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Research Article

Challenges and Opportunities in Jordan's Electricity Sector: A Comprehensive Review of Energy Security, Sustainability, and Future Pathways

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ABSTRACT

Jordan's electricity sector faces major challenges due to its heavy reliance on imported fossil fuels, rising electricity demand, and infrastructure inefficiencies. Approximately 94% of the country's energy needs are met through imports, making the sector vulnerable to geopolitical instability and price fluctuations. At the same time, population growth and economic development have increased electricity demand, highlighting the need for sustainable energy solutions.

This review analyzes the key challenges, infrastructure conditions, policy frameworks, and future opportunities in Jordan's electricity sector. Data from national institutions such as the Ministry of Energy and Mineral Resources (MEMR), National Electric Power Company (NEPCO), and international sources were examined to assess consumption trends, system losses, renewable energy potential, and regional interconnection projects.

Electricity consumption in Jordan increased from 6.1 billion kWh in 2000 to 17.0 billion kWh in 2021. Natural gas currently accounts for about 80% of electricity generation, while renewable energy contributes around 20%. Solar photovoltaic capacity has reached 2,063 MW and wind power 370 MW. However, transmission and distribution losses remain significant, and electricity tariffs remain below actual system costs, creating financial pressures.

The study concludes that expanding renewable energy, modernizing grid infrastructure, improving policy implementation, and strengthening regional energy cooperation are essential for enhancing energy security and sustainability. Jordan's strong solar and wind potential provides a promising pathway for reducing import dependence and achieving a more resilient electricity system.

1. INTRODUCTION

1.1 The Strategic Importance of Energy in National Development

Energy constitutes the lifeblood of modern economies, underpinning every aspect of social, economic, and industrial development. Reliable, affordable, and sustainable energy supplies are fundamental prerequisites for poverty reduction, economic growth, improved living standards, and enhanced quality of life (Erős et al., 2022; Jaber, Badran, & Abu-Shikhah, 2003). The intricate relationship between energy consumption and development indicators—GDP growth, industrialization, urbanization, and human development—has been extensively documented across both developed and developing nations (Loska, Wiechula, & Korus, 2004; Leong Cheng et al., 2022).

For nations lacking indigenous fossil fuel resources, the energy challenge is particularly acute. Dependence on energy imports exposes economies to global price volatility, geopolitical pressures, and supply disruptions, while diverting scarce foreign exchange resources from other development priorities (Al-Hamamre et al., 2017; Shahbaz, Chaudhary, & Ozturk, 2017). The imperative to secure reliable, affordable energy supplies while transitioning toward sustainable systems represents one of the most complex policy challenges facing resource-constrained nations in the 21st century.

1.2 Jordan's Energy Context: Vulnerability and Opportunity

Jordan exemplifies the energy challenges confronting nations heavily dependent on imported fossil fuels. The Hashemite Kingdom of Jordan possesses minimal indigenous conventional energy resources, importing approximately 94% of its energy requirements—primarily crude oil, refined petroleum products, and natural gas—at an annual cost of approximately 2.5 billion Jordanian Dinars (JOD) (approximately $3.5 billion), equivalent to 8-10% of Gross Domestic Product (GDP) (MEMR, 2021; Sandri, Hussein, & Alshyab, 2020).

This import dependence exposes Jordan's economy to multiple vulnerabilities:

- **Price volatility**: Fluctuations in global oil and gas prices directly impact national budgets, trade balances, and electricity tariffs
- **Supply security**: Regional conflicts and political instability threaten the continuity of energy supplies
- **Geopolitical leverage**: Dependence on specific supplier nations creates diplomatic vulnerabilities
- **Fiscal burden**: Energy imports consume foreign exchange reserves that could otherwise support development investments

Simultaneously, Jordan possesses exceptional renewable energy resources that remain substantially underutilized. The nation's geographic location provides:

- Average annual solar radiation of 5.5 kWh/m² (among the highest globally)
- Over 2900 hours of sunlight annually
- Wind speeds of 6-8 m/s in multiple regions suitable for commercial wind development
- Biomass potential from agricultural and municipal waste
- Oil shale reserves estimated at 40 billion tons

This juxtaposition of energy import dependence with abundant renewable resources creates both challenge and opportunity. The imperative to enhance energy security through indigenous resource development has positioned renewable energy at the center of national energy strategy, with ambitious targets for solar, wind, and other alternative sources.

1.3 Evolution of Jordan's Electricity Sector

Jordan's electricity sector has undergone significant transformation since the establishment of the first power plants in the 1960s. The sector's evolution can be characterized through several phases:

1960s-1980s: Foundation and Expansion: Initial electrification focused on major urban centers, with generation based primarily on diesel and heavy fuel oil. The Jordan Electricity Authority (JEA) was established to oversee sector development.

1990s: Liberalization and Privatization: The General Electricity Law (No. 64 of 2002) initiated sector restructuring, separating generation, transmission, and distribution functions. The National Electric Power Company (NEPCO) assumed responsibility for transmission and system operation, while generation was opened to private participation through Independent Power Producer (IPP) models.

2000s: Regional Integration and Natural Gas Shift: The Arab Gas Pipeline brought Egyptian natural gas to Jordan, enabling a substantial shift from oil-based generation to more economical and environmentally favorable natural gas. Regional interconnection projects connected Jordan with Egypt and Syria, enhancing grid stability and enabling energy exchange.

2010s: Crisis and Transformation: Disruptions in Egyptian gas supplies (beginning 2010) forced a return to expensive heavy fuel oil and diesel, dramatically increasing generation costs and creating substantial financial losses for NEPCO. This crisis catalyzed accelerated renewable energy development, with the Renewable Energy and Energy Efficiency Law (2012) establishing the framework for private sector participation in renewable projects.

2020s: Diversification and Sustainability: Renewable energy has emerged as a significant contributor to the national grid, with solar and wind capacity exceeding 2,400 MW by 2024. Energy efficiency programs, smart grid initiatives, and expanded regional interconnection are prioritizing the sustainable energy transition.

