGY IN IRAQ

ABSTRACT

The challenges faced by developing countries in meeting their energy demands are becoming increasingly complex. These challenges range from limited access to reliable and affordable energy sources to concerns about environmental sustainability. In recent years, the adoption of renewable energy technologies, particularly solar energy, has emerged as a promising solution to address these challenges. This thesis aims to explore the utilization of engineering management principles in overcoming obstacles and implementing solar energy solutions in developing countries, with a specific focus on Iraq as a case study.

This abstract provides a concise overview of a master's thesis that focuses on the energy sector in Iraq, particularly examining the current situation, challenges, and the potential of solar energy. The role of engineering management principles in adopting solar energy as a viable alternative in Iraq is also highlighted. Key sections of the thesis are outlined, including the introduction, literature review, energy sector in Iraq, solar energy in Iraq, research methodology, analysis and results, the role of engineering management principles, and the conclusion and recommendations.

First the topic is introduced, explained the purpose of the thesis is explained, and the published literature around different aspects of the subject-matter is reviewed.

Next, the thesis examines the electricity sector in Iraq, providing insights into its evolution over time, its current situation and future outlook. The challenges faced by the electricity sector in Iraq are also discussed, highlighting the key obstacles and issues that need to be addressed and why solar could be a solution.

Also, an elaboration is done on the state of solar energy in Iraq. The contextual suitability of solar energy in the country is examined while explaining the merits of solar energy, emphasizing the benefits, advantages, and potential impact on the energy sector and overall sustainability.

Following to that, an overview of the research methodology employed in the study is provided by outlining the approach, data collection methods, and analytical techniques used with an emphasis on the rigorous process undertaken to ensure the reliability and validity of the findings.

Later, the data analysis is conducted, and the results were derived, followed by discussing the key findings, insights, and trends identified. This analysis provides a comprehensive evaluation of the collected data, linking the results to the research objectives and addressing any research questions posed in the study.

Then the thesis delves into the role of engineering management principles in adopting solar energy as a viable alternative in Iraq. It explores how effective engineering management practices and can contribute to the successful implementation and utilization of solar energy projects in the country.

Finally, the conclusion and recommendations derived from the research findings were presented while summarizing the main outcomes and implications of the study, drawing on the analysis of the energy sector in Iraq and the potential of solar energy. The thesis is then closed with recommendations for policymakers, stakeholders, and researchers, suggesting a general roadmap to overcome challenges and maximize the benefits of solar energy in Iraq.

Keywords: *Energy sector, Iraq, Solar, Challenges, Potentials, Analysis, Engineering management principles, Adoption*

IRAK'TA GÜNEŞ ENERJİSİNİN BENİMSENMESİNDE MÜHENDİSLİK YÖNETİM İLKELERİNİN KULLANIMI

ÖZET

Gelişmekte olan ülkelerin enerji taleplerini karşılama konusundaki zorluklar giderek daha karmaşık hale gelmektedir. Bu zorluklar, güvenilir ve ekonomik enerji kaynaklarına sınırlı erişimden çevresel sürdürülebilirlik endişelerine kadar uzanmaktadır. Son yıllarda, özellikle güneş enerjisi başta olmak üzere yenilenebilir enerji teknolojilerinin benimsenmesi, bu zorlukları ele almak için umut vaat eden bir çözüm olarak ortaya çıkmıştır. Bu tez, Irak'ta güneş enerjisi çözümlerini geliştirme ve uygulama konusunda mühendislik yönetimi prensiplerinin kullanımını keşfetmeyi amaçlamaktadır.

Irak'ta enerji sektörüne odaklanan tez, özellikle sektördeki mevcut durumu, zorlukları ve güneş enerjisinin potansiyelini incelemektedir. Irak'ta güneş enerjisini uygun bir alternatif olarak benimsemeyi amaçlayan mühendislik yönetimi prensiplerinin rolü de vurgulanmaktadır. Tez, literatür taraması, Irak'taki enerji sektörü, güneş enerjisi çalışmaları, araştırma yöntemleri, analizleri, mühendislik yönetimi prensiplerinin rolü ve konu ile ilgili önerileri içerecek şekilde tasarlanmıştır.

Tez, Irak'taki elektrik sektörünü inceleyerek zaman içindeki evrimini, mevcut durumunu ve gelecek perspektifini sunar. Irak elektrik sektörünün karşılaştığı zorluklar da tartışma konusu olarak ele alınmış ve güneş enerjisinin bir çözüm olabileceği ana engeller ve sorunlar vurgulanmıştır.

Ülke içinde güneş enerjisinin bağlamsal uygunluğu incelenirken güneş enerjisinin avantajları, faydaları, enerji sektörüne ve genel sürdürülebilirliğe potansiyel etkileri incelenmiştir.

Tez, Irak'ta güneş enerjisinin uygun bir alternatif olarak benimsenmesinde mühendislik yönetimi prensiplerinin rolünü ele alır. Etkili mühendislik yönetimi uygulamalarının ülkede güneş enerjisi projelerinin başarılı uygulanmasına ve kullanılmasına nasıl katkı sağlayabileceğini araştırmıştır.

Son olarak, araştırma bulgularından türetilen sonuçlar ve öneriler sunulmuş, enerji sektörünün Irak'taki analizi ve güneş enerjisinin potansiyeli üzerine yapılan analize dayanarak ana sonuçları ve etkilerini özetlenmiştir. Tez, politika yapıcılara, paydaşlara ve araştırmacılara, Irak'ta güneş enerjisinin zorlukları aşmak ve faydalarını en üst düzeye çıkarmak için genel bir yol haritası sunmaktadır.

Anahtar Kelimeler: *Enerji sektörü, Irak, Güneş, Zorluklar, Potansiyeller, Analiz, Mühendislik yönetimi prensipleri, Benimseme*

1. INTRODUCTION

1.1 Study Topic

The energy challenges that Iraq has grappled with for decades are not to be underestimated. These challenges have been exacerbated by a series of factors, making them formidable obstacles to the country's energy sector development. Among these factors, war-induced infrastructure damage that has left Iraq with a legacy of vulnerability in its energy supply chain.

Another challenge for Iraq's energy sector is overreliance on a fossil fuel supply that is susceptible to global market fluctuations, obstructing a consistent and affordable energy supply.

Furthermore, the problem of illegal grid trespassing, where unauthorized entities drain electricity without proper payment or regulation, has further strained the energy sector's capacity. This has led to a lack of trust and unreliable power supply that has hindered progress and economic growth.

Amidst these challenges, however, Iraq has a transformative opportunity. The country possesses an abundance of sunlight, making it ideal for economically feasible solar power generation. The high solar direct normal irradiance (DNI) of up to 6.67 kWh/m² per day (Global Solar Atlas) in Iraq is a valuable, untapped resource that, if harnessed effectively, can revolutionize the energy landscape.

The core of this thesis lies in recognizing the pivotal role of engineering management principles in unlocking Iraq's solar energy potential. By employing systematic and strategic approaches, engineering management can help Iraq overcome its energy challenges. This involves not only harnessing solar energy but also optimizing its integration into the existing energy infrastructure.

The decision to select this thesis topic is grounded not only in Iraq's inherent potential but also in the tangible successes of neighbouring countries. The United Arab Emirates, for instance, serves as an example of how embracing engineering management principles has facilitated remarkable growth in solar power capacity to

2.3 Gigawatts (GW) and still growing. This success story is a testament to the effectiveness of the principles and practices that will be explored in this thesis.

Moreover, the global context adds urgency to this research. The steady increase in global investments in solar power, reaching over $239 billion (Bloomberg NEF) in a single year, demonstrates the growing recognition of solar energy as a critical component of the world's energy future. Iraq, by capitalizing on this trend, can reduce its economic vulnerability and create a new job market focused on the installation, maintenance, and management of solar infrastructure.

Importantly, embracing solar energy can have profound environmental benefits, helping Iraq reduce its carbon footprint and contribute to global climate goals. By transitioning away from fossil fuels, the country can improve air quality, mitigate climate change, and enhance the overall quality of life for its citizens.

In conclusion, this thesis topic is chosen not just to explore possibilities but to drive transformation.

1.2 Purpose of Thesis

This master's thesis focuses on using Iraq as a case study to investigate how the application of engineering management principles can facilitate the adoption of solar energy solutions in alignment with the global shift towards eco-friendly power sources. The aim is not only to explore the technical aspects but also to assess how engineering management science can contribute to enhancing human welfare by improving living standards. All of this is done while considering the economic viability and practicality of the proposed solutions.

The study has several specific tasks it intends to accomplish:

1) Provide an Overview of the Energy Sector in Iraq

   The thesis will begin by offering a comprehensive overview of Iraq's energy sector. This includes tracing its historical evolution, understanding the current challenges it faces, and highlighting the untapped potentials within the sector.

2) Prove the Advantages of Solar Power

   Despite being an oil-producing country, Iraq's exploration of solar power will be thoroughly examined. The thesis will seek to demonstrate the advantages

of solar energy compared to fossil-fuel power sources. This will underline the versatility and sustainability of solar power, even in a nation with abundant oil resources.

3) Present User-Based Data Analysis

   To provide concrete evidence and support the findings, the study will employ a user-based data analysis approach. This means that real-world data, potentially from surveys or similar sources, will be used to substantiate the research findings. This approach adds a practical dimension to the thesis, grounding it in real-world experiences.

4) Suggest a Roadmap for Solar Energy Adoption

   An essential aspect of the research is to propose a roadmap for adopting solar energy solutions in Iraq. This roadmap will be based on engineering management principles, emphasizing efficient project management, resource allocation, and implementation strategies. It will provide practical steps for the country to transition towards solar energy.

In pursuit of these objectives, the thesis conducted a thorough investigation. It gathered data through desk reviews and surveys, which were meticulously analyzed. The findings and insights obtained from this research process are expected to not only contribute to the academic understanding of the subject but also to the practical application of renewable energy solutions in the context of Iraq. Ultimately, the thesis aims to advance the cause of environmental sustainability and human welfare by advocating for the responsible adoption of eco-friendly energy sources in the country.

1.3 Global Outlook on the Adoption of Solar Energy

The 21st century has ushered in a new era of consciousness, where humanity faces the twin challenges of energy security and environmental sustainability. The overreliance on fossil fuels has led to severe consequences, such as climate change, air pollution, and resource depletion. In response to these concerns, the world has witnessed a growing recognition of the importance of sustainable and renewable energy sources, especially solar in the case of Iraq which is the centre of this thesis where the utilization of engineering management principles is explored to help tackle

the challenges that face the adoption of solar energy as a viable alternative source of power.

Fortunately, over the past few decades the world has witnessed a growing awareness of the need to transition from fossil fuels to sustainable and renewable energy sources. This urgency has been highlighted through various global summits and agreements aimed at addressing climate change and fostering a sustainable energy future. Notable among these are:

- The Intergovernmental Panel on Climate Change (IPCC) Reports:

  The IPCC, established by the UN in 1988, has been instrumental in collating scientific evidence on climate change and its impacts. The IPCC's special reports on renewable energy, such as "Renewable Energy Sources and Climate Change Mitigation" (2011) and "Global Warming of 1.5°C" (2018), have emphasized the necessity of a rapid transition to sustainable energy sources to mitigate the catastrophes of climate change.

- United Nations Framework Convention on Climate Change (UNFCCC)

  The UNFCCC, established during the Earth Summit in Rio de Janeiro in 1992 to lead the international efforts to address climate change. It laid the groundwork for subsequent climate negotiations and agreements like the Kyoto Protocol in 1997 and the Paris Agreement in 2015.

- International Renewable Energy Agency (IREA)

  Founded in 2009, the IREA plays a crucial role in promoting the widespread adoption of renewable energy on a global scale. It facilitates cooperation among member states, providing technical expertise, and supporting the development of policies and frameworks.

The lobbying efforts within those forums led to recognitions on decision-makers level, thus contributed to the adoption of many directives and policies worldwide, such as;

- Directive by the European Union (EU)

  The EU's Clean Energy Package, adopted in 2018, aims for at least 32% of total energy consumption to come from renewable sources by 2030. The

directive outlines measures to drive this transition, enhance energy efficiency, and foster innovation in clean technologies.

- Germany's Energiewende:

  Germany's transition to renewable energy, known as the Energiewende, aims to covering 65% of the country’s energy needs through renewable sources by 2030 to significantly reduce greenhouse gas emissions.

- China's Commitment to Renewables:

  China, being a global leader in renewable energy investment, has internally activated many policies such as Feed-in Tariffs (FiTs) and Grid Integration to promote renewable sources.

1.4 Literature Review

Electric power generation has played a pivotal role in shaping modern society, fuelling industrialization, technological advancements, and improving the quality of life. Understanding the historical development of electricity generation is essential for comprehending the current energy landscape.

This literature review provides an in-depth analysis of the history of electric power generation, examining its various phases and eras on a global scale while incorporating a specific focus on the development of electricity generation in Iraq. Furthermore, it emphasizes the significance of solar power as a sustainable solution for meeting energy needs. This review explored a range of scholarly articles, reports, books, and data to present a comprehensive overview of the topic.

1.4.1 Global development of electric power generation

- Early Beginnings and the Age of Steam

  The dawn of electric power generation was marked by the invention of the dynamo by Michael Faraday in the 1830s. The Age of Steam witnessed the use of reciprocating steam engines to generate electricity, with notable advancements made by Thomas Edison and Nikola Tesla, leading to the establishment of the first commercial power stations in the late 19th century. “After about 1905 steam turbines were the only drivers considered for

thermal power stations. In fact, 80-85 % of all the electricity produced in the world produced in generators driven by steam turbines" (Lovland, 2007).

- The Age of Fossil Fuels and Centralized Power Plants

  Even though the first gas-operated power station was built in New York, USA in 1882 and the same year witnessed the construction of the Holborn Viaduct power station in London, UK as the first oil-operated power station, but it is at the early 20th century when a global shift was witnessed towards centralized power plants fuelled by fossil fuels. These power plants, such as coal-fired steam turbines and gas turbine plants, became the backbone of electricity generation globally. Rapid industrialization and urbanization propelled the expansion of power grids, meeting the growing demand for electricity. "Since the 1990s, electricity production has been driven towards generation concentration and a higher degree of integration leading to the current centralized electricity paradigm" (Martin, 2009).

- Nuclear Power and the Atomic Age

  The mid-20th century marked the emergence of nuclear power as a significant source of electricity generation. Nuclear fission was harnessed to produce steam, driving turbines and generating electricity. "The first nuclear reactor to produce electricity (albeit a trivial amount) was the small Experimental Breeder Reactor (EBR-1) designed and operated by Argonne National Laboratory and sited in Idaho, USA. The reactor started up in December 1951… and in June 1954 the world's first nuclear powered electricity generator began operation at the FEI in Obninsk." (Hore-Lacy, 2007). Atomic Age saw the construction of nuclear power plants worldwide, although concerns regarding safety and waste management later influenced public opinion and policy decisions.

