



Universidad de Jaén

TÍTULO

Contribuciones para la integración de las energías renovables en Jordania

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By

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**In Partial Fulfillment of the Requirements for the Degree
of
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October, 2024



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RESUMEN EN CASTELLANO (150 palabras).

La tesis analiza la industria de energía renovable en Jordania para ayudar a los responsables de la toma de decisiones y a los inversores a planificar futuros proyectos. Evalúa la demanda energética actual y el papel de las fuentes renovables en garantizar la seguridad energética a largo plazo. A pesar de los beneficios, existen desafíos como los marcos políticos, el apoyo técnico y los recursos financieros. Jordania ha comenzado a abordar estos problemas, enfocándose en la gestión del sistema de energía, la infraestructura de la red y la capacidad de almacenamiento. El desarrollo de plantas de energía solar concentrada (CSP) en el sur podría impulsar la economía y reducir la dependencia del petróleo, pero son necesarios estudios de viabilidad. Establecer centros de energía renovable y apoyar la investigación universitaria puede formar una fuerza laboral capacitada. Atraer inversiones extranjeras mediante una guía para inversores y destacar el potencial renovable de Jordania es crucial. La Estrategia Nacional del Sector Energético 2020-2030 busca aumentar la energía renovable al 31% de la mezcla eléctrica y mejorar la eficiencia energética en un 9% para 2030.

RESUMEN EN INGLÉS (150 palabras)

The thesis analyzes Jordan's renewable energy industry to help decision-makers and investors plan future projects. It assesses current energy demand and the role of renewable sources in ensuring long-term energy security. Despite benefits, challenges include policy frameworks, technical support, and financial resources. Jordan has started addressing these issues, focusing on effective power system management, grid infrastructure, and storage capacity. Developing Concentrated Solar Power (CSP) plants in the south could boost the economy and reduce oil dependence, but feasibility studies are necessary. Establishing renewable energy centers and supporting university research on water, renewables, and the environment can build a skilled workforce. Attracting foreign investment through an investor's guide and highlighting Jordan's renewable potential is crucial. The National Energy Sector Strategy for 2020-2030 aims to increase renewable energy to 31% of the electricity blend and improve energy efficiency by 9% by 2030. Initiatives like the Green Growth National Action Plan show Jordan's commitment to advancing renewable energy.

ABSTRACT

The thesis provides an in-depth analysis of Jordan's renewable energy industry, with the aim of aiding decision-makers and investors in planning future projects. It delves into the current energy demand in the country and examines the role of renewable sources in ensuring long-term energy security. Despite the potential benefits of renewable energy, there are several challenges to overcome, including policy frameworks, technical support, and financial resources. However, Jordan has already begun taking steps to address these issues and capitalize on the opportunities presented by renewable energy. To further promote the adoption of renewable energy, Jordan should focus on managing its power system effectively and invest in grid infrastructure and storage capacity. Developing Concentrated Solar Power (CSP) plants in the southern region could not only boost the economy but also reduce reliance on imported oil. However, comprehensive feasibility studies are necessary before implementing such projects. Moreover, establishing renewable energy centers could facilitate research on grid integration and accelerate the development of innovative solutions. Supporting domestic universities in conducting research on water, renewables, and the environment can help build a skilled workforce equipped to drive the renewable energy sector forward. In addition to domestic efforts, Jordan should actively seek to attract foreign investment in its renewable energy sector. This could involve creating an investor's guide outlining the best energy technologies for each location in Jordan and highlighting the country's renewable potential and competitive advantages. The National Energy Sector Strategy for 2020-2030 sets ambitious targets for increasing the proportion of renewable energy in the electricity blend to 31% by the end of the decade. This plan also includes incorporating 15% from oil shale, which, when combined with renewable sources, is expected to elevate locally generated capacity to roughly 48.5%. Moreover, there is a projected 9% enhancement in the energy efficiency of diverse sectors by 2030 compared to 2018. Recent initiatives such as the Green Growth National Action Plan and the updated Nationally Determined Contributions (NDC) demonstrate Jordan's commitment to advancing its renewable energy agenda. In conclusion, Jordan has made significant strides in promoting renewable energy, but there is still much work to be done. By addressing key challenges and capitalizing on opportunities, Jordan can accelerate the transition to a sustainable energy future, reduce fossil fuel dependence, and promote economic development and energy resilience.

RESUMEN

La tesis ofrece un análisis exhaustivo de la industria de energía renovable en Jordania, con el objetivo de ayudar a los tomadores de decisiones e inversores en la planificación de proyectos futuros. Se adentra en la demanda energética actual en el país y examina el papel de las fuentes renovables en garantizar la seguridad energética a largo plazo. A pesar de los beneficios potenciales de la energía renovable, existen varios desafíos por superar, incluyendo marcos de políticas, apoyo técnico y recursos financieros. Sin embargo, Jordania ya ha comenzado a tomar medidas para abordar estos problemas y aprovechar las oportunidades que ofrece la energía renovable. Para promover aún más la adopción de energía renovable, Jordania debería centrarse en gestionar eficazmente su sistema eléctrico e invertir en infraestructura de red y capacidad de almacenamiento. El desarrollo de plantas de Energía Solar Concentrada (CSP) en la región sur podría no solo impulsar la economía, sino también reducir la dependencia del petróleo importado. Sin embargo, se necesitan estudios de viabilidad integrales antes de implementar dichos proyectos. Además, el establecimiento de centros de energía renovable podría facilitar la investigación sobre integración en la red y acelerar el desarrollo de soluciones innovadoras. Apoyar a las universidades locales en la realización de investigaciones sobre agua, renovables y medio ambiente puede ayudar a construir una fuerza laboral capacitada para impulsar el sector de la energía renovable hacia adelante. Además de los esfuerzos nacionales, Jordania debería buscar activamente atraer inversiones extranjeras en su sector de energía renovable. Esto podría implicar la creación de una guía para inversores que describa las mejores tecnologías energéticas para cada ubicación en Jordania y destaque el potencial renovable del país y sus ventajas competitivas. Se deben realizar evaluaciones ambientales detalladas antes de las aprobaciones de proyectos para garantizar un impacto mínimo en el área circundante y la población. Los inversores también deberían realizar evaluaciones ambientales antes de la aprobación del proyecto por parte del gobierno jordano. La Estrategia Nacional del Sector Energético para 2020-2030 establece objetivos ambiciosos para aumentar la proporción de energía renovable en la mezcla eléctrica al 31% para fines de la década. Este plan también incluye la incorporación del 15% de esquisto bituminoso, que, combinado con fuentes renovables, se espera elevar la capacidad generada localmente a aproximadamente el 48.5%. Además, se proyecta un aumento del 9% en la eficiencia energética de diversos sectores para 2030 en comparación con 2018. Iniciativas recientes como el Plan de Acción Nacional para el Crecimiento Verde y las Contribuciones Determinadas a

Nivel Nacional actualizadas (CDN) demuestran el compromiso de Jordania de avanzar en su agenda de energía renovable. En conclusión, Jordania ha avanzado significativamente en la promoción de la energía renovable, pero aún queda mucho por hacer. Al abordar los desafíos clave y aprovechar las oportunidades, Jordania puede acelerar la transición hacia un futuro energético sostenible, reducir la dependencia de los combustibles fósiles y promover el desarrollo económico y la resiliencia energética.

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WORK AREA 20 years' MRB experience in R&D executing sustainable energy projects, 2003-Current

Photovoltaic, Research and Development Manager

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- Spearhead research and development efforts in photovoltaic technology.
- Led mechanical design teams to optimize solar energy systems.
- Managed projects automating the design process and permit creation for solar systems.
- Developed customized solar PV data acquisition systems and weather stations.
- Created detailed mechanical and electrical drawings for system installations.

Mechanical Design Team Leaser

(JODDB) Jordan Design & Development Bureau / (KADDB) King Abdullah Design & Development Bureau Jan 2003 – Oct 2009

- Designed and manufactured armored vehicles for military and special operations.
- Integrated weapon systems and developed land systems and mechanisms.
- Led the design and analysis of engineering systems for various military applications.

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Natural Language Processing in Healthcare	Design of Chassis System.
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Vehicle Dynamics for Passenger Cars & Light Trucks.	Teamwork Skills
Design and analysis of engineering systems.	Leadership Skills
Structural & Thermal Simulation with Pro/Engineer.	(3D)Autodesk Inventor
Advanced Dimensional Management (GD&T)	(3D) ENOVIA PLM
Suspension & Steering System Design	(3D) Animation (3Ds MAX).
Six Steps to Success	ISO 9001:2000.
Production Management	(3D) CATIA CAD package
Creative Thinking & Innovation	(3D) Mechanical Desktop, AutoCAD.
Introduction to deep Learning	(3D) Inventor Professional
Problem Solving & Decision Making Skills	(3D) Solid Works/Solid Edge
Delegation, Coaching and Mentoring Skills	(3D) Creo Pro-Engineer.
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- Managed projects to automate the Photovoltaic system design process.
- Developed computer-aided design templates and procedures to automate permit creation for solar.
- Designed and installed customized Solar PV data acquisition systems including weather stations.

- Prepared accurate and detailed mechanical and electrical drawing sets for system installation.
- Experience in CAD, CAM modeling, Workshop DWG. Data pack, fixtures/jigs, Manufacturing techniques, factory machines fabrication and assembly operations.

Table of Contents

ACKNOWLEDGEMENT.....	3
WORK AREA 20 years' MRB experience in R&D executing sustainable energy projects, 2003-Current	8
Photovoltaic, Research and Development Manager	8
Mechanical Design Team Leaser	8
• Bachelor's Degree in mechanical engineering	8
EXPERIENCE AND QUALIFICATIONS	9
Table of Contents	10
List of Figures.....	13
Nomenclature	15
Chapter 1	1
Chapter 1	1
Introduction.....	1
1.1. Background and Context	1
1.2. Research Objectives and Scope	2
1.3. Contributions	3
1.4. Dissertation Organization.....	4
Chapter 2	5
Literature Review	5
Chapter 2	6

2.1	Global Perspectives on Renewable Energy Integration	6
2.1.1	Economic Benefits.....	6
2.1.2	Social Implications and Community Engagement Strategies.....	7
2.2	Energy sector in Jordan	7
2.2.1	Energy Source and Consumption Patterns	9
2.2.1.1	Policy and Regulatory Framework in Jordan.....	10
2.2.1.2	Wind Generation in Jordan.....	11
2.2.1.3.	Biomass Energy in Jordan.....	12
2.2.1.4	Hydropower Projects in Jordan.....	13
2.2.2	Policy and Regulatory Framework in Jordan.....	14
2.2.2.1	Challenges Facing the Renewable Energy Sector in Jordan.	16
2.2.3	Impact of COVID-19 on the Energy Sector in Jordan.....	19
2.2.3.1	Introduction	19
2.2.3.2	Indicators Impact	22
2.2.3.4	Environment Indicator	23
2.2.3.5	Economic Indicator:	24
2.2.3.6	Energy Indicator.....	28
Chapter 3.....	32	
Assessment of Jordan's capacity for renewable energy sources	32	
Chapter 3: Assessment of Jordan's capacity for renewable energy sources	33	
3.1	Case Studies on the Integration of Renewable Energy Projects in Jordan.....	33
3.1.1	Introduction.....	33
3.1.2	Profile of Renewables Energy in Jordan, a Geographic Overview	36
3.1.3	Investigating Renewable Energy Projects in Jordan.....	38
3.1.4	Solar Energy in Jordan	40
3.1.5	Estimation of solar radiation on the inclined surface.....	41
Chapter 5	44	
Chapter 5	45	

Challenges and Opportunities	45
5.1 Introduction.....	45
5.2 Identification of Integration Challenges and Barriers	47
5.3 Opportunities for Accelerating Renewable Energy Deployment	50
5.4 Strategies for Accelerating Renewable Energy in Jordan.	53
5.5 Policy Recommendations.....	57
Chapter 6: Conclusion.....	63
6.1 Summary of Key Findings and Contributions	63
6.1.1 The impact of the COVID-19 pandemic on National Electric Power Company ..	63
.1 Other challenges facing the energy sector's growth	63
6.1.2 Conclusion	64
6.2 Future Research Directions	68
References.....	72

List of Figures

Figure 2-1: Average daily sunshine hours for each month in Amman[12]	8
Figure 2-2: Jordan 1990–2019 total energy supply (TES) [14].....	9
Figure 2-3: Percentage of Total Electricity Consumption 2023	10
Figure 2-4: 1990-2019 Total Electricity Generation In Jordan [14].....	11
Figure 2- 5: Summary Of Wind-Energy Projects In Jordan[21].....	12
Figure 2-6: Jordan’s Greenhouse-Gas Avoided Emissions, 2020–2040.	24
Figure 2-7: Jordan’s Reference Price of Renewable Energy Sources. [61].....	26
Figure 2-8: Monthly electricity demand (KWh) in Jordan's city center over the last five years, including during the current pandemic[54].....	28
Figure 3.1:9Renewable Energy Potential Maps Of Jordan [21].....	37
Figure 3-2:10Summary Of Solar Energy Projects In Jordan [21, 111].	39
Figure 3-3:11Illustrates the imports of crude oil, oil products, and coal from 2014 to 2018, measured in thousand tons [10].	40
Figure 3-4: 12 Solar Array Tilt Angle And Energy Output [117].....	41
Figure 13-5: Jordan Provinces Map.....	43
Figure 5: 43 The Jordan Resources Weighted Scores Assigned to Various Renewable Energy.	52

List of Tables

Table 2.1: Summary Of Electrical Demand From 2016 To 2020 During The Time of Movement Restrictions Orders (March, April, And May)[54].	29
Table 3.1 : Jordan Provinces With Longitudinal, Latitude, And Elevation Information[119].	42
Table 3.2: Jordan's Share of Each Type of Biomass Resource[112]. Error! Bookmark not defined.	
Table 4.1: Comparison of Cleaning Technologies	Error! Bookmark not defined.
Table 4.2: Estimated cleaning PV panels cost in Jordan using different methods[241]. Error! Bookmark not defined.	
Table 4.3: Data of the controllable appliances.....	Error! Bookmark not defined.
Table 4.4: HVAC Parameters	Error! Bookmark not defined.
Table 4.5 : (stage 1).	Error! Bookmark not defined.

Nomenclature

CSP	Concentrated Solar Power
NDC	Nationally Determined Contributions
CDN	Content Delivery Network
MRB	Management Review Board
MEI	Millennium Energy Industries
PV	Photovoltaic
PMP	Project Management Professional
API	American Petroleum Institute
GD	Geometric Dimensioning
PLM	Product Lifecycle Management
MAX	Maximum
ISO	International Organization for Standardization
CATIA	Computer-Aided Three-dimensional Interactive Application
CAD	Computer-Aided Design
CFD	Computational Fluid Dynamics
XF	XFlow (CFD software)
FEA	Finite Element Analysis
UK	United Kingdom
CAM	Computer-Aided Manufacturing
DWG	Drawing (file format)
COVID	Coronavirus Disease
WWTP	Wastewater Treatment Plant
TES	Thermal Energy Storage
CO	Carbon Monoxide
RES	Renewable Energy Sources
IEA	International Energy Agency
JREEEF	Jordan Renewable Energy and Energy Efficiency Fund
GGGI	Global Green Growth Institute
GDP	Gross Domestic Product
US	United States
SWHS	Solar Water Heating System

EU European Union
 MW Megawatt
 EMRC Electricity and Minerals Regulatory Commission
 GW Gigawatt
 NEPCO National Electric Power Company
 MSW Municipal Solid Waste
 HVAC Heating, Ventilation, and Air Conditioning
 MT Metric Ton
 MWTH Megawatt Thermal
 MEMR Ministry of Energy and Mineral Resources
 IMF International Monetary Fund
 GG Green Growth
 NAP National Action Plan
 QAIA Queen Alia International Airport
 NCC National Climate Change
 EDAMA An organization for energy and environment in Jordan
 SARS Severe Acute Respiratory Syndrome
 JPSD Jordanian Public Security Directorate
 JPRC Jordan Petroleum Refinery Company
 BP British Petroleum
 LNG Liquefied Natural Gas
 EMME Eastern Mediterranean and Middle East
 GHG Greenhouse Gas
 MENA Middle East and North Africa
 MRV Monitoring, Reporting, and Verification
 JIC Jordan Investment Commission
 KW Kilowatt
 RE Renewable Energy
 PAEM Pan Arab Energy Market
 GCC Gulf Cooperation Council
 FES Friedrich-Ebert-Stiftung (a German foundation)
 AFEX Arab Future Energy Index
 RISE Regulatory Indicators for Sustainable Energy

PPA Power Purchase Agreement
TW Terawatt
AFOLU Agriculture, Forestry, and Other Land Use
CH Chapter
PJ Petajoule
IPCC Intergovernmental Panel on Climate Change
CHP Combined Heat and Power
GB Great Britain
NLK National Library of Kazakhstan
FM Frequency Modulation
MJ Megajoule
UNDP United Nations Development Programme
FDI Foreign Direct Investment
BIOE Bioenergy
ECOP Environmental Conservation and Optimization Program
POPD Population Policy Development
INOV Innovation
NR Natural Resources
FWG Future Work Group
TCI Technological Capability Index
EI Environmental Impact
RF Radio Frequency
PC Personal Computer
FW Fresh Water
USD United States Dollar
MPPT Maximum Power Point Tracking
ESP Electrical Submersible Pump
ARCI Advanced Research Center for Innovation
GLASS A technology related to renewable energy
SPICS Smart Photovoltaic and Integrated Control Systems
CV Curriculum Vitae
HEM High Efficiency Module
EV Electric Vehicle

DR Demand Response
 RTP Real-Time Pricing
 MILP Mixed-Integer Linear Programming
 MPC Model Predictive Control
 AC Alternating Current
 VIKOR A multi-criteria decision-making method
 IO Input/Output
 MODELLING The process of creating a model
 SOC State of Charge
 PJM Pennsylvania-New Jersey-Maryland Interconnection
 FE Finite Element
 TM Trademark
 RAM Random Access Memory
 AI Artificial Intelligence
 IR Infrared
 BRICS Brazil, Russia, India, China, and South Africa
 SDG Sustainable Development Goals
 KG Kilogram
 RL Reinforcement Learning
 JA Jordan
 WAY Name of a project or program
 IGA Investment Grade Audit
 IREC International Renewable Energy Conference
 AE Alternative Energy
 AL Aluminum
 NRS National Renewable Standards
 SWOT Strengths, Weaknesses, Opportunities, Threats
 MOPIC Ministry of Planning and International Cooperation
 JJMIE Jordan Journal of Mechanical and Industrial Engineering
 DC Direct Current
 SBR Sequencing Batch Reactor
 PCR Polymerase Chain Reaction
 SI International System of Units

ISSN International Standard Serial Number
ASET American Society for Engineering Education
WDK Wireless Data Kit
IGI Information Gatekeepers Inc.
USA United States of America
MIA Missing in Action
SEAI Sustainable Energy Authority of Ireland
VISP Visual Information Seeking Process

Chapter 1

Introduction

1.1. Background and Context

1.2. Research Objectives and Scope.

1.3. Contributions.

1.4. Dissertation Organization

Chapter 1

Introduction

1.1. Background and Context

Renewable energy is the central topic of the dissertation because it is essential to a cleaner and more sustainable future, and it is especially important in Jordan because of the country's energy security and environmental concerns, the dissertation looks at how Jordan can use renewable energy better to help the environment and also make their economy stronger. It looks at what Jordan is doing right now with renewable energy and suggests ways they can do even better. The dissertation also shares ideas that other places facing similar challenges could use. It uses information from different sources to see how well Jordan is doing with renewable energy and what more they can do. And it gives some practical tips and suggestions on how Jordan can improve their use of renewable energy, Incorporating specifics regarding various categories of renewable energy technologies. Solar and wind power, among other renewables, are currently the most cost-effective means of generating power nationwide. Over the past decade, the cost of setting up big solar panels (PV) has dropped by 85%, while other types of renewable energy, like wind, have also become much cheaper. This means that in almost every country, when they want to build new power plants, they're choosing renewables more often. With fossil fuel prices going up, it's even more likely that we'll see more investment in renewable energy because it's cheaper and better for the environment [1].