1.4 The Imperative for Comprehensive Analysis

Despite progress in renewable energy deployment and sector restructuring, Jordan's electricity sector continues to face substantial challenges:

- **Demand growth**: Electricity consumption has grown at an average annual rate of 6.8% over two decades, driven by population growth, economic development, and refugee influxes
- **System losses**: Technical and non-technical losses in transmission and distribution networks represent significant economic inefficiencies
- **Financial sustainability**: Tariff structures that maintain subsidized rates for consumers create substantial fiscal burdens and cross-subsidies
- **Infrastructure aging**: Generation, transmission, and distribution infrastructure requires modernization to improve efficiency and accommodate renewable integration
- **Policy implementation**: Gaps persist between policy formulation and effective implementation, particularly regarding building codes, efficiency standards, and enforcement mechanisms

These challenges, intersecting with the imperative of energy transition and climate commitments, necessitate comprehensive analysis to identify effective solutions and guide policy development.

1.5 Research Objectives

This comprehensive review addresses the following objectives:

1. **To systematically analyze** the structural challenges confronting Jordan's electricity sector across generation, transmission, distribution, and consumption dimensions.
2. **To evaluate historical and projected demand trajectories** and their implications for generation capacity and infrastructure development.
3. **To assess the potential of alternative energy resources**—renewable (solar, wind, biomass, hydropower) and non-renewable (oil shale, nuclear)—for enhancing energy security and sustainability.
4. **To examine regional interconnection projects** and their role in grid stability, energy exchange, and supply diversification.
5. **To analyze cost structures, tariff policies, and financial sustainability** of the electricity sector.

6. **To evaluate existing policy frameworks and governance mechanisms** and identify implementation gaps.
7. **To propose integrated solutions** for addressing identified challenges and advancing Jordan's energy transition toward enhanced security, sustainability, and affordability.

1.6 Scope and Structure

This paper encompasses the full spectrum of Jordan's electricity sector, from primary energy sources through generation, transmission, distribution, and consumption. The analysis integrates technical, economic, policy, and geopolitical dimensions to provide a holistic understanding of sector challenges and opportunities.

The remainder of this paper is organized as follows: Section 2 presents a comprehensive literature review of Jordan's energy sector research. Section 3 examines the challenges of energy security and sustainability. Section 4 provides detailed results and analysis across seven thematic areas. Section 5 explores promising solutions through renewable energy resources. Section 6 analyzes energy policy frameworks. Section 7 concludes with recommendations for sector development.

2. LITERATURE REVIEW

2.1 Energy Consumption and Economic Development

The relationship between energy consumption and economic development has been extensively studied in Jordanian and regional contexts. Al-Mulali and Ozturk (2015) examined the effect of energy consumption, urbanization, trade openness, industrial output, and political stability on environmental degradation in MENA countries, finding significant long-term relationships between these variables. Shahbaz and Lean (2012) demonstrated that financial development increases energy consumption in Tunisia, with implications for understanding similar dynamics in Jordan.

Population dynamics have emerged as critical factors in energy demand analysis. Zhao and Zhang (2018) documented the impact of urbanization on energy consumption in China over a 30-year period, providing methodological approaches applicable to Jordan's rapid urbanization. Kazim (2007) analyzed energy consumption patterns in the UAE, highlighting the role of per capita consumption growth in overall demand trajectories.

For Jordan specifically, Jaber, Marahleh, and Dalabeeh (2019) quantified emissions reductions resulting from renewable energy projects, linking energy policy to environmental outcomes. Meaton and Alnsour (2012) examined spatial and environmental planning challenges in Amman, demonstrating the interconnection between urban development and energy demand. El Hanandeh (2014) evaluated future power generation scenarios in Jordan, providing comparative environmental performance assessments.

2.2 Energy Security Challenges

Energy security in Jordan has been a focal point of research given the nation's import dependence and regional volatility. Sandri et al. (2020) conducted a comprehensive assessment of Jordan's energy sector sustainability, identifying key obstacles and outlining future objectives through desk research and expert interviews. Their study emphasized that Jordan's energy security is historically intertwined with relations with neighboring nations, exposing the kingdom to international shocks and political events.

The refugee crisis has substantially impacted Jordan's energy landscape. Since 2011, the influx of Syrian refugees has increased population by approximately 10%, with corresponding impacts on electricity demand, water pumping, and housing energy requirements. Jaber et al. (2019) documented these effects, noting that refugee camps and host communities have experienced significant increases in energy consumption.

Hrayshat (2007) provided foundational analysis of Jordan's renewable energy situation, documenting the technical potential and economic viability of solar and wind resources. This work established the basis for subsequent renewable energy policy development and project implementation.

2.3 Renewable Energy Potential

Jordan's exceptional renewable energy resources have attracted substantial research attention. Bani Younes (2017) affirmed that Jordan's geographical location and climate make the country one of the best globally for renewable energy generation, particularly solar photovoltaic and concentrating solar power technologies.

Azzuni et al. (2020) conducted a comprehensive energy security analysis for a 100% renewable energy transition in Jordan by 2050, concluding that such a transition is technically and economically feasible. Their modeling demonstrated that renewable resources are sufficient to meet all energy needs while enhancing security and reducing import dependence.

Mason, Al-Muhtaseb, and Al-Widyan (2009) provided early assessment of Jordan's energy sector and renewable energy potential, documenting solar radiation levels, wind speeds, and biomass availability. Abu-Ashour, Abu Qdais, and Al-Widyan (2010) estimated that annual energy from olive and animal waste is equivalent to 157,000 tons of oil equivalent (toe), demonstrating significant biomass potential.

Al-Soud and Hrayshat (2009) evaluated wind energy feasibility for rural electrification, identifying Zabda (80 km north of Amman) as suitable for small-turbine applications and Al-Risha regions for commercial-scale development. These assessments informed subsequent wind farm siting decisions.