- Renewable Energy, Specifically Solar

  Even though the research and experiments on the photovoltaic semiconductors have begun decades before, but it was "In 1954, while experimenting the newly discovered silicon transistors, three American scientists working for the Bell Laboratories, Daryl Chapin, Calvin Fuller, and Gerald Pearson developed a solar cell that could convert enough solar energy

into electricity to run any usual electrical equipment." (Szabó, 2017). From that point on started the journey for raising the system's capacity from the initial 6% to make it a viable option where "the USA in 1958, was the world's first solar-powered satellite" (Szabó, 2017). More breakthrough rapidly followed in the 1970s and 1980s and still happening in the semiconductors and photovoltaic industries where the efficiency is increased, and the economic feasibility greatly improved to make solar power systems the go-to option for most remote application.

1.4.2 Electric power generation in Iraq: phases and eras

Electricity generation in Iraq began in the early 20th century, specifically in 1917 in Baghdad on a small scale that gradually grew until "Al-Sarafia station was opened in 1933 … in 1955, Baghdad Light and Power limited company was nationalized." (Al-Saffar, 2021).

The construction of the Haditha Dam on the Euphrates River in the 1950s marked a significant milestone in Iraq's power generation history. Other hydroelectric projects, including the Mosul Dam and Dukan Dam, further contributed to the expansion of generation capacity.

Following the discovery of vast oil reserves in Iraq, the country witnessed a shift towards thermal power plants fuelled by oil and natural gas. Large-scale power plants, such as the Al-Quds Power Station and the Baiji Power Station, were constructed, providing a substantial share of Iraq's electricity needs. However, dependence on fossil fuels led to challenges related to price volatility, environmental concerns, and geopolitical factors.

In recent years, Iraq has recognized the importance of diversifying its energy mix and reducing dependence on fossil fuels. Renewable energy, particularly solar power, has gained prominence. Iraq's solar potential is significant due to its geographic location with ample sunshine. Initiatives have been undertaken to develop solar power plants, such as the Samawah Solar Power Plant, as well as solar rooftop installations in residential and commercial sectors.

The history of electric power generation globally and in Iraq reflects a remarkable journey of technological advancements and shifts in energy sources. While fossil fuels and nuclear power have dominated the energy landscape for

decades, the increasing recognition of renewable energy's potential, particularly solar power, is transforming the electricity sector, study “becomes necessity for vast investment to develop the solar energy infrastructure in terms of shared or localized plants with viable storage capacity to serve the growing demands” (Abed, 2014).

1.5 Hypothesis

The hypothesis for this thesis posits a strong and logical connection between the utilization of engineering management principles and the enhanced adoption of solar energy solutions in Iraq, ultimately leading to an improvement in living standards. By leveraging effective engineering management practices, such as project planning, risk assessment, and cost analysis, it is anticipated that the complex challenges associated with implementing solar energy systems in Iraq can be systematically addressed and mitigated. This, in turn, is expected to make solar energy solutions more accessible, economically viable, and reliable for the Iraqi population, thereby increasing their likelihood of adoption. As solar energy offers a sustainable and clean alternative to conventional energy sources, its greater adoption can lead to reduced greenhouse gas emissions, improved energy security, and lower energy costs, all of which contribute to an enhanced quality of life and socioeconomic development in Iraq. Consequently, this study seeks to explore the extent to which engineering management principles can serve as a catalyst for advancing the utilization of solar energy and, by extension, contribute to an improving the socio-economic well-being of the Iraqi population.

1.6 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” (Mingers, 2001).

On that count, this thesis combined a literature review (desk review) of the papers and research published in the relevant topics with a case study done in Iraq that involved a questionnaire.

To address the research objectives, this thesis began by understanding the power sector in Iraq and linked its challenges and opportunities to the project management principles through;

1) A comprehensive examination of the literature, including books, papers, websites, and electronic journals, was conducted to develop and assess competence models.
2) Perform research with end users and field experts and soliciting their feedback.
3) Statistically analyzing the gathered data to generate results and develop the conclusion and recommendations.

The following diagram details the specific methods utilized in this thesis.

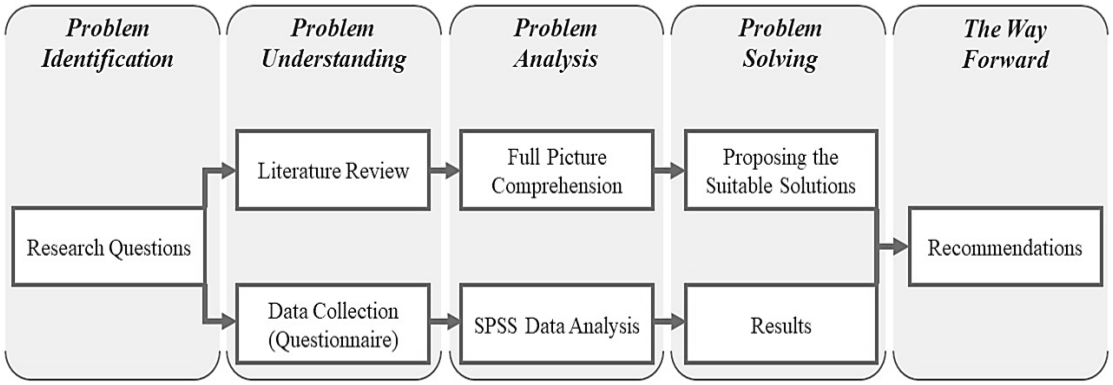

Figure 1.1: Research Framework

Source: Author

1.7 Limitations

In the pursuit to advancing sustainable energy solutions, the utilization of engineering management principles to drive the adoption of solar energy in Iraq holds great promise. However, this endeavour is restricted by a series of limitations that may impede its progress.

Key limitations include:

Geopolitical Instability and Security Concerns: The ongoing geopolitical instability and security issues in Iraq have cast its shadow over research and project implementation, posing challenges for data collection and long-term planning.

Infrastructural and Technological Constraints: The country’s inadequate infrastructure, particularly in remote areas, hinders the effective deployment of solar energy systems, making it difficult to execute projects and gather essential data.

Economic Challenges and Funding Shortages: Limited financial resources and economic constraints in Iraq present significant hurdles to both research efforts and the actualization of large-scale solar projects.

Cultural and Societal Factors: The deeply rooted cultural and societal familiarity with traditional energy sources, coupled with the need to align with local values and preferences, influence the initial acceptance and integration of solar energy solutions.

Data Accessibility and Quality: The availability and accuracy of data related to energy consumption, solar potential, and infrastructure conditions are inconsistent and challenging to access, affecting research precision.

Regulatory and Legal Framework: A lack of clear, supportive regulatory and legal frameworks can lead to bureaucratic obstacles and legal uncertainties, slowing down solar energy project implementation.

Environmental and Climate Factors: Iraq's unique climate conditions, one of which is the seasonal dust storms, may pose challenges for the performance and maintenance of solar energy systems.

In navigating these multifaceted limitations, it is imperative to take a holistic and multidisciplinary approach based on a comprehensive risk management plan to ensure that the right measures are established and are applicable. Acknowledging that the complexities are not only technical but also the social, economic, and political is essential for a successful solar energy integration. Overcoming these challenges will be instrumental in realizing the vast potential of sustainable energy solutions in Iraq.

2. ELECTRICITY SECTOR IN IRAQ

2.1 Overview on Iraq’s Electricity Sector

Iraq is endowed with abundant energy resources, primarily oil (as one of the biggest oil producers in the world, and the 5th in oil reserve capacity), natural gas, water, and solar irradiance. Some of these resources serve as the backbone of the country's electricity generation, while other are still untapped fully, with most power plants relying on fossil fuels.

Iraq's electricity demand that reaches up to 35 GW has consistently outstripped its supply that ranges between 23 to 30 GW in best cases (Obeid, 2021) through a mix of thermal, hydro, and few renewable energy sources, resulting in frequent power shortages, especially during the scorching summer months when demand peaks.

The electricity grid in Iraq consists of a network of high-voltage transmission lines and substations, followed by distribution systems that deliver electricity to consumers. However,

The electricity sector faces chronic underinvestment and aging infrastructure. This has led to inefficiencies in power generation and distribution, and significant losses.

The political instability has also hampered Iraq's electricity sector leading to inconsistent policies, corruption, and mismanagement. These issues have hindered efforts to attract foreign investment and implement much-needed reforms.

Also, the frequent military conflicts have left the electricity infrastructure vulnerable to attacks and sabotage by various insurgent groups and militias, leading to disruptions in power generation and distribution.

Moreover, the strain on Iraq's economy due to factors like low oil prices, the fight against ISIS, and the COVID-19 pandemic have limited the government's ability to invest as much as needed in the electricity sector.

Despite all these issues, Iraq has been undertaking initiatives to rehabilitate and upgrade its electricity infrastructure, explore diversifying its energy mix by investing in renewable energy sources, working to attract foreign investment and expertise through “Encouraging the private sector to invest in building renewable energy power plants and creating the incentives for it” (Iraq’s Electracy Law, 2017), and explored regional electricity cooperation agreements, including those with neighbouring countries like Iran.

In conclusion, Iraq's electricity sector continues to face significant challenges, but the government is making efforts to address these issues and build a more reliable energy infrastructure. Success in this endeavour will not only improve the quality of life for Iraqis but also contribute to the country's economic growth and stability, and potentially position Iraq as a key player in the regional energy landscape in the future.

2.2 Consumption Patterns

In Iraq, electricity consumption is divided into several sectors, each with its unique demands (residential, industrial, governmental, commercial, and agricultural). Among these sectors, the residential category stands out as the largest consumer of electrical energy. This predominance is primarily driven by several factors. Iraq's population has been steadily increasing, and with growing urbanization, more households are connected to the grid. Moreover, the reliance on electricity for essential daily needs such as lighting, heating, cooling, and household appliances has surged.

However, the concentration of electricity consumption in the residential sector has significant consequences that are particularly acute in the context of Iraq. The heavy demand for electricity often strains the national power grid, leading to frequent power shortages and outages. These disruptions have a direct impact on the daily lives of residents, affecting their ability to access essential services, run businesses, and maintain a comfortable living environment.

Furthermore, the challenge is compounded by the fact that Iraq relies heavily on fossil fuels, such as natural gas and oil, for electricity generation. This dependence on fossil fuels not only contributes to environmental issues, including air pollution

and greenhouse gas emissions but also poses financial challenges for the government. Subsidizing electricity for residential users places a significant burden on the national budget.

To address these issues, Iraq is actively pursuing strategies to mitigate the consequences of heavy residential electricity consumption. This includes efforts to diversify its energy sources, promote energy efficiency measures in households, and invest in renewable energy projects to reduce reliance on fossil fuels. Such initiatives aim to improve the reliability of electricity supply, reduce environmental impact, and ensure sustainable energy access for all citizens.

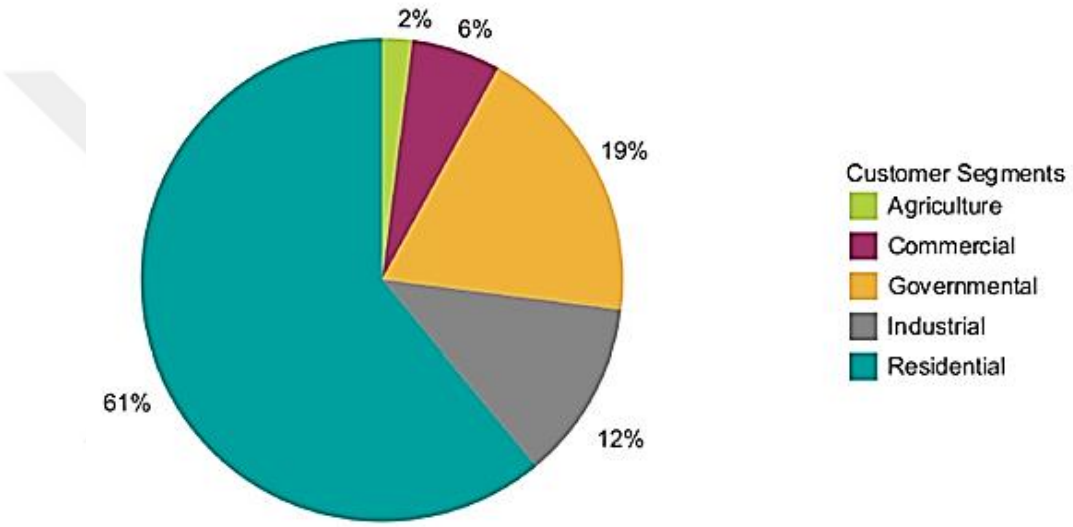

Figure 2.1: Electricity Consumption in Iraq by Category

Source: Iraq Electricity Sector Overview, KAPITA, 2021

2.3 Key Challenges Facing Iraq's Electricity Sector

Numerous challenges hinder the progress and stability of Iraq's electricity sector and have profound effects on the lives and livelihoods of the Iraqi people. Below are the key challenges, their reasons, and impact.

- Supply insufficiency vs. the growing demand

  One of the most pressing challenges in Iraq's electricity sector is the inability to meet the ever-increasing demand for electricity. The population growth, urbanization, and industrial expansion have led to unprecedented surge in electricity consumption.

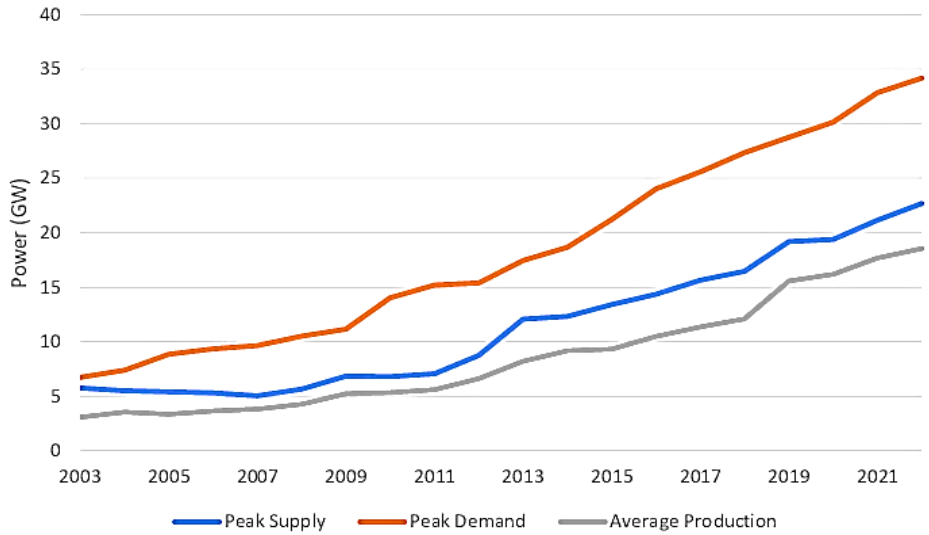

Figure 2.2: Electricity Supply-Demand gap in Iraq

Source: Harry Istepanian and Friedrich Ebert Stiftung, 2022

- Infrastructure Deficiencies

  Decades of conflict (including acts of sabotage, bombings, and attacks), neglect, and underinvestment have deteriorated Iraq's electricity infrastructure which is in constant need rehabilitation. Aging power plants and distribution networks contribute combined with illegal trespassing and theft led to reduced overall efficiency and huge power loss percentage up to 58% compared to only 8% global average (EIA, 2022). The resulting power outages have far-reaching consequences, affecting healthcare, education, economic activities, and overall stability.