Also, keeping global warming below 1.5 degrees Celsius is looking more and more like an insurmountable mountain to climb unless we take drastic and immediate action. This latest edition of the World Energy Transitions Outlook outlines how we can address both challenges by accelerating the transition to renewable energy, expanding its use across various sectors. The economic case for embracing renewables is becoming stronger, and the benefits will be widespread. However, achieving this requires clear plans and strategies. The time for action is now. To keep the goal of reducing global warming to 1.5 degrees Celsius by 2050 within reach, the ten years preceding 2030 are of the utmost importance [1]. The increased usage of fossil fuels has resulted in a rise in atmospheric CO₂ levels, leading to global warming, also known as climate change According to experts, this is one of the worst environmental problems we've seen recently [2]. Additionally, the global increase in population density and energy

consumption for basic needs and improved living standards has heightened the demand for energy, prompting many developed countries to seek alternative energy solutions. Renewable energies are considered the most viable solution to meet energy needs while reducing reliance on traditional energy sources and lowering greenhouse gas emissions. [3]. The sustainable energy sector has witnessed a recent surge, with businesses focusing on converting renewable energies into profitable ventures. In recent decades, numerous countries have intensified their efforts to exploit and invest in renewable energy sources (RES) to bolster electricity production and combat climate change. As per the International Energy Agency (IEA) [1], there was a 3% rise in renewable energy output from 2015 to 2019, with sustainable energy now constituting approximately 28% of global electricity generation. Energy encompasses more than just electricity; it serves as the cornerstone of the economy and a catalyst for sustainable development. Despite improvements in utilizing RES, the growth in renewable energy adoption still falls short of the required level. Because renewable energy sources are rather expensive to produce, fossil fuels remain dominant in the energy generation market. Still, plans are afoot to increase the proportion of power generated by RES, which includes hydropower, wind turbines, solar photovoltaics, biofuels, geothermal power, and marine power, with the goal of reaching 40% by 2030 [2].

1.2. Research Objectives and Scope

The primary aims of the dissertation can be outlined as follows:

1. **Assessment of Current Energy Landscape:** Evaluate the existing energy situation in Jordan, including sources, consumption patterns, and challenges.
2. **Analysis of Renewable Energy Potential:** Investigate the feasibility and potential of renewable energy sources, such as solar and wind, in Jordan.
3. **Identification of Integration Challenges:** Identify and analyze the technical, economic, regulatory, and social barriers to the integration of renewable energy into Jordan's energy mix.
4. **Evaluation of Policy and Regulatory Framework:** Assess the effectiveness of existing policies and regulations related to renewable energy in Jordan and propose recommendations for improvement.
5. **Exploration of Technological Solutions:** Investigate technological advancements and innovations relevant to renewable energy integration in Jordan.

6. **Assessment of Social and Economic Impacts:** Evaluate the potential social and economic impacts of renewable energy integration on communities and the country as a whole.
7. **Development of Recommendations:** Provide practical recommendations for policymakers, industry stakeholders, and other relevant parties to promote the successful integration of renewable energy in Jordan.

1.3. Contributions

Jordan's journey towards renewable energy integration is underscored by a comprehensive regulatory framework. The passage and subsequent modifications to the Renewable Energy and Energy Efficiency Law establish a strong foundation for the efficient utilization of renewable energy sources. In addition to promoting the use of renewable energy sources, these regulations aim to improve energy efficiency across the board and protect the environment. Jordan has implemented initiatives such as the Feed-in Tariff (FiT) Program and the Renewable Energy and Energy Efficiency Fund (JREEEF) to encourage the adoption of renewable energy sources through targeted financial assistance. Jordan's energy transformation strategy sets ambitious renewable energy goals. The National Energy Sector Strategy for 2020–2030 aims to boost capacity by 31% by 2030 by increasing renewable energy in the electrical mix [9]. The policy also highlights oil shale's potential, promoting local energy. Jordan is committed to reducing fossil fuel use and moving toward cleaner, sustainable energy. Jordan's proactive engagement with international partners and alignment with global climate initiatives highlight its leadership in climate action. Collaborations with organizations like the Global Green Growth Institute (GGGI) and updates to its Nationally Determined Contributions (NDC) showcase Jordan's commitment to combating climate change. Jordan aims to achieve a 31% reduction in greenhouse gas emissions by 2030 through adjustments to its objectives. Jordan underscores its commitment to actively contribute to the global climate agenda.

These international partnerships not only provide valuable support but also position Jordan as a key player in driving renewable energy transition regionally and globally. Lockdowns nationwide due to the COVID-19 outbreak have made it harder for businesses and households to meet basic needs. Therefore, energy industry investments have decreased, making it harder to fund new energy projects. These factors are projected to cause more electricity shortages along with supply chain disruptions and maintenance delays. Thus, this thesis analyzes energy sector factors and proposes solutions. The COVID-19 crisis has

underscored the necessity of investigating alternative systems for regulating energy consumption, enhancing efficiency, and advocating for natural resource utilization and renewable energy sources. It also extensively studies Jordan's energy sector.

1.4. Dissertation Organization

The dissertation is structured into seven chapters, each providing a brief overview of the content. The introduction outlines the groundwork for integrating renewable energy, outlining research objectives, contributions, and organization. The literature review explores global perspectives on renewable energy integration, discussing economic benefits, social implications, and community engagement strategies. The energy sector in Jordan is examined, including current policies and regulatory frameworks. The COVID-19 pandemic's effects on Jordan's energy industry are also discussed. The analysis of renewable energy potential in Jordan is presented through case studies and bioenergy assessments. Technological solutions are explored, including an innovative solar panel cleaning mechanism with rainwater harvesting enhancement and a methodical framework for smart prosumers. The integration of technological innovations is explored for enhanced renewable energy deployment. Challenges and opportunities are identified, with potential opportunities for accelerating renewable energy deployment. Strategies for overcoming challenges and maximizing opportunities are discussed, along with policy recommendations for support. The conclusion provides a summary of major discoveries and contributions, future research directions, and a comprehensive bibliography of sources cited in the dissertation.

Chapter 2

Literature Review

2.1. Global Perspectives on Renewable Energy Integration

2.1.1 Economic Benefits

2.1.2 Social Implications and Community Engagement Strategies

2.2. Energy sector in Jordan

2.2.1. Energy sources and consumption patterns

2.2.2. Policy and Regulatory Framework in Jordan

2.2.3. Impact of COVID-19 on the Energy Sector in Jordan

Chapter 2

Literature Review

2.1 Global Perspectives on Renewable Energy Integration

Energy isn't just about electricity; it's a fundamental driver of economic growth and a cornerstone of sustainable development. Despite progress in using renewable energy sources, the global energy challenge still stems from the need for diversity. While renewable energy usage has improved, it hasn't reached the necessary levels yet. Jordan stands out as having significant potential to tap into renewable energy. With resources like hydropower, wind, solar energy, and biomass, along with vast desert areas ideal for renewable energy projects, Jordan is primed for development in this area. Therefore, the government has established a thorough, long-term energy strategy to guarantee a steady supply of energy. Increasing the usage and growth of clean energy sources in the power sector is the objective of this strategy, which seeks to achieve the goal of obtaining 50% of the nation's electricity from renewable sources by 2030 [3]. The potential for increasing disparity in energy distribution is high when relying on renewable energy sources, as they offer a sustainable way to ensure continuous energy supply while also reducing greenhouse gas emissions. For this reason, a lot of people are working on distributed energy resource designs that use renewable power sources. These sources can include things like solar photovoltaics (PV), wind turbines, diesel engines, biomass gasifiers, battery banks, fuel cells, and more. These resources are particularly important in rural areas where they can be used to power essential loads [16].

2.1.1 Economic Benefits

The prevalence of desert ecosystems in Jordan covers approximately 80% of the country's land, with 88% of the population residing on less than 20% of the land. A substantial portion of the country's gross domestic product (GDP) and exports (about 12 percent) come from agriculture, which is essential despite the scarcity of farmable land. Jordan experiences a high population growth rate of 2.4% annually, exacerbated by a substantial influx of refugees. This demographic trend poses challenges but also presents opportunities for economic growth and development[4].

The country heavily relies on imported energy, with 96% of all energy consumed being imported. The cost of energy imports is estimated at US\$3.6 billion, equivalent to 13.5% of GDP.

This dependency on imported energy underscores the urgency for alternative energy solutions to enhance energy security and reduce reliance on costly imports. Jordan boasts significant renewable energy potential, primarily in the form of direct solar energy. Leveraging this potential can not only broaden the energy portfolio but also yield economic advantages by fostering the growth of renewable energy endeavors. Through investment in renewable energy infrastructure, Jordan has the opportunity to diminish its reliance on imported energy, decrease energy expenses, and catalyze economic expansion by generating employment opportunities and investment avenues [5].

2.1.2 Social Implications and Community Engagement Strategies

Since 2015, about 14% of Jordanian houses have installed solar water heating systems (SWHS) [6]. The cumulative count of SWHSs rose to 16,000 by the conclusion of 2018, reached 24,000 in 2020, and further escalated to 30,000 by the end of 2021, attributed to an annual growth rate averaging 20%. The upward trajectory would not have been possible without initiatives such as those funded by the Jordan Renewable Energy and Energy Efficiency Fund (JREEEF). In 2019, 2,200 solar water heaters were installed, and in 2020, that number jumped to 3,000. Nevertheless, additional expansion has been hindered by the sluggish implementation of rules mandating the installation of SWHS in bigger residential complexes and commercial buildings [7]. Although practically every Jordanian now has access to electricity, several areas are also installing off-grid renewable energy technologies, such as standalone units. The use of such systems is more common in rural areas, border checkpoints, telecommunications stations, desert camps, and communities [8, 9]. Solar photovoltaic (PV) systems installed independently have shown to be a practical and economical way to power these regions. In support of renewable energy adoption in agriculture and water management, the Renewable Energy and Energy Efficiency Program, funded by the EU, installed approximately 106 solar pumps in the Highlands and 214 in the Jordan Valley [7]. These systems can provide more than 1,000 kW of power when used together. Another sign of increasing interest in these systems is the recent green light for the first 9 MW stand-alone project (no feed-in). These projects, which require distribution company authorization, are expected to be overseen by the Energy and Minerals Regulatory Commission (EMRC) soon [7, 10].

2.2 Energy sector in Jordan

Jordan is a Middle Eastern nation that shares boundaries with both the Red Sea and the Gulf of Aqaba at its southernmost point. Its geographical position is between 29.1830° N latitude and

36.2677° E longitude. Just 60 kilometers via Palestine separate you from the Mediterranean. The overall area of the land is 89,320 km² (34,487 mi²), and the length of the shoreline is 26 km (16.2 mi). This land area makes up around 112% of Maine's total area. Consequently, Jordan ranks as the 112th largest nation globally and the 21st smallest in Asia. Urban areas accommodate a notably high percentage of 92% of the population, with Amman housing over one-third of the populace [11]. The figure 2.1 below displays the average daily sunshine hours for each month in the region of Amman-Jordan. It is important to note that the number of hours of sunshine represents the time when the sun is visible without any obstruction caused by clouds, fog, or mountains. As shown in the table 2.1, July has the highest number of daily sunshine hours, with an average of 12 hours per day.

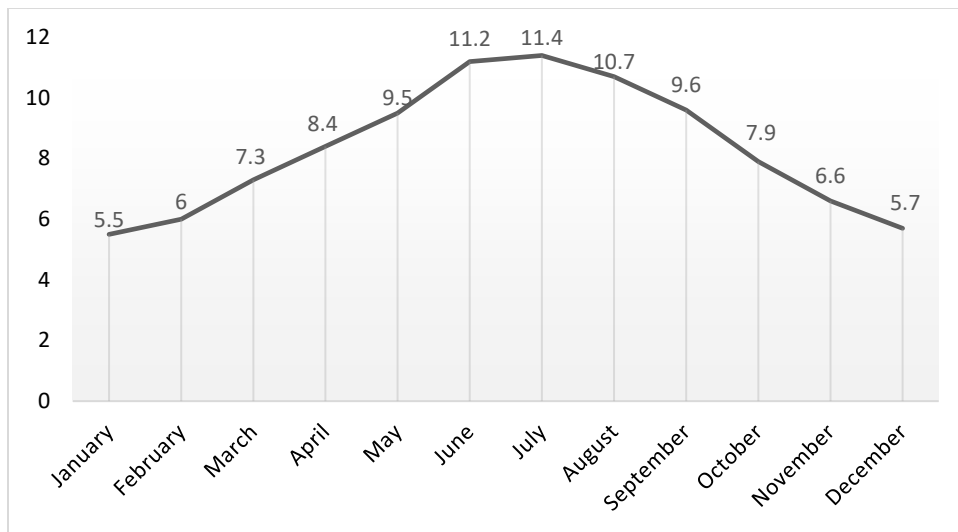


Figure 2-1: Average daily sunshine hours for each month in Amman[12]

Challenges arising from rapid population increase, expanding industrial and commercial sectors, expensive imported energy sources, and elevated greenhouse gas emissions are causing the Jordanian government to scramble. So, making sure people can get their hands on affordable, sustainable energy has become a major issue. Renewable energy projects, including those that use waste, biomass, solar, and wind power, have been prioritized by the government as a means to overcome these challenges. Ranked 66th in the world for energy transition by the World Economic Forum, Jordan fell sharply to 82nd place. Overall, the country's score dropped to 49.5% in 2019, despite attaining 53%. The energy system efficiency score for Jordan dropped from 56% to 46%, which is noteworthy, even if it had improved slightly from 50% to 53% before the default. Furthermore, despite a 0.4% decline in the labor force participation rate during the fourth quarter

of 2020, the unemployment rate surged to 24.7% from 9.3% in the first quarter [13]. The provided graph illustrates Jordan's total energy supply (TES) from 1990 to 2019, categorized by source [14].

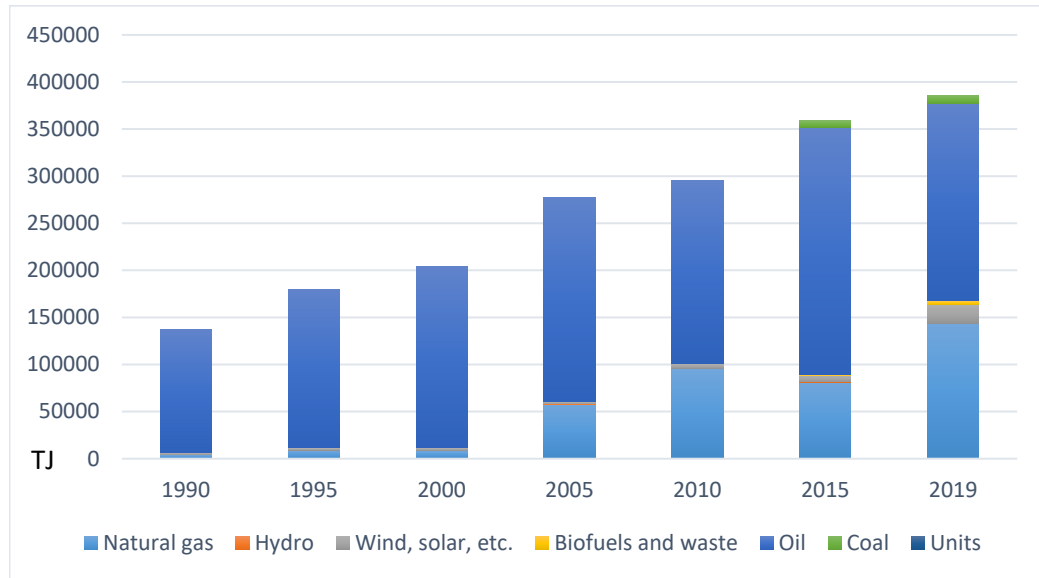


Figure 2-2: Jordan 1990–2019 total energy supply (TES) [14].

In 2023, a slowing economy will result in a 1.3% increase in global energy demand. Despite decarbonization goals, coal use will increase somewhat to make up for gas supply shortages. The energy transition will be delayed by more frequent extreme weather occurrences that will compel many nations to revert to using fossil fuels. Asia is poised to spearhead a global surge in renewable energy consumption, with an anticipated 11% increase, even as investment in the sector is projected to decline. Concurrently, certain countries may reverse their plans to gradually phase out nuclear power usage in response to the energy crisis.[15].

2.2.1 Energy Source and Consumption Patterns

With increases of 5.5% in 2019 and 7.4% in 2020, Jordan's peak load was noticeably higher than in 2019. Energy usage increased by around 3.1% per year on average between 2010 and 2020 [9]. Renewable energy sources, which are alternative, clean, and dependable, are becoming increasingly important in addressing the increasing energy demands, as the ability to generate electricity reached 5,424 MW by 2020. In 2020, traditional sources accounted for 72% of the local available capacity, while renewables made for about 28%. It's worth mentioning that in 2020, just 8% of the potential capacity of renewable energy systems was utilized for power generation. Consequently, the government of Jordan is looking into ways to sell power to nearby nations. the

data shows a 4.3 percent increase in per capita electricity usage compared to the previous year, with consumption reaching 1,821 kilowatts per hour in 2023, up from 1,746 kilowatts per hour in the previous year. Residential electricity consumption made up 47.9 percent of the total, while industrial usage accounted for 21.2 percent, and commercial consumption stood at 14.7 percent. Additionally, 14.2% of electricity consumption was attributed to water pumping, and street lighting contributed 2% to the overall usage. Furthermore, the data indicated a 13.3% energy loss, with electricity being supplied to 99.9% of the population [16]

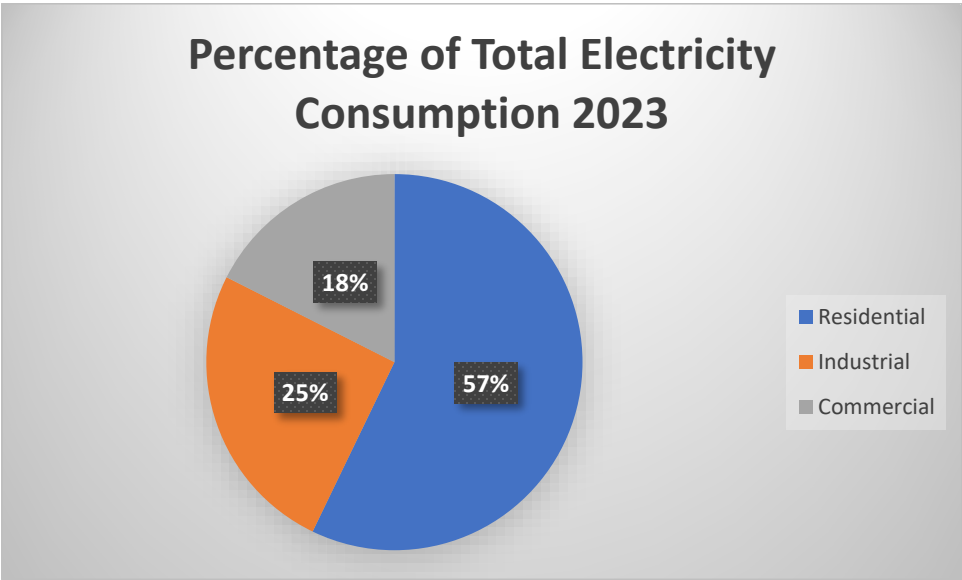


Figure 2-3: Percentage of Total Electricity Consumption 2023

2.2.1.1 Policy and Regulatory Framework in Jordan

Fossil fuels constitute 52% of the nation's overall energy consumption, with natural gas closely trailing at 38%. The average per capita consumption stands at 0.7 toe/cap, which includes 1850 kWh of electricity. Households are charged \$0.100 per kilowatt-hour for electricity, while businesses pay slightly more at \$0.123 per kilowatt-hour. These rates encompass all associated fees, including taxes, distribution expenses, and energy charges. For homes and businesses, respectively, the average global price of energy during that time was \$0.139 per kilowatt-hour.[18]. The Fig. 2.4 below shows 1990-2019 Total electricity generation in Jordan by source in Jordan

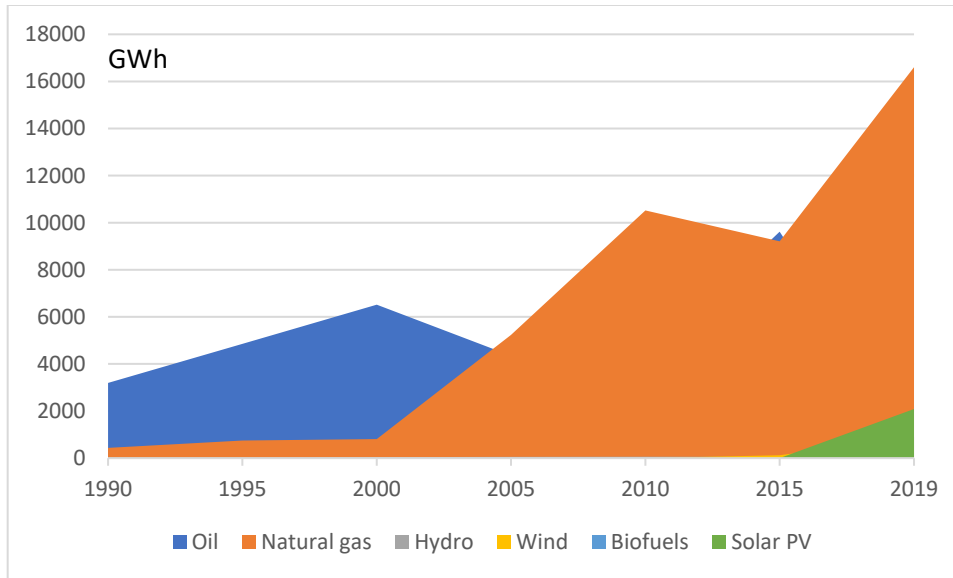


Figure 2-4: 1990-2019 Total Electricity Generation In Jordan [14].