2.4 Energy Policy and Governance

The policy framework governing Jordan's energy sector has been analyzed by multiple researchers. Abu-Rumman, Khdair, and Khdair (2020) conducted a detailed assessment of Jordan's energy landscape and renewable energy investment potential, reviewing government programs, financial incentives, and tax breaks aimed at encouraging renewable energy projects.

The Organisation for Economic Co-operation and Development (OECD, 2005) evaluated Jordan's electricity regulatory framework, characterizing the Electricity Regulatory Commission (ERC) as a viable approach to market liberalization. GTZ (2007) provided comprehensive analysis of energy-policy framework conditions for electricity markets and renewable energies in Jordan.

Fichter, Kern, and Trieb (2013) examined challenges in Jordan's electricity sector, projecting capacity requirements and evaluating technology options. Their analysis highlighted the need for substantial new generation capacity and the role of renewable energy in meeting future demand.

Nadejda et al. (2017) assessed the Renewable Energy and Energy Efficiency Fund, documenting its establishment, funding sources, and role in promoting renewable energy deployment.

2.5 Research Gaps and Contribution

Despite substantial research on Jordan's energy sector, several gaps remain:

1. **Comprehensive integration**: Most studies focus on specific aspects (renewable potential, policy analysis, demand forecasting) without providing integrated analysis across the full sector spectrum.
2. **Loss quantification**: Detailed quantification of losses across generation, transmission, and distribution with policy implications is limited.
3. **Regional interconnection assessment**: Analysis of existing and planned interconnection projects and their implications for energy security requires updating.
4. **Post-crisis analysis**: The impacts of Egyptian gas supply disruptions and subsequent renewable energy acceleration warrant comprehensive documentation.
5. **Policy implementation assessment**: Gaps between policy formulation and effective implementation require systematic analysis.

This review addresses these gaps by providing comprehensive, integrated analysis of Jordan's electricity sector, synthesizing data from multiple sources, and offering actionable recommendations for policy and investment.

3. CHALLENGES OF ENERGY SECURITY AND SUSTAINABILITY IN JORDAN

3.1 Structural Challenges in the Electricity Sector

The fundamental challenge confronting Jordan's electricity sector is ensuring that supply consistently exceeds demand while maintaining financial sustainability and environmental responsibility. This challenge has been exacerbated by the absence of significant new investments in generation capacity over the past seven to eight years, creating potential supply-demand gaps as demand continues growing (MEMR Reports, 2017, 2019).

3.1.1 Regulatory and Institutional Barriers

Effective sector transformation requires clear regulatory frameworks and defined institutional setups. Without these foundational elements, meaningful change remains elusive. Key regulatory challenges include:

Licensing and Permitting: While the General Electricity Law establishes licensing requirements, implementation can be protracted, creating uncertainty for investors. Generating units up to 1 MW are exempt from licensing, but larger projects face comprehensive review processes that can delay implementation.

Tariff Setting: The Electricity Regulatory Commission (ERC) has responsibility for tariff setting, balancing cost recovery with consumer affordability. The requirement to enable "efficient licensees to recoup the whole cost of their business activities while earning a respectable return on capital investment" (General Electricity Law) creates tension with social objectives of maintaining affordable electricity access.

Market Structure: The single-buyer model, with NEPCO as the sole off-taker for generation, concentrates risk and creates financial vulnerabilities. When generation costs exceed revenues, losses accumulate at NEPCO, ultimately requiring government intervention or tariff adjustments.

3.1.2 Technical Infrastructure Challenges

Jordan's electricity infrastructure faces multiple technical challenges:

Aging Generation Assets: Several power plants have operated beyond their design life, exhibiting reduced efficiency and increased maintenance requirements. Thermal efficiency declines increase fuel consumption per kWh generated, exacerbating import dependence and emissions.

Transmission Network Constraints: The transmission network, while generally robust, experiences bottlenecks during peak demand periods and faces challenges integrating variable renewable generation. Voltage stability and frequency regulation become more complex with increasing renewable penetration.

Distribution System Inefficiencies: Distribution networks suffer from technical losses (due to conductor resistance, transformer inefficiencies) and non-technical losses (theft, metering inaccuracies, billing errors). These losses represent wasted generation capacity and revenue losses for distribution companies.

3.1.3 Price, Availability, and Accessibility

Three interconnected factors constrain energy sector development:

Price: Electricity prices in Jordan are among the highest in the region when expressed in absolute terms, yet remain below cost-recovery levels for many consumer categories. This paradox—high absolute prices yet insufficient for cost recovery—reflects the high cost of imported fuels and inefficiencies in the system.

Availability: Supply reliability has improved substantially but periodic constraints occur, particularly during extreme weather events or fuel supply disruptions. The integration of variable renewable energy introduces new challenges for maintaining supply-demand balance.

Accessibility: Jordan has achieved near-universal electricity access (approximately 99.9%), a significant accomplishment. However, affordability remains a concern for low-income households, requiring targeted subsidies that complicate tariff structures.

3.1.4 Consumption Patterns and Behavioral Factors

Consumption patterns in Jordan reflect multiple influences:

Cultural Factors: Energy consumption behaviors are influenced by cultural norms, awareness levels, and historical pricing. Air conditioning, water heating, and lighting constitute major end-use categories.

Pricing Distortions: Subsidized tariffs for certain consumer categories (particularly residential and agricultural) dampen incentives for efficiency investments and conservation.

Socioeconomic Consequences: Tariff increases to align with costs must be carefully managed to avoid adverse impacts on vulnerable populations. The socioeconomic implications of energy pricing are particularly acute given Jordan's relatively high poverty rates and refugee populations.

3.2 Regional Cooperation Challenges

Regional electricity interconnection offers substantial benefits: enhanced grid stability, optimized generation dispatch, energy trading opportunities, and improved supply security. However, realizing these benefits requires overcoming significant political and technical challenges.

