The Limits of Energy Transition in Arab Countries: An Analytical Study Using the Analytic Hierarchy Process (AHP) to Determine The Optimal Energy Mix

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Abstract

Amid accelerating global challenges posed by climate change and the urgent need to transition to sustainable energy, Arab countries face a complex set of structural constraints that hinder a successful transition. These constraints span technical, social, environmental, and financial dimensions. The region's economies remain heavily reliant on fossil fuels as the primary energy source, increasing their vulnerability to global market fluctuations and environmental disruptions. Key challenges include limited access to critical raw materials and minerals required for renewable energy technologies, difficulties with energy storage due to the intermittent nature of renewable sources, and the geographical concentration of these resources in remote areas far from consumption centers.

Moreover, financial constraints pose a significant barrier, as most Arab countries rely on hydrocarbon revenues to fund energy projects, limiting their ability to diversify investment in clean energy. This study seeks to address the following question: how can Arab countries overcome these constraints to achieve an optimal energy mix that balances sustainability with economic efficiency? The research adopts a mixed-methods approach, combining a qualitative literature review with quantitative analysis using the Analytical Hierarchy Process (AHP), a multi-criteria decision-making tool for evaluating alternatives and prioritizing energy strategies. Data are collected through expert surveys, technical reports, and regional case studies.

Keywords: Energy Transition, Renewable Energy, Energy Mix, Arab Countries, AHP, Financial Constraints.

JEL Classification Codes : Q42 – Q48 – C44

1. Introduction

Energy transition is one of the most significant strategic challenges facing nations in the twenty-first century. This challenge stems from accelerating climate change, rising energy security pressures, and the global shift toward clean, sustainable energy sources. The transition from conventional fossil-fuel–based systems to renewable energy frameworks has become a central objective of national and international policies because of its direct impact on economic stability, environmental protection, and sustainable development.

In this context, Arab countries—being among the leading oil-producing and exporting regions—face unique and complex challenges in their energy transition pathways. These challenges stem from their hydrocarbon-dependent

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economies, infrastructure limitations, and socio-environmental and financial constraints that hinder progress toward integrating renewable energy.

This paper aims to examine the limits of the energy transition in Arab countries through an analytical and scientific lens, focusing on identifying the optimal energy mix that balances economic and environmental sustainability with the practical realities of technological and financial capacities. The importance of this research lies in the urgent need for Arab countries to adapt to the emerging global energy landscape and foster more inclusive and sustainable development outcomes—particularly given their commitments under international climate agreements such as the Paris Agreement and the growing need to diversify sources of national income. The central research problem is articulated as follows:

How can Arab countries overcome technical, environmental, social, and financial constraints to achieve an effective energy transition that leads to an optimal energy mix?

This central question is explored through the following sub-questions:

1. What are the main barriers hindering energy transition in Arab countries?
2. How do limited financial resources and dependence on oil revenues slow down the transition process?
3. To what extent is the Analytic Hierarchy Process (AHP) an effective method for evaluating energy alternatives?
4. What constitutes the optimal energy mix for Arab countries under these constraints?

Based on these inquiries, the research proposes to test the following hypotheses:

1. Arab countries face multidimensional constraints that impede sustainable energy transition.
2. Achieving an optimal energy mix requires adopting multi-criteria decision analysis tools that account for national specificities.
3. The AHP methodology represents an appropriate and effective tool for evaluating and prioritizing available energy options according to national and strategic objectives.

Methodologically, this study adopts a descriptive-analytical approach with a dual nature—combining qualitative analysis, through a review of the literature and previous studies on the energy transition in the Arab context, with quantitative analysis using the Analytic Hierarchy Process (AHP) as a robust decision-support technique for multi-criteria assessment. The research instruments include a structured questionnaire distributed to a panel of energy experts, complemented by analysis of technical reports and case studies relevant to the Arab region.

The paper is organized into three main sections:

1. Theoretical Framework: presenting key concepts related to energy transition, renewable energy significance, and approaches to analyzing energy mixes.
2. Limits of Energy Transition in Arab Countries: analyzing current developments and prospects of renewable energy deployment, along with technical, social, environmental, and financial barriers.
3. Application of the AHP Method: detailing the implementation steps of the AHP approach in the Arab context—from defining criteria and alternatives to weighting priorities and determining the optimal energy mix.

Through this structure, the study aims to provide not only a theoretical contribution but also a practical analytical tool to help policymakers formulate more integrated and sustainable energy policies tailored to the economic and social realities of Arab countries.

2. Literature Review: Energy Transition in Arab Countries

Amid the global shift toward sustainable energy, energy transition issues in Arab countries have attracted growing scholarly and policy attention, given the region's complex challenges—namely, heavy dependence on fossil fuels, limited access to technology and finance, and underdeveloped infrastructure. Several recent studies have examined these challenges from multiple angles, focusing on regional disparities and pathways for improvement. The following review highlights five key recent contributions that address the dynamics of the energy transition in the Arab region.

1. Jameel Al-Naffakh (2025), in his study "Assessment of Carbon Intensity Dynamics in Electricity Generation: A Comparative Analysis of Middle Eastern Countries (2013–2023)", offers one of the most significant quantitative assessments based on long-term data. The research shows that Gulf Cooperation Council (GCC) countries have made progress in reducing carbon emissions, whereas other states with weaker infrastructure have lagged. Although this study focuses primarily on environmental performance, the present paper extends the discussion by adopting a multidimensional framework that incorporates technical, financial, and social considerations**.**

2. KF Bou-Hamdan et al. (2025), in "Carbon Capture, Utilization, and Storage in the MENA Region: A Regional Review of Projects and Challenges," explored the potential of carbon capture and storage (CCS) technologies as transitional tools for decarbonization. While this perspective offers valuable technical insight, the study focuses on a single technology. In contrast, our research conducts a comparative multi-criteria evaluation of several energy alternatives using the Analytic Hierarchy Process (AHP) to identify the most balanced energy mix.