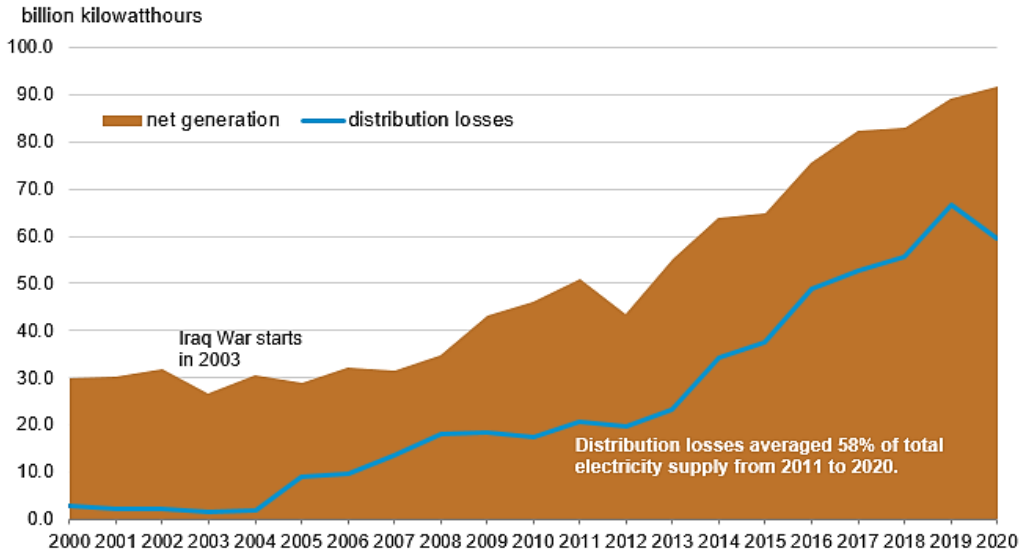

Figure 2.3: Iraq's Electricity Distribution Losses

Source: Energy Information Administration (EIA)

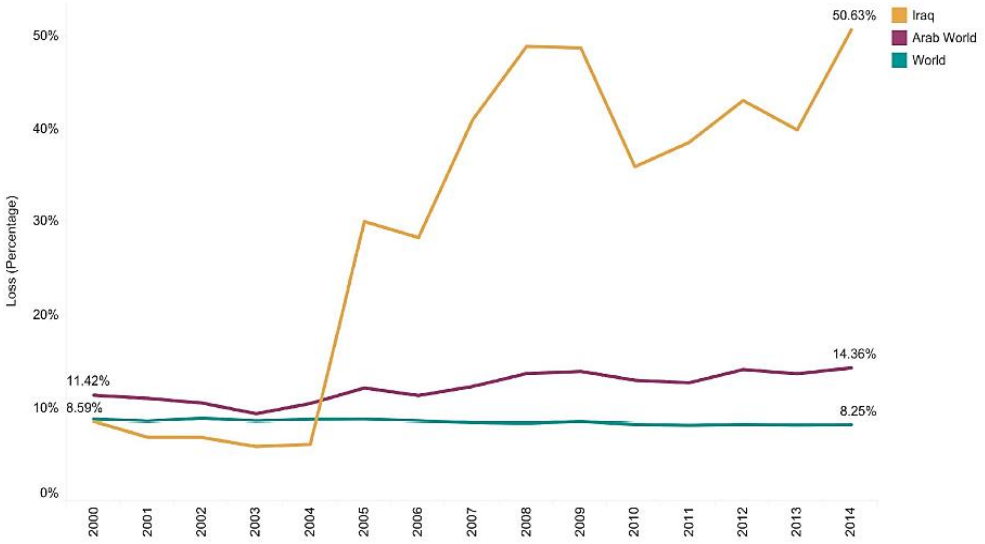

Figure 2.4: Iraq's Electricity Losses Compared to Arab and Global Rates

Source: Iraq Electricity Sector Overview, KAPITA, 2021

- Political Instability and Security Concerns

  Political instability and security concerns significantly hinder Iraq's electricity sector development, impacting its stability and vital services. Frequent government changes and disputes disrupt long-term planning, discouraging investment. Security issues, including attacks on infrastructure due to regional conflicts, lead to electricity disruptions. These challenges affect essential services, hamper industries, and deter foreign investments crucial for sector modernization. To address these issues, Iraq needs political stability, consistent energy policies, and enhanced security measures to safeguard infrastructure. This multifaceted approach can attract investments and foster sector development.

- Corruption, and Mismanagement

  Corruption and mismanagement are major problems to Iraq's electricity sector, hindering its progress and capacity to meet rising power demands. Corruption, including bribery and embezzlement, diverts funds from infrastructure development, leading to underinvestment and an overburdened power grid. Mismanagement exacerbates these issues through nepotism, affecting project quality and timelines. This impacts reliability, causing frequent power outages, disrupting daily life, and straining essential services. Additionally, corruption and inefficiency strain Iraq's budget, diverting

resources from vital public services and infrastructure. Addressing these problems requires anti-corruption measures, transparency in procurement, and improved resource allocation and project management to ensure reliable electricity access and foster broader development.

- Lack of Investment

  The lack of investment is a significant obstacle to Iraq's electricity sector development, hindering its ability to meet rising demand. Despite support from international organizations, a substantial funding gap remains. Attracting private sector investment is challenging due to security concerns and bureaucratic complexities, impeding modernization and expansion efforts. Security issues and regulatory uncertainties deter potential investors, while bureaucratic hurdles slow project implementation. This dearth of investment leaves Iraq with outdated infrastructure and frequent power disruptions, impacting daily life and economic activities. To overcome this challenge, Iraq must create a more investor-friendly environment by improving security conditions, streamlining bureaucracy, and clarifying regulations to encourage private sector participation and revitalize the electricity sector.

- Environmental Concerns

  The heavy reliance on fossil fuels, particularly oil and natural gas, for electricity generation contributes to environmental degradation and air pollution. Iraq's commitment to cleaner energy sources and sustainable practices is hampered by the sector's current composition.

  Also, climate change impacts in Iraq are significant, leaving the country highly vulnerable to temperature extremes, water scarcity, and environmental risks such as dust storms. These factors directly affect energy infrastructure, increase energy demand for cooling, pose health risks, and impact agricultural productivity, thereby affecting the well-being, livelihoods, and resilience of the Iraqi population.

- Regulatory and Governance Issues

  Inefficient regulatory frameworks and governance mechanisms deter potential investors, creating uncertainty and impeding modernization efforts.

Additionally, inefficient pricing methods and subsidies strain public finances, impacting the government's ability to allocate resources effectively. Furthermore, the widespread illegal use of the electricity network by millions of users results in a substantial loss of state revenues, driven by socio-economic factors like poverty and dissatisfaction with service quality. These issues collectively impede progress in the electricity sector and hinder its ability to provide reliable and accessible electricity. Addressing these challenges requires comprehensive regulatory reforms, efficient pricing strategies, targeted subsidies, and broader efforts to alleviate socio-economic factors driving illegal connections.

- Regional and International Dynamics

  Regional and global factors pose significant challenges to Iraq's electricity sector, impacting stability, economic growth, and citizens' well-being. Iraq relies heavily on neighboring nations for electricity due to limited domestic resources and regional complexities. This dependence leads to energy insecurity and interruptions, disrupting daily life and economic planning. Industries, like agriculture and manufacturing, are affected, hindering job creation and economic potential. Complex geopolitics further complicate energy negotiations and agreements, and require Iraq to diversify energy sources, invest in infrastructure, and engage diplomatically with neighbors for stable energy relations. By doing so, Iraq can enhance energy security, foster growth, and improve citizens' lives while mitigating external complexities in its electricity sector.

3. SOLAR ENERGY IN IRAQ

3.1. Solar Energy vs. Fossil-Fuel Energy

Solar energy and fossil-fuel energy are two vastly different sources of power, each with its own set of advantages and disadvantages. When comparing them, especially in the context of environmental sustainability, solar energy holds several key advantages that favour its use over fossil fuels. The below comparison highlights the factors that make investing in developing Iraq's solar energy sector appealing:

Table 3.1: High-Level Comparison between Solar Energy and Fossil-Fuel Energy

Criteria	Solar Energy	Fossil-Fuel Energy
Environmental Impact	Solar power generation produces zero greenhouse gas emissions and has a minimal environmental footprint. It helps combat climate change, reduces air and water pollution, and decreases the reliance on fossil fuels that release harmful pollutants and contribute to global warming.	Fossil fuels, such as coal, oil, and natural gas, release large quantities of carbon dioxide (CO_2) and other pollutants when burned, leading to air pollution, acid rain, and damage to ecosystems. These emissions are a major contributor to climate change.
Sustainability	Solar power is a renewable energy source. The sun's energy is inexhaustible and available for billions of years, making solar a sustainable and long-term solution for power generation.	Fossil fuels are finite resources, and their extraction and consumption contribute to resource depletion and price volatility.
Energy Independence	Solar panels can be installed on-site, reducing dependence on centralized power grids and foreign sources of energy. This promotes energy security and resilience.	Many countries rely on fossil fuel imports, which can make them vulnerable to geopolitical tensions and price fluctuations in the global energy market.
Cost Trends	The cost of solar panels and installation has been steadily declining, making solar power increasingly affordable. Government incentives and tax credits often further reduce the cost for consumers.	Fossil fuel prices are subject to fluctuations due to supply and demand, geopolitical events, and production costs. These uncertainties can lead to volatile energy prices for consumers.

Table 3.1: (Cont.) High-Level Comparison between Solar Energy and Fossil-Fuel Energy

Criteria	Solar Energy	Fossil-Fuel Energy
Job Creation	The solar industry has been a significant source of job creation, employing a wide range of professionals from manufacturing and installation to maintenance and research and development.	While the fossil fuel industry also provides employment, it tends to be less labour-intensive and is more prone to automation
Energy Efficiency	Solar panels have become increasingly efficient in converting sunlight into electricity, with ongoing technological advancements improving their performance	Fossil fuel power plants have inherent inefficiencies in converting the energy stored in fuel into electricity, resulting in waste heat and energy losses.
Infrastructure Resilience	Distributed solar installations enhance grid resilience by reducing the risk of large-scale power outages due to extreme weather events or equipment failures.	Centralized fossil fuel power plants are vulnerable to supply disruptions and are often affected by extreme weather conditions.

While solar energy offers numerous advantages over fossil fuels, it's essential to acknowledge that a proper transition to solar energy will require significant investment, infrastructure development, and ongoing research to address challenges such as energy storage and intermittency. Nonetheless, the long-term benefits in terms of environmental sustainability and energy security make solar energy a favourable choice for the future.

3.2. Overview on Iraq’s Solar Electricity Capacity

Iraq is known for its rich history, vast energy resources, and an abundant sunshine throughout the year. With an average of 300 sunny days annually, Iraq is perfectly located for harnessing solar power especially in the southern and western regions that have the highest solar irradiance levels.

On that front, the government of Iraq has initiated several solar projects, both in the form of utility-scale solar farms and distributed solar installations. The under-construction solar projects in Iraq include a 750 MW plant in Al-Samawah, and Al-Dibdibah project with a capacity of 300 MW with other projects in the study and design phases. These projects aim to diversify Iraq's energy mix, reduce greenhouse gas emissions, and decrease its reliance on fossil fuels.

Even though Iraq's solar potential is immense, there are several challenges and barriers to overcome such as political instability, security concerns, infrastructure investments and financing, integration into the existing electricity grid, and the need for clear and supportive policies, regulations, and incentives to encourage the development of solar power sector.

Despite these challenges, Iraq's commitment to solar power remains strong, and while the current percentage of electricity generated by solar energy is less than 1%, the government has an ambitious vision, aiming to generate up to 30% of the national demand from renewable resources (including solar) by 2030 (IEA, 2019).

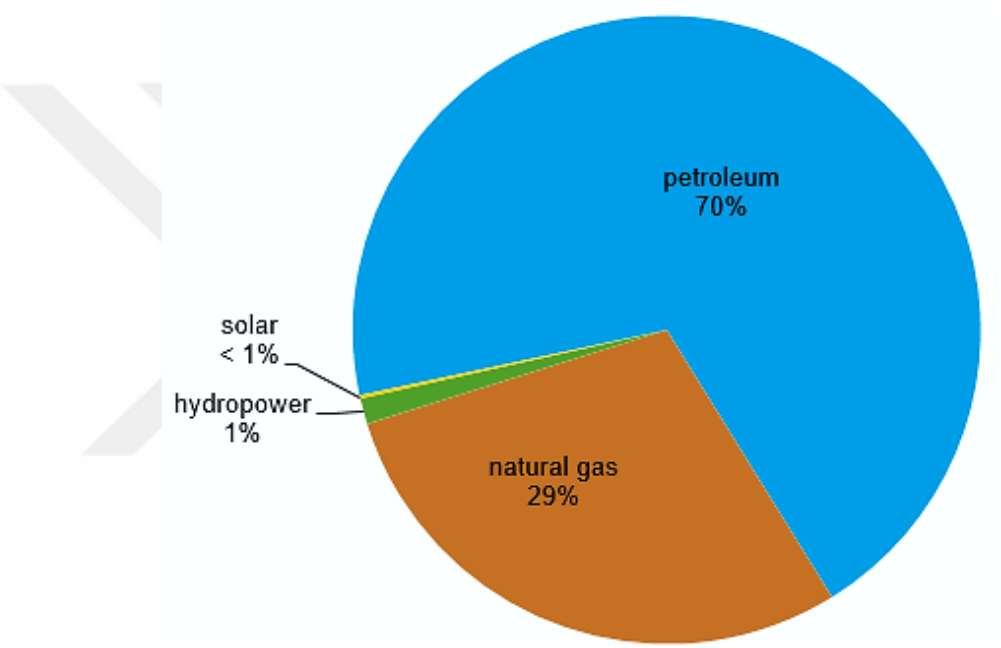

Figure 3.1: Electricity Generation Percentage by Source in Iraq

Source: US Energy Information Administration, Statistical Review of World Energy, 2022

3.3. Potentials of Solar Energy in Iraq

Iraq, a country that lies in the heart of the Middle East and that comes with an immense potential. Despite its turbulent history, Iraq should now take the chance and start to embrace a sustainable future through solar energy.