3.2.1 Political Barriers

Regional Instability: The Middle East region has experienced persistent instability, with conflicts in Syria, Iraq, and other neighboring countries disrupting infrastructure and undermining cooperation. The Syrian conflict, in particular, has affected interconnection with Turkey and Lebanon.

Lack of Political Will: Despite recognition of mutual benefits, sustained political commitment to regional energy cooperation has been inconsistent. Changes in government priorities and bilateral relations affect project continuity.

Trust Deficits: Historical tensions and competing national interests create trust deficits that impede long-term cooperation agreements.

3.2.2 Technical and Infrastructure Challenges

Grid Synchronization: Interconnecting networks with different technical standards, frequency control mechanisms, and operating protocols requires substantial technical coordination. The European Network of Transmission System Operators (ENTSO-E) connection with Turkey exemplifies the complexity of synchronizing different grid systems.

Infrastructure Investment: Interconnection projects require substantial investment in transmission lines, substations, and control systems. While infrastructure partially exists (e.g., connections to Syria, Egypt), upgrading capacity and ensuring reliability requires continued investment.

Operational Coordination: Real-time coordination across multiple control areas requires robust communication systems, standardized operating procedures, and institutional mechanisms for dispute resolution.

3.2.3 Legal and Commercial Frameworks

Effective regional cooperation requires comprehensive legal agreements addressing:

- Tariff structures for energy exchange
- Wheeling charges for transit across intermediate networks
- Dispute resolution mechanisms
- Liability allocation for supply interruptions
- Investment recovery for interconnection assets

These frameworks remain incomplete for several proposed interconnections, delaying implementation.

3.3 System Losses: A Persistent Challenge

Losses in Jordan's electricity system occur at multiple stages—generation, transmission, and distribution—representing both technical inefficiency and economic waste.

3.3.1 Generation Losses

Generation losses represent the difference between fuel energy input and electrical energy output. Thermal power plants typically achieve efficiencies of 35-45%, meaning 55-65% of fuel energy is lost as heat. While these losses are inherent to thermal conversion, efficiency varies significantly with plant age, maintenance, and operating conditions. Older plants in Jordan's fleet operate at lower efficiencies, consuming more fuel per kWh generated.

3.3.2 Transmission Losses

Transmission losses occur due to resistance in conductors, transformer losses, and corona discharge. Jordan's transmission network operates at 400 kV and 132 kV levels, with typical losses of 3-5%. Table 1 presents transmission loss data for recent years.

Table 1. Transmission Losses in Jordan's Electricity System (2015-2018)

Year	Generated Energy (GWh)	Sent Out Energy (GWh)	Losses (GWh)	Loss Percentage (%)
2015	18,516	17,945	571	3.08
2016	18,924	18,415	509	2.69
2017	18,690	18,191	499	2.67
2018	19,146	18,726	420	2.19

3.3.3 Distribution Losses

Distribution losses are substantially higher than transmission losses, reflecting the lower voltage levels, longer distances, and greater exposure to non-technical losses. Table 2 presents distribution loss data.

Table 2. Distribution Losses in Jordan's Electricity System (2015-2018)

Year	Received Energy (GWh)	Sold Energy (GWh)	Losses (GWh)	Loss Percentage (%)
2015	18,213	15,862	2,351	12.91
2016	17,176	14,898	2,278	13.26
2017	18,320	16,112	2,208	12.05
2018	17,985	15,838	2,147	11.94

3.3.4 Causes of Losses

Technical losses result from:

- Inadequate conductor sizing for current levels
- Poor power factor increasing reactive current
- Imbalanced loading on three-phase systems
- Transformer inefficiencies
- Long distribution distances

Non-technical losses include:

- Electricity theft through illegal connections
- Meter tampering and bypassing
- Metering inaccuracies
- Billing and collection errors

Addressing these losses requires investment in network upgrades, improved monitoring and control systems, enhanced enforcement against theft, and public awareness campaigns.

4. RESULTS AND ANALYSIS

4.1 Sources of Electricity Generation and Losses

Jordan's electricity generation mix has evolved substantially over the past two decades, reflecting changing fuel availability, policy priorities, and market conditions. Figure 1 illustrates the evolution of primary energy sources for electricity generation between 2012 and 2021.

Figure 1. Energy Power Supply Resources in Jordan (2012-2021)

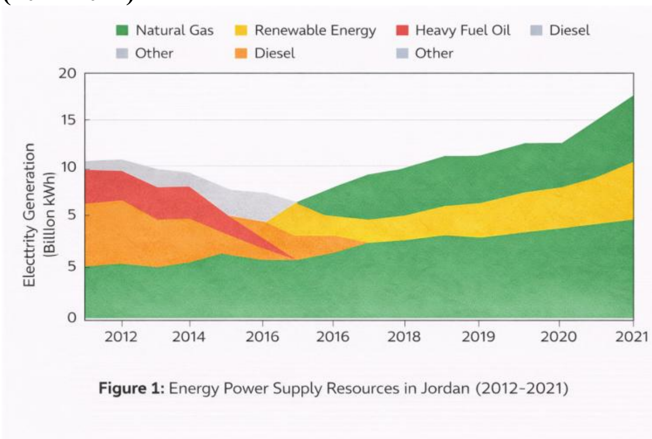


Figure 1: Energy Power Supply Resources in Jordan (2012-2021)

Legend: Stacked area chart showing the contribution of natural gas, heavy fuel oil, diesel, renewable energy, and other sources to electricity generation over the decade, demonstrating the shift toward natural gas and renewable energy.

4.1.1 Historical Evolution of Generation Sources

2000-2003: Iraqi Crude Oil Era: Until the 2003 Iraq War, Jordan benefited from access to Iraqi crude oil at preferential prices, with most electricity generated using crude oil. This arrangement provided relatively low-cost energy but created dependence on a single supplier vulnerable to geopolitical events.

2003-2010: Egyptian Natural Gas Transition: Following the Iraq War, Jordan gradually shifted to Egyptian natural gas supplied through the Arab Gas Pipeline. Natural gas offered lower costs and environmental benefits compared to oil, becoming the dominant generation fuel by the late 2000s.