3. Wang Q. (2024), in "China's Three Roles in the Solar Surge of the Gulf Region," analyzes how Chinese financing and technology accelerated solar energy expansion in Saudi Arabia and the UAE. This study is notable for highlighting the geo-economic dimension of the energy transition. However, its geographical scope is limited to the GCC countries, whereas our research adopts a broader regional perspective encompassing the entire Arab world.

4. L. Fawcett (2025), in her work "New Regional Order in the Middle East: Plus Ça Change?", examines the geopolitical implications of the energy transition, arguing that the rise of renewables could shift power dynamics as the strategic importance of oil declines. Although the study provides valuable theoretical insights, it remains largely conceptual. In contrast, our paper offers an applied quantitative framework that empirically ranks energy options and supports evidence-based policy formulation.

5. Ayasi et al. (2025), in "Application of Spiking Neural Networks for Solar Forecasting in Arab Countries," applied artificial intelligence models to predict solar irradiation patterns in the region, emphasizing how advanced algorithms can enhance renewable energy efficiency. Despite the novelty of this approach, the study is limited to the solar energy sub-sector, whereas our research integrates multiple renewable and conventional sources using the AHP model, providing a holistic evaluation of the total energy mix.

In summary, the reviewed literature reflects the diversity of approaches to analyzing the energy transition in the Arab world yet remains fragmented—each study addressing an isolated dimension. The distinct contribution of this paper lies in its effort to construct a comprehensive, integrative framework that considers the economic, technical, and socio-environmental structures of Arab countries. By employing multi-criteria decision analysis (AHP), the study provides a rigorous and practical tool for identifying the optimal energy mix for the region's transition toward sustainability.

3. Theoretical Framework of Energy System Transformation: From Fossil-Based Models to a Low-Carbon Economy

Throughout history, energy systems have undergone fundamental transformations closely tied to human development and evolving lifestyles. Each major transition in energy sources has marked a qualitative leap in productive and social capabilities. From the early use of fire to the harnessing of wind and water power, and finally to the large-scale reliance on fossil fuels initiated by the Industrial Revolution, the evolution of energy systems has reflected the dynamic relationship among natural resources, technological innovation, and changing economic and social needs.

The eighteenth-century transition from traditional renewable sources to coal, and later to oil and gas, marked humanity's shift from dependence on intermittent, uncontrollable natural flows to stored, manageable, and distributable resources. This shift enabled the reorganization of production, economic, and industrial systems and laid the foundation for modern industrial civilization.

The contemporary energy transition differs from its predecessors in both scope and purpose. Its driving forces are no longer limited to improving efficiency or increasing output but are primarily motivated by the urgent need to reduce greenhouse gas emissions, mitigate climate change, and ensure long-term energy security. In this context, *energy transition* refers to a structural and systemic shift in energy production and consumption—from a carbon-intensive, fossil-fuel-based model to one centered on renewable energy, energy efficiency, and the decarbonization of the energy cycle (CHÂTEAU B, 2021).

One of the earliest milestones in this paradigm shift was the seminal 1972 Club of Rome report, The Limits to Growth, which called for a fundamental transformation of the global energy and growth model toward environmentally and economically sustainable patterns. The report defined the energy transition as a "deliberate and organized movement from an accelerated growth model threatening planetary stability to a balanced, sustainable system" (MEADOWS H. Donella, 1972, p. 184).

The term "Energiewende"—literally, "energy transition"—first appeared in German academic literature in the 1980s and later gained prominence in scientific and environmental debates, especially after the 1973 oil crisis, which exposed the vulnerabilities of excessive reliance on fossil fuels (Emmanuel, 2016).

A review of the scientific literature reveals a multiplicity of definitions of the energy transition, reflecting its complex and multidimensional nature. Smil (SMIL, 2010, p. 192) defines it as "a gradual change in the composition of primary energy sources." In contrast, Rojey (ROJEY, 2008, p. 218) conceives it as a shift from a fossil-fuel-based model to one dominated by low-carbon energy. Bigot (BIGOT, 2013, pp. 300-301) emphasizes the complementary relationship between renewable and fossil energies, focusing on the pillars of efficiency, rationalization, and decarbonization. The NégaWatt Association in France presents a national perspective that links the energy transition to three simultaneous levers: energy conservation, improved efficiency, and expanded use of renewable energy. Similarly, the Institute Montaigne summarizes the transition as "a transformation in the way we produce and consume energy, aimed at preserving essential uses while reducing emissions."

The International Renewable Energy Agency defines the transition as “the process of transforming the global energy sector from reliance on fossil fuels to one that is carbon-neutral by 2050, while ensuring inclusive and sustainable development.” The Algerian Commission for Renewable Energies and Energy Efficiency adds a pragmatic national dimension, describing it as “a deep restructuring of the energy system leading to large-scale integration of renewables, while considering the prevailing model to avoid unplanned disruptions (CEREFE, 2020, p. 67).

The contemporary energy transition—especially in developing and Arab countries—is characterized by the interplay of economic, environmental, social, and technological dimensions. Economically, it is linked to diversification and reduced rent dependence; environmentally, to fulfilling international climate commitments; socially, to ensuring equitable resource distribution; and technologically, to localizing innovation. Therefore, studying this transformation requires a comprehensive theoretical framework that integrates historical analysis of energy systems, mechanisms of technological innovation, and the interplay between energy policy and national economic structures.