Settled in an arid landscape, and with a suitable weather condition, Iraq also has abundant sunshine year-round, making it an ideal candidate for solar energy development.

To elaborate, below are the key country-specific potentials that make solar energy such a viable option for Iraq:

1) Abundant Solar Irradiance

Iraq's strategic location in the Sun Belt region ensures an exceptional solar energy potential, with abundant solar irradiance due to its long, hot summers. This consistent sunlight is a valuable and reliable resource, making Iraq well-suited for harnessing solar energy. With clear skies and intense solar radiation, the country enjoys allowing an uninterrupted sunlight exposure that maximizes the efficiency of solar power systems. Iraq's high solar insolation, coupled with long daylight hours, further boosts its capacity to generate electricity from solar.

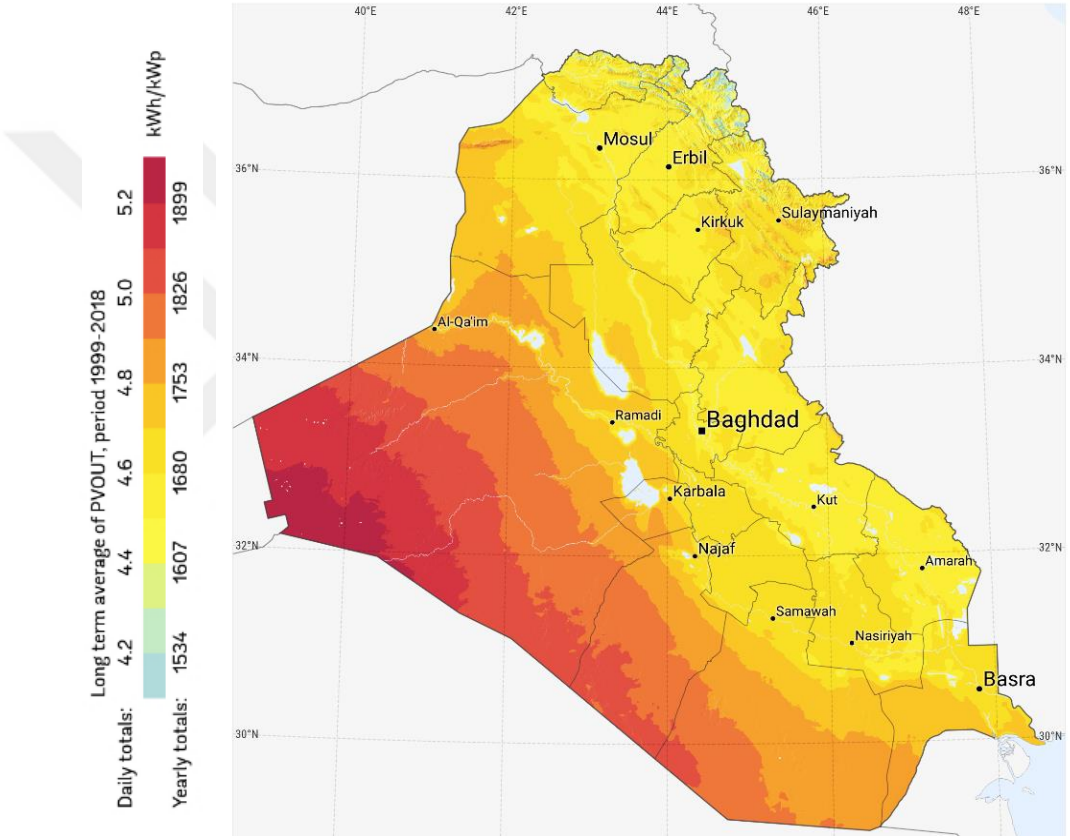

Figure 3.2: Photovoltaic Power Potential in Iraq

Source: Global Solar Atlas (https://globalsolaratlas.info)

2) Optimal Land Availability

Iraq's extensive flatlands in the southern and western regions offer ideal terrain for large-scale solar energy projects. These vast, level areas provide ample space for solar panel installations, making them well-suited for meeting the country's growing electricity needs. Since many of these lands are deserts, there are minimal land-use conflicts, and solar installations can be deployed without significant disruptions. The flat terrain ensures uninterrupted sunlight exposure, optimizing

energy production. Overall, Iraq's open terrains are conducive to large-scale solar power projects, minimizing environmental impact and contributing to energy security and sustainability goals.

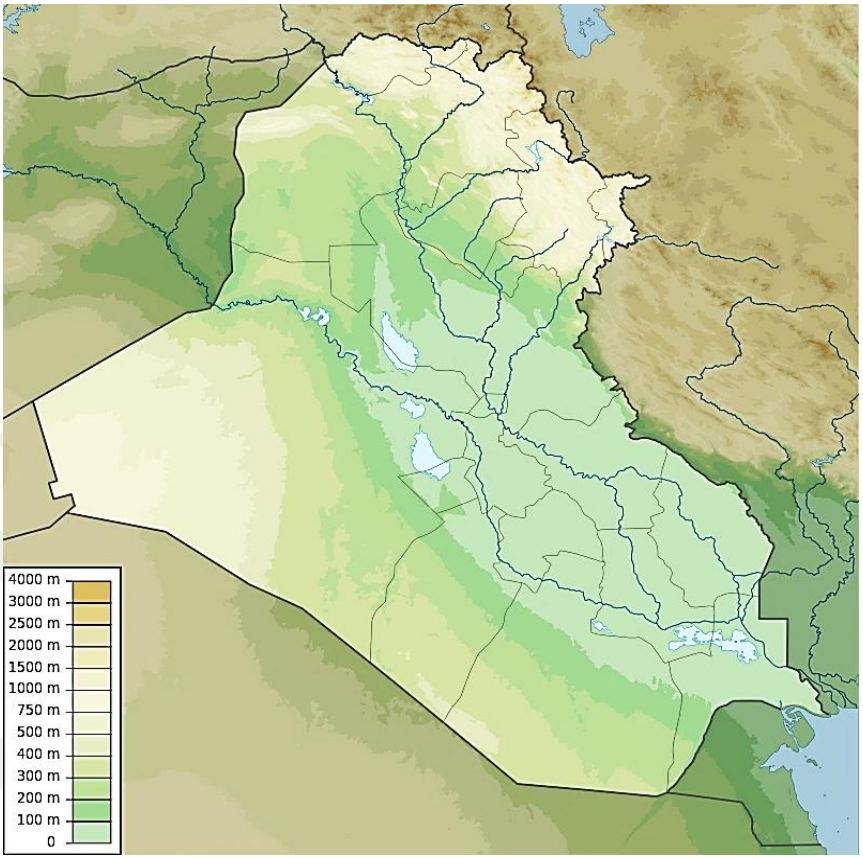

Figure 3.3: Iraq’s Topographic Map

Source: www.google.com

3) Low Precipitation

Iraq's solar energy potential benefits from its climate, including low annual precipitation levels and minimal cloud cover. Clouds can diminish solar panel performance by scattering and blocking sunlight. In regions with frequent cloud cover, solar energy generation can be inconsistent. Yet, in Iraq's arid regions with clear skies, there are fewer obstacles between the sun and solar panels, ensuring maximum sunlight absorption and a more predictable energy generation pattern. This reliability benefits both energy consumers and providers. Consumers enjoy stable electricity, while providers benefit from efficient grid management.

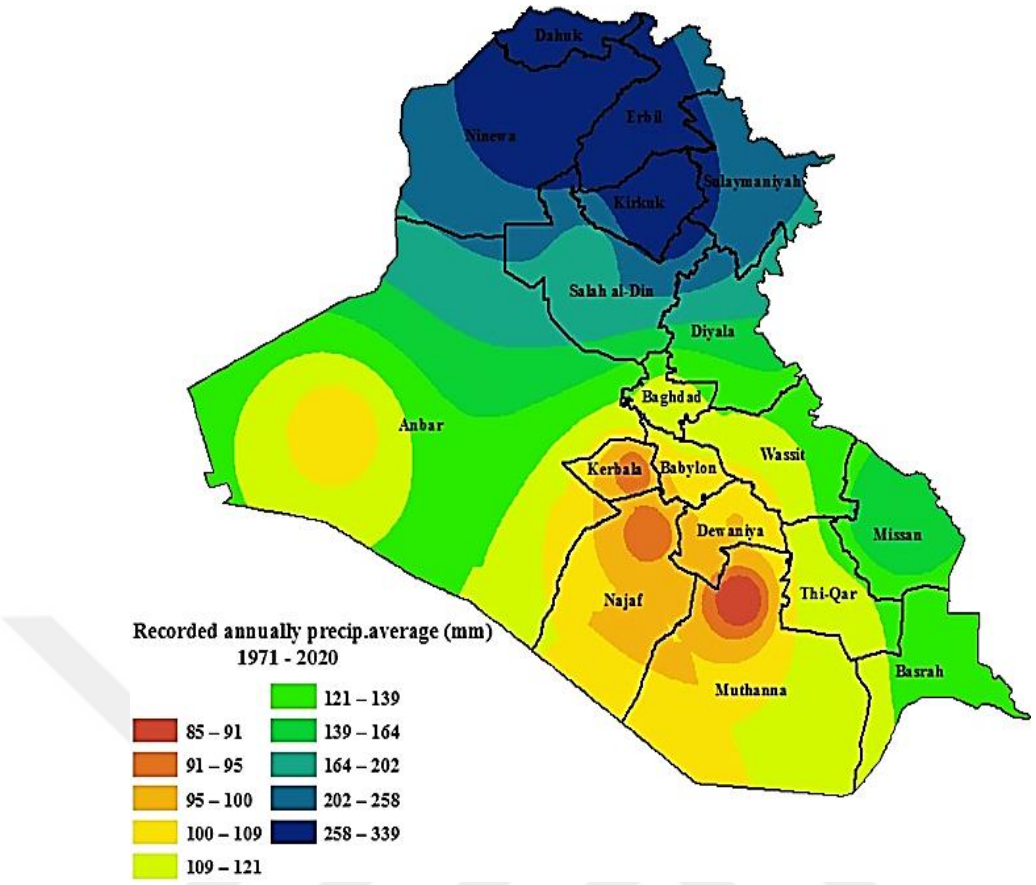

Figure 3.4: Iraq's Precipitation Map

Source: www.google.com

By leveraging these factors, Iraq can transition towards a sustainable and resilient energy future, reducing dependence on fossil fuels, mitigating environmental impact, and promoting economic development. However, a successful implementation requires supportive policies, investment in infrastructure, capacity building, and stakeholder collaboration. With a comprehensive strategy, Iraq can unlock the full potential of solar power and pave the way towards a sustainable and resilient energy future.

3.4. Potentials of Solar Power in Addressing Iraq's Electricity Problems

Addressing these challenges requires a comprehensive approach, encompassing infrastructure rehabilitation, energy diversification, policy reforms, good governance, regional cooperation, and climate change adaptation strategies. By effectively tackling these challenges, Iraq can enhance energy security, improve the quality of life for its citizens, and foster sustainable socio-economic development.

The challenges analysed include the destruction of infrastructure due to armed conflicts, high costs of fossil fuel, illegal trespassing by millions of users, reliance on neighbouring countries and political complexity, degradation of operation requirements, and climate change.

Solar power sources have the potential to play an integral part in that comprehensive approach for tackling the electricity issues due to the following features and capabilities:

1) Infrastructure Resilience and Independence

   Solar power provides a decentralized energy solution that is less vulnerable to infrastructure damage caused by armed conflicts. With the ability to install solar panels on rooftops and scattered locations, solar systems can enhance the infrastructure resilience and ensure a reliable energy supply to communities affected by conflicts.

2) Quick Rehabilitation and Reconstruction

   Solar power offers a rapid and cost-effective solution for energy infrastructure rehabilitation, especially in the conflict-affected areas. Compared to traditional power plants, solar installations can be deployed quickly, requiring less time for reconstruction, and bringing back electricity supply to the affected communities sooner.

3) Cost-Effectiveness and Reduced Dependence on Imports

   On the long-term, solar power provides a cost-effective alternative to expensive fossil fuel imports. By harnessing abundant sunlight, solar power reduces the dependence on costly fuel imports, thereby mitigating the financial burdens.

4) Lower Energy Costs and Increased Affordability

   Adopting solar power can lead to reduced energy costs for consumers, making electricity more affordable and accessible. The availability of affordable energy can improve living standards, stimulate economic growth, and enhance opportunities for social development.

5) Enhanced Energy Access and Improved Governance

   Solar power can help combat illegal trespassing by providing legal and affordable energy options. By expanding energy access and offering cost-effective solutions, solar power discourages unauthorized connections and promotes a culture of legal energy consumption.

6) Revenue Generation and Loss Reduction

   Adopting solar power enables revenue generation for the government and utility companies through legal connections and proper billing mechanisms. This revenue can be reinvested in improving energy infrastructure and services, reducing losses, and enhancing the overall sustainability of the energy sector.

7) Energy Independence and Geopolitical Stability

   Solar power offers a pathway to reduce reliance on energy imports, mitigating geopolitical risks, and improving energy independence. By diversifying the energy mix, Iraq can enhance its energy security and reduce vulnerability to external political dynamics.

8) Regional Cooperation and Interconnectivity

   Solar power presents an opportunity for regional cooperation, developing the cross-border renewable energy projects. Collaborative initiatives can foster political stability, improve energy trade, and strengthen economic ties among neighbouring countries.

9) Efficient Water Management and Conservation

   Solar power requires minimal water for operations compared to traditional energy sources, reducing the strain on water resources. This conservation of water supports sustainable development, especially in regions facing water scarcity and competing demands.

10) Natural Gas Preservation for Industrial Use

    By utilizing solar power for electricity generation, Iraq can preserve natural gas resources for other industrial uses, thus reducing the pressure on natural gas supply and promoting sustainable economic growth.

11) Clean and Low-Carbon Energy Generation

Solar power is a clean and renewable energy source that produces minimal greenhouse gas emissions. By shifting to solar power, Iraq can honour its commitments and contribute to global climate change mitigation efforts and reduce its carbon footprint.

12) Resilience to Climate Change Impacts

Investing in solar power helps build resilience against climate change impacts. Solar installations can operate in extreme weather conditions, ensuring a reliable energy supply during heatwaves or other climate-related events, thus enhancing the overall resilience of the energy sector.