The amount of energy that Jordan imported in 2021 was 2.8 billion dinars, the amount of energy that was used up was 8166 tons of oil equivalent, and the amount of electricity and natural gas that was consumed per capita was 1.746 kWh. Power generation also saw a decrease, with the contribution falling to 73% from 80% in 2020. In 2021, 28% of the electricity came from local sources, which was an increase from 22% the year before. Imports of crude oil totaled 13 million barrels from September to December of 2021, while output from the Hamza oil field was 105,000 barrels [19].

2.2.1.2 Wind Generation in Jordan

If renewable energy is to become more resilient and sustainable, the incorporation of wind turbines is now essential. Strategic investments in wind turbine projects have allowed Jordan to make substantial progress in this sector. In 2014, the nation began wind farm projects with modest capacities of approximately 1.4 MW. With the aim of boosting power generation in Jordan by 4%, advancements were evident in the establishment of four wind power plants by 2016: Ibrahimya, Hofa, Ma'an, and Tafilah. In early 2020, two wind farms with a combined capacity of 145 MW were commissioned, as per an agreement reached in 2016. It followed that by 2021, Jordan's total installed wind generating capacity had risen to 622 MW, and projections suggested that the nation could produce 1,595 to 2,076 GWh of energy annually. According to both [9] and [20], this would have supplied roughly 11% of the nation's electricity needs that year. About 15.3% of the system-peak demand in 2021 came from wind-generated units, according to NEPCO's annual report.

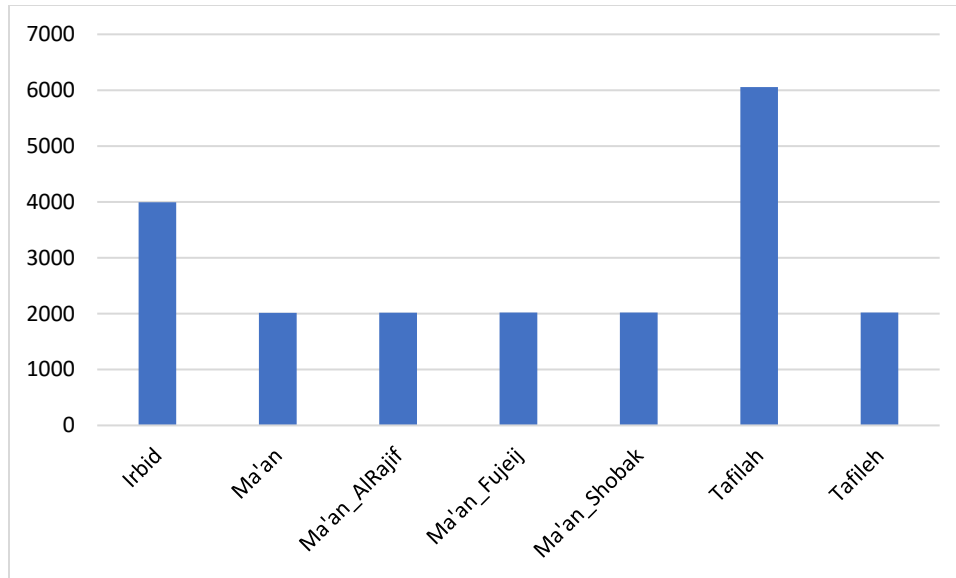


Figure 2- 5: Summary Of Wind-Energy Projects In Jordan[21].

2.2.1.3. Biomass Energy in Jordan.

Jordan primarily relies on municipal solid waste (MSW) as its main bioenergy resource. The country inaugurated its initial MSW-based pilot plant near Amman in 2000, boasting a capacity of 3.5 MW. With the population of Jordan on the rise, the generation of waste has followed suit, emphasizing the significance of MSW as a vital resource[21]. Estimates suggest a daily generation of one kilogram per capita, with over 50% constituting organic waste. Every year, Jordan produces almost 2.7 million tons of solid garbage, which instead of being used as a resource for energy or the economy, causes environmental problems [22]. The energy demands of Jordan are met by other sources, with biomass accounting for just 0.1% of that total at the moment [22]. A biogas project was launched by the Greater Amman Municipality to recover methane from the Ghabawi landfill. The project's target capacity is 7 MW, which should be reached by 2023. at 2019, The government sanctioned a biogas pilot facility at the Zaatari Refugee Camp in Mafraq, indicating the potential for investment in generating power from biogas derived from household solid waste deposits. Evidence suggests that 656 metric tons of natural gas—or about 24 percent of Jordan’s main energy demands in 2012—could have been supplied with the biogas that was produced. Projects with waste-to-energy capacity of 40–50 MW were targeted for establishment by the Jordanian government by 2020 [24, 25].

Jordan is home to a variety of biomass resources, such as agricultural dung, olive groves, and industrial byproducts. Home HVAC systems are the intended beneficiary of these funds from

the government. The olive oil harvesting process produces around 19,000 metric tons (MT) of Jift each year, which could be used as fuel or feed [26]. Even if these materials are plentiful, we still need to figure out how to make the most of our biomass resources to generate renewable energy.

2.2.1.3 Geothermal Projects in Jordan.

Jordan's energy sector is progressively exploring geothermal energy as a promising resource. The nation possesses geothermal reservoirs, particularly hot mineral water sources found in springs and wells located along the Rift Valley. Notably, the northeastern region and the Dead Sea escarpment exhibit significant temperature variations, with gradients reaching up to 50°C per kilometer of depth (°C/km). Despite these resources, the temperature remains below the threshold required for electricity production (below 100 °C). Nonetheless, hot water is currently utilized for recreational purposes in numerous hotels and resorts across Jordan [22]. Several public facilities in Jordan have adopted small-scale indirect geothermal systems to provide space heating and cooling. Instances comprise the National Center for Research, the American University of Madaba, and the development building of the Higher Council of Science and Technology [23]. According to data from the International Geothermal Association [24], Jordan's current geothermal energy utilization capacity stands at 153.3 MW thermal (MWTH), constituting merely 0.42% of the nation's total geothermal energy potential. Geothermal energy offers potential for diverse applications like aquaculture, horticultural heating, and usage in the food industry. Nevertheless, further investigation is crucial to assess its viability and encourage its adoption in Jordan [23].

2.2.1.4 Hydropower Projects in Jordan.

Jordan's investment in hydropower faces challenges due to the scarcity of suitable water bodies necessary for constructing large-scale hydroelectric plants. Currently, only two operational hydropower facilities exist: the King Talal Dam, with a capacity of 4 MW, and the Aqaba Power Station, with a capacity of 6 MW [22]. The hydroelectric plant at Aqaba utilizes water from the Gulf of Aqaba to provide cooling for a thermal power plant. Together, these installations generate approximately 60 gigawatt-hours per year, representing about 0.4% of Jordan's total power production in 2018 [22, 25]. Moreover, the considerable difference in elevation between the Red Sea and the Dead Sea presents a significant opportunity for hydropower development. Estimates indicate that this could result in an electrical output capacity ranging from 400 to 800 MW [22]. Several studies conducted in Jordan, such as those by Stoyanov et al. [26], Al-Addous et al. [27], and Al-Masri et al. [28], have investigated the feasibility of establishing hydropower facilities in

the region, highlighting promising investment opportunities. Al-Addous et al. [27] assessed the viability of micro-hydro power generation in Jordan, focusing on its cost-effectiveness and sustainability as a solution for off-grid and rural areas.

2.2.2 Policy and Regulatory Framework in Jordan.

With the hope of increasing the proportion of renewable energy in its overall energy use, etc., Jordan has enacted a number of laws and regulations. Energy Efficiency and Conservation Law, Net Metering, the National Energy Strategy, and Feed-in Tariff Program are all part of this [22]. Nevertheless, there are still obstacles to overcome in order for these policies to be effectively implemented and utilized. One area of special concern is the regulation of energy storage across all stages of the energy life cycle, from production to transmission, distribution, and consumption. The development of battery storage infrastructure, which is essential for improving grid stability and reliability, is impeded by the lack of comprehensive laws. To ensure the most efficient use of resources and the long-term viability of the environment, new policies are needed to promote the use of electric vehicles and handle problems with recycling and decommissioning of solar power plants.

To promote the usage of solar energy for water heating in several sectors, including healthcare facilities, schools, and corporations, Jordan has initiated awareness programs and performed energy audits [8]. A growing proportion of residential and medium-sized commercial buildings in Jordan are integrating solar energy into their energy plans by installing grid-connected photovoltaic systems. Financial institutions, in collaboration with the Ministry of Energy and Mineral Resources (MEMR), have joined forces to provide financial assistance covering 30% of the total installation expenses for solar water heating and PV systems in households. This program has significantly boosted the number of installations [9, 29].

The government's cessation of electricity subsidies in 2017 resulted in an initial surge in electricity rates, followed by a reduction in tariffs by 2019 [25]. The imposition of higher tariffs had a negative impact on the ability of local industry to compete, leading some enterprises to explore alternative renewable energy sources. This, in turn, resulted in the loss of clients who consumed a significant amount of energy [22]. In 2022, an electricity subsidy price was implemented based on suggestions from the IMF program. The goal is to modify energy tariffs in order to support Jordanian households and important economic sectors, with the possibility of also increasing electricity usage. Nevertheless, the implementation of the new rates has created

complications for small-scale renewable energy projects, thereby impacting their economic feasibility within the modified tariff framework. The declining expense of concentrated solar power (CSP) technology has enhanced its appeal to Jordan's industrial segment, prompting its integration via legislative initiatives delineated in the Jordan Green Growth National Action Plans (GG-NAP). Successful collaboration among the private sector, civil society entities, and governmental bodies is essential for the uptake of CSP technology, particularly emphasizing the installation of CSP facilities in southern Jordan. The objective is to stimulate economic growth and diminish dependence on imported oil [31, 32, 33, 34].

A Based on the EMRC study [35], Jordan has approximately 506 registered installation businesses, out of which 20 are actively involved in the renewables sector. In addition, nine energy audit-service companies have obtained permits to operate in the country. The proliferation of enterprises in the renewables industry has resulted in heightened competition, ultimately advantageous for both consumers and businesses. The variability in solar radiation has important implications for the development and implementation of solar energy projects in Jordan, as certain places are more suitable for large-scale solar projects than others. Therefore, it is crucial for policymakers and investors to have a thorough understanding of solar radiation patterns in various regions and provinces. This knowledge will enable them to make well-informed judgments on the most suitable location and design for solar energy projects.

According to the MEMR (2013), the transportation sector accounts for 51% of Jordan's overall energy consumption. Biodiesel, bioethanol, biogas, and algae fuels are sustainable alternatives to conventional transportation fuels, and the government should investigate them. Yet, the distribution, creation, and implementation of alternative fuels must be in sync with the aims and policies of the local government. The growth of Jordan's biofuel industry is being fueled by the country's efforts to reduce reliance on imported fossil fuels and address the impacts of climate change [36]. The MEMR has released guidelines outlining the criteria for issuing permits to facilities engaged in the production of biofuel. These rules cover both industrial fuel and biodiesel manufacturing processes. Investors are required to meet some broad criteria, This involves conducting an assessment of environmental impact, feasibility, and network impact before obtaining clearance. The results will have importance for developing policies and improving services, with the goal of offering better assistance to the public in dealing with and recovering

from complex difficulties that impact their lifestyles and health situations. Moreover, they will suggest [37].

2.2.2.1 Challenges Facing the Renewable Energy Sector in Jordan.

The net-metering system and JREEEF are two programs that the Jordanian government has implemented to encourage small-scale investments in renewable energy. Because of their narrow focus and lack of financial incentives, however, these rules have come under fire from renewable energy industry professionals [22, 38]. A lack of easily available finance options and the high initial expenses of installing renewable energy systems at the household level are major obstacles to the success of small-scale initiatives in Jordan. In addition, the difficulties in building small-scale renewable energy projects have been exacerbated by the recent adoption of new electricity rates in Spring 2022. The economic feasibility of such undertakings is undermined since these tariffs do not provide system owners with enough assistance. As a result, it is becoming more and more challenging to encourage participation in these programs, especially for low-income households.

A major problem with Jordan's electrical system dependability assurance measures is the lack of adequate technical support, which is preventing renewable energy projects from expanding. Major problems caused by variations in energy demand were brought to light in 2021 by the widespread power outages that occurred across the nation. There is a lack of flexibility and capacity in the existing electrical system to integrate many power generation sources [22]. The installation of small-scale renewable energy projects and electric vehicle charging stations also receives insufficient funding. Consequently, a renewable energy control center must be set up in order to improve the ability of government institutions to implement these technologies and to enable thorough monitoring, reporting, and analysis in the energy sector [22, 39]. Through the implementation of the Green Corridor project and the introduction of innovative grid designs, Jordan is actively addressing technological challenges. A total investment of \$172 million was allocated for the Green Corridor project in the southern region. As part of this initiative, a new 400/132 kilovolt (kV) substation was constructed in Ma'an, along with the 132/33 kV substations in Qatrana and at the airport. By 2019, the project was completed, with the Ma'an, Qatrana, and Queen Alia International Airport (QAIA) substations interconnected via double-circuit overhead lines. One of the primary objectives of the Green Corridor project is to alleviate the strain on transmission lines by facilitating the transfer of power from the southern region to the central loads

in the country's interior. Additionally, in 2019, Jordan launched a 23 MW/12.6 MWh lithium-ion solar battery project, recognizing the importance of storage in grid management [22, 32].

Foreign investment has played a significant role in driving the growth of Jordan's renewable energy industry, contributing to 75% of total investment thus far, while local financial institutions have had minimal involvement. Local investors have shown limited interest in funding large-scale renewable energy projects, resulting in a reliance on secured loans from foreign lenders, which strains the state budget. Additionally, the high costs associated with renewable energy technologies pose a significant barrier to their widespread implementation in Jordan.

As local power demand and renewable energy generation both surge, Jordan aims to expand its presence in the energy export market by linking to transmission lines in neighboring nations to export its renewable energy output. Encouraging the transportation sector to transition to electric vehicles is one strategy to mitigate the gradual increase in electricity demand [2]. However, Jordan is concerned about the potential adverse impacts of climate change, such as hotter temperatures, reduced rainfall, and accelerated evaporation rates, which could lead to higher energy costs and shortages [3]. Climate variability can also disrupt service reliability, damage infrastructure, and exacerbate these challenges. Peak and average power consumption in Jordan fell sharply from 2019 levels in 2020 as a result of the COVID-19 pandemic's influence on the country's power sector. The primary causes of this drop were a decrease in industrial activity and an increase in the connection of residential renewable energy systems to the distribution grid. In order to guarantee energy security, the National Control Center (NCC) placed restrictions on the deployment of renewable energy sources. As a consequence, the grid's reliability and stability were further compromised, and all renewable wheeling projects that were linked to it were disconnected [40, 41].

Research conducted by the Association for Energy, Water, and Environment (EDAMA) underscored the negative impacts of the pandemic on companies operating in the renewable energy sector. According to the survey, 37% of these companies reported a decline in revenues, while 32% were unable to generate any income due to the COVID-19 lockdown measures implemented in 2020 [42]. Furthermore, several scheduled renewable energy initiatives encountered setbacks, affecting electricity production costs. Despite these challenges, the Jordanian government emphasizes the importance of integrating clean energy and environmental objectives into recovery programs to achieve more efficient outcomes. Investing in renewable energy resources can bolster

socioeconomic resilience and accelerate economic revitalization. Jordan is actively shifting towards a renewable energy-oriented framework to align with its economic development objectives across multiple sectors. However, the advancement of the renewable energy sector faces several challenges, broadly categorized as Challenges in Jordan.

- **Grid Infrastructure:** Jordan's grid infrastructure may not be adequately developed to handle the integration of large-scale renewable energy projects, leading to challenges in grid stability and reliability.
- **Energy Storage:** The limited capacity for energy storage presents a notable obstacle to the integration of renewable energy in Jordan, as it restricts the capacity to store surplus energy generated during peak production for later use when renewable energy generation is low.
- **Investment and Financing:** Securing long-term investments and financing for renewable energy projects can pose challenges due to perceived risks, including political and economic instability, as well as uncertainties regarding project financial viability. Sufficient financial resources are crucial for the advancement and execution of renewable energy initiatives in Jordan. Despite attracting investments in the renewable energy sector, ongoing financial backing is vital to broaden renewable energy adoption and overcome financial challenges. Access to financing mechanisms, such as grants, loans, and investment incentives, can facilitate the development of renewable energy projects and ensure their economic feasibility. Furthermore, innovative financing models and collaborations between the public and private sectors can mobilize additional financial resources and expedite the transition to renewable energy [43].
- **Counterparty Risks:** Renewable energy projects in Jordan rely on agreements with entities like the National Electric Power Company (NEPCO) for power purchase, but these entities may face financial challenges or delays in payments, posing risks to project developers.
- **Regulatory Framework:** Despite efforts to improve the regulatory framework for renewable energy, challenges remain in terms of bureaucracy, permitting processes, and regulatory uncertainty, which can hinder project development and investment.
- **Electricity Tariffs and Subsidies:** The structure of electricity tariffs and subsidies in Jordan can impact the economic viability of renewable energy projects, Especially when renewable energy producers are not fairly remunerated for their role in supporting the grid.

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- **Intermittency and Forecasting:** Solar and wind, as renewable energy sources, exhibit intermittency, presenting grid operators with challenges in forecasting and balancing supply and demand, thereby potentially resulting in grid instability.
 - **Competition with Fossil Fuels:** The fossil fuel industry in Jordan may resist the expansion of renewable energy due to vested interests and economic dependencies, creating barriers to renewable energy sector growth.
 - **Technical Constraints:** Competition with Fossil Fuels: The fossil fuel industry in Jordan may resist the expansion of renewable energy due to vested interests and economic dependencies, creating barriers to the growth of the renewable energy sector. There is a need for enhanced technical support to overcome these challenges and ensure the efficient integration of renewables. Enhancing grid stability, mitigating intermittency challenges linked with renewable energy sources, and bolstering the technical proficiency of stakeholders engaged in the renewable energy sector are imperative. Cooperative endeavors among governmental bodies, research establishments, and industry stakeholders are vital to offer sufficient technical assistance and surmount technical hurdles.
 - **Possible roadblocks** to speeding up Jordan's transition to renewable energy sources include: people Awareness and Acceptance: The general people may be unaware of and unconvinced by the advantages of renewable energy sources.