2010-2015: Crisis and Reversion to Oil: Beginning in 2010, sabotage attacks on the Arab Gas Pipeline in Egypt's Sinai Peninsula disrupted gas supplies, with interruptions becoming increasingly frequent and prolonged. By 2012, gas flows were virtually eliminated, forcing Jordan to revert to expensive heavy fuel oil and diesel for generation. This crisis dramatically increased generation costs, creating substantial financial losses for NEPCO and the national budget.

2015-Present: Diversification and Renewables: The post-2015 period has seen two parallel developments: (1) resumption of natural gas imports, now through liquefied natural gas (LNG) terminals at Aqaba, and (2) accelerated renewable energy deployment under the Renewable Energy and Energy Efficiency Law. By 2024, renewable energy contributed approximately 20% of consumed electricity, substantially exceeding the original 10% target for 2020.

4.1.2 Current Generation Mix

As of 2024, Jordan's electricity generation mix comprises:

- **Natural gas**: Approximately 75-80% (imported LNG and limited domestic production from Risha field)
- **Renewable energy**: Approximately 20% (solar PV, wind)
- **Oil products**: Less than 5% (primarily for peaking plants and emergency backup)

This mix represents a substantial improvement in diversification compared to the pre-2015 period, though natural gas import dependence remains significant.

4.1.3 Energy Supply and Import Trends

Figure 2 illustrates Jordan's primary energy supply and import trends, demonstrating the persistent import dependence despite growing indigenous renewable production.

Figure 2. Primary Energy Supply and Imports in Jordan (2000-2021)

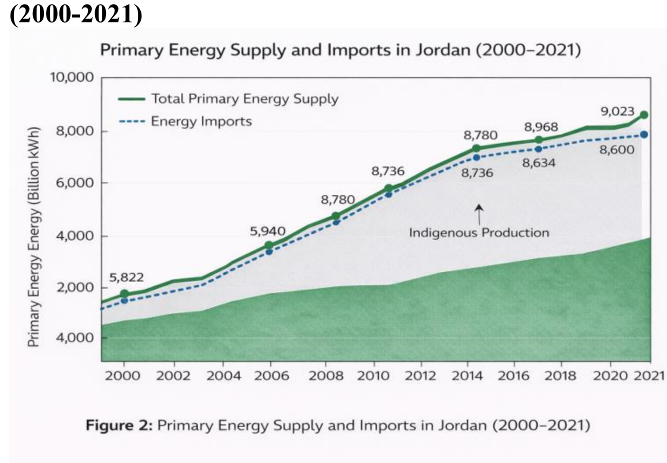


Figure 2: Primary Energy Supply and Imports in Jordan (2000–2021)

Legend: Line graph showing total primary energy supply and energy imports, with the gap between lines representing indigenous production (primarily renewable energy and limited fossil fuel extraction).

Key observations from Figure 2:

- Total primary energy supply has grown from approximately 6,000 ktoe in 2000 to over 9,000 ktoe in 2021
- Imports have consistently accounted for 94-97% of supply, with indigenous production rarely exceeding 6%
- The post-2015 increase in renewable energy has slightly reduced the import share but not substantially altered the fundamental import dependence

4.1.4 Final Energy Consumption Patterns

Figure 3 disaggregates final energy consumption by sector, revealing important patterns for policy development.

Figure 3. Final Energy Consumption by Sector (2018)

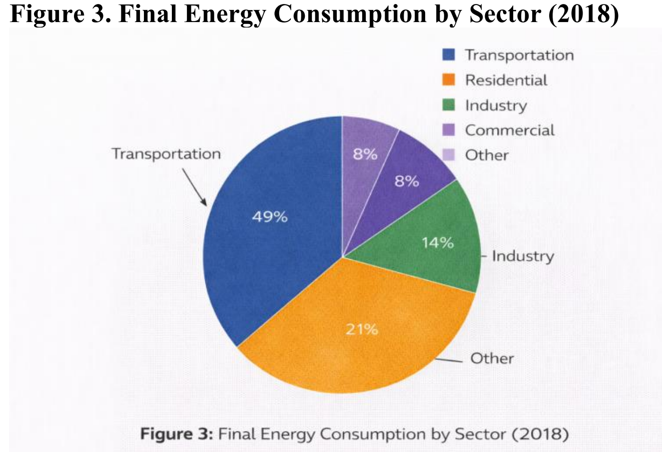


Figure 3: Final Energy Consumption by Sector (2018)

Legend: Pie chart showing transportation (49%), residential (21%), industry (14%), commercial (8%), and other sectors (8%).

Transportation dominates energy consumption, accounting for approximately half of total final energy. This sector's dependence on imported petroleum products represents a significant component of overall import vulnerability. Electrification of transport (electric vehicles) could shift some of this consumption to the electricity sector, with implications for generation capacity and grid management.

Residential consumption (21%) is the second-largest category, with significant potential for energy efficiency improvements through building codes, appliance standards, and behavioral programs. Industrial consumption (14%) includes manufacturing, mining, and construction, with energy intensity varying substantially across subsectors.

4.2 Growth of Electricity Demand

Electricity demand in Jordan has grown rapidly over the past two decades, driven by population growth, economic development, and changing consumption patterns. Table 3 presents annual electricity consumption data from 2000-2021.

Table 3. Jordan Annual Electricity Consumption (Billion kWh), 2000-2021

Year	Consumption	Year	Consumption	Year	Consumption
2000	6.10	2007	8.39	2014	13.54
2001	6.59	2008	9.85	2015	14.00
2002	7.09	2009	9.58	2016	14.56
2003	6.86	2010	10.40	2017	16.00
2004	6.86	2011	10.40	2018	16.82
2005	7.09	2012	11.30	2019	16.82
2006	7.96	2013	13.54	2020	16.82
				2021	17.00

Source: Ministry of Energy and Mineral Resources (2021)

4.2.1 Demand Growth Analysis

Analysis of consumption data reveals:

Compound Annual Growth Rate (CAGR) : Over the 21-year period (2000-2021), electricity consumption grew at an average annual rate of 5.0%. However, growth has been uneven, with periods of acceleration and deceleration corresponding to economic conditions, population dynamics, and major events.