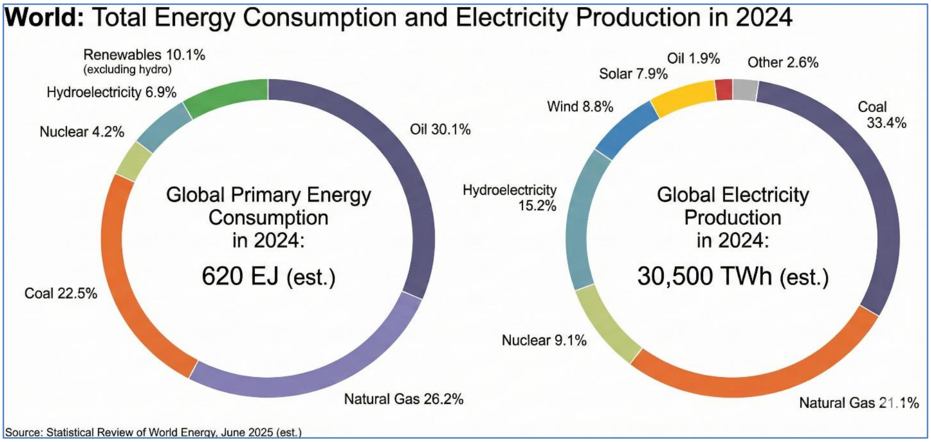
With rapid advances in energy storage, artificial intelligence for grid management, and solar and wind technologies, the contours of future energy systems are increasingly clear: decentralized, low-carbon, community-driven, and smart. Yet success in this transformation hinges on countries—particularly in the Arab world—embedding institutional and structural reforms into their energy strategies and shifting from a rent-based logic to a productive, sustainable energy development model.

Within this broader transformation, the concept of the energy mix has become a key analytical tool for understanding national and regional energy transition dynamics. The term refers to the distribution and diversity of primary energy sources consumed within a specific country or region to meet needs such as heating, transportation, industry, and electricity generation. This mix encompasses all primary energy forms, whether directly consumed, converted, or imported, including fossil fuels (oil, natural gas, coal), nuclear power, and renewable resources (biomass, solar, wind, hydro, and geothermal).

Energy mix composition varies widely across countries—and even within a single country over time—due to evolving economic, technological, social, and geopolitical contexts. Despite notable progress in renewable energy deployment, data from the International Energy Agency (IEA) and other specialized institutions indicate that fossil fuels still account for more than 80% of the global primary energy mix, underscoring the immense challenge of the transition to low-carbon systems (RAMAIN, 2015, p. 11).

Analyzing the energy mix is strategically significant in studying the energy transition in Arab countries, particularly given the rentier nature of most regional economies and their heavy dependence on oil and natural gas as primary energy sources and key pillars of fiscal and economic stability. Accordingly, evaluating the current energy mix and forecasting the optimal configuration that balances resource sustainability, supply security, and economic viability constitutes a fundamental entry point for any systematic approach to energy transition.

Figure (1): Global energy consumption and electricity generation by source (2024)



Source : (The Energy Institute, 2025)

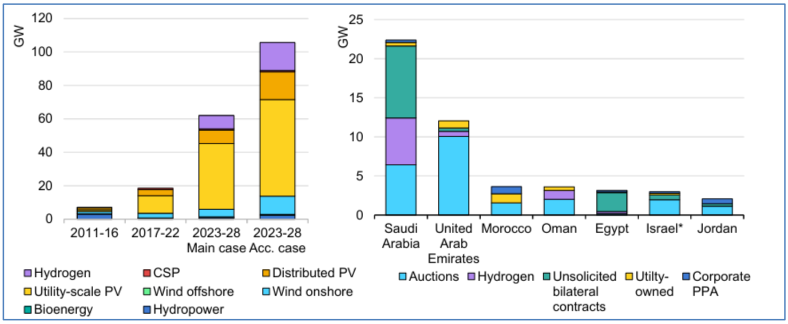
4. Developments in Renewable Energy Use in Arab Countries

Arab countries are experiencing rapid growth in deploying renewable energy. Between 2023 and 2028, the region's total installed renewable energy capacity is projected to increase by 62 gigawatts, a threefold increase compared with the growth over the previous five-year period. This sharp acceleration underscores the region's growing commitment to clean energy adoption.

Solar photovoltaic (PV) energy dominates this expansion, accounting for about 85% of the projected capacity addition, with onshore wind power and concentrated solar power (CSP) following (IEA, 2023, pp. 46-47).

The bulk of this growth is concentrated in seven Arab countries, which together account for 90% of the regional increase. Saudi Arabia leads the region, contributing roughly one-third of the additional capacity, followed by the United Arab Emirates, Morocco, Oman, Egypt, and Jordan, among others, actively expanding their renewable energy portfolios.

Figure (2): Arab countries' capacity additions, and primary drivers of utility-scale growth by country

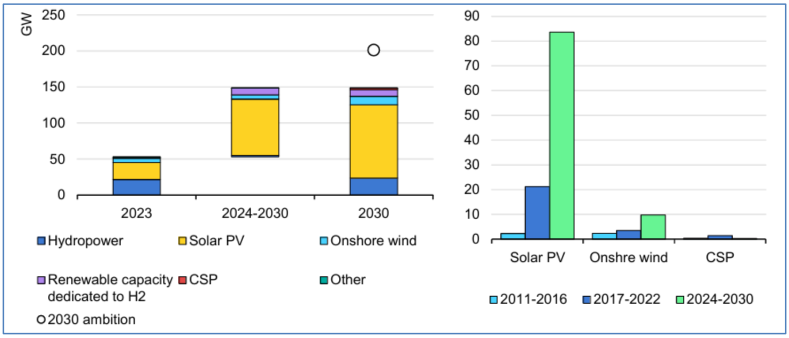


Source: (IEA, 2023, p. 47)

According to the accelerated scenario, the installed renewable energy capacity in Arab countries is projected to triple by 2030, rising from 53 gigawatts (GW) in 2023 to nearly 150 GW. Solar photovoltaic (PV) energy will remain the primary driver of this expansion, supported by low-cost utility-scale projects, favorable financing conditions, and abundant land availability (IEA, October 2024, p. 61).