2.2.3 Impact of COVID-19 on the Energy Sector in Jordan.

2.2.3.1 Introduction

The 11-million-person metropolis of Wuhan in the Chinese province of Hubei was the site of the 2019 coronavirus SARS-CoV-2 outbreak. By late January and February 2020, China faced a surge in COVID-19 cases, with tens of thousands reported daily. This outbreak rapidly evolved into a global crisis, with significant outbreaks observed in countries like South Korea, Iran, and the United States, resulting in numerous infections and fatalities worldwide. As a result, the world is navigating through the challenges posed by the pandemic while also contemplating a post-COVID-19 future. Comprehensive social research is essential for gaining deeper insights into the current and potential future social impacts of COVID-19. The pandemic coincided with governments worldwide finalizing their annual budgets in 2020, leading to an unprecedented health crisis that profoundly affected global economies. In response to the pandemic, governments

enacted various precautionary measures within their monetary and financial policies to alleviate its impact [44]. The COVID-19 outbreak precipitated a global recession in 2020, leading to a substantial decrease in per capita income across most nations, marking the largest decline since 1870. Advanced economies witnessed a contraction of 7%, while emerging market and developing economies experienced a 2.5% downturn due to their own domestic outbreaks. This economic slump underscores the immediate necessity for addressing the health and economic repercussions of the pandemic, protecting vulnerable populations, and laying the groundwork for a sustainable long-term recovery.

The Middle East's energy sector is encountering considerable risks due to recent fluctuations in energy markets and economic uncertainties stemming from the global COVID-19 outbreak. These challenges are anticipated to adversely affect the sector's vitality, particularly impacting energy supply chains and production across the region. With many countries implementing precautionary measures such as travel restrictions and the suspension of international flights to contain the virus spread, along with the closure of numerous businesses and production facilities, energy consumption has notably decreased. This situation poses a significant threat to the global energy landscape, with the oil and natural gas sectors facing heightened vulnerability [45]. Projections suggest a global decline in crude oil demand by at least 3 million barrels per day, with some forecasts indicating a sharper contraction exceeding 10%, equivalent to 10 million barrels. This reduced demand is expected to considerably affect liquefied gas exports from the region due to the anticipated slowdown in the global industrial and transportation sectors. Initial reports from Indian and Chinese energy companies, major importers from Middle Eastern countries, indicate the declaration of force majeure in importing liquefied gas, signifying conditions preventing crude importation. Persistent decreases in oil prices will place substantial strain on the revenues of oil-exporting nations in the Middle East. As per the Institute of International Finance, should the average price per barrel of oil remain at \$40, oil exporters across the Middle East and North Africa could encounter a revenue shortfall of \$192 billion, amounting to 11% of GDP. This could potentially lead to severe ramifications for the economies of the region [46].

The Jordanian government enforced a nationwide lockdown on March 21, 2020, with the objective of containing the spread of the virus, resulting in notable economic consequences for the region. During this lockdown period, strict preventive measures were enforced nationwide,

including mandatory population quarantine and the closure of schools, mosques, stores, hotels, and food shops. Additionally, national and international flights were suspended, non-essential ports and airports were closed, and non-essential businesses and sectors were shut down. The average demand in the energy market decreased as a consequence of these COVID-19 actions, which in turn reduced power consumption. The examination of regular consumption patterns and consumer pricing made it clear how these measures affected the demand for energy in Jordan. Particularly, consumption during working hours dropped dramatically due to the lockdown's impact on hourly consumption patterns brought about by the closure of tertiary businesses and factories. Even if a lot more people started working from home, the rise in home usage wasn't enough to make up for the overall fall in demand [47]. In the last three months of 2020, the Jordanian jobless rate reached 24.7%, according to the Jordanian Public Statistics Department (JPSD) [48].

In addition to influencing public health, the present global health crisis has had extensive repercussions for global economies, energy consumption patterns, and carbon dioxide emissions. The energy demand of countries under full lockdown decreased by 25% weekly, while that of countries under partial lockdown decreased by 18% weekly. The extent of demand drops coincides with the duration and intensity of lockdown measures, according to data from 30 nations, which represent over two-thirds of worldwide energy usage [45]. As a developing country with less natural resources than its neighbors, Jordan has seen the COVID-19 pandemic wreak havoc on its energy sector and economic structure. A major participant in the energy sector of the Kingdom, the Jordan Petroleum Refinery Company (JPRC) is on track to incur losses in the first half of 2020, according to its most recent financial report [49]. Accounting standards used to evaluate the variations in value between the refinery's stock balance at the end of 2019 and June 2020 caused the current losses, rather than the refinery's operating activity. The expected large drop in oil prices necessitates this adjustment, which amounts to approximately 122 million dinars. Although oil was anticipated to be worth around \$68 per barrel last year, its value has dropped to under \$25 per barrel so far this year. The sharp drop in value differences from year-end to Q1 [49] necessitated an explanation from the company's upper echelons.

Prospects for finding gas in Jordan diminished following British Petroleum's (BP) 2013 withdrawal [50]. Technical difficulties and political considerations, according to the former head of the Jordanian parliament's energy committee, played a role in BP's decision. Authorities may

have aimed to derail public trust in domestic gas and oil reserves—especially fracking—in order to speed up a contract with Noble Energy for Israeli gas, which is located nearby across the Mediterranean Sea. Beginning in 2001, work began on the pipeline that will eventually connect Aqaba, Jordan, with Arish on the Sinai Peninsula. The pipeline was extended from Aqaba to the Syrian border, Lebanon, and finally the Turkish border with the addition of additional portions [52]. The original plans to use the Risha field to extract 700 mcf/d of natural gas have been progressively shelved. This quantity would be roughly twice what Jordan uses every day. As early as 2015, Jordan was projected to receive no less than 300 mcf/d from this region. There was a steady fall in Jordan's purchases of LNG from Egypt after the 2011 Egyptian revolution. As a result, from 80% in 2010 to 20% in 2012, the usage of LNG for generating power dropped dramatically. Uncertainty, poor management, and political interference are among the most pressing problems. No one knows for sure how much of an impact these variables had on BP's choice to end exploration in Jordan [53]. This section details the study technique that was used, which includes numerous important steps. At the outset, we will undertake a comprehensive literature analysis on the topic of energy in Jordan and the effects of the COVID-19 pandemic on energy worldwide. In addition, in order to investigate the impact of COVID-19, we will review past surveys that were carried out in Jordan. The effects of COVID-19 on Jordan's energy industry will be carefully studied. Furthermore, in order to identify the precise effects of COVID-19 on Jordan's energy demand, the dissertation will compare electricity consumption prior to and after the pandemic. In the end, recommendations and documentation will be based on the dissertation's results.

2.2.3.2 Indicators Impact

When evaluating the success and results of renewable energy projects in Jordan, impact indicators are crucial. To measure progress toward sustainability goals including reducing carbon emissions, increasing energy efficiency, and encouraging the adoption of renewable energy sources, these metrics are used. Important metrics include the share of energy that comes from renewable sources, changes in carbon emissions over time, trends in investments in renewable energy projects, and the pace of implementation of renewable energy solutions. The impact of renewable energy policies and projects may be assessed, problem areas can be identified, and informed decisions can be made to advance Jordan's sustainable energy environment by keeping an eye on these indicators.

2.2.3.4 Environment Indicator

Carbon emissions must be closely monitored and efforts like the Global Carbon Stocks Program must be actively pursued if we are to fight climate change and join the worldwide movement towards sustainable economies. A decrease in greenhouse gas emissions and home air pollution was an unintended consequence of the COVID-19 epidemic. This was because energy usage was lowered. The implementation of statewide curfews in Jordan led to a precipitous drop in industrial activity, which in turn reduced energy demand and emissions of greenhouse gases. The Ministry of Environment has been working on the Green Growth National Action Plan 2021–2025 since the latter half of 2018, with the goal of putting the plan's proposals into action. In order to help Jordan achieve its goal of sustainable and ecologically friendly economic development and to make the country more resilient to unexpected shocks like the COVID-19 pandemic, this plan provides a thorough framework for implementing green growth policies and initiatives across different sectors [55]. The Eastern Mediterranean and Middle East (EMME) region is seeing a concerning trend of rapidly increasing greenhouse gas (GHG) emissions, which are now higher than emissions from EU member states, according to recent research [3, 56]. This area has warmed up at a faster rate than other heavily populated regions in the past several years, making a big contribution to global warming. Temperature increases are expected to continue, although this trend might be slowed with international cooperation to cut emissions of greenhouse gases [3]. Jordan highlighted energy, transportation, water, health, and agriculture as critical areas for reducing emissions at the 2019 United Nations Framework Convention on Climate Change's 25th Conference of the Parties in Madrid. Since energy-related activities are responsible for 64% of Jordan's overall national emissions [8], the government has pledged to reduce GHG emissions by 31% by 2030. Consequently, it is reasonable to put an emphasis on reducing emissions in the power generating sector, where renewable energy projects such as solar photovoltaic (PV) and wind farms are crucial in achieving this goal [22].

New goals for reducing greenhouse gas emissions through a variety of programs, policies, laws, and foreign assistance are outlined in the Nationally Determined Contributions (NDC). By putting an emphasis on renewable energy sources and improving energy efficiency, we can significantly reduce emissions, according to forecasts, and bring overall GHG emissions down by 2040 [32]. The NDC has set a goal of increasing energy efficiency by 9% and increasing the proportion of renewable energy in electricity production to 35% by 2030. Furthermore, there is

hope for substantial reductions in GHG emissions through the implementation of Concentrated Solar Power (CSP) plants [32]. To evaluate the potential effects on the local ecosystem and population, comprehensive environmental evaluations must precede the green light of any renewable energy project [58].

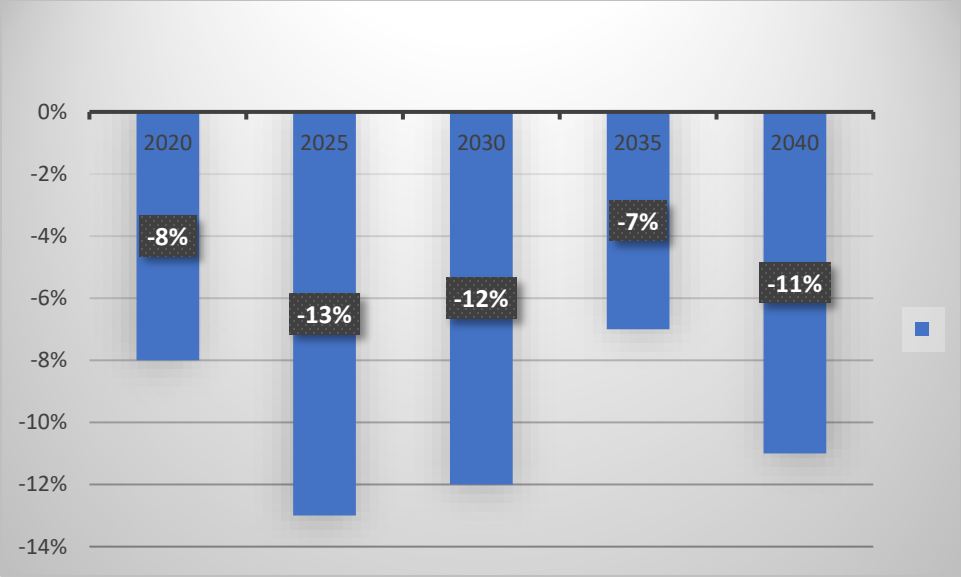


Figure 2-6: Jordan’s Greenhouse-Gas Avoided Emissions, 2020–2040.

2.2.3.5 Economic Indicator:

Renewable energy sources are well-suited to Jordan's climate, as mentioned above. While hydropower, biofuel, and geothermal sources are acknowledged to a lesser degree, several government assessments (cited in [22, 31, 32]) highlight wind and solar power as the nation's most accessible renewable resources. The creation of a clean, sustainable, and economically viable energy supply has been a priority for Jordan due to various considerations, including the increasing prices of imported fuel, the inflow of refugees, the growth of the domestic sector, and the requirement to reduce greenhouse gas emissions. In addition to improving social fairness and welfare, investing in renewable energy can boost the Jordanian economy, create green jobs, and increase investment[22].

With the National Energy Strategy Plan covering the years 2007–2020, Jordan launched its investment program in response to the uncertainty of imported energy sources and the need to guarantee energy independence. The plan included a wide range of energy sources, including renewables, nuclear power, and oil shale extraction, with the goal of attracting investments totaling

\$20 billion by 2020 [25]. After three years of recognition from Bloomberg’s ClimateScope 2019 Index, this strategic endeavor established Jordan as a leader in the MENA region for creating the most favorable environment for renewable energy investment. In addition, Ernst & Young [60] ranked Jordan as the 38th best market in the world for renewable energy investments. Accolades like this help with growth, change, and efficiency in operations by giving investors useful information and boosting confidence in the financial markets. The Green Growth National Action Plan for 2021–2025 (GG-NAP) was introduced by Jordan, marking a decisive step towards encouraging a sustainable economy. An estimated \$85.3 million will be needed to undertake the 12 priority activities outlined in this comprehensive strategy, which aim to improve green growth, especially in the energy sector. An industrial renewable roadmap and investment plan are being developed. The Jordan Renewable Energy and Energy Efficiency Fund (JREEEF) is being accredited under the Green Climate Fund. The adoption of the United Nations Energy Sector Monitoring, Reporting, and Verification (MRV) System is also a key action. With an overall goal of reaching a 7.5% economic growth rate by 2025, these initiatives are expected to mainly receive funding from the public budget, donors, partners, and private sector investors. Jordan has quickly diversified its energy mix thanks to its impressive progress in developing renewable energy projects, which have attracted investments totaling over US\$5 billion [31].

Eligible investors interested in constructing renewable energy projects under a build-own-operate framework have been invited to submit proposals in three consecutive phases by the Jordanian government. In order to attract international investment in these projects and provide investors with certainty about future earnings while reducing risk, the Ministry of Energy and Mineral Resources (MEMR) has also set feed tariffs. Feed tariffs, originally implemented in the first round, outline, as shown in Figure 2.6, the recommended rates for electricity generation from different renewable energy sources [25, 61]. A total of 200 MW of solar capacity and 117 MW of wind capacity were reserved for projects in the southern region of Ma'an during the first round (2012–2015). The government of Jordan then instituted a bidding process with subsequent rounds of competition. Phase two, which ran from 2013 to 2019, distributed 200 MW of power to the country's eastern and northern regions. Midway through 2018's third round of direct proposal submissions, bids dropped to \$0.026/kWh. The National Electric Power Company (NEPCO) paid around \$0.11/kWh for electricity that came from renewable sources, as opposed to \$0.12/kWh for

electricity that came from traditional sources [2]. Two hundred megawatts (MW) of solar power and one hundred megawatts (MW) of wind power are included in this most recent round [62, 63]..

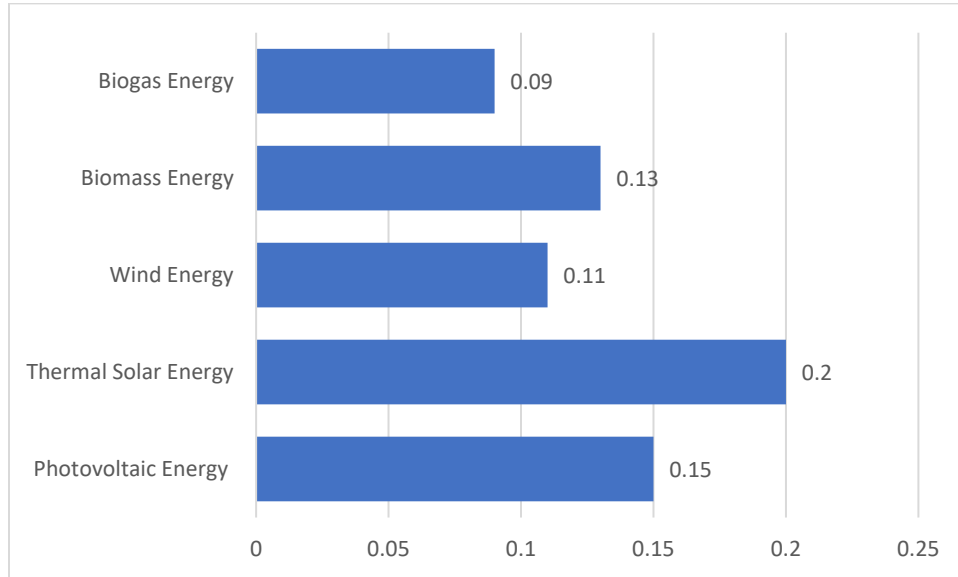


Figure 2-7: Jordan’s Reference Price of Renewable Energy Sources. [61]

With storage prices continuing to fall, renewable energy sources like solar photovoltaic (PV) are becoming more attractive as a power sector alternative to solutions based on imported fuels. With massive investments in wind and solar power, the Jordanian government reached a major milestone in 2020, producing 2,063.3 MW of electricity [22]. Also, in 2021, there were 863 applications for renewable energy permits from a variety of industries, including oil and its derivatives, natural resources, radiological and nuclear, and a significant 23% rise over the previous year.

A number of programs have been launched by the Jordanian government to encourage more investment in renewable energy. Some of these measures include improving tax incentive programs and creating an energy fund to support the construction of renewable energy installations. Investors in certain areas slated for socioeconomic development may be eligible for a tax break of up to 100% for a maximum of ten years. To further expedite the process and avoid drawn-out competitive bidding procedures, investors can also choose to negotiate directly with the Ministry of Energy and Mineral Resources (MEMR). Furthermore, by agreeing to buy power from renewable energy projects, NEPCO gives guarantees. By developing investment ideas, promoting projects to prospective international investors, and easing foreign investment within the country, the Jordan Investment Commission (JIC) is crucial in attracting funding for green growth

initiatives [64]. Due to the COVID-19 epidemic, Jordan's ranking on the Energy Transition Index, which is put out by the World Economic Forum, fell 16 spots to 82. In the 2019 index, Jordan achieved a score of 53%, which decreased to 49.5% in the latest assessment. Similarly, there was a decline in energy system performance, dropping from 56% to 46%, and readiness, declining from 50% to 53% [65]. Efforts to enhance the economy by reducing domestic fuel consumption, increasing export revenue, optimizing infrastructure for renewable energy utilization, and establishing a robust energy network in line with Jordan's population growth and urbanization are gaining traction both locally and internationally. With a 1.3% contraction in Q1 2020, Jordan's economy clearly felt the effects of the epidemic. Despite a small drop in the labor force participation rate, the unemployment rate increased to 24.7% in Q4-2020 from 19.3% in Q1-2020, a reflection of the substantial disruptions experienced by the labor market. Looking ahead, the pandemic is expected to continue affecting Jordan's economy and opportunities, similar to its impact on trading partners and the MENA region[66]. However, lower energy prices and efforts to enhance production and competitiveness are expected to facilitate Jordan's economic recovery in the medium term. Efforts to improve the economy by reducing domestic fuel consumption, increasing export share, optimizing utilities, and supporting energy infrastructure development alongside population growth and urbanization are gaining recognition globally and internationally [67].

2.2.3.6 Energy Indicator.

Load demand profiles are shown in this section. by examining monthly demand over five-year periods. Figure 2.8 illustrates the trends in demand for monthly charges in Downtown over five years.