Pre-2010 Growth: From 2000-2010, consumption grew from 6.10 to 10.40 billion kWh, a CAGR of 5.5%. This period corresponded to sustained economic growth and infrastructure development.

2010-2013 Acceleration: Between 2010 and 2013, consumption surged from 10.40 to 13.54 billion kWh, a CAGR of 9.2%. This acceleration coincided with the Syrian refugee influx, which substantially increased population and associated electricity demand.

Post-2013 Moderation: From 2013-2021, growth moderated to approximately 2.9% annually, reflecting economic challenges and the impacts of energy efficiency programs. The plateau in 2019-2020 likely reflects COVID-19 pandemic impacts.

Figure 4 illustrates the growth trajectory graphically.

Figure 4. Growth of Electricity Demand in Jordan (2000-2020)

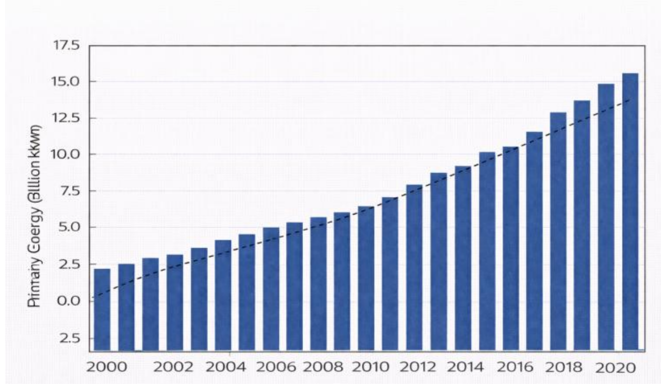


Figure 4: Growth of Electricity Demand in Jordan (2000–2020)

Legend: Bar chart showing annual electricity consumption with trend line, demonstrating the sharp acceleration post-2010 and subsequent moderation.

4.2.2 Peak Demand Evolution

Peak demand (maximum instantaneous power consumption) is critical for capacity planning. Historical peak demand data:

- **2012**: 2,380 MW (day), 2,840 MW (night)
- **2015**: Approximately 3,000 MW
- **2021**: Approximately 3,300 MW

The day-night differential (approximately 460 MW in 2012) reflects the predominance of lighting and residential loads in evening peaks.

4.2.3 Demand Projections

NEPCO and MEMR have developed demand projections for planning purposes:

- **2020 projection**: 4,300 MW (actual peak approximately 3,500 MW, reflecting over-estimation)
- **2030 projection**: 8,130 MW
- **2040 projection**: 15,000 MW (Worley Parsons, 2011)

These projections assume continued economic growth and population increase, with annual growth rates of 5-7%. However, recent experience suggests lower growth rates (2-3%), and projections may require downward revision.

4.3 Electricity Generating Alternative Resources

Jordan's energy strategy emphasizes diversification of energy sources to enhance security and sustainability. This section evaluates alternative resources, both renewable and non-renewable.

4.3.1 Renewable Energy Targets and Achievements

The National Energy Strategy (2015-2025) set ambitious targets for renewable energy:

- **2020 target**: 10% of electricity from renewables (achieved and exceeded)
- **2025 target**: 20% of electricity from renewables (on track for achievement)
- **2030 target**: 50% of electricity from renewables (announced by Energy Minister, 2021)

As of 2024, renewable energy contributes approximately 20% of consumed electricity, substantially ahead of the original trajectory. This achievement reflects successful implementation of the Renewable Energy and Energy Efficiency Law (REEL), feed-in tariffs, and private sector investment.

4.3.2 Investment Requirements

The 2008 energy strategy plan projected $18 billion in investments across the energy sector through 2020, including:

- **Power generation**: $4 billion in new capacity
- **Transmission and distribution**: Infrastructure upgrades and expansion
- **Renewable energy**: $1.7 billion for achieving 10% renewable share (actual investment exceeded this)
- **Energy efficiency**: $150 million for efficiency programs

These investments have been partially realized, with substantial private capital mobilized for renewable energy projects under the IPP framework.

4.4 Electricity Networks Connection and Export

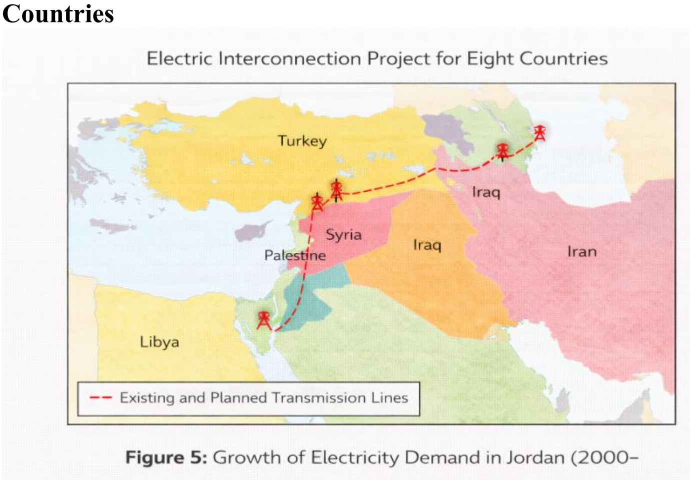
Regional interconnection represents a key element of Jordan's energy strategy, enabling energy exchange, enhancing grid stability, and creating potential for electricity exports.

4.4.1 Eight Countries Electric Interconnection Project

The Eight Countries Electric Interconnection Project aims to connect the electrical networks of Egypt, Iraq, Jordan, Lebanon, Libya, Palestine, Syria, and Turkey. This ambitious initiative would create a regional electricity market with substantial benefits for all participants.