In contrast, the future of concentrated solar power (CSP) remains uncertain because its production costs are higher than those of PV, whose prices have fallen dramatically with continuous technological advancements. Meanwhile, onshore wind power is also expanding significantly, particularly in countries with strong wind potential, such as Morocco, Egypt, and Jordan.

Figure (3): Renewable Energy Additions in Arab Countries by Technology (in GW)



Source: (IEA, October 2024, p. 62)

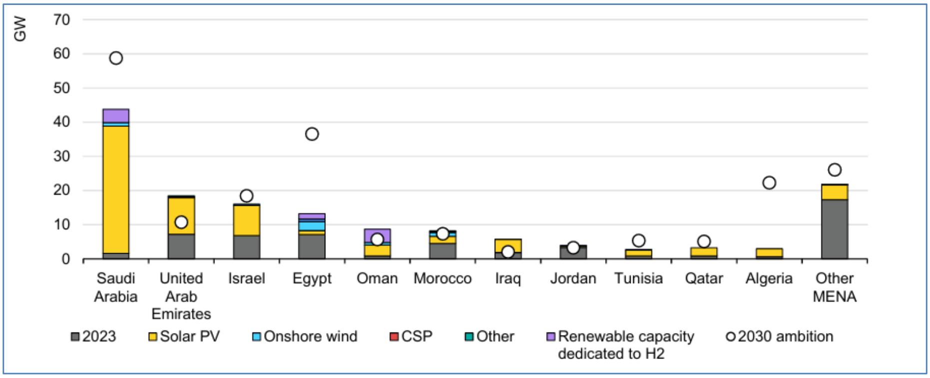
Despite the rapid growth of solar photovoltaic (PV) and onshore wind energy, the expansion of concentrated solar power (CSP) in Arab countries is expected to slow significantly over the next six years compared with the 2017–2023 period. During that earlier period, CSP capacity increased by 1.4 gigawatts (GW); however, less than 300 megawatts

(MW) of additional capacity is projected to be installed by 2030, largely due to the lack of advanced projects under implementation.

In 2023, the 600 MW CSP project in the United Arab Emirates was completed — marking the region's last major CSP project, with no new projects currently under construction.

These trends underscore a growing uncertainty surrounding the future of CSP technologies in the Arab region. Although Kuwait launched a tender for a CSP project in 2024, it is unlikely to achieve financial closure or become operational before 2030, due to lengthy planning phases and procedural complexities (IEA, October 2024).

Figure (4): Middle East and North Africa installed capacity forecast in 2030 by country and technology vs current renewable capacity ambitions



Source: (IEA, October 2024, p. 63)

Considering these challenges, solar photovoltaic (PV) and wind power are expected to remain the primary drivers of renewable energy growth across Arab countries, particularly as these technologies are increasingly linked to the development of green hydrogen projects. By contrast, concentrated solar power (CSP) is likely to remain a limited option, with deployment depending heavily on the clarity of government policies and the ability to overcome technical and economic barriers.

Future renewable energy expansion in the Arab region will be driven by rising electricity demand, decarbonization plans, and efforts to boost energy exports. Saudi Arabia is projected to lead this regional growth, accounting for more than 40% of total renewable capacity additions from 2024 to 2030. Following Saudi Arabia, the United Arab Emirates, Oman, Egypt, Iraq, Morocco, and Algeria are expected to collectively account for 44% of the region's growth.

The regional expansion model primarily relies on two contractual mechanisms: competitive bidding and bilateral agreements with utility companies. A significant share of this growth will stem from rising domestic electricity demand, driven by rapid population and economic growth.

Electricity consumption reached unprecedented levels in countries such as Kuwait, Egypt, Algeria, Oman, and Iraq in 2023, driven by rising temperatures that increased air-conditioning use. In Egypt, this mounting pressure led to recurrent power outages (load shedding), while Kuwait experienced its first-ever grid load-shedding incident due to excessive consumption. In Saudi Arabia, electricity demand hit record highs, prompting the government to accelerate renewable energy projects to meet growing local needs (IEA, October 2024, pp. 63-64).

The Arab countries collectively aim to reach 201 gigawatts of installed renewable energy capacity by 2030. However, projections suggest that actual growth may fall about 26% short of this target, as several countries continue to face implementation challenges. Despite notable progress in Saudi Arabia, Egypt, and Algeria, their expected installed capacities remain below their stated ambitions. In contrast, the United Arab Emirates, Oman, and Morocco are likely to exceed their goals, while Jordan and Iraq appear capable of further raising their renewable energy targets as projects expand.

To achieve these ambitions, Arab countries must address three core challenges. First, accelerating tendering processes is essential, as completing bidding rounds and signing Power Purchase Agreements (PPAs) can take more than a year in some cases, delaying project commissioning. Second, the regulatory and policy environment must be improved to better support distributed solar PV deployment, including self-consumption frameworks and net metering mechanisms. Although several countries have introduced legal frameworks, implementation remains limited outside the United Arab Emirates, underscoring the need for further reforms to boost adoption in both residential and commercial sectors.

Third, efforts must focus on advancing industrial electrification and opening energy markets to a broader range of private actors by removing barriers to corporate PPAs.

Taken together, these measures could accelerate renewable energy growth and help achieve the 2030 targets, thereby strengthening the Arab region's position as a global hub for clean energy investment and innovation.