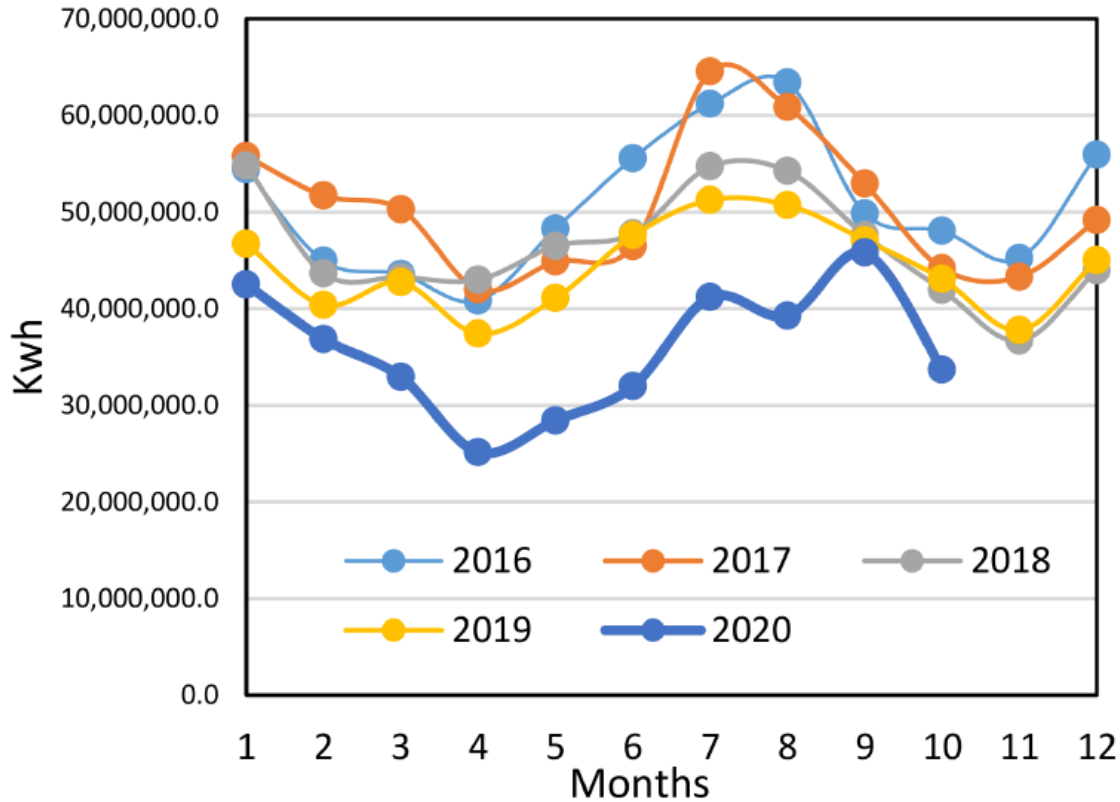


Figure 2-8: Monthly electricity demand (KWh) in Jordan's city center over the last five years, including during the current pandemic[54].

Between March and May of 2020, while the global COVID-19 epidemic was in full swing, there was a sharp drop in the demand for monthly load. The widespread effects of the epidemic on many parts of people's everyday lives are mirrored in this pattern. There is a robust relationship between the monthly averages during the five-year period and the load profiles shown in the figure. In addition, when compared to prior years, 2020 saw a decrease in both the minimum and average demand. Take 2020 as an example; in 2018, the minimum demand was 1219 MWh, and in 2019, it was 1029 MWh. In a similar vein, average demand fell 37% in 2020 and 40% in 2019 compared to the previous two years. Table 2.1 shows that early measurement period (March 2020–May 2020) peak demand and demand activities had a direct impact on power consumption [54].

Table 2.1: Summary Of Electrical Demand From 2016 To 2020 During The Time of Movement Restrictions Orders (March, April, And May)[54].

	Electricity Demand (MWh)				
	2016	2017	2018	2019	2020
Maximum demand	2098	1839	1735	1768	1296
Minimum demand	1128	1189	1219	1029	765
Average demand	1443	1492	1444	1319	941

A Feed-in-Tariff program for renewable power sources and an energy efficiency fund were both created by the Renewable Energy and Energy Efficiency Law. By 2020, the government hopes to have met 10% of its energy demands using renewable sources, hence it is increasing its power generating capacity from 1.13 GW to 1.8 GW. The goal of current initiatives is to strengthen the country's energy sector by increasing the use of renewable energy sources. These sources include solar thermal, geothermal, bio-energy, and wind energy. The Jordanian Energy Sector Updated Strategy (2007-2020) expanded upon the 2004 National Strategy by resolving issues that had previously impeded project execution. Notably, terms like "resilience" and "sustainability" were absent in both the 2007-2020 Strategy and its predecessor [70].

The plan outlines Jordan's primary energy challenges, categorized into resilience and sustainability. While not explicitly labeled as such, energy security has long been acknowledged by the government as a persistent hindrance to the country's development [71]. Moreover, reports highlight the critical need for resilience in Jordan's energy sector, given its vulnerability to external shocks like price fluctuations, with significant economic implications [72]. Rapid population growth in certain governorates over the past three years has significantly increased energy demand, straining national infrastructure, even impacting humanitarian efforts in refugee camps due to unsustainable energy costs [73]. Faced with these challenges, a strategic plan prioritizing stable, clean, efficient, and cost-effective energy, preferably through self-reliance and source diversification, has become imperative. Thus, the focus has shifted towards enhancing the green energy sector and promoting energy conservation. By prioritizing energy conservation as the foundation, followed by energy production and demand management, and finally green energy

adoption, Jordan aims to conserve resources, reduce dependence on imported energy, and improve the climate for current and future generations. Notably, Jordan has made significant strides in attracting renewable energy projects through various rounds of proposals and initiatives such as wheeling and net metering projects, both on transmission and distribution grids.

When compared to other established nations in the area, Jordan's power grid's integration of wind and solar energy represents great capacities. With the help of Jordan's electric power infrastructure, renewable energy projects are projected to increase generating capacity by about 2400 MW by the end of 2021. Following the agreed-upon timeline, NEPCO intends to complete the green corridor project, which will allow the transfer of 800-1000 MW of renewable energy from the southern region to load centers [74]. Jordan has the potential to be one of the world's leading green energy nations because to public-private partnerships. Contributing to Jordan's growth and development, these initiatives seek to generate power while simultaneously building capacity and enhancing local skills. Jordan is now rated third internationally in attracting investment to this industry. Legislative measures are being considered to raise the share of renewable and innovative energy to 10% by 2020 and 7% by 2015 in response to increasing energy demand. Future strategies aim to find more cost-effective alternatives [68]. Changing from fossil fuels to renewable energy is the best way to solve several environmental, political, and economic problems. Renewable energy has proven resilient in the face of certain little challenges during the COVID-19 epidemic. On the other hand, studies examining how the pandemic affected the renewable energy industry are few and few between. Potential threats to the expansion of the sector include disturbances in the supply chain, changes in the stock market, and the end of government incentives [75]. Numerous articles have focused on Jordan's energy landscape and renewable energy success stories, drawing attention to the country's use of renewable energy resources [76]. Solar radiation and weather data have been systematically studied and reported on in studies carried out at Jordan's Hashemite University [77], [78]. Furthermore, studies have looked at Amman's building codes and come up with new standards to make sure that modern homes have enough solar accessibility [79]. Additionally, methods to encourage the use of solar power in industrial settings in the Arab world, with a focus on Jordan, have been investigated, and the compatibility of load fluctuation patterns with renewable energy generation has been evaluated [80], [81].

So yet, research on how the COVID-19 pandemic would affect Jordan's energy industry has been lacking. Looking at how the pandemic affected the energy industry and what comes next goes beyond simple economics; it includes studying a turning point in world history that could cause massive adjustments in power and geopolitics. Nationwide energy overproduction and RE's inherent unpredictability are two key technological obstacles to RE's expansion. Despite renewables' small 2018 contribution of only 0.05 percent, the Jordanian government has refocused its efforts to aim for 50 percent by 2030, with the help of numerous projects. Furthermore, member nations of the Pan-Arab Electricity Market (PAEM) have access to the GCC-established and Arab Fund-funded cross-border electrical interconnection infrastructure. The PAEM has the second-highest potential cumulative capacity in the world, at about 300 GW, but getting there will necessitate a lot of work and money. Although there were a lot of procedures to take in order to launch the PAEM, the lessons learned and the fact that future challenges have been identified could make politicians more determined and speed up the process.

Chapter 3

Assessment of Jordan's capacity for renewable energy sources

3.1 Case Studies of Renewable Energy Integration Projects in Jordan

3.2 Review of Bioenergy potential

Chapter 3: Assessment of Jordan's capacity for renewable energy sources

3.1 Case Studies on the Integration of Renewable Energy Projects in Jordan

3.1.1 Introduction

Global energy demand is steadily increasing, particularly in developing nations, driven by economic growth. Projections outlined in the International Energy Outlook [82] anticipate a 50% surge in global energy consumption from 2020 to 2050. Recent fluctuations in oil and natural gas prices, influenced by events like the COVID-19 pandemic and geopolitical tensions, have strained the global economy [83, 84]. Heightened concerns about climate change have underscored the urgency for cleaner energy alternatives. According to a recent report by the Renewable Energy Policy Network for the 21st Century [85], renewables contributed around 28.3% to global electricity generation in the first quarter of 2021, up from 26% in the same period of 2019. This uptick in renewables is attributed to higher costs associated with coal and natural gas, coupled with the increasing affordability of solar and wind energy. However, coal and natural gas still play substantial roles in global electricity supply, comprising approximately 60%. There's an expectation of increased demand for renewables due to their lower operational costs. Yet, transitioning to renewable energy for electricity generation necessitates significant investments in new transmission technology [86].

From a worldwide viewpoint, the use of renewable energy sources, Zhao et al. [87] illustrated that increased reliance on renewable sources can expedite global energy conservation endeavors and diminish emissions. Additionally, their research demonstrated that increasing energy efficiency through the use of renewable energy sources can significantly reduce energy poverty worldwide, especially in European countries. Similarly, Radmehr et al. [88] determined a robust one-way association between renewable energy consumption and economic expansion. Many European nations have followed suit in developing energy and environmental policies that are in line with EU sustainability goals, reflecting these findings. Furthermore, the IEA reports that the COVID-19 epidemic not only caused a short-term drop in energy demand worldwide, but it also accelerated the use of renewable energy sources. Additionally, there exist collaborative

international endeavors to combat climate change, with numerous governments implementing policies and actions to foster the growth of the renewable energy sector. These initiatives have accelerated the transformation of energy infrastructure [90].

Global energy demand witnessed a rebound following the downturn caused by the pandemic in 2020 but encountered another setback due to the outbreak of the Russian-Ukrainian War in March 2022 [83]. Besides the significant damage inflicted on Ukraine's energy infrastructure, the military conflict has far-reaching implications for the global energy landscape expected to endure for years. Being the largest fossil fuel exporter and a crucial supplier to Europe, Russia's involvement has underscored a significant strategic vulnerability for Europe. The ongoing conflict continues to disrupt energy markets, leading to inflationary pressures and hindering global economic growth. During the early stages of the conflict, energy costs, particularly natural gas in European markets, spiked significantly. On the flip side, renewable energy has maintained its rapid expansion [83]. Quickly in response, some governments—including the US and EU—introduced new measures to boost investments in renewable energy and advance energy efficiency. A number of Middle Eastern nations have made great strides in the previous decade toward fully integrating renewable energy sources. Factors like population growth, conflicts, and economic instability in the region have direct implications for the renewable energy sector. Despite being a major hub for oil production, the Middle East faces risks of resource depletion with continued extraction, potentially leading to a severe crisis [91]. One way to strengthen the region's political and economic stability is to increase the use of renewable resources [8]. Potential for renewable energy is high in the Middle East because of the region's tidal movements, substantial solar and wind resources [29]. Factors such as population expansion, increasing demand for cooling, and continued industrial development are boosting power demand in a country with a considerable population of 578 million and an average economic growth rate of 2.5%. Electricity demand increased by 4% in 2021, and experts predict that consumption will climb by 2.6% in 2022 [83]. Still, a big chunk of the region's pollution comes from power plants. As a result, a lot of global groups think that using renewable energy sources to generate electricity is a good idea [85] [83]; [88], [88], and [88]..

In terms of renewable energy capability to meet domestic demands, Jordan ranks third among Arab nations, according to the Friedrich-Ebert-Stiftung (FES) [92]. As an added bonus,

in 2021, excluding hydropower, Jordan had the highest proportion of renewable energy contribution among Arab countries, according to the Arab Future Energy Index Report (AFEX) [93] from the Regional Center for Renewable Energy and Energy Efficiency, which assessed the renewable energy enabling environment in the region. In addition, AFEX recognized Jordan as a frontrunner among regional nations for creating a favorable climate for investments in energy efficiency and renewable sources. The Regulatory Indicators for Sustainable Energy (RISE) also found that in 2017, the MENA region's leading sustainable energy countries were Tunisia, Jordan, and the United Arab Emirates. These countries' policies were particularly strong in promoting energy efficiency, renewable sources, and energy access.

Jordan is realizing the growing importance of renewable energy sources. Renewable energy adoption is still lower than in more developed economies, notwithstanding recent strong growth [7]. If properly utilized, Jordan's renewable resources have the potential to increase energy security and decrease consumer energy costs. Further, reducing emissions of greenhouse gases (GHGs) is an important step toward protecting the environment, which is why the renewable energy sector must grow. Consequently, it is critical to prioritize the expansion of Jordan's renewable energy capacity while taking into account current energy trends, such as the exploitation of concentrated solar technology [7, 95, 96]. In 2021, imported oil and natural gas constituted 93% of Jordan's energy supply, posing a serious problem for the country because of its limited fossil fuel sources [35]. Approximately 10% of the country's GDP in 2019 was spent on imported energy, which is a large amount [7]. At present, the power generation industry is responsible for approximately US\$7.18 billion, or nearly 20% of the public debt issued by the National Electric Power Company (NEPCO) [97]. But overall energy consumption was up by 22% and power consumption went up by 14% from 2014 to 2018, mostly because more than 1.4 million refugees flooded in, making things worse [98]. Consistent growth in power usage of 3.7% in 2021 and 5.7% in 2022 were noted in a 2023 report from NEPCO.

If Jordan wants to solve its energy problems, it should diversify its energy sources and put more money into renewable energy [7]. Using renewable energy sources can help the economy and industry grow sustainably without draining public coffers [99, 100]. With a significant increase from about 26% in 2021 to 2,526 MW in 2022—representing 29% of the overall electricity mix—the Jordanian government has achieved great strides in increasing the share of

energy produced from renewable sources [96, 101] [38]. In addition, from 2014 to 2020, Jordan attracted investments in a local renewable energy sector by offering financial incentives, tax reductions, and customs exemptions. Important projects have also been implemented with the help of substantial financial and technical assistance from foreign governments and international organizations [25]. Jordan is well-positioned to attract additional investment in renewable energy due to its stable government and strong regulatory frameworks, which it has used to great effect in implementing multiple large-scale renewable energy projects. There have been a lot of studies looking at renewable energy in Jordan over the last decade, trying to figure out how to switch to cleaner power. To what extent do financial incentives, tax breaks, and government regulations encourage the expansion of renewable energy sources? Abu-Rumman et al. [25] investigated this question. Others [8] assessed Jordan's energy requirements and the role renewable energy can play in meeting them. Additionally, researchers [102] identified suitable locations for wind farms in Jordan, while Azzuni et al. [103] discussed various solar projects. However, there remains a gap in comprehensive research detailing all renewable energy projects in Jordan and tracking overall progress. Furthermore, there is a lack of guidance for investors seeking to identify optimal locations for energy projects, whether large-scale grid-connected initiatives or smaller decentralized projects across Jordan. Access to such information is essential for Jordan to strategically prioritize and invest in renewable energy projects.

3.1.2 Profile of Renewables Energy in Jordan, a Geographic Overview

There are 11.2 million people living in Jordan, yet around 75% of the country's territory is desert. Because of its proximity to the Tropic of Cancer, it receives a lot of sunshine. With an average temperature of 17.2 degrees Celsius, the weather in Amman, the capital, is a combination of desert and Mediterranean climates [104]. Approximately 316 days a year, Jordan enjoys abundant sunshine. The sun is stronger in the summer because it is higher in the sky [105]. Daily, the average amount of solar energy per square meter is approximately 5.6 kilowatt-hours. Total annual sunshine intensity is between 1800 and 2700 kilowatt-hours per square meter. Because of its favorable climate, Jordan is an excellent location for solar power installations [39].

Figure 3.1 displays three important maps regarding Jordan's potential for renewable energy: (a) a map showing the amount of sunlight received annually, (b) a map showing the average wind

speeds, and (c) There are 11.2 million people living in Jordan, yet around 75% of the country's territory is desert. Because of its proximity to the Tropic of Cancer, it enjoys abundant sunshine. With an average temperature of 17.2 degrees Celsius, the weather of Amman, the capital, is a combination of desert and Mediterranean climates [104]. Approximately 316 days a year, Jordan enjoys abundant sunshine. Sunlight is stronger in the summer because the sun is higher in the sky [105]. Daily, the average amount of solar energy per square meter is approximately 5.6 kilowatt-hours. Total annual sunshine intensity is between 1800 and 2700 kilowatt-hours per square meter. Because of its favorable climate, Jordan is an excellent location for solar power installations [39, 99, 100].

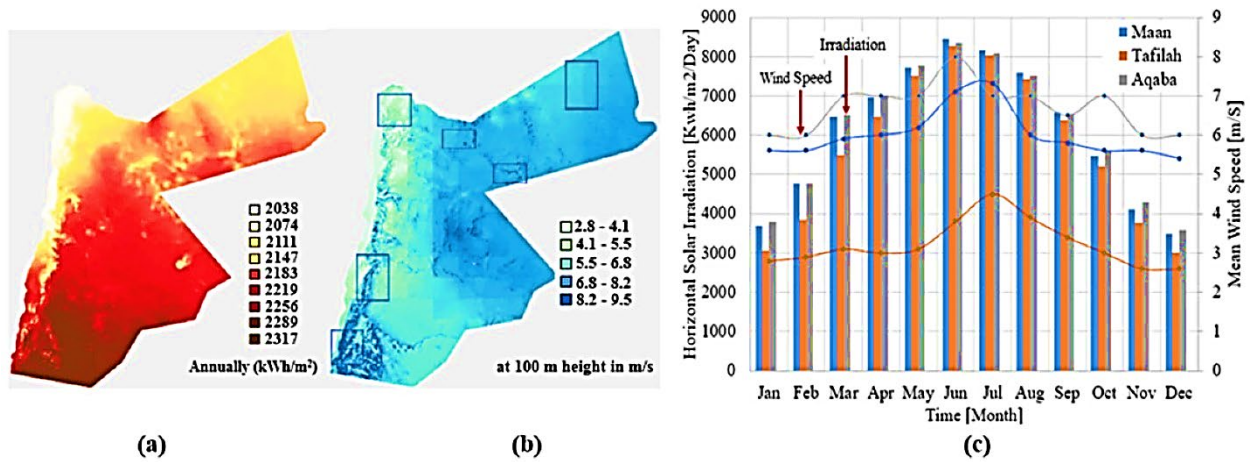


Figure 3.1: Renewable Energy Potential Maps Of Jordan [21].

The wind speeds in Jordan range from 7 to 11 meters per second (m/s), and the country's pleasant climate is perfect for wind turbine installations due to its consistently clear skies and mild temperatures. About 16% of Jordan's land area, or 3.6 GW, might be used to generate wind power, according to the country's Ministry of Energy and Mineral Resources [106]. Investments in wind and solar energy have great potential in southern regions like Ma'an, Tafilah, and Aqaba, as shown in Figure 3.2 [39, 106-108]. With an average of 7300 watt-hours per square meter per day (Wh/m²/day), Ma'an and Aqaba stand out among other areas when it comes to high levels of direct normal radiation [102, 109]. Furthermore, Jordan is well-positioned to integrate power networks and facilitate energy import/export to global markets due to its unique geographical location at the

crossroads of Asia, Africa, and Europe. Aside from the Gulf of Aqaba and the areas surrounding the Red and Dead Seas, Jordan's terrain does not offer many large bodies of water or waterfalls that may be used to build hydropower plants [25, 110]. All around Jordan, you may find geothermal wells. By tapping into these subsurface reservoirs for heating and cooling, you can help lessen your need on traditional energy sources. Even while the Dead Sea rift valley contains hot mineral water, its temperatures are still too low (below 100° C) to be used for power generation [7].