Current Status: Jordan, Egypt, Syria, and Libya currently have fully interconnected electrical networks, forming the core of the regional system. Figure 5 illustrates the interconnection network.

Figure 5. Electric Interconnection Project for Eight Countries



Legend: Regional map showing existing and planned transmission lines connecting the eight participating countries, with operational connections highlighted.

4.4.2 Existing Interconnection Projects

Jordan-Egypt Interconnection:

- **Connection**: 13 km, 400 kV submarine cable across Gulf of Aqaba
- **Capacity**: 550 MW exchange capacity
- **Agreement**: Renewed in 2012
- **Operation**: Enables energy exchange and emergency support

Jordan-Syria Interconnection:

- **Connection**: 58 km, 400 kV overhead single-circuit transmission line
- **Capacity**: 1,000 MW exchange capacity
- **Agreement**: Extended to 2012
- **Status**: Operational, though affected by Syrian conflict

Energy Exchange Statistics (2011) :

- NEPCO imported 1,457.6 GWh from Egypt
- NEPCO imported 280.5 GWh from Syria
- Jordan exported 4.2 GWh to Egypt
- Jordan exported small quantities to Jerusalem District Electricity Company and Border Trabeel

Wheeling charges for energy transit across Jordanian networks provide revenue while facilitating regional energy trade.

4.4.3 Under Construction and Planned Interconnections

Syrian-Turkish Electric Interconnection:

- Turkish side: Completed since 1997
- Syrian side: Completed mid-2003
- Status: Island interconnection operation; full synchronization with ENTSO-E planned in stages
- ENTSO-E (European Network of Transmission System Operators for Electricity) connection completed September 18, 2011, though experimental operation delayed

Syrian-Lebanese Electric Interconnection:

- Line completed and operational: April 27, 2009 (without synchronization)
- Full synchronization expected 2012 (delayed)
- Enables Lebanon to import Egyptian electricity via Jordanian and Syrian networks

Iraqi-Turkish Electric Interconnection:

- Current: 154 kV island interconnection
- Planned: Second 400 kV interconnection line
- Status: Iraqi side 90% complete; Turkish side not started
- Expected completion: 2012 (delayed)

Syrian-Iraqi Electrical Interconnection:

- 400 kV substations completed on Syrian side
- Transmission lines under construction
- Iraqi side completed 28 km interconnection line (100%)
- Operational once studies complete and networks fortified

Egyptian-Libyan Electrical Interconnection:

- Capacity expansion planned: 500 kV on Egyptian side, 400 kV on Libyan side
- Feasibility studies completed
- Implementation pending

4.4.4 Benefits of Regional Interconnection

Regional interconnection provides multiple benefits:

Technical Benefits:

- Enhanced grid stability through shared reserves
- Optimized generation dispatch across broader geographic area
- Integration of variable renewable energy through geographic smoothing
- Emergency support during contingencies

Economic Benefits:

- Reduced need for spinning reserves (capacity savings)
- Access to lower-cost generation
- Revenue from wheeling charges

- Potential for electricity exports

Strategic Benefits:

- Enhanced energy security through supply diversification
- Reduced import dependence
- Regional cooperation building trust and interdependence

4.5 Cost Analysis

The financial sustainability of Jordan's electricity sector depends critically on the relationship between costs and revenues.

4.5.1 Generation Costs

Generation costs are primarily determined by fuel prices and plant efficiencies. Key cost components:

- **Fuel**: 70-80% of generation cost
- **Operation and maintenance**: 10-15%
- **Capital recovery**: 10-15%

The shift from Egyptian natural gas (low cost) to heavy fuel oil/diesel (2010-2015) dramatically increased generation costs. The subsequent transition to LNG and renewable energy has moderated but not eliminated cost pressures.

4.5.2 System Costs vs. Tariffs

A fundamental challenge is the gap between system costs and consumer tariffs:

- **System cost**: Approximately 190 fils/kWh (including generation, transmission, distribution, and subsidies)
- **Average tariff**: Approximately 88 fils/kWh (varies by consumer category)

This gap (approximately 102 fils/kWh) represents a substantial implicit subsidy, funded through:

- Direct government budget transfers
- NEPCO accumulated losses
- Cross-subsidies between consumer categories

4.5.3 Tariff Structure

Jordan employs a tiered tariff structure with different rates for:

- **Residential**: Increasing block tariffs (lower rates for initial consumption blocks)
- **Industrial**: Time-of-use rates and demand charges
- **Commercial**: Higher rates reflecting lower cross-subsidies
- **Agricultural**: Subsidized rates for irrigation pumping
- **Street lighting**: Special tariff

Recent tariff adjustments have averaged 20-25% increases, reaching up to 88 fils/kWh for some categories. However, these remain substantially below cost-recovery levels.

4.5.4 Financial Implications

The tariff-cost gap has significant implications:

- **NEPCO financial position**: Accumulated losses estimated at several billion JOD
- **Government budget**: Direct and indirect subsidies strain fiscal resources
- **Investment attractiveness**: Uncertain cost recovery affects private sector confidence
- **Sector sustainability**: Persistent losses are unsustainable long-term

Addressing this challenge requires balancing cost recovery with social protection, a politically sensitive undertaking.

4.6 Promising Solutions: Renewable Energy Resources

Jordan's renewable energy resources offer the most promising pathway for enhancing energy security while reducing environmental impacts.

4.6.1 Solar Energy

Jordan possesses exceptional solar resources, ranking among the best globally for solar energy development.

Solar Resource Characteristics:

- Average annual solar radiation: 5.5 kWh/m²/day
- Annual sunshine duration: Over 2,900 hours
- Clear sky conditions: 300+ days per year
- Direct normal irradiance: Suitable for concentrating solar power

Solar PV Development:

- Total installed capacity (2024): 2,063 MW
- Share of electricity consumption: Approximately 15-18%
- Project types: Utility-scale farms, commercial rooftops, residential systems
- Leading projects: Multiple IPP-developed solar farms

Solar Contribution: Solar energy now accounts for approximately 20% of consumed electricity, a remarkable achievement given that virtually no solar capacity existed before 2014.