5. Structural Constraints to Renewable Energy Transition in Arab Countries

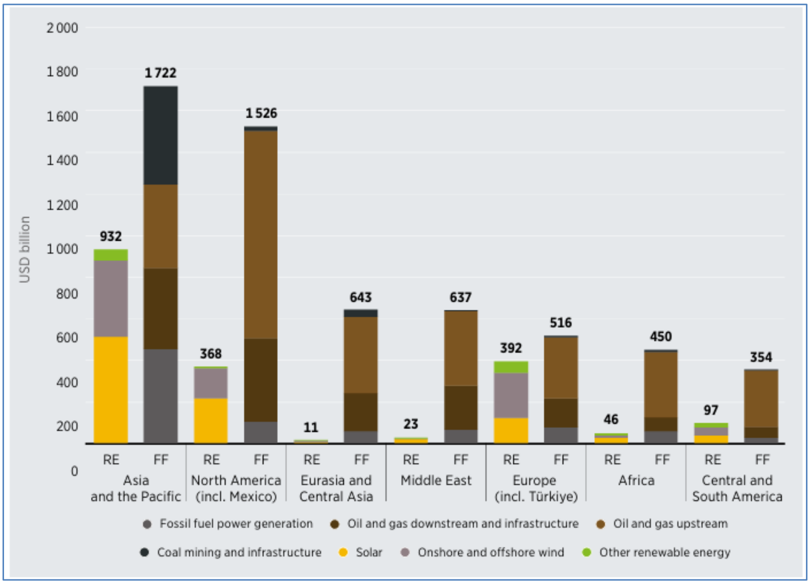
In their pursuit of energy transition strategies, Arab countries face intertwined, multidimensional challenges that hinder a smooth shift toward more sustainable energy systems. This slowdown is driven by technical, economic, and institutional factors that impose real structural limits on the effective integration of renewable energy into national energy mixes.

The first and most fundamental constraint lies in the dominance of fossil fuels within the energy structures of Arab economies. According to the International Energy Agency, over 90% of total energy production in the Arab region is derived from oil and natural gas, reflecting the rentier nature of these economies and their structural dependence on hydrocarbon revenues. This dominance constitutes an institutional barrier to bold renewable energy policies, given the entrenched economic interests of the hydrocarbon sector—both in government revenues and employment opportunities (IEA, 2023).

The financial and investment constraints represent another major obstacle to the deployment of renewable energy projects in the region. Despite the more than 80% decline in the cost of solar and wind power generation over the past decade, the Arab world accounts for less than 1.5% of global renewable energy investment, according to the International Renewable Energy Agency. Between 2015 and 2020, global energy investment exceeded USD 1.7 trillion, with fossil fuel investments in the Middle East being 28 times higher than those in renewable energy. This imbalance reflects the persistence of a carbon-dependent energy model. The causes include weak regulatory and legal frameworks, limited public–private partnerships (PPPs), and the absence of clear fiscal and financial incentives, all of which discourage both domestic and international investors from entering the renewable energy market (IRENA, 2023).

In addition to the investment volume gap, the pace and flow of renewable energy financing remain insufficient to expand access to sustainable and inclusive energy across the region. For instance, off-grid renewable energy solutions in Arab countries attracted only USD 0.5 billion in investment in 2021, far below the USD 2.3 billion required annually to meet global rural electrification targets—excluding additional needs for mini-grid systems (IRENA, 2023).

Figure (5): Annual investments in renewable energy vs. fossil fuel by region, 2015-2020



Source: (IRENA , 2023, p. 38)

A third major challenge in the Arab world's energy transition is the growing dependence on critical minerals—the essential inputs for renewable energy technologies and low-carbon systems. The success of the global energy transition depends heavily on the availability and sustainability of these minerals and rare earth elements, which are vital for manufacturing solar panels, wind turbines, electric vehicle batteries, and other clean energy technologies. However, the sector faces significant challenges in securing adequate and sustainable supplies, given limited global reserves, uneven geographic distribution, and price volatility of these materials.

Recognizing these vulnerabilities, several industrialized countries have developed national "critical materials lists"—either comprehensive or sector-specific—including those designated for the energy and renewable energy sectors (Michèle, 2019). The classification of critical minerals is based on a comprehensive risk assessment that considers market structures, price volatility, and strategic vulnerabilities associated with supply disruptions. Addressing these challenges requires integrated strategies that encompass supply diversification, recycling technologies, improvements in resource efficiency, and investment in research and development to identify sustainable alternatives. Effectively managing these issues is essential to accelerating the global transition toward a sustainable, renewable-based energy future.

According to a World Bank (2020) report, low-carbon technologies—including solar photovoltaic (PV), wind, and geothermal energy—require significantly more minerals than fossil fuel–based technologies. Because of their material intensity, any shortage in mineral supply could slow the global energy transition. The report estimates that, under a scenario limiting global warming to below 2°C, demand for key clean-energy minerals such as graphite, lithium, and cobalt could increase by more than 450% by 2050 relative to 2018 levels. Meanwhile, demand for aluminum and copper is expected to rise by 300% and 200%, respectively. These projections exclude infrastructure and auxiliary components, such as transmission networks and electric vehicle structures (World Bank, 2020).

Similarly, the International Energy Agency (IEA, 2024) projects that global demand for critical minerals will rise by approximately 400% by 2040, driven by the rapid expansion of clean energy technologies. The agency warns of potential supply shortages and intensified global competition, especially given the Arab world's limited reserves. This situation leaves Arab economies—largely lacking mineral endowments—highly vulnerable to international market fluctuations and supply chain disruptions. Consequently, this poses a major constraint on the localization of clean technology production and the development of integrated renewable energy industries.

Beyond mineral dependency, the infrastructure and grid challenges remain significant. Renewable energy integration requires flexible, smart distribution networks capable of managing the intermittent nature of solar and wind power. According to the World Bank, electrical transmission and distribution losses exceed 20% in some Arab countries, reflecting structural inefficiencies that undermine grid reliability and limit the integration of renewable sources (OAPEC, 2024).

Finally, institutional and regulatory weaknesses constitute a fundamental structural barrier. Poor intergovernmental coordination, short-term policy horizons, and hesitancy to reform fossil fuel subsidies have created a fragmented and unstable policy environment. Reports from the United Nations indicate that over 60% of Arab countries still lack clear, binding policies for increasing the share of renewables in their energy mix by 2030 (IPCC, 2010).