3.1.3 Investigating Renewable Energy Projects in Jordan

In this section, we will look at how renewable energy sources can help Jordan fulfill its energy needs. It delves into Jordan's integration of renewable energy across different sectors, assessing the progress made and identifying both challenges and opportunities for further expansion. It also takes a look at the national strategies and policies that have helped Jordan generate and use renewable energy in the last ten years. The purpose of conducting capacity assessments of renewable energy projects is to provide light on the renewable energy industry's present status in the nation. Since 2015, Jordan has achieved substantial advancements in developing many solar photovoltaic (PV) projects. Table 2.1 presents an overview of noteworthy installations throughout the country, including their capacity and geographical distribution. The majority of these activities entail the signing of power purchase agreement (PPA) proposals between 2015 and 2018. These agreements involve stakeholders from different development areas, including Ma'an, Mafraq's King Hussein Bin Talal Development Area, as well as additional investors in Aqaba and Amman. By 2021, Jordan's total installed solar energy capacity had reached 1,831 MW, accounting for 75% of the whole renewable energy capacity. This increase was mostly due to the launch of a solar energy project with a capacity of 200 MW in 2020 [9, 31]. Table 2.1 outlines three main strategies for executing solar power projects: direct power purchase agreements (PPAs), distributed small-scale renewable energy schemes (net metering), and power-energy wheeling. These programs have garnered substantial backing from the public budget, donors, partners, and foreign capital.

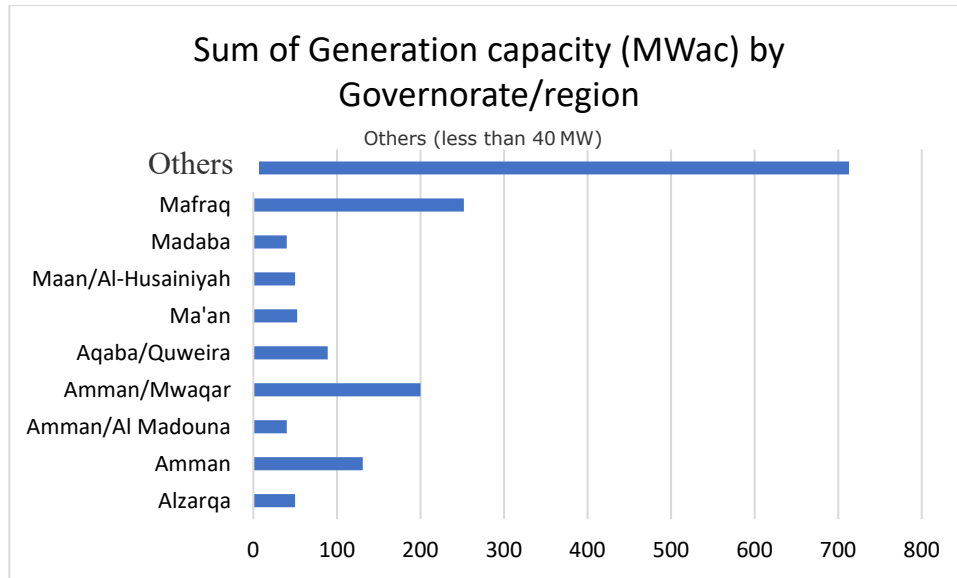


Figure 3-2: Summary Of Solar Energy Projects In Jordan [21, 111].

In Jordan, solar and wind energy are the most easily accessible renewable options, while bioenergy, hydropower, and geothermal energy offer fewer opportunities. Biomass, however, holds significance among renewables, yet ensuring sustainability is paramount for its broader adoption across various industries. Exploring innovative methods to electrify specific sectors is crucial. Jordan has committed to reducing its greenhouse gas emissions by 14% by the year 2030 as part of its nationally determined contribution (NDC) [112]. This pledge emphasizes the dedication to the development and utilization of renewable energy sources, while also promoting financial investments in the industry. Jordan's progress highlights the feasibility of shifting towards a decarbonized energy blend while guaranteeing reliable electricity supply. In 2018, the implementation of solar photovoltaic (PV) and wind power technologies resulted in the reduction of around 1.5 million metric tons of carbon emissions [7]. In addition, the Jordan Renewable Energy and Energy Efficiency Fund promoted the use of solar water heaters, which were previously the main renewable energy source for heating and cooling. In 2021, Jordan had a total renewable energy capacity of 2445.7 megawatts. This included 1,498 megawatts from projects that supplied electrical businesses, and 947.6 megawatts from non-commercial systems owned by people and institutions. This signifies a 26% surge in energy production in relation to the previous year, 2020 [113].

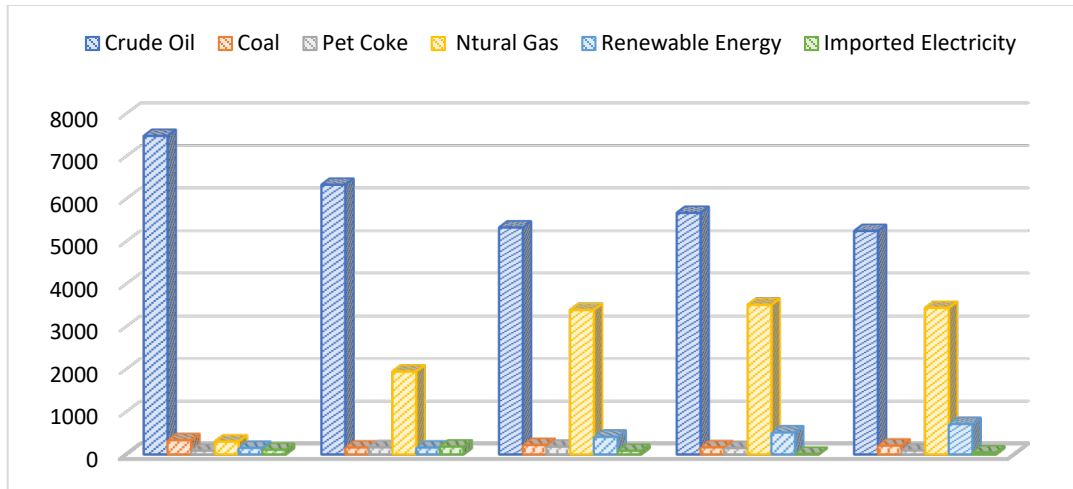


Figure 3-3: Illustrates the imports of crude oil, oil products, and coal from 2014 to 2018, measured in thousand tons [10].

According to the reference price list used to determine the highest price for buying electricity produced from renewable sources, different tariff limits have been set for various types of renewable energy. These include rates of \$0.12 for wind energy, \$0.19 for solar thermal, \$0.17 for photovoltaic, \$0.13 for biomass, and \$0.08 for biogas. These rates will be binding for the successful bidders participating in direct procurement processes for renewable energy projects. Moreover, if a facility is entirely of Jordanian origin, there is a possibility of a 15% tariff increase. Given the significant decrease in expenses associated with renewable energy technologies in the last ten years, it would be wise for the Jordanian government to consider enhancing the prominence of renewables in the future energy mix [114].

3.1.4 Solar Energy in Jordan

Solar energy is an auspicious and enduring substitute for conventional fossil fuels that has garnered escalating scrutiny in recent years. Solar panels and solar thermal collectors harness the sun's plentiful energy to generate electricity and heat, respectively. Solar energy has diverse applications, encompassing residential and commercial buildings, transportation, and industrial processes[115]. The effectiveness of solar panels is influenced by several factors, one of which is the degree of inclination of the panels in relation to the sun. Research has indicated that modifying the inclination angle of solar panels according to the latitude of the site can substantially enhance their energy production. Furthermore, the alignment of the panels in relation to the sun's azimuth angle can also affect their energy production[116].

Figure 3.4 depicts the correlation between the tilt angle of a solar array and its energy production efficiency. The energy production efficiency of a solar array demonstrates an upward trend as the tilt angle increases until it reaches a peak, beyond which it begins to decline. This optimal tilt angle is determined by the latitude and local climate conditions of the installation site. The figure highlights the importance of proper tilt angle selection in maximizing the energy output efficiency of a solar array.

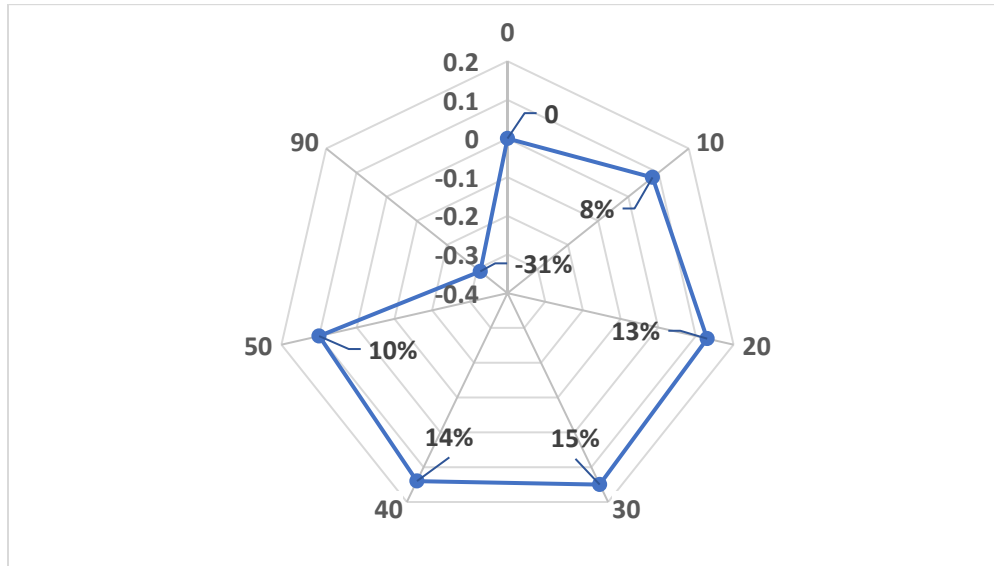


Figure 3-4: Solar Array Tilt Angle And Energy Output [117].

3.1.5 Estimation of solar radiation on the inclined surface

Calculating solar radiation on an inclined surface is crucial for establishing the ideal tilt angle for installing solar panels. Multiple techniques have been devised to calculate solar radiation on a tilted surface. One such method is the solar position algorithm, which uses a set of equations to calculate the sun's position in the sky at any given time and location. Another method is the Perez model, which is based on empirical data and considers atmospheric conditions such as aerosol content, water vapor, and cloud cover. Additionally, the Hay and Davies model considers the reflection and scattering of solar radiation from the ground and surrounding objects. The literature extensively use these methods to estimate solar radiation on inclined surfaces and ascertain the optimal tilt angle for solar panels. Nevertheless, it is crucial to thoroughly evaluate

the constraints and ambiguities associated with each technique before deciding on the best suitable approach for a certain site and purpose.

Jordan boasts abundant solar energy resources, evident from its annual average solar irradiation, which ranks among the highest globally, ranging from 4 to 8 kWh/m². Coupled with over 300 days of sunlight annually, this results in a yearly total of 1400-2300 kWh/m² [118]. Table 3.1 provides information on the longitudinal, latitude, and elevation of twelve provinces in Jordan. The cities included include Ajloun, Amman, Aqaba, Balqa, Irbid, Jarash, Karak, Ma'an, Madaba, Mafraq, Tafilah, and Zarqa. The data can be useful for various applications, including solar energy and climate studies.

Table 3.1 : Jordan Provinces With Longitudinal, Latitude, And Elevation Information[119].

No	Jordan Provinces	Longitudinal	Latitude	Elevation
1	Amman	35.87° E	31.96° N	777 m (2,549 ft)
2	Aqaba	34.98° E	29.53° N	25 m (82 ft)
3	Balqa	35.73° E	32.03° N	820 m (2,690 ft)
4	Irbid	35.85° E	32.56° N	620 m (2,034 ft)
5	Jarash	35.89° E	32.28° N	330 m (1,083 ft)
6	Karak	35.70° E	31.18° N	1,010 m (3,310 ft)
7	Ma'an	35.72° E	30.19° N	1,260 m (4,130 ft)
8	Madaba	35.79° E	31.72° N	776 m (2,546 ft)
9	Mafraq	36.26° E	32.33° N	690 m (2,260 ft)
10	Tafilah	35.60° E	30.83° N	1,200 m (3,900 ft)
11	Zarqa	36.10° E	32.05° N	619 m (2,031 ft)
12	Ajloun	35.75° E	32.33° N	800 m (2,625 ft)



Figure 13-5: Jordan Provinces Map.

The solar radiation in Jordan varies considerably across different regions and provinces. The quantity of solar radiation received is contingent upon several parameters, including latitude, height, and weather conditions. The southern and eastern sections of the country often experience higher levels of solar radiation in comparison to the northern areas. The provinces of Aqaba, Ma'an, and Zarqa exhibit elevated amounts of solar radiation, whilst the western districts, including Amman and Irbid, see comparatively lower levels.

Chapter 5

Challenges and Opportunities

5.1. Introduction

5.2. Identification of Integration Challenges and Barriers

5.3. Opportunities for Accelerating Renewable Energy Deployment

5.4. Strategies for Accelerating Renewable Energy Integration in Jordan

5.5. Policy Recommendations

Chapter 5

Challenges and Opportunities

5.1 Introduction

While Jordan has made significant strides in expanding its renewable energy capacity, several challenges lie ahead in terms of infrastructure, investments, affordability, and conflicts of interest with the fossil fuel economy and electricity utility. One of the primary challenges is the need for a reliable infrastructure to support the energy transition. Integrating significant amounts of renewable energy into the grid requires a large and flexible grid infrastructure, but grid expansions and modernization efforts have been lagging in Jordan and many other parts of the world. This lack of infrastructure creates bottlenecks for scaling up renewable energy deployment. Additionally, since much of Jordan's renewable energy comes from variable sources like solar and wind, the intermittency of power generation can affect grid reliability and stability. The reliance on expensive thermal power to cover peak demand exacerbates the challenge, as there has been a failure to fully utilize peak supply from solar power.

Furthermore, to effectively harness additional renewable power and reduce reliance on fossil fuels, Jordan needs to invest in massive energy storage capacity, which it currently lacks. Energy storage systems are capital-intensive and would require significant financing and de-risking measures to implement successfully. While financing and cooperation with other countries, particularly Gulf Arab states, have supported the development of Jordan's renewable energy industry, securing long-term investments and creating a favorable business investment climate remains challenging due to perceived risks. Political and economic risks, as well as grid connection and procurement risks, are significant concerns. NEPCO, responsible for purchasing power, is highly indebted and faces financial challenges, further complicating investment prospects. NEPCO's debt is partly attributed to high fuel and electricity subsidies, despite efforts to eliminate them. Inadequate cost recovery of electricity, driven by cross-subsidization and high-risk premiums in power purchase agreements (PPAs), contributes to the financial strain. The freeze on large-scale renewable energy projects from 2019 to 2022 reflects the challenges of integrating renewable energy into the grid without sufficient storage capacity.

Distributed renewable energy also poses challenges to utility companies like NEPCO, as large consumers switch to renewable energy generation, impacting utility revenues. This competition between renewable energy, the fossil fuel economy, and national electricity utilities is not unique to Jordan and underscores the need for strategic planning and policy measures to balance competing interests. While Jordan has initiatives like EDAMA focused on advancing its green economy, vested interests in the fossil fuel industry pose challenges to the transition. As Jordan explores shale oil production, these interests may expand, highlighting the need for comprehensive strategies to navigate the transition to renewable energy while addressing economic and political complexities.

The Ministry of Energy and Mineral Resources in Jordan is actively pursuing initiatives to position the country as a regional leader in the production and exportation of green hydrogen, aligning with global trends towards clean energy. Collaborating with the U.S. Agency for International Development (USAID), the ministry has developed a comprehensive strategy aimed at elevating Jordan's status as a hub for green hydrogen production. This strategy, which is nearing final approval by the Cabinet, reflects King Abdullah II's directives to accelerate green hydrogen projects to address global energy demands and combat climate change. A central focus of this strategy is the development of policy frameworks to attract investments in green hydrogen production. The ministry's efforts have already resulted in the signing of 13 memoranda of understanding with interested companies, demonstrating the government's commitment to expanding clean energy resources. Additionally, legislative initiatives are underway to revise laws governing renewable energy, optimizing the integration of renewable sources into the national grid [250].

Collaborations with international entities, including the World Bank, underscore Jordan's commitment to establishing robust legal and regulatory frameworks for green hydrogen production. These partnerships are crucial for shaping Jordan's transition towards sustainable energy practices on a global scale. In parallel, efforts are being made to transition towards electric transportation, including evaluating infrastructure readiness and charging station tariffs. These steps are essential for reducing carbon emissions and embracing cleaner transportation modes in Jordan. Furthermore, the ministry is exploring the development of smart grid networks and infrastructure enhancements to optimize energy resources. Initiatives such as the establishment of

natural gas pipelines to industrial zones aim to reduce energy expenses in the industrial sector [250].

The ministry's progressive installation of smart meters across electricity distribution networks highlights Jordan's commitment to modernizing its energy infrastructure. Additionally, plans for natural gas distribution networks in major cities present lucrative investment opportunities, signaling a significant capital infusion into the energy sector. Efforts are also underway to streamline financial procedures for key energy projects, including the Fourth Expansion Project of the Jordan Petroleum Refinery Company. Additionally, the ministry is spearheading the development of oil fields, aiming to increase production and meet growing energy demands. In terms of electrical interconnection projects with neighboring countries, feasibility studies are ongoing to expand interconnection capacity and enhance regional cooperation. The ministry's initiatives aim to strengthen Jordan's energy security and foster economic growth through energy exports. Moreover, the ministry is actively promoting environmental sustainability initiatives, including the installation of solar water heaters and energy audits in industrial facilities. These efforts reflect Jordan's commitment to social welfare and environmental protection. Despite notable progress, the ministry acknowledges challenges encountered in implementing energy sector initiatives, including technical constraints and delays in project approvals. However, these challenges are being addressed through strategic planning and collaboration with stakeholders[250].

In summary, Jordan's energy sector is undergoing a transformative phase, driven by initiatives to promote renewable energy, enhance energy efficiency, and foster sustainable development. By means of coordinated endeavors and strategic alliances, Jordan is positioned to establish itself as a frontrunner in the region with regards to the generation of renewable energy and groundbreaking concepts. This would make a significant contribution to worldwide initiatives aimed at mitigating climate change and attaining energy security.

5.2 Identification of Integration Challenges and Barriers

Obstacles to the implementation of renewable energy sources in Jordan consist of operational complexities, including a substantial decline in net demand and synchronous inertia, both of which present difficulties for the power system operator [251]. Furthermore, when energy demand is minimal during peak power generation, approximately 17% of Jordan's total wind energy capacity is curtailed [252]. Successful administration of renewable energy initiatives requires specific

proficiencies and knowledge that are not found in conventional engineering management [253]. Furthermore, Jordan is compelled to import crude oil and natural gas due to its inadequate reserves of energy resources, including fossil fuels and natural gas. In order to surmount these challenges and advance the adoption of renewable energy, it is critical to implement approaches for energy curtailment, enhance the utilization of reduced energy, and cultivate expertise and capabilities in the renewable energy industry [254].

The incorporation of sustainability principles into public works in Jordan encounters numerous obstacles. To begin with, it is widely acknowledged that environmental principles must be considered during the construction process in order to reduce energy and water usage, enhance air quality, and minimize pollution. This will result in substantial reductions in overall consumption and greenhouse gas emissions. Efforts have been made, including discussions at international conferences on sustainable construction, to emphasize the importance of environmental protection and resource conservation through reduced consumption and increased use of renewable resources. Secondly, the social aspect of sustainability must be considered, not only for end-users but also for the workforce involved in project development, ensuring their well-being and inclusivity[255]. This involves designing products with considerations for disabled individuals and the elderly, as well as promoting diversity and ensuring healthy environments for workers and users. Thirdly, the economic principle of sustainability aims to improve project performance and efficiency while reducing life cycle costs[256, 257]. Although initial costs may be higher for sustainable construction, long-term benefits include lower operation and maintenance costs, improved project performance, and increased productivity for occupants. Additionally, regulations, such as the Privatisation Regulation of 2008, emphasize the importance of sustainability in ongoing projects, highlighting the need for new regulations to promote sustainable practices in both public and private sectors. As a result, Jordan's development strategy endeavors to improve the standard of living for its populace through the promotion of cooperation between the public and private domains. and raising awareness of sustainable practices among the general public. Embracing sustainability in public works can significantly improve project delivery capabilities and contribute to sustainable development, particularly in resource-constrained countries like Jordan [258].