However, a successful implementation necessitates the establishment of a robust framework comprising supportive policies, substantial investments in research and development, the enhancement of capacity building initiatives, and fostering collaborative partnerships among stakeholders. With a comprehensive and multifaceted strategy firmly in place, Iraq can confidently pave the way towards a sustainable, secure, and resilient energy future that not only meets its immediate energy needs but also contributes to a globally responsible and eco-conscious tomorrow.

4. RESEARCH METHODOLGY

4.1 Definition of Research

Research, as defined by (Rajasekar, 2006), “is a logical and systematic search for new and useful information on a particular topic.” It is the study of using logical and systematic reasoning to solve complex problems in the natural and social sciences. In other words, it's an effort to learn something new, or unearth some previously unknown facts. In this context, "knowledge" refers to factual data. Information could be gathered from a wide variety of places, including personal observation, interviews, observation of nature and people, reading… etc.

Research is the only method that allows for the possibility of making new discoveries. While performing research, some of the most valuable instruments are the study, experiment, observation, analysis, comparison, and logic.

Researchers usually employ a wide variety of methodologies which are examined in this chapter.

The various research methodologies are outlined, along with the two most common ones: qualitative research as well as quantitative research. The research methodology employed in this study is analyzed, and the rationale for selecting this particular strategy is provided.

When a study is conducted, it implies that an answer was provided to a question, meaning that the study itself would be a research process because; it has been conducted in accordance with a preexisting methodology, and is built with objectivity in mind. It is then accepted to say, when questions are validly answered, it is because proper methods have been used.

The term "reliability" describes the consistency and precision of a measurement process and the level of confidence in the products of this process. While the term "objectivity" refers to the absence of any biases in the analysis or decision-making process, as well as the ability to draw conclusions without introducing any interference or personal stake in the matter.

Bottomline, research is a methodical investigation that employs standard scientific methodology to generate generalizable new knowledge and/or answer questions. The scientific method is based on the systematic collection, organization, and analysis of reliable and authenticated data.

4.2 The Research Characteristics

The aim of any good research project should be to provide answers to specific questions by means of a systematic process of data collection, analysis, and interpretation. However, in order to be classified as research, the process must have the following qualities:

- Controlled: There is a number of unknowns and variables in the real world that can change the result. To determine whether or not a third factor/variable influences a given relationship between two factors/variables, researchers must employ the concept of control.
- Rigorous: Users need to be very careful that the methods used to solve problems are appropriate and well-supported.
- Methodical: This suggests there is a methodical order to the steps taken to investigate. Meaning that certain steps are prerequisites for others.
- Valid and verifiable: The idea behind this is that the conclusions you draw from the research are true and can be independently confirmed.
- Empirical: Consequently, any inferences made are founded on verifiable evidence gleaned from direct experience or observation.
- Critical: Examination of the methods and processes utilized in a study is essential. The investigation procedure needs to be completely dependable and danger. The method chosen and the methods employed must hold up under close inspection.

4.3 Types of Research

There are many types of research, and researchers choose the type that best suits their objectives and the nature of the phenomenon they are studying. Often, a single research project may incorporate elements of multiple types of research to

provide a comprehensive understanding of the topic. Below are the most common ones:

- Descriptive Research:

  This type of research aims to describe and document the characteristics of a phenomenon or group. It does not seek to establish causal relationships but focuses on providing a clear picture of what exists.

- Exploratory Research:

  This is conducted when the topic is not well-defined or understood. It aims to explore a subject, generate initial insights, and identify potential research questions. It often involves literature reviews, interviews, or focus groups.

- Explanatory Research:

  It seeks to explain why something happens or why there is a relationship between variables. It typically involves conducting experiments, causal-comparative studies, or regression analysis to identify causal relationships.

- Analytical Research:

  Mainly focuses on understanding a complex problem by breaking it down into smaller components. It involves critical thinking, problem-solving, and a deep examination of data or information. Case studies and SWOT analyses are examples of analytical research.

- Quantitative Research:

  This type involves collecting and analyzing numerical data to answer research questions. It often uses surveys, experiments, and statistical methods to draw conclusions. The goal is to provide precise and quantifiable results.

- Qualitative Research:

  It is concerned with understanding human behavior, experiences, and motivations. It relies on non-numerical data such as interviews, focus groups, observations, and content analysis to explore and interpret phenomena in depth.

- Action Research:

  This one is typically conducted by practitioners to solve real-world problems within their own context. It involves a cyclical process of identifying a problem, taking action, reflecting on the results, and making further adjustments. It is often used in education and organizational settings.

- Experimental Research:

  It is when research involves manipulating one or more variables to observe their effects on other variables. It aims to establish cause-and-effect relationships and is often conducted in controlled settings to minimize external influences.

- Survey Research:

  Surveys are used to collect data from a large number of respondents through structured questionnaires or interviews. Survey research is widely used in social sciences and market research to gather information about people's opinions, attitudes, and behaviors.

- Longitudinal Research:

  This research type involves studying the same subjects or groups over an extended period to observe changes or trends over time. It is useful for studying developmental processes, trends, and long-term effects.

- Cross-Sectional Research:

  It is done when data is collected from a diverse group of participants at a single point in time. It is often used for comparing different groups or assessing the prevalence of a particular phenomenon at a specific moment.

- Comparative Research:

  This type of research is mainly based on comparing two or more entities (e.g., countries, organizations, or individuals) to identify similarities and differences. It can help researchers understand the impact of different variables on outcomes.

4.4 Research Ethics

"Research ethics refers to the appropriateness of researcher behavior to the rights of those who become the subject of researcher work or are affected by it." (Saunders, 2007)

Research ethics can also be defined as a set of moral guidelines and principles that govern the conduct of research, ensuring the responsible and ethical pursuit of knowledge, which include:

- Informed Consent: It is the voluntary and well-informed agreement of individuals to participate in research. It involves providing clear information about the study's purpose, procedures, potential risks, and benefits, allowing a conscious decision to participate or not, and ensuring a willingly contribute to research without coercion or deception.
- Privacy and Confidentiality: Researchers must protect participants' personal information and ensure that data collected remains confidential. This safeguarding is vital to building trust with participants. It also prevents potential consequences due to data disclosure.
- Minimizing Harm: Researchers have a duty to minimize any physical, psychological, or emotional harm that participants may experience during a study, ensuring that no harm outweighs the potential benefits of the study.
- Data Integrity: Researchers should collect, analyze, and report data accurately and truthfully. This involves avoiding data manipulation, fabrication, or selective reporting that could distort the findings. This is critical for the outcomes' credibility and reliability.
- Transparency and Accountability: Researchers must be transparent about their methods, funding sources, and potential conflicts of interest. They should also be open to scrutiny and peer review, allowing others to verify and reproduce their finding.

4.5. Research Approach

The following steps were taken to conduct robust research and generate reliable results:

1. Design of Questionnaire

For the purpose of collecting relevant information from respondents, a questionnaire with the following four sections was created:

- Personal information: This part included information about the respondents who participated in the questionnaire in terms of age and specialization, which enhances the credibility of the information.
- Background information: This set of questions sorts the background information of respondents, for example, type of organization, position, education, work experience, etc. The aim is to identify the influence of their background on the use of solar.
- Efficiency and habits of the user's consumption of electricity: The purpose of this part of the questionnaire is to give a realistic idea of efficiency and experience of the user's consumption by identifying the pattern of electrical energy use.
- Attitude and Position on Renewable (Solar) Energy: About 6 billion people depend on fossil fuels. Therefore, it is crucial to understand the personal and social stand on converting to the solar energy.

2. Questionnaire Dissemination and Seeking Feedback

Distributing questionnaires via web links and waiting for responses was used during this research as a preferred method over the traditional method of conducting postal surveys, because it offers several advantages that make it a more efficient and practical approach in the digital age, such as:

- Ease of Access: One of the primary benefits of web-based questionnaires is the widespread availability of the internet. Today, a significant portion of the population has access to the internet, which makes it easier to reach a broader and more diverse audience compared to postal surveys.
- Minimal Time and Effort: Responding to an online questionnaire typically requires minimal time and effort. With just a few clicks, respondents can access the questionnaire, and submit their responses. This convenience often leads to higher response rates.

- Customization and Flexibility: Internet-based survey platforms offer a high degree of customization. Researchers can design questionnaires tailored to their specific research objectives, including branching logic, skip patterns, and question randomization.
- Limiting Answers: Online questionnaires can include features that prevent incomplete or inconsistent answers. For instance, mandatory fields can ensure that no questions are left unanswered, and predefined response options can minimize data entry errors.
- Data Verification and Cleaning: Internet-based survey platforms often include built-in mechanisms for data verification and cleaning, reducing the need for manual data cleaning, which is often required in postal surveys.
- Real-time Data Analysis: Online survey platforms enable real-time data analysis. Researchers can access response data as soon as it's collected, allowing for immediate insights. This real-time feedback loop is not feasible with postal surveys, where data collection and analysis are typically more time-consuming.
- Cost-Efficiency: Conducting web-based surveys is generally more cost-effective. There are no expenses associated with printing, postage, or data entry, which can be significant in traditional postal survey methods.
- Environmentally Friendly: Internet-based questionnaires contribute to reduced paper usage and waste, making them a more environmentally sustainable option.

3. Data Collection

Most researchers begin by reanalyzing secondary data in order to answer or begin to answer research questions and objectives; secondary data analysis is then backed up by primary data collection methods. Both secondary and primary data were used in this study to help collect all the information needed. Acknowledging that certain secondary data might not exactly match the study in-hand, since it was acquired for other aims, still, common elements can be derived and used.

4. The Pilot Study

After standardizing the survey method, a pilot testing was done in two steps:

- To test the questionnaire wording, design, and layout, it was first administered to a number of people with a background in data collection and analysis. Then, the survey was amended and finalized based on the feedback.
- Lastly, a wide-scale distribution took place, with by 150 questionnaires distributed, out of which 123 valid responses were collected.

5. Data Processing

After the initial phase of gathering information, the subsequent step in research is data analysis, a crucial phase that translates collected data into meaningful insights. This process serves a dual purpose: addressing research questions and achieving research objectives. Data analysis encompasses the presentation and interpretation of both qualitative and quantitative findings, extracting valuable insights, and identifying patterns and trends within the data.

It's imperative to underscore that data analysis is not a standalone activity; it is an integral part of a comprehensive research process. Beyond numerical analysis and graphical representation, researchers must contextualize their findings within the theoretical framework. This step bridges the divide between theory and practical application.

Ultimately, the outcome of data analysis culminates in well-grounded conclusions firmly rooted in the data, the analytical process, and the interpretation of results. These conclusions provide answers to research questions and offer valuable insights. In the context of this study focusing on the transition to renewable energy sources, a diverse range of research strategies is employed to capture the intricate nature of this multifaceted challenge, considering the various perspectives and stakeholders involved.

In summary, data analysis represents a pivotal phase in the research journey, facilitating the transformation of raw data into actionable insights. However, it forms just one facet of a comprehensive research process that encompasses interpretation, the formulation of conclusions, and the bridging of theory with practical application. This holistic approach is especially valuable when examining the transition to renewable energy, given its complexity and the diverse array of perspectives and stakeholders at play.

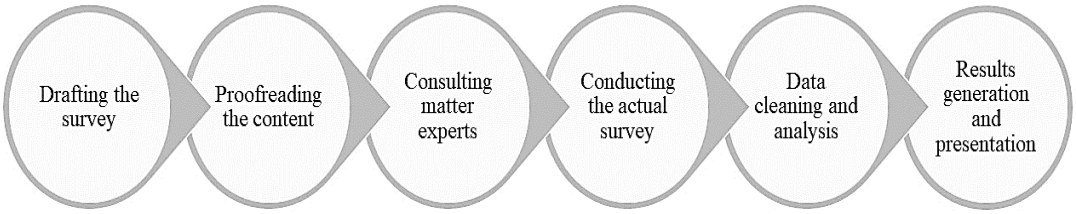

Figure 4.1: Research Pathway

Source: Author

5. DATA ANALYSIS AND RESULTS

5.1 Introduction

In this chapter, we present empirical data that was collected using a standard questionnaire. To analyze the collected data, we utilized SPSS 22, a widely used data analysis software tool. The primary aim of this analysis was twofold: to measure the energy users' habits and perceptions around solar energy in Iraq, so that their answers would feed into the research topic.

A total of 150 respondents participated in this data collection phase, following the specific research methodology employed in this study. These individuals were approached to complete a detailed questionnaire designed to capture the information and insights relevant to the research's focus.

The participants selection criteria were designed to ensure that the sample is majorly representative of the Iraqi people, and would deliver the appropriate response by being Divers, Inclusive, and Relevant where the invitations shared with males and females of different ages, educational levels, employment status, and the relationship as an electric power user.

It's noteworthy that the response rate was substantial, with 123 individuals agreeing to participate and subsequently providing their responses. This high response rate of 82% participation rate, shows the high interest in the research topic, and underscoring the effectiveness of the data collection approach.

The collected data was then subjected to thorough examination and discussion, being the cornerstone of the research's empirical foundation. By scrutinizing the data in detail, we aimed to derive meaningful findings, identify significant patterns, and draw informed conclusions.

In essence, this chapter signifies a critical juncture in the research journey, where data collection efforts transition into actionable insights through comprehensive analysis. The robust participation rate further reinforces the credibility of the findings and enhances the research's overall validity and reliability.

5.2. Response Ratio

The response ratio for the data collection is beneficial in assessing the efficiency of the questionnaires returned in the study. Table (5.1) displays the distribution of the questionnaire for the survey method. 150 questionnaires were distributed directly either sent questionnaire link (Google format) through the social media numbers and email addresses, and then 123 completed questionnaires were then returned, which resulted in an (82 %) of participants.

$$\textbf{Response ratio} = \frac{123}{150} * 100 = \qquad \textbf{(5.1)}$$

Table 5.1: Questionnaire Response Ratio Validation

Case Processing Summary		
Responses Validity	**N**	**%**
Valid	123	100.0
Excluded	0	0
Total	**`123**	**100.0**

5.3 The Reliability

The reliability coefficient (alternatively referred to as Cronbach's Alpha) may be calculated using a statistical tool such as SPSS. Cronbach's Alpha is a number that ranges from 0 to 1. The greater the value, more the dependable the tools and items in the survey become.

For this reason, it may be seen as an indicator of the cohesiveness of a set. This research has an excellent Cronbach's Alpha of 0.806, as seen in the accompanying table, indicating that reliability was strong and that the items had a reasonably high internal consistency. It is worth noting that a dependability coefficient of 0.70 or above is regarded as satisfactory (George and Mallery, 2010). Table 5.2 shows the values of the Reliability Statistics for the study.