In summary, the transition to renewable energy in the Arab world is not merely a technical or financial challenge but a systemic and structural transformation that requires reconfiguring the entire energy governance framework—from policy and investment models to technological infrastructure and institutional coordination. Therefore, any conception of an optimal energy mix in the Arab context must be grounded in a deep understanding of these structural limitations.

6. Application of the Analytic Hierarchy Process (AHP) to the Energy Transition in Arab Countries

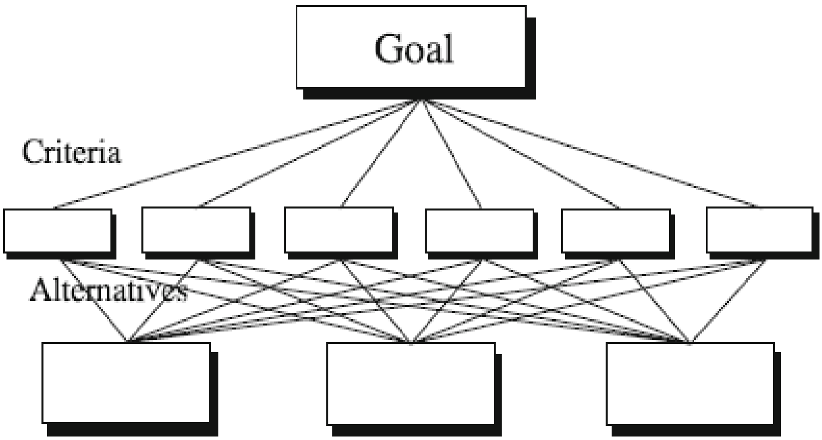
Given the interconnected and multifaceted challenges Arab countries face in pursuing an effective energy transition, it has become essential to employ rigorous analytical tools that support strategic decision-making reflecting each country's economic, social, and technological specificities. Among these tools, the Analytic Hierarchy Process (AHP) stands out as one of the most effective multi-criteria decision analyses (MCDA) methodologies, providing a systematic framework for decision-making in complex contexts with multiple, often competing criteria (RIVEST, 2019, p. 2).

6.1 Overview of the AHP Methodology

The Analytic Hierarchy Process (AHP) is one of the most prominent methods within Analytic Decision-Making and Control (ADMC) and represents a practical application of operations research to real-world decision problems. This methodology is particularly valued for its ability to provide structured, transparent, and rational solutions in situations with multiple alternatives and diverse evaluation criteria. In applied research and policy contexts, AHP is typically employed in three principal scenarios (SAATY, 2012):

1. Selecting the best alternative options, where decision-makers must choose from a defined set of options. For instance, when deciding whether to establish an electricity generation facility, the choice may lie among technologies based on natural gas, coal, biomass, or biofuels.
2. Ranking the most suitable alternatives (Top K Alternatives) is common when decision-makers aim to identify the most promising options before making a final decision. This is typical, for example, when selecting an information management system for national power grids.
3. Comprehensive prioritization of alternatives — the most common and analytically robust application of AHP. In this case, alternatives are ranked using either unweighted or weighted methods, enabling analysts to assess the relative performance of each option and to construct an optimal composite solution (Saaty, 2012).

Figure (6) : The Three Hierarchical Levels of the AHP Structure



Source: (SAATY, 2012, p. 3)

Although AHP can be applied to all three cases, its greatest strength lies in the third scenario, where it provides a precise mechanism for ranking alternatives by assigning quantified weights to multiple evaluation criteria. The method has achieved widespread application across a broad spectrum of disciplines, including economics, finance, public governance, human resource management, environmental sciences, and engineering.

The methodology was originally proposed by Thomas L. Saaty, an Iraqi American mathematician, in the 1970s (1977, 1980), and has since undergone continuous refinement—reaching a mature, improved version in 2012, shaped by decades of research aimed at enhancing its accuracy, adaptability, and theoretical robustness (CAMM D. Jeffrey, 2022, p. 662).

The AHP method decomposes complex decision problems into a hierarchy of interrelated elements, simplifying analysis while preserving logical coherence. The process begins with the primary goal at the top of the hierarchy, followed by the main criteria, which may be subdivided into sub-criteria, and ends with the set of decision alternatives at the base.

Pairwise comparisons are then conducted across all levels to determine the relative priorities among elements. Each criterion and sub-criterion is assigned a relative weight that reflects its importance in achieving the overall goal.

The strength of AHP lies in its ability to integrate both quantitative data (e.g., measurable variables such as cost, efficiency, or capacity) and qualitative judgments (e.g., expert opinions, contextual relevance, stakeholder preferences). This hybrid capability allows for the inclusion of subjective and contextual dimensions of decision-making—an aspect that makes AHP particularly valuable for analyzing complex, multidimensional issues such as the energy transition and determining an optimal energy mix.

Structurally, AHP provides a hierarchical decision framework with several levels that together ensure a balanced, systematic evaluation of all relevant factors. By combining expert judgment with quantitative consistency checks, the method yields results that are both empirically grounded and policy-relevant, thereby supporting evidence-based energy planning in the Arab region.

6.2 Analysis of the Application Results of the Analytic Hierarchy Process (AHP) to the Energy Mix in Arab Countries

The Analytic Hierarchy Process (AHP) offers an effective framework for evaluating the optimal energy mix in Arab countries, given the complexity of the regional energy landscape and the diversity of strategic pathways pursued by national actors. The strength of this methodology lies in its ability to decompose a multidimensional decision problem, such as designing a future energy mix, into measurable and comparable components. It allows for integrating economic, environmental, social, and strategic dimensions into the decision-making process — a particularly crucial aspect in a region characterized by heterogeneous policy priorities and increasing pressure to accelerate the energy transition.