Numerous obstacles and challenges impede Jordan's transition to a more sustainable energy future via the incorporation of renewable energy sources. Notwithstanding the considerable

capacity of the nation to produce renewable energy, a number of impediments impede the smooth assimilation of these sources into the preexisting energy infrastructure.

- **Policy and Regulatory Frameworks:**

A significant impediment is the absence of consistent and transparent governmental regulation pertaining to the utilization of renewable energy sources in Jordan. Notwithstanding the endeavors of the government to promote the adoption of renewable energy, including feed-in tariffs and net metering, investors and project developers remain uninformed as a result of the perpetual policy and regulatory modifications. Timely implementation of renewable energy projects is further hindered by bureaucratic impediments and delays in obtaining licenses and permissions.

- **Grid Infrastructure Limitations:**

The existing grid infrastructure in Jordan is another significant barrier to renewable energy integration. Due to its primary design intention of accommodating power generation derived from conventional fossil fuels, the grid is inadequately outfitted to manage the intermittent characteristics inherent in renewable energy sources like solar and wind power. Technical constraints and limited transmission and distribution capacity present obstacles to the seamless integration of renewable energy into the grid. To fully harness the potential of renewable energy in Jordan, it is critical to address the constraints of the grid infrastructure and modernize it to accommodate bidirectional power flow.

- **Financial Constraints:**

Financial constraints represent a significant barrier to renewable energy integration, particularly for small-scale projects and rural communities. High upfront capital costs, limited access to financing, and perceived investment risks deter investors and developers from investing in renewable energy projects. While the government has introduced financial incentives and support mechanisms, including tax credits and subsidies, the availability of funding remains a challenge. Moreover, the lack of long-term financing options and investment guarantees further exacerbates financial barriers to renewable energy deployment.

- **Technological Challenges:**

Jordan faces technological obstacles that impede the extensive implementation of renewable energy technologies, such as concerns regarding their accessibility and dependability. The nation possesses ample solar and wind resources; however, due to their intermittent characteristics, efficient energy storage solutions are imperative in order to safeguard the stability and

dependability of the power grid. Additionally, the lack of local manufacturing capabilities and skilled workforce for renewable energy technologies increases reliance on imported equipment and expertise, adding to project costs and complexities.

- **Social and Cultural Acceptance:**

Renewable energy technology uptake and acceptance in Jordan may also be impacted by social and cultural variables. There is a strong correlation between public opinion, community involvement, and the success of renewable energy initiatives. Community opposition, worries about aesthetic and environmental repercussions, and ignorance of renewable energy's advantages are all factors that might slow down project planning and execution. To establish credibility and encourage societal support for renewable energy projects, it is crucial to involve stakeholders via outreach, education, and participatory decision-making procedures.

- **Interconnection with Neighboring Countries:**

Jordan's plans to interconnect its grid with neighboring countries present both opportunities and challenges for renewable energy integration. While grid interconnections can enhance energy security, facilitate cross-border trade, and enable the sharing of renewable energy resources, they also entail technical, regulatory, and geopolitical complexities. Harmonizing grid standards, resolving cross-border regulatory issues, and negotiating equitable terms for energy exchange are critical for successful grid interconnection projects. Additionally, regional conflicts and geopolitical tensions pose threats to the dependability and stability of cross-border energy infrastructure. Jordan must incorporate renewable energy sources into its energy matrix in order to promote sustainable development, reduce greenhouse gas emissions, and enhance energy security.

However, several challenges and barriers hinder the seamless integration of renewable energy, including policy and regulatory uncertainties, grid infrastructure limitations, financial constraints, technological challenges, social and cultural acceptance issues, and complexities associated with grid interconnection with neighboring countries. To effectively tackle these challenges, a comprehensive and synchronized strategy is necessary, which must incorporate the cooperation of civil society organizations, government agencies, regulatory bodies, and private sector stakeholders. By surmounting these obstacles, Jordan can transition towards a more sustainable and resilient energy future and realize the complete potential of renewable energy.

5.3 Opportunities for Accelerating Renewable Energy Deployment

At present, wind and solar energies are widely acknowledged as the most embraced renewable energy sources globally, owing to two primary reasons: the maturation and continuous enhancement of technological advancements in both sectors over the past two decades, and the significant reduction in the costs of power generation facilitated by these technologies. However, despite their widespread recognition, several challenges persist, particularly in developed countries, impeding the extensive adoption of these technologies. The challenges at hand include deficiencies in institutions, insufficient legal frameworks, concerns regarding economies of scale, distortions in pricing, and a scarcity of information regarding the resource base. Government policy support is considered essential in overcoming these challenges and is the fundamental pillar upon which the progress of commercial renewable energy (RE) initiatives is built. Financial incentives are of utmost importance in facilitating the growth of commercial markets and alleviating the financial burdens associated with the life-cycle of RE technologies. In addition, it is critical to incorporate energy policy support components, including meticulous prioritization and effective long-term planning. Furthermore, positive results are expected from collaborative efforts between commercial and governmental institutions in the fields of renewable energy research and development, technology transfer, and coordinated initiatives.

Differentiating between financial and economic incentives is of the utmost importance. Financial incentives are intrinsic processes associated with accounting and recordkeeping that exert an impact on the earnings or losses of a pre-existing organization. On the contrary, economic incentives pertain to the viability of a project as they are external instruments implemented prior to the establishment of a commercial entity. Trends on a global scale demonstrate that numerous nations have instituted incentives to promote the use of RE. In Senegal, for instance, investment decisions in the RE sector are scrutinized using an optimization technique in conjunction with cash flow analysis, thereby promoting the sustainable deployment of renewable energy sources in remote areas. Government subsidies for installation costs and incentive programs including investment deductions and accelerated depreciation are implemented in Taiwan in accordance with RE development legislation that aims to achieve a 12% RE share in the energy mix by 2020. In a similar vein, the Indian government provides significant incentives to foster the renewable energy sector. These incentives comprise expedited depreciation of up to 80% for investments in RE, alleviation of customs and excise duties, and exemptions from central sales tax.

Regulatory and voluntary mechanisms are adopted throughout the European Union (EU) in an effort to advance RE through direct or indirect strategies. In contrast to direct strategies, which are driven by capacity or price, indirect strategies are predicated on environmental levies or voluntary agreements. A wide range of incentives are offered, such as monetary assistance for each kilowatt (kW) of installed capacity or for each kWh generated and sold utilizing renewable energy sources. Investment-oriented incentives, including tax incentives and rebates, are widely observed in conjunction with pricing mechanisms such as feed-in-tariff systems and net-metering. Through fiscal measures and subsidies, direct tax incentives, such as flexible depreciation and favorable tax treatment for third-party financing, may also be implemented. EU practices such as accelerated depreciation in the United Kingdom and the Netherlands, percentage deductions in Year 1, and investment in third-party projects in the Netherlands and Ireland serve as illustrative instances. Several research studies have investigated Jordan's efforts to promote renewable energy sources [23, 33, 39, 108]. An example of this can be seen in the research conducted by Rahoma and Obeidat [23], who utilized multi-criteria decision analysis (MCDA) to assess the renewable energy alternatives accessible within the nation. They considered factors like the environment, economy, politics, and technology, using various techniques to assign weighted scores to each option. The results, shown in Table 4.3, provide useful insights for policymakers and investors when deciding on the best strategies to pursue.

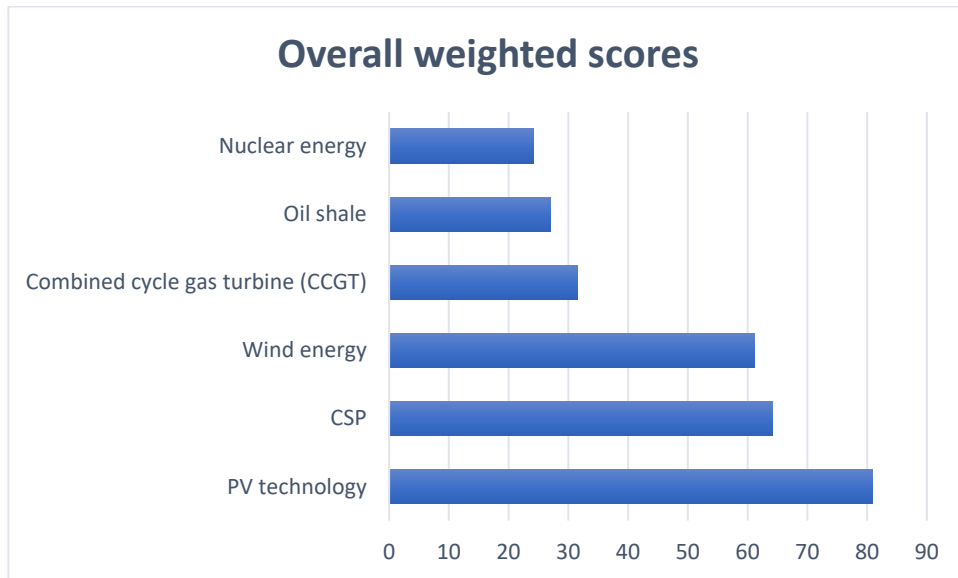


Figure 5: The Jordan Resources Weighted Scores Assigned to Various Renewable Energy.

In addition to improving environmental conservation, these investments have the potential to boost the competitiveness of local industries. A 400 kV electric cable already connects Jordan's power grid to that of Syria and Egypt; new agreements with Iraq and Lebanon will further increase this network's connectivity capacity [30]. Also, the AlRama substation is going to be built, which means that NEPCO will be able to provide twice as much power to the Jerusalem District Electricity Company. An interconnection arrangement between Saudi Arabia and Jordan is almost finalized, adding to the growing number of Arab electrical interconnection projects that aim to increase Jordan's ability to export power to neighboring states [22, 30]. It's worth noting that renewable energy efforts also have a big impact on the economy, helping to create jobs and new businesses, especially in poor countries.

According to IRENA publications [22, 101], the standard 50 MW solar energy projects and onshore wind farms of the same capacity require specific skill sets and a certain amount of manpower. The most labor-intensive parts of a PV project are the operating and maintenance phases, which account for 56% and 43% of the total labor demand, respectively. Operations and maintenance jobs last the whole project, in contrast to the more transient manufacturing and installation duties. Half of Jordan's 5,000 renewable energy workers were involved in solar photovoltaic (PV) projects in 2020. More than 6,000 new positions will open up in the energy efficiency industry, according to IRENA's [22] projections, mostly in the building, lighting, and renewable energy industries. Despite this, women still only make up about 5% of these roles, and that number is only going to grow as the workforce is predicted to quadruple by 2030 [271].

Many foreign companies have great opportunities to get involved in renewable energy in Jordan. This includes making and selling things like solar panels, wind turbines, and batteries, as well as providing advice and services. The country is working to make its electricity grid bigger to handle more power from renewable sources. This creates a good chance for businesses, both local and international, to invest in projects related to renewable energy, especially in making the electricity grid better and offering related services.

5.4 Strategies for Accelerating Renewable Energy in Jordan.

Jordan's pursuit of renewable energy strategies has been a dynamic journey, driven by the need to diversify energy sources, bolster energy security, and address environmental concerns. The National Energy Strategy (NES) lays out a comprehensive roadmap, setting long-term targets and actionable steps. Through initiatives like the Feed-in Tariff (FiT) Program, the country incentivizes

investment in solar and wind power by offering fixed tariffs for renewable electricity. Net metering schemes empower consumers to generate their own renewable energy and contribute surplus power to the grid. The JREEEF provides funding to help with project development, while the Energy Efficiency and Conservation Law requires energy-efficient practices. Jordan also works with other countries to pool their resources and expertise. These integrated efforts aim to expedite the transition towards sustainability, reduce reliance on fossil fuels, and stimulate economic growth while enhancing energy resilience.

To foster the expansion of the renewable energy sector, the Jordanian government has implemented several policies, as outlined in Table 4.2. Establishing and enforcing energy-efficiency standards has been pivotal in transitioning towards renewable energy. In 2012, Law No. 13 on Energy Efficiency and Renewable Energy, along with subsequent revisions, played a significant role in this regard. This legislation aimed at efficiently harnessing renewable energy sources, promoting conservation, optimizing energy usage, and enhancing efficiency across industries. Investors were provided with opportunities to propose and develop grid-connected electricity production projects under this law. Additionally, the prerequisites and protocols for directly submitting proposals for renewable energy and connecting to the grid were delineated in Bylaw No. 50 of 2015. Moreover, in an effort to promote the adoption of renewable energy sources, Jordan established domestic financial institutions such as the Renewable Energy and Energy Efficiency Fund (JREEEF). Established in 2015, JREEEF assists the government in energy efficiency initiatives and schemes while investing in a variety of renewable energy sources. Due to the declining costs of affiliated technologies, these policies and regulations have enabled a significant increase in the proportion of electricity generation from renewable sources in Jordan's energy mix, which has risen from 0.7% in 2014 to over 20% by 2020.

The National Energy Sector Strategy delineates ambitious objectives with the purpose of revolutionizing Jordan's energy environment by substantially increasing the proportion of renewable energy sources in the electricity composition. By 2030, the plan targets to elevate the proportion of renewables to 31%, representing around 3,200 MW of installed capacity. Furthermore, the strategy incorporates 15% from oil shale, ultimately striving to achieve a locally generated capacity of approximately 48.5%. Additionally, concerted efforts are directed towards enhancing energy efficiency across various sectors, with a projected 9% improvement by 2030 compared to 2018 levels. Consistent with these goals, the Ministry of Environment, with the

backing of the Global Green Growth Institute, has launched a Green Growth National Action Plan for 2021–2025. The principal objective of this plan is to encourage the adoption of renewable energy sources as a means to foster a greener energy portfolio. Furthermore, Jordan has strengthened its resolve to combat climate change by revising its Nationally Determined Contributions (NDC) to the Paris Agreement. In doing so, the country has established an even more ambitious objective of diminishing greenhouse gas emissions by 31% by 2030.

Jordan is currently facing considerable obstacles in its efforts to simultaneously reduce dependence on imported fossil fuels, mitigate the effects of climate change, and satisfy its rapidly increasing energy demands. In order to address these obstacles and accelerate the incorporation of renewable energy sources into the nation's energy infrastructure, it is critical to implement strategic goals and policies. This article examines ten critical approaches to expedite the integration of renewable energy sources in Jordan, concentrating on capacity building, policy frameworks, investment incentives, and infrastructural development.

- **Establishing Ambitious Renewable Energy Targets:**

Establishing ambitious renewable energy targets is of utmost importance in order to furnish Jordan with a distinct trajectory and a sense of immediacy regarding the deployment of renewable energy sources.. The government should establish long-term targets for renewable energy capacity and generation, aligned with international climate commitments and national energy security objectives. These objectives may provide policymakers, investors, and stakeholders with a road map, stimulating investment and innovation in the renewable energy industry.

- **Strengthening Regulatory and Policy Frameworks:**

A robust regulatory and policy framework is essential for creating an enabling environment for renewable energy investment and deployment. Jordan should prioritize the development and implementation of supportive policies, including feed-in tariffs, net metering schemes, renewable energy quotas, and streamlined permitting processes. Additionally, policymakers should ensure policy coherence and consistency to provide certainty and confidence for investors.

- **Enhancing Grid Infrastructure and Energy Storage:**

Energy storage and grid infrastructure investments are essential for Jordan's electricity grid to incorporate variable renewable energy sources such as solar and wind power. The government should prioritize the expansion and modernization of transmission and distribution networks, including grid interconnections with neighboring countries. Furthermore, incentivizing the

deployment of energy storage technologies can enhance grid stability and flexibility, facilitating higher penetration of renewables.

- **Promoting Public-Private Partnerships (PPPs):**

Public-private partnerships (PPPs) have the potential to greatly facilitate the implementation of renewable energy sources through the utilization of private sector knowledge, capital, and fresh ideas. It is recommended that Jordan proactively advocate for public-private partnerships (PPPs) in the context of renewable energy endeavors, encompassing utility-scale wind and solar farms, distributed generation systems, and energy efficiency initiatives. PPP frameworks should be designed to optimize risk sharing, ensure transparency, and align incentives between public and private stakeholders.

- **Fostering Innovation and Research Collaboration:**

Investments in innovation and research collaboration are essential for driving technological advancements and cost reductions in renewable energy technologies. Jordan should establish research and development (R&D) incentives, grants, and funding programs to support innovation in renewable energy. Moreover, fostering collaboration between research institutions, universities, industry partners, and international organizations can accelerate technology transfer and knowledge exchange.

- **Implementing Financial Incentives and Support Mechanisms:**

Financial support mechanisms and incentives are essential for reducing the financial barriers to renewable energy adoption and attracting investment. It is recommended that Jordan implement a range of financial mechanisms to support renewable energy initiatives, including tax credits, subsidies, grants, and low-interest loans. These measures should be specifically designed to assist small and medium-sized enterprises (SMEs) and rural communities.. Additionally, establishing dedicated financing facilities, green banks, and venture capital funds can mobilize private sector investment in renewable energy.

- **Enhancing Energy Efficiency and Demand-Side Management:**

Complementing the deployment of renewable energy sources with demand-side management strategies and energy efficiency improvements can reduce peak demand and overall energy consumption.. Jordan should prioritize energy efficiency measures in buildings, industry, transportation, and agriculture sectors, including building energy codes, energy-efficient appliances, and fuel-efficient transportation systems. Demand-side management programs, such

as time-of-use tariffs and smart grid technologies, can optimize energy consumption and grid operation.

- **Building Institutional Capacity and Human Resources:**

Building institutional capacity and developing a skilled workforce are essential for effective renewable energy planning, implementation, and management. Jordan should invest in capacity building initiatives, training programs, and professional development opportunities for government agencies, regulatory bodies, utilities, and renewable energy industry stakeholders. Moreover, fostering partnerships with educational institutions, vocational training centers, and international organizations can enhance knowledge transfer and skill development in the renewable energy sector.

- **Strengthening International Cooperation and Collaboration:**

International cooperation and collaboration can provide valuable resources, expertise, and best practices to support renewable energy integration in Jordan. The government should actively engage in partnerships with international organizations, development agencies, donor countries, and regional initiatives to access funding, technical assistance, and capacity-building support. Furthermore, participating in international forums, conferences, and knowledge-sharing platforms can facilitate peer learning and exchange of experiences with other countries facing similar challenges.

- **Raising Public Awareness and Stakeholder Engagement**

Raising public awareness and fostering stakeholder engagement are essential for building support and momentum for renewable energy integration in Jordan. Community-based programs, public education campaigns, and outreach initiatives should be implemented by the government in order to increase awareness of the advantages associated with sustainable development, energy conservation, and renewable energy.. In addition, to make sure that renewable energy programs and policies represent the interests of all parties involved, it is important to encourage consultations, debates, and participatory decision-making among many stakeholders. Legislative frameworks, infrastructure development, and investment incentives must collaborate to accelerate the integration of renewable energy sources into Jordan's energy matrix.

5.5 Policy Recommendations

To meet future renewable energy targets, Jordan should execute its plans to upgrade the grid and deploy energy storage systems and implement power sector and business climate reforms.

The World Bank is assisting Jordan with its plans through an electricity sector roadmap and funding for climate responsive investments (\$400m) and electricity sector efficiency and supply reliability (\$250m). Jordan can also benefit from efficiency and demand-side management. To help, the regulator introduced a time-of-use tariff in April 2022. The Jordanian government is working with USAID on the development of an energy services company model which could incentivize energy efficiency at scale[274].

It is also crucial to upgrade the grid and create a framework and financing mechanism for the development of the energy storage industry to ensure the sustainability of renewable energy projects. Rolling out electric mobility will help mop up peak supply and moderate peak demand, while production of green hydrogen and ammonia fertilizers are being explored for the longer term. But energy transition in the power sector cannot happen in a vacuum and is heavily impacted by the sector's overall status. Therefore, reforming the power sector, including reducing the overall cost of electricity and restructuring the electricity utility into a new business model (possibly moving away from the single-buyer model) are critical first steps.