Table 5.2: Cronbach's Alpha

Alpha Coefficient Range	**Strength of Association**
$\alpha < 0.6$	Poor
$0.6 < 0.69$	Moderate
$0.7 < 0.79$	Good
$0.8 < 0.89$	Very Good
$\alpha \geq 0.9$	Excellent

Source: Hair, 2003

Table 5.3: Questionnaire Reliability Statistics

Reliability Statistics	
Cronbach's Alpha	N of Items
0.806	12

5.4. Likert Scale

The data was analyzed using descriptive statistics; the questionnaire, which was designed to allow respondents to respond to the different variables based on their personal experiences and opinions, was scored on a Likert scale (for example, on a scale from 1 to 5, with strongly disagree=1 and strongly agree=5). Likert scales are appropriate and commonly utilized in many situations for opinion measurement on a scale with a range of values the findings of the questionnaires being assessed in this study will be presented in the following format:

Table 5.4: Evaluation of Likert Factor

Evaluation	Strongly agree	5
	Agree	4
	Neither agree nor disagree	3
	Disagree	2
	Strongly disagree	1

5.5 Respondents Educational Levels

According to Table 5.5, the highest percentage of respondents (48.8 %) hold a bachelor's degree, and the lowest is (9.8 %) for PHD holders, which aligns to the natural distribution of average academic qualification.

Table 5.5: Questionnaire Respondents Educational Levels

Educational Level	Frequency	Percent	Valid Percent
PHD	12	9.8	9.8
MSC	16	13.0	13.0
BSC	60	48.8	48.8
Diploma	18	14.6	14.6
High School	17	13.8	13.8
Total	123	100.0	100.0

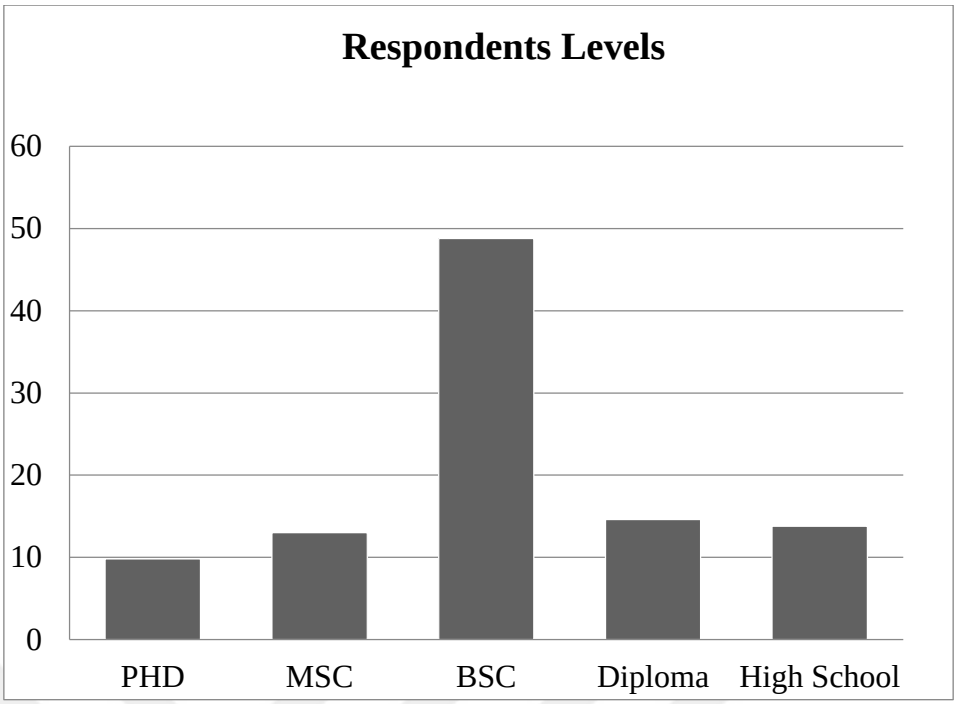

Figure 5.1: Respondents Educational Level

5.6 Employment Status

According to Table 5.6 about 37,4 % of respondents in the Employee group and 26.0% in the Free business categories, had more than 4.1 % of others in the Retired.

Table 5.6: Questionnaire Respondents Employment Status

Valid Respondents	Frequency	Percent	Valid Percent	Cumulative Percent
Student	27	22.0	22.0	22.0
Employee	46	37.4	37.4	59.3
Free business/freelancer	32	26.0	26.0	85.4
Retired	5	4.1	4.1	89.4
Housewife	13	10.6	10.6	100.0
Total	123	100.0	100.0	

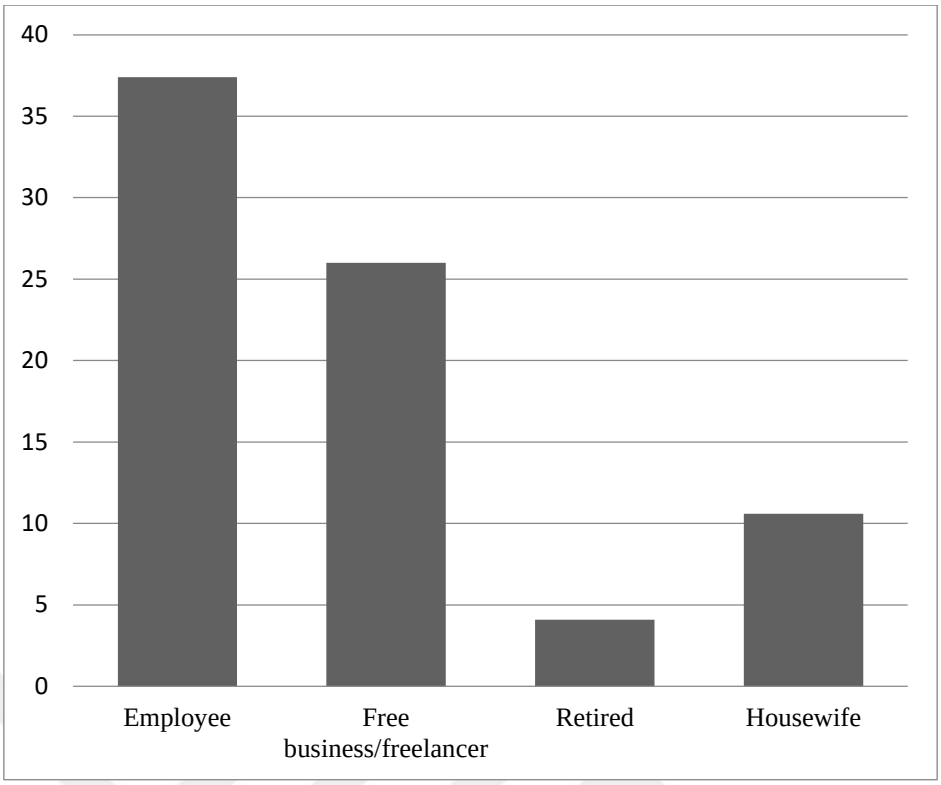

Figure 5.2: Respondents Employment Status

5.7 Standard Deviation

The standard deviation is a measure of dispersion in a dataset in relation to the mean, and it is computed by taking the square root of the variance. When comparing one set of data to another, it's useful to know how far each value is from the average. In the table (5.6) the Standard Deviation value for items of questionnaire was 0.739 for item (SE11) to (1.188) for item (SE3).

5.8 Mean Value

The mean is the average value in a mathematical or statistical set. There are several approaches to calculate the mean, the most common of which is the arithmetic mean by adding up all the numbers and dividing by the total number of observations. The mean value of items as shown in table (5.8), where the values tanged from 4.32 for item (SE13) to 3.53 for item (SE11)

5.9. Rank Correlation

Rank correlation is a statistical method used to assess the relationships between rankings of ordinal variables. Ordinal variables are those with inherent rankings but no precise numerical values. This analysis helps measure the agreement or disagreement between different sets of rankings, providing insights into relationships without relying on specific numerical values. It's valuable in fields like social sciences and economics where ordinal data prevail. This method is essential for understanding relationships in data where the order of items (being first, second, third ...etc.) matters.

Table 5.7: Statical Analysis of Questionnaire Items

No.	Items	Code	Mean	Std. Error of Mean	Std. Deviation	Vrnce.
1	Protecting the environment is everyone's responsibility, not just the specialized professionals	SE1	4.00	.084	.932	.869
2	Recently, it has been evident that it is getting increasingly important to adopt alternative clean and renewable energy sources instead of the fossil-fuel systems	SE2	4.07	.087	.960	.921
3	Adopting alternative clean and renewable energy sources will contribute to improving the life quality of future generations as it helps reduce the deterioration in human habitats and preserve the natural environment.	SE3	3.76	.107	1.188	1.411
4	It would make an accumulative big difference to the power consumption, hence power generation if each one of us switches off the lighting and the devices that are not needed during the daytime. which leads to causing less harm to the environment.	SE4	3.81	.092	1.019	1.039
5	Similarly, the last person leaving a room should switch off lighting and all unnecessary appliances (such as TV and computer) for the same reason.	SE5	3.81	.084	.926	.858
6	Using energy-saving LED lights and home appliances (such as AC units) is a better option in both economic and environmental aspects.	SE6	4.06	.085	.943	.890

Table 5.7: (Cont.) Statical Analysis of Questionnaire Items

No.	Items	Code	Mean	Std. Error of Mean	Std. Deviation	Vrnce.
7	Insulating house surfaces will contribute to environmental improvement because less power will be needed to cool or heat them.	SE7	3.95	.077	.857	.735
8	The government agencies are doing sufficient efforts and their plans are enough to spread awareness on the importance and benefits of converting to alternative clean and renewable energy sources	SE8	3.90	.083	.918	.843
9	Strongly Disagree More needs to be done by the government, supporting agencies, and private sector when it comes to promoting the benefits of using alternative clean and renewable energy sources	SE9	3.94	.072	.803	.644
10	In your personal opinion, please select the most appropriate source of renewable energy sources for investment in Iraq?	SE10	4.20	.077	.859	.737
11	Please choose the most important elements to which renewable energy contributes (you may select more than one)	SE11	3.53	.067	.739	.546
12	Contribution from government agencies to subsidize the costs of renewable energy technologies will encourage citizens to use them	SE12	4.15	.075	.827	.683
13	It is important that government agencies increase the construction of renewable energy facilities to generate electric power.	SE13	4.32	.075	.833	.694
14	The main reasons for hesitating not to use renewable (solar) energy systems are: (you may select more than one)	SE14	3.84	.081	.900	.809
15	In the long term, investing in installing renewable energy sources (solar) is more financially feasible.	SE15	4.14	.076	.843	.710

Table 5.8: Mean and Rank of Questionnaire Items

No.	Items	Code	Mean	Rank
1	It is important that government agencies increase the construction of renewable energy facilities to generate electric power.	SE13	4.32	1st
2	In your personal opinion, please select the most appropriate source of renewable energy sources for investment in Iraq?	SE10	4.20	2nd
3	Contribution from government agencies to subsidize the costs of renewable energy technologies will encourage citizens to use them	SE12	4.15	3rd
4	In the long term, investing in installing renewable energy sources (solar) is more financially feasible.	SE15	4.14	4th
5	Recently, it has been evident that it is getting increasingly important to adopt alternative clean and renewable energy sources instead of the fossil-fuel systems	SE2	4.07	5th
6	Using energy-saving LED lights and home appliances (such as AC units) is a better option in both economic and environmental aspects.	SE6	4.06	6th
7	Protecting the environment is everyone's responsibility, not just the specialized professionals	SE1	4.00	7th
8	Insulating house surfaces will contribute to environmental improvement because less power will be needed to cool or heat them.	SE7	3.95	8th
9	Strongly Disagree More needs to be done by the government, supporting agencies, and private sector when it comes to promoting the benefits of using alternative clean and renewable energy sources	SE9	3.94	9th
10	The government agencies are doing sufficient efforts and their plans are enough to spread awareness on the importance and benefits of converting to alternative clean and renewable energy sources	SE8	3.90	10th
11	The main reasons for hesitating not to use renewable (solar) energy systems are: (you may select more than one)	SE14	3.84	11th
12	Similarly, the last person leaving a room should switch off lighting and all unnecessary appliances (such as TV and computer) for the same reason.	SE5	3.81	12th
13	It would make an accumulative big difference to the power consumption, hence power generation if each one of us switches off the lighting and the devices that are not needed during the daytime. which leads to causing less harm to the environment.	SE4	3.81	13th

Table 5.8: (Cont.) Mean and Rank of Questionnaire Items

No.	Items	Code	Mean	Rank
14	Adopting alternative clean and renewable energy sources will contribute to improving the life quality of future generations as it helps reduce the deterioration in human habitats and preserve the natural environment.	SE3	3.76	14th
15	Please choose the most important elements to which renewable energy contributes (you may select more than one)	SE11	3.53	15th

5.10 Summary of Findings

1) The response ratio which stands at 82% reflects the high interest in the topic and provides an assuring percentage of credible and reliable representative data.
2) Through the SPSS analysis, a data reliability index of 0.806 was determined, which is considered particularly good being above the accepted reference value of 0.7.
3) Since the topic of the thesis is related to technologically advanced topic, most of the questionnaire recipients were educated of different levels, with the majority of them holding bachelor's degree.
4) The inputs from different sectors of the community (including housewives) were sought because the matter of solar energy transition affect everyone's lives and livelihoods.
5) The highest frequency is for item SE13 (It is crucial that government agencies boost the building of renewable energy facilities to generate electricity) corresponds to a high scale of agreement that government holds the primary responsibility to promote solar energy.
6) Statistical analysis of mean value, standard deviation, variance, and ranking shows consistency in results for the questionnaire items, where the majority of the response emphasizes on:
7) The importance and usefulness of renewable energy on many levels including economic and environmental.

8) The Criticality of government role in advancing the transition towards solar energy.

9) And the social responsibility through commitment to power-conservative practices.