6.2.1 Data Collection and Sampling

The empirical component of this analysis is based on a structured questionnaire designed and administered to a purposefully selected sample of experts in energy economics, public policy, banking and finance, and academic research. A purposive sampling technique was used to ensure that participants had advanced technical knowledge and strategic insight into national energy systems, thereby enhancing the reliability and validity of expert judgments.

Of the 62 responses received, 48 were retained after excluding incomplete or logically inconsistent questionnaires, based on the consistency ratio (CR) criteria recommended by Saaty (2012). This final expert sample adequately represents a diverse cross-section of perspectives from both energy-exporting and energy-importing Arab economies, allowing for a nuanced reflection of regional priorities and constraints (SAATY, 2012).

Data collection was conducted between April and June 2025 using a semi-structured online survey distributed through professional and institutional networks (including academic associations and the Ministry of Energy). The survey included pairwise comparison matrices structured according to the AHP framework, enabling respondents to express their judgments regarding the relative importance of criteria and energy sources on a nine-point Saaty scale.

6.2.2 Analytical Procedure:

The analysis followed the standard AHP implementation protocol, consisting of the following steps:

1. **Defining the hierarchy of objectives:** The overarching goal was to identify the *optimal energy mix* for Arab countries, balancing sustainability with economic and social feasibility.
2. **Selection of evaluation criteria:** Four key dimensions were identified, reflecting the multifaceted nature of the energy transition:
   - **Economic development considerations:** including impacts on growth, government revenues, trade balance, and social welfare.
   - **Exports revenues:** given the centrality of oil and gas exports as primary sources of external income.
   - **Environmental protection:** encompassing emission reduction commitments, ecosystem preservation, and air quality improvement.
   - **Energy security:** reflecting stability, accessibility, and independence of energy supply.
3. **Identification of energy alternatives:** Six major energy sources were evaluated based on their current or potential relevance within Arab energy systems:
   - Oil is a dominant economic and fiscal resource.
   - Natural gas is the backbone of electricity generation in most Arab states.
   - Shale gas is an emerging but controversial alternative due to environmental and cost concerns.
   - Solar photovoltaic (PV) energy is considered the most mature and feasible option given the region's abundant solar potential.
   - Concentrated solar power (CSP) is a technologically promising but underutilized option.
   - Wind power, which remains modestly developed despite significant untapped potential.

Other sources, such as coal and nuclear energy, were excluded from the model due to limited feasibility, high technological and political complexity, and low medium-term potential in the Arab context.

4. **Pairwise comparison and weight determination:** Experts compared each criterion and energy alternative pairwise, assigning relative importance values.
   The resulting pairwise comparison matrices were processed using normalized eigenvector methods to derive priority weights. The consistency ratio (CR) for all matrices was kept below 0.1, confirming the internal coherence of expert judgments.
5. **Aggregation and synthesis:** Weighted scores for each alternative were combined to generate the composite energy mix ranking.

Applying the Analytic Hierarchy Process (AHP) to the Arab energy context yielded qualitative and quantitative insights that reflect the perceptions and evaluative judgments of key actors and experts in the regional energy sector. After excluding inconsistent or contradictory responses using the Consistency Ratio (CR < 0.1) criterion, the final dataset provides a robust reference framework for estimating the relative contribution of each major energy source to a prospective energy mix.

These results are structured around four core evaluation criteria:

1. Economic development considerations, encompassing the impact of energy composition on growth, government revenues, and social welfare;
2. Export revenues, reflecting the dependence of Arab economies on hydrocarbon exports;
3. Environmental protection, related to emission reduction, air quality, and ecosystem conservation;
4. Energy security, measuring the stability and resilience of energy supply systems.

Table (1): Final Relative Weights of Energy Alternatives According to Their Expected Role in the Future Energy Mix

Rank	*Share within Energy Mix (%)*	*Final AHP Score*	*Energy Source*
1	21.33%	0.307	Natural Gas
2	20.79%	0.299	Shale Gas
3	20.29%	0.292	Oil
4	13.12%	0.189	Solar Photovoltaic (PV) Energy
5	12.65%	0.182	Wind Energy
6	11.83%	0.170	Concentrated Solar Power (CSP)

Source: Author's calculations based on expert responses (2025).

As shown in Table 1, fossil-based energy sources continue to dominate the projected Arab energy mix, with natural gas leading at 21.33%, followed closely by shale gas (20.79%) and oil (20.29%). The narrow range of these values underscores the structural persistence of hydrocarbons as the backbone of energy systems in Arab economies. This pattern suggests that the energy transition remains cautious and incremental, constrained by institutional, financial, and infrastructural dependencies on fossil fuels — even as awareness of the strategic importance of renewables continues to grow.

In contrast, renewable energy sources show a tangible but limited share in the expert-based projection. Solar photovoltaic (PV) energy accounts for 13.12%, wind power for 12.65%, and concentrated solar power (CSP) for 11.83%. Although these proportions represent a notable improvement over current deployment levels, they remain insufficient to offset hydrocarbon dominance in the foreseeable future.

These results indicate that although renewables are gaining ground, they have not yet reached a critical threshold to transform the Arab energy landscape. Consequently, more ambitious and integrated policy frameworks are required — particularly those that stimulate investment, diversify the energy portfolio, and strengthen regulatory and financial incentives for renewable deployment.

Table (2): Final Relative Weights of Energy Alternatives by Energy Policy Objective

Total	Energy Security	Environmental Protection	Export Revenues	Economic Development	Energy Source
1	0.400	0.041	0.264	0.296	Oil
1	0.274	0.066	0.342	0.319	Natural Gas
1	0.297	0.087	0.434	0.182	Shale Gas
1	0.176	0.467	0.078	0.280	Solar Photovoltaic (PV)
1	0.134	0.545	0.062	0.259	Concentrated Solar Power (CSP)
1	0.151	0.499	0.062	0.287	Wind Energy

Source : Author's calculations based on expert responses (2025).