Overall, economic reform to attract long-term investors is also necessary. For this to happen, it is vital to reduce vested interests in the fossil fuel sector and ensure a political commitment to the energy transition, especially in light of energy sector developments in gas and oil shale. This is a hard needle to thread. Jordan has made strides in renewable energy deployment and is at the forefront of the industry in the Middle East. But conflicts of interests with the fossil fuel economy and electricity utility, along with challenges in grid infrastructure, lack of storage capacity, low investments and affordability are key challenges for the sector. To meet renewable energy targets and realise its ambition of turning Jordan into a regional hub for green energy production, the Jordanian government should carry out both infrastructure upgrades and wider power sector and business climate reforms. To achieve its future renewable energy targets, Jordan must prioritize several key actions, including grid upgrades, energy storage deployment, power sector reforms, and improvements in the business climate. Collaborating with international organizations like the World Bank, which is providing financial support and technical assistance, is crucial in this endeavor. Upgrading the grid and implementing energy storage systems are essential steps to ensure the reliability and sustainability of renewable energy projects. The World Bank's assistance in developing an electricity sector roadmap and funding climate-responsive

investments and supply reliability initiatives will support these efforts. Efficiency measures and demand-side management strategies can further enhance Jordan's energy landscape. The introduction of a time-of-use tariff by the regulator and collaboration with USAID to develop an energy services company model are positive steps toward incentivizing energy efficiency on a broader scale[274].

Moreover, transitioning to electric mobility can help balance peak supply and demand, while exploring the production of green hydrogen and ammonia fertilizers offers promising opportunities for long-term sustainability. However, addressing the challenges in the power sector requires comprehensive reform efforts. Reducing the overall cost of electricity, restructuring the electricity utility into a more efficient business model, and potentially moving away from the single-buyer model are critical steps in this process. Economic reforms aimed at attracting long-term investors are also imperative. This entails reducing vested interests in the fossil fuel sector and garnering political commitment to the energy transition, particularly amidst developments in gas and oil shale exploration. Despite the progress made in renewable energy deployment, Jordan still faces significant challenges, including conflicts of interest with the fossil fuel economy, grid infrastructure limitations, insufficient storage capacity, low investment levels, and affordability issues. To overcome these hurdles and realize its vision of becoming a regional green energy hub, Jordan must undertake comprehensive infrastructure upgrades and enact broader power sector and business climate reforms. These efforts will not only advance Jordan's renewable energy goals but also contribute to its economic development and environmental sustainability[274]. The successful operation of Jordan's renewable energy industry in the coming years is contingent on the establishment of comprehensive policy frameworks that encourage investment, nurture innovation, and advance sustainable development. Drawing upon an analysis of the present condition of renewable energy in Jordan and worldwide exemplary approaches, the subsequent policy suggestions are put forth:

- **Enhancement of Regulatory Clarity and Stability:**

To provide investors with confidence and certainty, it is imperative to establish clear and stable regulatory frameworks for the renewable energy sector in Jordan. This includes streamlining permitting processes, clarifying licensing requirements, and ensuring consistency in policy implementation. Moreover, regulatory bodies should engage in proactive stakeholder consultation to address emerging challenges and opportunities effectively.

- **Incentivization of Renewable Energy Adoption:**

Subsidies, feed-in tariffs, and tax credits are important incentive mechanisms that drive the adoption of renewable energy. Future policies should aim to enhance existing incentive schemes and introduce new mechanisms to stimulate investment in renewable energy projects. Tailored incentives for specific sectors, such as industry, agriculture, and transportation, can further accelerate the transition towards renewable energy sources.

- **Promotion of Distributed Generation and Energy Storage:**

Distributed generation, including rooftop solar PV systems, offers significant potential to enhance energy resilience and reduce reliance on centralized power generation infrastructure. Policymakers should prioritize the development of supportive policies for distributed generation projects, including net metering arrangements, grid interconnection standards, and financial incentives for residential and commercial installations. Furthermore, the implementation of policies that provide incentives for energy storage technologies can effectively promote the integration of variable renewable energy sources into the electrical infrastructure, thereby contributing to the overall stability of the grid.

- **Facilitation of Public-Private Partnerships (PPPs):**

Public-private partnerships (PPPs) can be advantageous for renewable energy projects because they enable the sharing of risks and responsibilities, in addition to the release of additional capital and expertise. In order to facilitate public-private partnerships (PPPs) in the renewable energy industry, future policies should aim to simplify procurement procedures, provide clear criteria for selecting projects, and ensure that the necessary legal and regulatory frameworks are in place. Major renewable energy projects and infrastructure can be advanced by joint efforts between public and commercial organizations, such as development financing institutions and government agencies.

- **Capacity Building and Workforce Development:**

Building local capacity and fostering a skilled workforce are essential for the sustainable growth. Future policies should prioritize investments in education, training, and vocational programs that equip individuals with the knowledge and skills required for careers in renewable energy. Additionally, partnerships between educational institutions, industry associations, and government agencies can facilitate knowledge transfer, technology adoption, and innovation in the renewable energy workforce.

- **Integration of Renewable Energy into Urban Planning:**

Urban areas present unique opportunities for renewable energy deployment, including rooftop solar PV, district heating and cooling systems, and energy-efficient building design. Urban planning processes, zoning rules, and building codes should incorporate renewable energy concerns in order to fully exploit the potential for adopting renewable energy in urban areas. Providing incentives for green building certification, energy-efficient retrofitting, and sustainable urban development can encourage the incorporation of renewable energy technology in cities and towns around Jordan.

- **Promotion of Research, Development, and Innovation (RDI):**

Research, development, and innovation (RDI) are essential for driving technological advancements and improving the efficiency and performance of renewable energy technologies. Future policies should prioritize investment in RDI initiatives, including research grants, technology incubators, and innovation hubs focused on renewable energy. Collaboration between academic institutions, research organizations, and industry partners can accelerate the pace of innovation and support the commercialization of cutting-edge renewable energy solutions.

In conclusion, the future of Jordan's renewable energy sector depends on the proactive implementation of forward-thinking policies that foster innovation, incentivize investment, and promote sustainable development. By embracing these policy recommendations, Jordan can unlock its vast renewable energy potential, reduce reliance on imported fossil fuels, and contribute to a more resilient, equitable, and sustainable energy future.

Chapter 6

Conclusion

6.1. Summary of Key Findings and Contributions

6.2 Future Research Directions

Chapter 6: Conclusion

6.1 Summary of Key Findings and Contributions

6.1.1 The impact of the COVID-19 pandemic on National Electric Power Company

A substantial decline in electricity consumption—estimated at around 10%—was caused by the economic downturn brought on by the COVID-19 epidemic, which had a profound effect on Jordan's power market. But NEPCO's long-term payment obligations to gas and power suppliers under existing contracts did not reflect this drop. Also, from the middle of March 2020 until the middle of May 2020, payments from the distribution companies to NEPCO were suspended since their ability to recover energy purchasing costs decreased. Due to severe working capital problems, NEPCO was forced to defer payments after subsequent payment delays had a significant impact on the organization's operational cash flows. As a result, as of April, NEPCO could only pay its green and traditional private independent power producers (IPPs) 75% of what they were due. These IPPs provide approximately half of the country's electricity. This issue jeopardized Jordan's power supply and the industry's foundational contractual integrity. That kind of unpredictability might make Jordan less appealing as an FDI destination and put its position as a renewable energy industry role model in the SEMED area at risk. In order to resolve these issues, the Bank worked closely with NEPCO, the Jordanian government, investors, and other IFIs. As a result of these initiatives, NEPCO has agreed to pay off its debts and restore strict payment discipline with all renewable energy IPPs by the middle of 2021. The planned loan will not be signed until NEPCO has negotiated a comparable agreement with traditional power suppliers. Given the enormous investment needed for Jordan's and the region's continuing shift to renewable energy, this coordinated effort is a critical step towards regaining investor trust.

1. Other challenges facing the energy sector's growth

- A. It is clear that energy efficiency ideas are being implemented with delays.
- B. The advantages of energy efficiency are not well understood by the general public.
- C. Neither the database nor the information it contains are clear.

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- D. There is a lack of regulation when it comes to the execution of Jordanian building codes.
 - E. The Energy Efficiency Applications Law enforcement team needs more members.
 - F. Low-income household energy efficiency projects do not receive enough funding.
 - G. The availability of energy efficiency education, empowerment, and training programs is still low.

A number of Jordanian statutes necessitate reevaluation; one such statute is Article (10) of Bylaw No. (73) of 2012 concerning the Regulation of Procedures and Means for Energy Conservation and Efficiency Improvement, which became effective on April 1, 2013. More than two-thirds of homes are exempt from the law's prohibition on using Solar Water Heaters (SWHs) in single-family homes or apartments with floor plans smaller than 250 square meters.

6.1.2 Conclusion

This dissertation offers a comprehensive examination of Jordan's renewable energy sector, with the aim of providing valuable insights to policymakers and investors for strategic planning. It delves into the country's current energy landscape, emphasizing the significance of renewable sources in ensuring sustainable and secure energy supplies over the long term. While challenges such as policy frameworks, technical support, and financial resources are acknowledged, Jordan is already taking proactive measures to overcome these hurdles and leverage its renewable energy potential.

If Jordan is serious about speeding up the deployment of renewable energy sources, it should prioritize investment in grid infrastructure and storage capacity, as well as improving power system management. The southern region's economy and dependence on imported oil might be bolstered by conducting a comprehensive feasibility study of constructing Concentrated Solar Power (CSP) plants. It would be much easier to study grid integration and come up with new ideas if renewable energy centers were set up. In order to foster a trained labor force that is capable of propelling the renewable energy agenda ahead, it is crucial to support local institutions in their water, renewable energy, and environmental studies research endeavors.

A comprehensive investor's guide should be formulated to attract investment, offering detailed insights into optimal energy technologies tailored to different regions within Jordan. Emphasizing

the country's renewable potential and competitive advantages, such a guide would serve as a valuable resource for prospective investors. Furthermore, rigorous environmental impact assessments should precede project approvals to ensure minimal disruption to local ecosystems and communities. Investors must also commit to conducting thorough environmental assessments prior to project initiation, demonstrating their commitment to sustainability and responsible development in collaboration with the Jordanian government.

The global spread of the COVID-19 pandemic has resulted in the loss of hundreds of thousands of lives, severe economic dislocation, and mounting pressure on all nations. Expectations indicated that this pandemic will cause significant and long-lasting changes, and As the COVID-19 epidemic has demonstrated, Jordan is not alone in this regard; businesses and services around the world, including health institutions, have their share of shortcomings. When compared to fossil fuels, renewable and sustainable sources appear to be being used more frequently. The uncertainty of energy planning is exacerbated by worries about reliance, a lack of planning for the long future, and the limitations of science and technology. The influence of these factors on energy policy, however, will diminish significantly if Jordan pursues energy independence. This can be accomplished by utilizing shale, gas, and existing renewable energy sources rather than importing gas and heavy crude oil. Solar and wind power, among other renewables, hold a lot of potential for Jordan. With minimal investments in energy generation and optimization, some companies can generate savings of up to 20%. The following suggestions, derived from this report, need to be considered if the priorities and targets are to be met:

- These findings highlight the need for Jordan to transition away from traditional energy sources and toward renewable ones. This supports the goals of economic growth, energy independence, and environmental protection by taking into account the lessons learned from the COVID-19 pandemic and the current state of the global energy market. Unlike other countries, Jordan's current energy strategy ignores the pandemic and fails to address the need to reevaluate and adapt policies in light of new information.
- Decreasing the cost barrier in line with the expansion of Jordan's clean technology industry. as well as gathering and analyzing information regarding renewable power sources like solar and wind in addition, we are performing technical and commercial research on solar panel applications in multi-family homes and small businesses [76].

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- Providing more resources to solar energy-related projects so the government may step up its efforts in this area. In addition, in order to make it easier to get licenses, the government should look over the rules that govern solar energy system installations. There needs to be a focus and channeling of investments in energy-saving strategies, such as the development of renewable, practical energy technology.
 - In light of recent technological advances, we need to prepare the power system for a future devoid of conventional energy sources if we want to be seen as potential exporters of electric power..
 - In the first three months of 2020, COVID-19 dealt a severe blow to fuel prices, causing oil prices to plummet by half. In light of the results and allegations mentioned earlier, it is important to inform all relevant Jordanian stakeholders of this..Both supply and demand shocks pose significant risks to oil prices, as mentioned in reference 276. A mix of higher fuel output and weak global demand will keep oil prices low for the foreseeable future [277].
 - Governments at all levels, including those at the state and federal levels, must give energy efficiency (EE) policy their full attention. and revise, update, and rewrite EE standards so they can better meet the dynamic needs of the Jordanian market.
 - Making public and industry-specific information about rules, regulations, and exemptions for EE equipment more widely available. To ensure the country's electrical needs are adequately met, we are also considering new tactics and technologies.
 - Construct a more effective national mass transit system and finish new public transportation projects like Bus Rapid Transit to link all of the governorates in the Kingdom in a streamlined and efficient manner. Light Rail Transit (LRT) and underground metro networks (subways) are new projects that need to be implemented to reduce the number of personal automobiles and increase the demand for public transportation.
 - It should be the country's first priority to restore and activate the railway so that it may serve all governorates as an official form of transportation. Public transportation should also be given high attention by policymakers. It would be easier to negotiate with regulators if the government had greater control over public transportation, as there would only be a small number of airlines to deal with instead of thousands. Operators on a grand scale will thus be able to take advantage of scale economies. They could keep or improve services that smaller operators can't handle while cutting operating costs per passenger or mile traveled.

- To solve the problem of EVs malfunctioning because their batteries don't have enough juice, we should:
 - Build more charging stations for electric vehicles. Research and development of energy storage technologies is equally crucial. Government incentives, such tax and customs exemptions, for EVs and electric vehicles are not easily accessible everywhere.

- Propose the concept of ridesharing, offering individual's savings on fuel expenses, tolls, and travel time. Ridesharing not only cuts down on air pollution, carbon emissions, and traffic congestion but also diminishes the demand for parking, making it an environmentally friendly and economically efficient transportation alternative.

- Allocate resources towards enhanced scientific research and innovative ideas in this domain, emphasizing a methodical strategy for collecting, documenting, and monitoring data, ensuring unbiased and objective theoretical analyses.

Also In this dissertation, a novel four-stage interval-based HEM program has been presented. The novel proposal is suitable for smart prosumers with RTP tariff, V2H capability and PV-based onsite generation. The developed HEM system considers uncertainties on PV generation, EV behaviour, energy prices, non-controllable appliances demand and outdoor temperature. Interval numbers are used to model the various unpredictable processes that are gradually included into the scheduling task. This method enables the execution of the home asset scheduling plan from a variety of viewpoints, ranging from optimistic to pessimistic. According to the first view, residential customers should try to discover a scheduling plan that reduces their power cost as much as possible within the intervals indicated, even when faced with the most unfavourable value for the unknown factors. On the other hand, the created HEM software presumes that the uncertainties take positive values if the users choose an optimistic view.

An RTP tariff and V2H capable benchmark prosumer environment was used to validate the new HEM system. Results obtained were coherent thus validating our proposal and proving its effectiveness. The influence of the users' attitude and the uncertain level on the results obtained has been extensively analysed. In addition, it has been reported that the developed solution framework is computationally light and tractable by standard solvers and average machines.

Ongoing works are being conducted on extending the novel proposal to cooperative game-oriented scheduling mechanisms on virtual power plant schemes. Studying the applicability of the developed interval-based scheduling tool for renewable-based isolated microgrids might suppose a promising future research line as well.

6.2 Future Research Directions

As the renewable energy sector continues to evolve rapidly, there are several key areas that warrant further research to advance understanding, address challenges, and capitalize on opportunities. Given the current state of renewable energy in Jordan, this section suggests avenues for further study in this area.

- **Policy and Regulatory Frameworks:**

The current rules and regulations that control Jordan's renewable energy sector should be the subject of future studies that assess its efficacy. This involves looking at how things have changed when policies were changed, such how electricity subsidies were removed and how new pricing structures were put in place. Additionally, there is a need to explore innovative policy instruments that can further incentivize renewable energy investment and deployment while ensuring sustainability and equity.

- **Technological Innovation and Integration:**

Improving the efficiency, dependability, and affordability of renewable energy systems requires ongoing technological innovation. Technologies including smart grids, energy storage, and enhanced solar photovoltaics (PV) should be the focus of future studies. In addition, grid modernization and demand-side management approaches are two parts of the energy infrastructure that need to be studied in order to find the best way to incorporate renewable energy into it.

- **Economic Viability and Financing Models:**

Research into the economic viability of renewable energy projects is critical for attracting investment and scaling up deployment. Future studies should assess the cost-effectiveness of various renewable energy technologies, considering factors such as upfront capital costs, operational expenses, and long-term returns on investment. To further address financial obstacles and mobilize funds for renewable energy projects, it is worth investigating alternative financing structures like crowd-funding platforms, public-private partnerships, and green bonds.

- **Environmental and Social Impacts:**

It is imperative to comprehend the environmental and societal repercussions of implementing renewable energy to foster sustainable growth. Subsequent studies ought to delve into the ecological impact of renewable energy technologies through comprehensive evaluations of their life cycles and environmental ramifications. Furthermore, it is vital to evaluate the socio-economic

advantages and obstacles linked with renewable energy initiatives, encompassing aspects like employment generation, community involvement, and conflicts over land usage.

- **Market Dynamics and Energy Security:**

If we want to know if renewable energy transitions are sustainable in the long run, we need to look at market dynamics and energy security factors. Research in this area should focus on renewable energy markets, investment trends, and customer behavior. In order to inform decisions on energy policy and planning, it is crucial to study how renewable energy may improve energy security, lessen reliance on imported fossil fuels, and lessen the impact of geopolitical threats.

- **Capacity Building and Human Capital Development:**

Enhancing local capacity and nurturing a proficient workforce are indispensable for fostering the sustainable expansion of the renewable energy sector. Future endeavors should prioritize the design and implementation of targeted training programs, educational frameworks, and career advancement initiatives specifically tailored to meet the evolving demands of the renewable energy industry. Additionally, facilitating knowledge sharing, fostering collaborative endeavors, and facilitating technology transfer mechanisms among academia, industry players, and government entities are vital steps to stimulate innovation and entrepreneurial endeavors within the renewable energy domain. By cultivating a conducive environment for skill development and fostering synergistic partnerships, Jordan can bolster its position as a frontrunner in renewable energy innovation and adoption.

- **Community Engagement and Stakeholder Participation:**

Effective community engagement and stakeholder participation are essential for ensuring the social acceptance and successful implementation of renewable energy projects. How to include locals, indigenous peoples, and others in renewable energy development decision-making processes is an important question that needs answering in the future.. Additionally, investigating mechanisms for fostering dialogue, resolving conflicts, and promoting inclusive decision-making can help build trust and consensus around renewable energy initiatives.

- **Cross-sectoral Linkages and Synergies:**

Examining the interconnectedness between renewable energy and other sectors, such as water, agriculture, and transportation, can uncover synergies and co-benefits that enhance overall sustainability. Future research should explore integrated energy-water-food systems approaches, circular economy principles, and multi-sectoral planning frameworks that optimize resource use

and minimize environmental impacts. In addition, comprehensive policy and planning approaches can be informed by evaluating the possible synergies between renewable energy and the objectives of reducing greenhouse gas emissions, protecting biodiversity, and achieving sustainable development. Finally, there is a vast array of multidisciplinary subjects that could be explored in future studies pertaining to Jordan's renewable energy sector, including policy and regulatory frameworks, technological innovation, economic viability, environmental and social impacts, market dynamics, capacity building, community engagement, and cross-sectoral linkages. Knowledge advancement, informed decision-making, and a more rapid shift to a sustainable energy future in Jordan and abroad can all be achieved if stakeholders devote resources to these research goals.

List of Articles in RUJA

- 2023- A four-stage framework for optimal scheduling strategy of smart prosumers with vehicle-to-home capability under real time pricing based on interval optimization.
 - **RUJA Link:** <https://hdl.handle.net/10953/2924>
 - DOI:10.1049/gtd2.12952
- 2023 - Review of Bioenergy Potential in Jordan
 - **RUJA Link:** <https://hdl.handle.net/10953/2925>
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