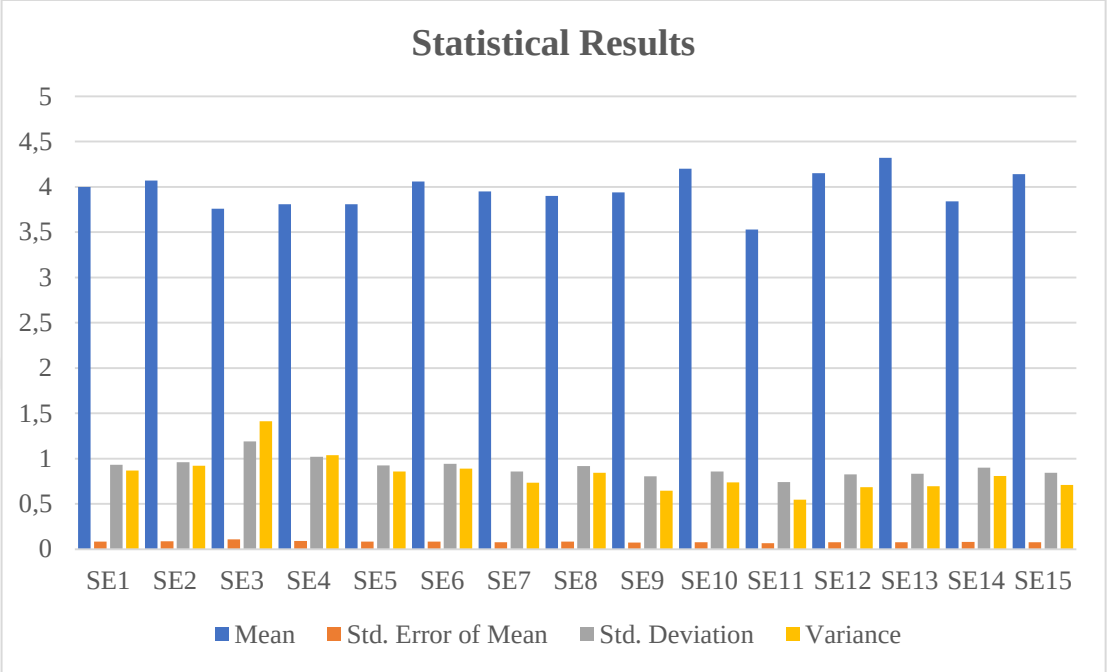

Figure 5.3: Questionnaire Statistical Results

Source: Author

6. ENGINEERING MANAGEMENT PRINCPLES AND APPLICATIONS

6.1 Introduction

"Engineering management is the stage that speaks to the move from the technical thinking to the act of the management thinking, with the skills to integrate." (Mlangeni, 2017). Hence, it is a multidisciplinary field that blends the principles of engineering with those of management to effectively oversee complex engineering projects and organizations. It can be more precisely defined as the art and science of planning, organizing, allocating resources, and directing and controlling engineering activities to achieve specific objectives efficiently. It involves the integration of engineering principles and management techniques, making it a crucial discipline in today's rapidly evolving technological landscape.

The pursuit of renewable energy sources, particularly solar power, has become an imperative worldwide. For a country like Iraq, which faces multifaceted energy challenges and environmental concerns, adopting solar power is a crucial step toward a sustainable future. However, the successful implementation of solar power projects requires a strategic approach that integrates key engineering management principles.

This chapter explores how the principles of Engineering Management can be effectively employed to facilitate the adoption of solar power as an alternative energy source in Iraq. By examining each principle's application within the context of solar energy projects, a comprehensive guidance is provided into the decision-making process, can address the unique challenges and opportunities associated with transitioning to solar power in Iraq.

6.2 Historical Evolvement of Engineering Management

The origins of engineering management can be traced back to the late 19th and early 20th centuries when Frederick W. Taylor developed his principles of scientific management. Taylor's work placed a strong emphasis on the systematic

analysis and optimization of work processes, laying a foundational framework for efficient engineering project management.

In the 1930s, a pivotal shift occurred with Elton Mayo's Hawthorne experiments. These experiments redirected the focus from mere scientific efficiency to recognizing the paramount importance of human factors in the realm of management. This marked the inception of understanding the profound impact of interpersonal skills and motivation within the field of engineering management.

During the mid-20th century, the emergence of systems engineering became a cornerstone in engineering management. Systems engineering brought to the forefront the significance of adopting a holistic approach to project management. It underscored the necessity of considering the intricate interdependencies among various components and subsystems, particularly vital in managing complex engineering endeavors.

The 1980s witnessed a significant transformation with the ascendancy of Total Quality Management (TQM) principles, notably advocated by luminaries such as W. Edwards Deming and Joseph M. Juran. And even though “There is no explicit definition of total quality management. Some people define it as providing the customer with quality products at the right time and at the right place” (Kerzner, 2017). TQM principles championed continuous improvement, the paramount importance of customer satisfaction, and active employee involvement. These principles have since become integral components of engineering management, emphasizing the need for quality assurance, ongoing process enhancement, and a steadfast commitment to meeting customer expectations.

In recent decades, engineering management has seen the maturation of project management as a specialized domain within its purview. This evolution introduced sophisticated techniques like the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT). Concurrently, it has adapted to the emerging frontiers of sustainability, innovation management, and agile project management, further attesting to the dynamic nature of engineering management in responding to the ever-evolving demands of the modern world.

6.3 Fields of Application for Engineering Management

Engineering management is a versatile discipline that finds application in various fields due to its focus on efficient project management, technical leadership, and effective decision-making. Here are some key fields of application for engineering management:

- Construction Management: Engineering managers play a critical role in planning, executing, and overseeing construction projects. They ensure that projects are completed on time, within budget, and in compliance with safety and quality standards.
- Manufacturing and Production: In manufacturing industries, engineering management is essential for optimizing production processes, quality control, and supply chain management. It involves overseeing manufacturing operations to enhance efficiency and productivity.
- Information Technology (IT) Management: IT project management requires engineering managers to lead software development, system integration, and IT infrastructure projects. They ensure that IT projects align with organizational goals and are delivered on schedule.
- Product Development: Engineering managers are involved in product design, development, and launch processes. They oversee cross-functional teams, manage resources, and ensure products meet customer requirements and quality standards.
- Energy and Environmental Management: In the energy sector, engineering managers focus on optimizing energy production and distribution systems. They also work on environmental projects related to sustainability, renewable energy, and emissions reduction.
- Aerospace and Defense: Engineering management is crucial for complex aerospace and defense projects. It involves project planning, risk management, and compliance with strict regulations for safety and quality.
- Automotive Industry: In automotive manufacturing, engineering managers oversee the design, production, and quality control of vehicles and

components. They manage teams responsible for innovation and technology integration.

- Telecommunications: Engineering managers in the telecommunications sector lead projects related to network infrastructure, system upgrades, and deployment of technologies like 5G.
- Healthcare and Biotechnology: Engineering management is applied to medical device development, pharmaceutical manufacturing, and healthcare system improvement projects. It ensures compliance with regulatory standards and patient safety.
- Civil and Environmental Engineering: In this field, engineering managers focus on infrastructure projects such as bridges, roads, water treatment facilities, and environmental remediation. They address challenges related to public safety and environmental sustainability.
- Transportation and Logistics: Engineering managers oversee the planning and optimization of transportation networks, including rail, air, and shipping. They aim to improve efficiency and reduce operational costs.
- Project Management Consulting: Some engineering managers work in consulting firms, providing project management expertise to clients across various industries. They help clients plan, execute, and monitor complex projects.
- Renewable Energy and Sustainability: With the growing focus on sustainability, engineering managers are involved in renewable energy projects, sustainable building design, and environmental impact assessments.
- Research and Development (R&D): In R&D departments of technology-driven companies, engineering managers lead teams responsible for innovation, new product development, and cutting-edge research.
- Quality Assurance and Compliance: Ensuring products and processes meet quality and regulatory standards is a key responsibility of engineering managers across industries.

The diversity of these fields, among many others, illustrate the wide applications of engineering management, reflecting its importance in guiding

projects, enhancing efficiency, and delivering high-quality results in various sectors of the economy.

6.4 Principles of Engineering Management

Engineering management is a multifaceted and expansive field with a wide range of principles and practices that can be approached and categorized in various ways, each shedding light on different aspects of the field. In the context of this thesis, we will organize the main engineering principles into seven distinct categories for clarity and focused analysis:

1) Integration of Engineering and Management
2) Project Management
3) Total Quality Management
4) Risk Management
5) Cost Management
6) Innovation and Technology Management
7) Ethics and Sustainability

6.5 Utilization of Engineering Management Principles in the Solar Energy Transition

1) Integration of Engineering and Management

Such integration emphasizes the synergy between technical and managerial functions. In the context of solar power adoption in Iraq, this involves harmonizing the engineering design and operational aspects with strategic management plans and decisions.

Action Point:

- Strategic Alignment: Develop a clear solar energy strategy that aligns with Iraq's broader energy goals and sustainability targets. This strategy should encompass economic, environmental, and social dimensions, facilitating decisions that are congruent with the nation's objectives.

- Cross-Functional Collaboration: Create interdisciplinary teams that include engineers, project managers, environmental experts, and policymakers. These teams should collaborate to address technical challenges while also considering the project's financial, regulatory, and environmental dimensions.
- Effective Communication: Establish robust communication channels between engineering and management teams. Regular feedback loops and reporting mechanisms are essential for monitoring project progress and making timely adjustments.

2) Project Management

Efficient Project Management is a critical principle for the successful execution of complex projects such as solar energy projects. It involves defining project scopes, allocating resources, setting milestones, and managing risks to ensure projects are completed on time and within budget.

Action Points:

- Project Planning: Clearly define project objectives, scopes, and deliverables for solar power initiatives. Develop comprehensive project plans that include timelines, resource allocation, and budget estimates.
- Resource Allocation: Allocate resources efficiently, including skilled personnel, equipment, and materials, to maximize project productivity. Identifying and addressing potential resource constraints early in the planning phase is crucial.
- Monitoring and Evaluation: Implement key performance indicators (KPIs) to track project progress and quality. Regularly review project milestones to ensure they align with the established timeline.

3) Total Quality Management:

Also known as (TQM), which is a philosophy that centers on continuous improvement, customer satisfaction, and the pursuit of excellence. In the context of solar power adoption, TQM ensures that projects meet or exceed performance standards and expectations.

Action Points:

- Defining Quality Standards: Define quality standards and specifications for solar panels, inverters, and other components. Ensure adherence to international quality certifications to guarantee reliable and efficient solar systems.
- Quality Assurance: Iraq should enforce stringent quality control measures for solar equipment procurement and installation. Ensuring that components meet international standards reduces the likelihood of failures and increases the lifespan of solar installations.
- Process Improvement: Implement continuous improvement processes throughout the project lifecycle. This includes regular audits, feedback loops, and corrective actions to enhance project efficiency and effectiveness.
- Training and Capacity Building: TQM also extends to workforce training and skill development. Iraq should invest in training programs to enhance the competence of technicians and engineers involved in solar projects. Well-trained personnel are more likely to adhere to quality standards and ensure the long-term performance.
- Customer Satisfaction: Emphasizing on the end-user satisfaction. In the context of solar power adoption, this means ensuring that end-users receive reliable and efficient energy services. Iraq should establish mechanisms for gathering feedback from solar power consumers to identify areas for improvement and making necessary adjustments to meet their needs and expectations.
- Supplier Quality: Collaborate with reputable suppliers who adhere to quality standards. Establish strong partnerships with suppliers to ensure a consistent supply of high-quality components.

4) Risk Management:

This is the aspect of management that involves identifying, assessing, and mitigating potential risks that may impact project success. In solar power adoption,

risks can encompass technological challenges, financial uncertainties, and regulatory hurdles.

Action Points:

- Risk Identification: Conduct a comprehensive risk assessment to identify potential threats and opportunities related to solar energy projects. Categorize risks into technical, environmental, financial, and regulatory domains.
- Risk Mitigation: Develop risk mitigation strategies for each identified risk. This may involve diversifying energy sources, securing project financing, and implementing disaster recovery plans.
- Risk Mitigation: Prepare contingency plans to address unforeseen events, such as extreme weather conditions or supply chain disruptions. Ensure that these plans are well-documented and regularly updated.
- Risk Monitoring: Continuously monitor project risks and reassess their potential impact. Implement risk registers and key risk indicators (KRIs) to proactively manage risks.

5) Cost Management:

Being related to financial resources, this is vital for controlling project expenses and ensuring that solar power adoption remains economically viable. It involves budgeting, cost estimation, and cost control measures.

Action Points:

- Cost Estimation: Develop accurate cost estimates for solar energy projects, considering all expenses, including equipment procurement, installation, maintenance, and operational costs over the project's lifespan.
- Budget Allocation: Allocate budget resources judiciously, ensuring that funds are available for critical project phases, while considering long-term financial sustainability.
- Cost Control: Implement cost control mechanisms to prevent cost overruns. Regularly track expenses, compare them to the budget, and take corrective actions when necessary.

- Value Engineering: Explore value engineering techniques to optimize project costs without compromising quality. Identify cost-effective solutions and alternatives during the project's design, execution, and procurement.

6) Innovation and Technology Management:

This category includes identifying and leveraging technological advancements to enhance project efficiency and effectiveness. In the solar energy sector, this includes staying abreast of cutting-edge technologies and incorporating them into projects where appropriate.

Action Points:

- Technology Assessment: Continuously assess emerging solar technologies to identify those that offer improved efficiency, durability, and cost-effectiveness. Evaluate the feasibility of adopting these technologies in Iraqi solar projects.
- Research and Development: Invest in research and development activities to adapt solar technologies to Iraq's specific climate and environmental conditions. This may involve partnerships with research institutions and industry experts.
- Pilot Projects: Implement pilot projects to test new solar technologies and evaluate their performance in real-world conditions. Use the data and insights from these pilots to inform broader project deployments.
- Knowledge Transfer: Foster knowledge transfer among project teams and stakeholders to ensure that the latest technological advancements are effectively incorporated.
- Adaptation to local context: Innovation should also consider local conditions and needs. Solar solutions should be adapted to Iraq's unique climate and energy requirements for optimal performance.

7) Ethics and Sustainability:

The principles and practices of ethics and sustainability guide the responsible conduct of solar energy projects. They ensure that projects consider the long-term well-being of society and environment.

Action Points:

- Environmental Impact Assessment: Conduct comprehensive environmental impact assessments before and during project implementation. Ensure that solar power projects do not harm local ecosystems and mitigate any adverse effects.
- Social Engagement: Involve local communities/end-users in the planning and decision-making processes to ensure that the benefits of solar power adoption are equitably distributed.
- Transparency and Accountability: Maintain transparency in project financing, procurement, and operations. Implement accountability mechanisms to prevent corruption and mismanagement and promote responsible/ethical behaviour.
- Compliance with Regulations: Adhere to local and international regulations governing environmental protection, labour rights, and social responsibility throughout the projects.

Iraq's shift towards solar power is a pivotal step in sustaining its energy sector, where engineering management principles play a vital role, aligning technical expertise with strategic vision.

Effective project management ensures timely and cost-effective planning and execution, while total quality management ensures both process and system reliability. Integrating risk and cost management strategies is crucial in safely navigating financial and operational challenges. Also, innovation and technology management drive the progress and positioning Iraq as a solar technology champion country. Lastly, a true commitment to ethics and sustainability ensures responsible and upright adoption.