1.

Table 2 presents the relative contribution of each energy source to the four principal dimensions of Arab energy policy—economic development, export revenues, environmental protection, and energy security. This multi-criteria view shows how each alternative aligns with the region's strategic energy transition objectives.

Economic Development: Natural gas emerges as the most strongly associated source with national development objectives (weight = 0.319), followed closely by oil (0.296) and solar PV (0.280). Shale gas registers the lowest 2. developmental contribution (0.182), reflecting persistent skepticism about its cost-effectiveness and environmental acceptability. This outcome suggests that while hydrocarbons still underpin economic performance, renewables are gradually being recognized for their developmental spillovers, particularly in job creation and technological learning.

Export Revenues: As expected, fossil fuels dominate this criterion, with shale gas (0.434), natural gas (0.342), and oil (0.264) ranking first, second, and third. Renewable energy sources score significantly lower, underscoring the limited exportability of clean energy commodities under current market structures. This pattern mirrors the region's 3. continued dependence on traditional export-rent models and highlights the need for export diversification into green hydrogen or renewable-technology industries.

Environmental Protection: In sharp contrast, renewable energy technologies lead decisively in this dimension. Concentrated solar power (CSP) ranks first (0.545), followed by wind energy (0.499) and solar PV (0.467). Fossil fuels, by comparison, show low weights, reflecting their high carbon intensity and ecological footprint. The environmental prioritization of renewables reflects growing awareness among experts of the climate and sustainability 4. imperatives driving global energy policy.

Energy Security: Oil remains dominant under this criterion (0.400), benefiting from established infrastructure, reliable supply, and domestic availability. It is followed by shale gas (0.297) and natural gas (0.274). Renewable sources rank lower in perceived security contributions, although solar PV (0.176) shows a relatively higher valuation than wind (0.151) or CSP (0.134), indicating optimism about distributed generation and grid integration potential.

The results underscore a structural asymmetry between the ambition of the energy transition and the current economic and institutional realities of Arab states. While renewable energy dominates the environmental dimension, its marginal presence in economic and security indicators limits its near-term capacity to displace fossil fuels. This divergence highlights a policy gap: environmental awareness has not yet been translated into fiscal incentives, regulatory reforms, or industrial diversification that can elevate renewables within national energy strategies.

The continued reliance on hydrocarbons reflects not only energy dependence but also their macroeconomic centrality—as sources of fiscal revenue, foreign exchange, and employment. Nonetheless, the relatively high weights assigned to solar PV and CSP under environmental and developmental criteria indicate an emerging paradigm shift: an increasing recognition of renewables as strategic assets for long-term sustainability and competitiveness, especially amid falling global production costs.

In summary, the AHP-based findings reveal a dual-track trajectory for Arab energy policy: maintaining short-term hydrocarbon stability while cautiously integrating renewables into the national energy portfolio. Bridging this gap will require coordinated policy interventions, including targeted subsidy reforms, green investment mechanisms, and technology transfer partnerships to enhance renewable adoption and strengthen energy system resilience.

7. Conclusion

This study has shed light on the structural challenges and emerging opportunities facing Arab countries as they pursue a sustainable energy transition. Using a multi-criteria analytical framework based on the Analytic Hierarchy Process (AHP), it assessed the capacity of Arab economies to overcome technical, economic, and environmental barriers in designing an energy mix that balances development needs, environmental protection, and energy security.

The empirical application of the AHP method yielded several significant insights. Foremost among them is the continued dominance of fossil fuels—notably natural gas, shale gas, and oil—in the projected Arab energy mix. These three sources ranked first, with relative weights between 20% and 21%, underscoring their enduring centrality to regional economies. Fossil fuels remain the backbone of Arab energy systems, both as engines of economic growth and as guarantors of energy security and export revenues.

By contrast, renewable energy sources, particularly solar photovoltaics and wind power, play a moderate but growing role in the estimated energy mix. Although their current contribution remains limited relative to overall energy demand, their growing weight in environmental objectives underscores the growing recognition of the strategic necessity of transitioning to a low-carbon model.

Nevertheless, the pace and effectiveness of this transition remain contingent on a series of institutional, financial, and technological reforms. Without them, renewable energy is likely to remain peripheral to national energy policies. The findings of this study should not be interpreted as prescriptive solutions but rather as an analytical reference to inform future policy design and expand stakeholder participation—particularly among policymakers, financial institutions, and the private sector.

Ultimately, the success of the energy transition in the Arab world does not lie merely in replacing one energy source with another. It requires a comprehensive restructuring of the entire energy system—encompassing governance, investment, infrastructure, and innovation—to strengthen energy sovereignty and address climate and development imperatives.

Achieving this transformation requires a long-term strategic vision grounded in energy equity, environmental efficiency, and technological resilience, an indispensable foundation for building a sustainable energy future for the region.

Based on the findings of this research, the study puts forward the following recommendations:

- Adopt gradual and adaptive transition policies that account for the economic, social, and political realities of Arab countries, ensuring the expansion of renewable energy sources without compromising national energy security.
- Restructure investment incentives to create a more attractive environment for renewable energy investors, with a focus on solar and wind power, the most promising technologies aligned with the region's climatic and geographic conditions.
- Diversify financing mechanisms by strengthening public–private partnerships, mobilizing green finance instruments, and leveraging international climate and energy initiatives to support large-scale renewable energy projects.
- Enhance technical and human capacities through sustained investment in research and development for energy storage technologies, smart grids, and localized renewable energy, thereby promoting technological self-reliance in the region.
- Institutionalize multi-criteria decision-making tools, such as the Analytic Hierarchy Process (AHP), within energy ministries and regulatory authorities to guide strategic policy formulation grounded in empirical evidence and realistic implementation scenarios.

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