By incorporating these principles into solar projects design, implementation, and management, Iraq will chart a course to a sustainable, energy-efficient, and responsible future.

Figure 6.1: Engineering Management Principles and Solar Energy Transition in Iraq

Source: Author

7. CONCLUSION, RECOMMENDATIONS AND WAY FORWARD

7.1 Conclusion

Through the conducted research using the secondary and primary data in the literature review and empirical questionnaire process, it was clearly concluded that:

Nowadays, transition towards renewable energy (especially solar) is becoming an increasingly global trend. It is formally regulated through specially mandated entities that are concerned with research, planning, advocacy, and promotion of solar energy.

The transition to solar energy offers a multitude of advantages for individuals, communities, and the environment alike. Primarily, solar power is renowned for its clean and renewable nature, playing a pivotal role in reducing greenhouse gas emissions and combatting climate change. Furthermore, the economic appeal of solar energy is evident, with continually improving technologies making solar panels increasingly affordable and efficient. This translates into long-term cost savings, reduced electricity bills, and a dependable source of energy. Beyond the economic benefits, solar power enhances energy independence, reducing reliance on centralized grids and bolstering resilience during power disruptions. Importantly, solar energy contributes significantly to environmental preservation by curbing air and water pollution, conserving precious natural resources, and championing a sustainable and eco-conscious future for generations to come.

Solar energy stands as an exceptionally fitting choice for Iraq's unique context, supported by several compelling factors. Iraq boasts an abundance of sunlight year-round, with vast desert landscapes and a climate conducive to harnessing high levels of solar energy. This aligns well with the nation's urgent need for diversifying and modernizing its energy infrastructure, making solar power a sustainable and dependable alternative that reduces reliance on fossil fuels. Given Iraq's economic challenges, transitioning to solar energy holds the promise of substantial long-term cost savings, easing financial burdens and promoting energy

self-sufficiency. Additionally, solar projects have the potential to generate employment opportunities, stimulate local industries, and enhance energy security, all of which align seamlessly with Iraq's objectives of sustainable development and environmental responsibility.

The majority of the questionnaire respondents (which are taken as a representative sample of energy users in Iraq) support the notions of converting to cleaner and more reliable source of power (solar), approve energy conservation practices, and expect the government to lead the execution of large-scale initiatives towards solar energy adoption.

Among the wide-range of application for engineering management, the key principles of integrating engineering with management, project management, cost management, risk management, quality management, innovation and technology management, and ethics and sustainability can together pave the energy transition pathway.

7.2 Recommendations

In light of the research findings explained earlier, it is evident that transitioning towards more reliance on solar energy in Iraq requires a comprehensive and multi-layered approach that requires a true collaboration among the key players internally and externally. This transformative initiative holds the potential to enhance Iraq's energy security, promote sustainable development, and mitigate environmental impacts. To successfully navigate this transition, it is imperative to engage various stakeholders, each with defined roles and responsibilities.

The key stakeholders of this transition are (the government of Iraq, the private sector, the international community, neighbouring countries, research and academic institutions, and the citizens of Iraq), and below is the roadmap that explains each one’s role in it:

In Iraq's journey towards the widespread adoption of solar energy, several key stakeholders have distinct roles and responsibilities to ensure the success and sustainability of this transition. Here is a description of the contributions and commitments of each stakeholder:

1) Government of Iraq:

   The government holds a pivotal role in spearheading the solar energy integration effort. It must lead by example and establish the necessary policies and regulations to facilitate this transition. This includes the development of a comprehensive regulatory framework tailored to renewable energy, addressing aspects such as licensing, tariffs, and incentives. Furthermore, the government should create financial mechanisms, including subsidies and tax incentives, designed to encourage private sector investments in solar projects. To support the growth of solar power generation, the government must allocate resources for the development of a national grid infrastructure capable of effectively distributing solar-generated electricity. Lastly, investments in research and development are essential to enhance solar technologies and advance energy storage solutions, ensuring the long-term viability of solar energy in Iraq.

2) Private Sector:

   Private companies play a critical role in the development and operation of solar projects. They are responsible for investing in the construction and maintenance of solar power plants, which contributes significantly to grid stability and resilience. Collaboration with international firms is crucial to facilitate technology transfer, share knowledge, and acquire expertise necessary for efficient project implementation. Private sector entities must also engage actively with local communities to ensure that solar projects align with social and environmental sustainability goals, fostering goodwill and community support. Additionally, exploring public-private partnerships is essential to expand solar capacity and enhance investment opportunities, promoting sustainable energy growth.

3) International Community:

   The support of the international community, including the United Nations, governments, and non-governmental organizations, is instrumental in accelerating Iraq's solar energy transition. Financial aid and grants provided by these entities can significantly facilitate the development of solar infrastructure in Iraq. They should also offer technical expertise and promote

knowledge sharing through international organizations and partnerships, helping Iraq benefit from the experiences of other nations that have undergone similar energy transitions. Furthermore, facilitating collaborations between Iraqi institutions and global research centers can lead to mutual benefits and promote technological advancements. Collaboration on regional energy initiatives, particularly those encouraging cross-border sharing of solar power, strengthens regional energy security and sustainability.

4) Neighbouring Countries:

Collaborating with neighbouring nations holds the potential to enhance both local and regional energy security. To achieve this, Iraq and its neighbours should explore cross-border energy trade agreements, efficiently utilizing surplus solar power to meet regional energy demands. Sharing best practices and lessons learned in solar energy integration is essential, fostering regional knowledge exchange and collective growth. Joint research and development programs should be established to promote advancements in solar technologies, ultimately benefiting the entire region. The creation of a regional consortium for renewable energy can further drive sustainable energy practices, fostering a collaborative approach to address energy challenges.

5) Research and Academic Institutions:

Research and academic institutions have a critical role to play in driving innovation, development, and education in renewable energy. They should conduct research focused on advancing solar technology, striving to enhance efficiency and cost-effectiveness. Specialized education and training programs should be offered to cultivate a skilled workforce capable of supporting the renewable energy sector. Collaboration with international counterparts is essential to facilitate knowledge exchange and cross-border research projects, ensuring that Iraq remains at the forefront of renewable energy advancements. Additionally, these institutions should provide government and industry stakeholders with data-driven insights to inform policy and investment decisions, enabling evidence-based decision-making.

6) Citizens of Iraq:

The active involvement of citizens is paramount to the success and sustainability of solar projects in Iraq. They must actively participate in energy conservation and efficiency programs, contributing to the reduction of overall energy demand. Engaging in community-based solar projects and initiatives that promote local renewable energy solutions helps build a sense of ownership and sustainability at the grassroots level. Citizens also have a role in advocating for sustainable energy policies and practices, both locally and nationally, to ensure that the government's initiatives align with their interests and needs. Educating themselves about the benefits of solar power adoption and advocating for its use among peers and communities can further drive awareness and support for solar energy in Iraq.

7.3 The Way Forward

Developing a roadmap for the adoption of solar energy in Iraq requires a coordinated effort from all the concerned stakeholders according to a logically contextualized plan to guide the way forward.

This roadmap can be divided into the following phases:

Phase 1: Establishing Regulatory Framework and Infrastructure (Years 1-2)

- Government of Iraq:
    - Develop and publish a comprehensive regulatory framework for renewable energy, including clear guidelines for licensing, tariffs, and incentives.
    - Allocate initial funding for subsidies and tax incentives to attract private sector investments.
    - Initiate the development of a national grid infrastructure capable of accommodating solar power generation.
    - Allocate resources for research and development in collaboration with academic institutions.

- Private Sector:
    - Begin investing in the construction of small-scale solar power plants to demonstrate feasibility and encourage further investment.
    - Explore partnerships with international firms to acquire solar technology expertise.
    - Engage with local communities to identify suitable project locations and address environmental concerns.
    - Investigate public-private partnerships for pilot projects.
- Research and Academic Institutions:
    - Start research on improving solar technology efficiency and cost-effectiveness.
    - Begin offering specialized education and training programs to create a skilled workforce.
    - Collaborate with international counterparts for knowledge exchange.

Phase 2: Scaling Up Solar Energy (Years 3-5)

- Government of Iraq:
    - Expand the regulatory framework to support larger solar projects and encourage private sector participation.
    - Increase subsidies and tax incentives for solar energy projects.
    - Invest in grid expansion and modernization to accommodate increased solar capacity.
    - Continue to fund research and development efforts.
- Private Sector:
    - Scale up solar power plant construction, with a focus on grid-connected installations.
    - Collaborate with international partners for technology transfer and knowledge sharing.

- Continue community engagement and consider larger, utility-scale projects.
- Explore opportunities for public-private partnerships on a larger scale.

- International Community:
  - Provide financial aid and grants to support the expansion of solar infrastructure.
  - Offer technical expertise and facilitate knowledge sharing through international organizations.
  - Promote collaborations between Iraqi institutions and global research centers.
  - Support regional energy initiatives that encourage cross-border sharing of solar power.

Phase 3: Achieving Energy Security and Sustainability (Years 6-10)

- Government of Iraq:
  - Strengthen the regulatory framework and incentives to attract significant private sector investments.
  - Accelerate grid expansion to integrate a substantial share of solar energy into the national grid.
  - Continue funding research and development to stay at the forefront of solar technology.

- Private Sector:
  - Continue expanding solar power capacity, with a focus on utility-scale projects.
  - Explore export opportunities for surplus solar energy with neighbouring countries.
  - Share best practices and collaborate on R&D initiatives regionally.
  - Consider joining a regional consortium for renewable energy.

- Neighbouring Countries:
    - Collaborate with Iraq on cross-border energy trade agreements.
    - Share knowledge and experiences in solar energy integration.
    - Establish joint R&D programs to promote collective growth in solar technologies.
    - Develop a regional consortium for renewable energy.

Phase 4: Ensuring Long-Term Sustainability and Community Involvement (Years 11-15)

- Government of Iraq:
    - Maintain a stable regulatory environment to ensure the long-term viability of solar projects.
    - Encourage private sector innovation and investments in energy storage solutions.
    - Continue support for grid expansion and modernization.
    - Promote energy efficiency programs.
- Private Sector:
    - Continue to innovate and invest in the latest solar technologies.
    - Explore energy storage solutions to enhance grid stability.
    - Maintain community engagement and support local renewable energy solutions.
    - Advocate for policies that promote sustainable energy practices.
- Citizens of Iraq:
    - Sustain energy conservation and efficiency efforts.
    - Participate in community-based solar projects and support local renewable energy initiatives.
    - Advocate for sustainable energy policies at local and national levels.
    - Continue to educate and raise awareness about the benefits of solar power adoption.

This roadmap outlines a comprehensive plan for the adoption of solar energy in Iraq, with a focus on collaboration and long-term sustainability. It involves a gradual transition, starting with regulatory groundwork and gradually scaling up solar capacity while involving all relevant stakeholders in the process. And as stated by (Istepanian, 2020) "The path towards a sustainable energy future in Iraq is by no means simple, but a solution certainly exists ".

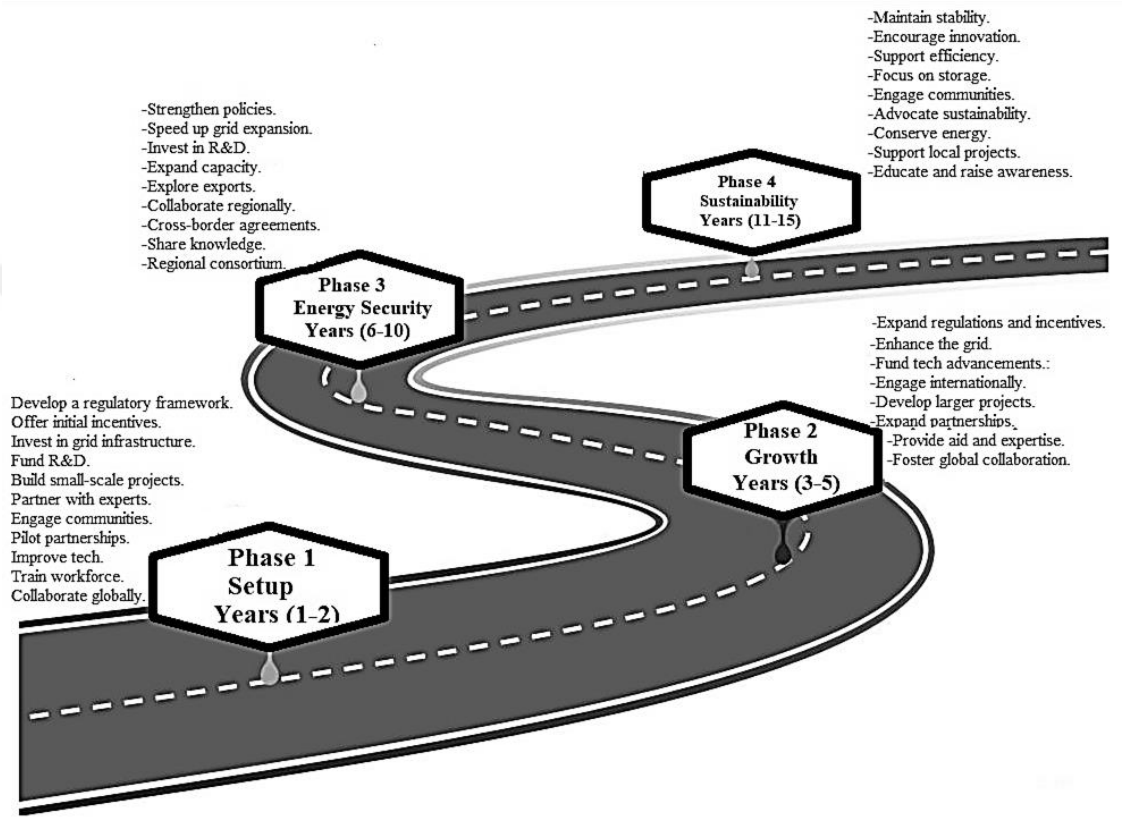

Figure 7.1: Iraq's Roadmap to Adoption of Solar Energy

Source: Author

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RESUME

Ahmed K. Albo HAMED

EDUCATIONAL:

- Bachelor's Degree in Mechanical Engineering Department from the University of Tikrit, Iraq.
- Management Engineering, Istanbul Gedik University, Istanbul, Turkey in 2023.

WORK EXPERIENCE:

- In The International Aid and Development Sector: As a program manager, business advisor, and site engineer, For the United Nation's World Food Program, International Organization for Migration and Mercy Corps International.
- In The Private Sector: As a senior site engineer for Trojan Holding, Royal Group, UAE.

CERTIFICATE:

- English Language Diploma – Level C.
- Emerging Leadership Program Diploma
- Project Management for Development Professionals
- Regional Economic Advancement in Developing Sectors
- Business Development Certified Advisor