4.6.2 Wind Energy

Jordan's wind resources are substantial in specific geographic areas.

Wind Resource Assessment:

- Jordan Wind Atlas developed 1988 with Danish RISO National Laboratory
- Annual mean wind speed at 100 m: 6-8 m/s in suitable locations
- High-potential areas: Southern highlands, northern ridges

Wind Farm Development:

- Tafillah Wind Farm: 117 MW
- Maan Wind Farm: 86 MW
- Alfujajj Wind Farm: 89 MW
- Total installed capacity: 370 MW

Wind Energy Potential: Additional sites have been identified for future development, with potential for 1,000+ MW ultimately.

4.6.3 Biomass Energy

Biomass resources, while more modest than solar and wind, offer baseload generation potential.

Resource Assessment:

- Olive waste and animal waste: 157,000 toe/year equivalent (Abu-Ashour et al., 2010)
- Municipal solid waste: Significant energy recovery potential

Existing Projects:

- Russiafah closed landfill: 4 MW power generation
- Alghabawi rubbish dump (Amman): 4.8 MW biogas plant
- Wastewater treatment plants: Sewage sludge biogas recovery for combined heat and power (CHP)

Future Potential: Co-combustion of olive oil industry solid waste offers additional opportunities.

4.6.4 Hydropower
Hydropower potential in Jordan is limited by water scarcity but includes:

Existing Plants:
- King Talal Dam: 5 MW
- Aqaba Thermal Power Station: 6 MW (waste heat recovery)

Future Potential:
- Red Sea-Dead Sea Conveyor Project: Proposed 550 MW hydropower utilizing 420 m elevation difference
- Project status: Feasibility studies completed; implementation pending international agreements

4.6.5 Oil Shale
Jordan possesses substantial oil shale resources, estimated at 40 billion tons, representing a significant potential indigenous energy source.

Resource Characteristics:
- Deposits located primarily in central and southern Jordan
- Estimated recoverable reserves sufficient for decades of production

Development Status:
- Contracts awarded to Shell and Eseti Energia for exploration
- Attarat Power Plant project (oil shale-fired power plant) under development
- Technology: Direct combustion (power generation) and retorting (liquid fuels)

Challenges:
- High capital costs
- Water requirements for processing
- Environmental impacts (greenhouse gas emissions, land disturbance)

4.6.6 Nuclear Energy
Jordan's nuclear energy program has evolved from ambitious large-scale plans to more measured small modular reactor (SMR) approach.

Historical Plans:
- Original goal: 1,000 MW nuclear power plant(s)
- Agreement with Rosatom (Russia) for two 1,000 MW plants (later cancelled)

Current Approach:
- Focus on Small Modular Reactors (SMRs): 200-700 MW capacity
- Expected operation: 2025-2030 timeframe
- Applications: Power generation and water desalination

Challenges:
- High capital costs
- Regulatory framework development
- Public acceptance
- Proliferation concerns
- Waste management

5. ENERGY POLICY FRAMEWORK
5.1 National Energy Strategy
Jordan's energy policy is guided by multiple national plans, with the National Energy Strategy providing overarching direction.

5.1.1 National Energy Strategy (2011-2020)
The 2011-2020 strategy prioritized energy supply diversification to reduce import dependence. Key objectives:
- Reduce oil product share from 82% (2011) to 40% by 2020
- Increase natural gas share to 29%
- Increase renewable energy share to 10%
- Introduce oil shale (14% of energy mix)
- Introduce nuclear (6% of energy mix)

Outcome Assessment:
- Oil product share reduction: Partially achieved (shift to natural gas and renewables)
- Natural gas share: Approximately 75-80% of generation (exceeding target)
- Renewable energy: 20% of electricity (exceeding 10% target)
- Oil shale: Delayed but progressing
- Nuclear: Scaled back to SMR approach

5.1.2 National Energy Strategy (2015-2025)
The current strategy emphasizes indigenous resource development and renewable energy. Key elements:
- Increase energy supply security through diversification
- Harness indigenous renewable energy capability
- Reduce reliance on foreign energy sources
- Target: 20% renewable electricity by 2025

Progress:
- Renewable energy target substantially exceeded (20% achieved by 2024)
- Energy efficiency programs advancing
- Regional interconnection expanding

5.1.3 Long-term Vision
Jordan's official objective extends beyond import reduction to becoming a net energy exporter by 2030. This ambitious vision relies on:
- Substantial renewable energy development
- Oil shale utilization for power and liquid fuels
- Nuclear energy (SMRs) for baseload and desalination
- Regional electricity exports
- Energy efficiency reducing domestic demand growth

5.2 Legislative Framework
5.2.1 General Electricity Law
The General Electricity Law (No. 64 of 2002, with amendments) provides the foundational legislation for Jordan's electricity sector.

Key Provisions:
- Established Electricity Regulatory Commission (ERC)
- Liberalized electricity market structure
- Separated generation, transmission, and distribution
- Defined licensing requirements
- Established tariff-setting principles

Regulatory Independence: The ERC operates independently to regulate prices, issue licenses, and ensure sector efficiency, reliability, and development (OECD, 2005).

Tariff Principles: Tariff methodology must:

- Enable efficient licensees to recover costs and earn reasonable return
- Provide incentives for continuous improvement
- Provide economically credible signals to consumers

Licensing: The ERC issues licenses for generation, transmission, and distribution. Exemptions apply to:

- Generating units ≤ 1 MW
- Local supply networks ≤ 100 kW
- Self-consumption power plants

Procurement: Power purchase from plants > 5 MW requires public procurement procedures.

Figure 6 illustrates the regulatory framework hierarchy.

Figure 6. Hierarchy of the Regulatory Framework for Jordan's Electricity Sector

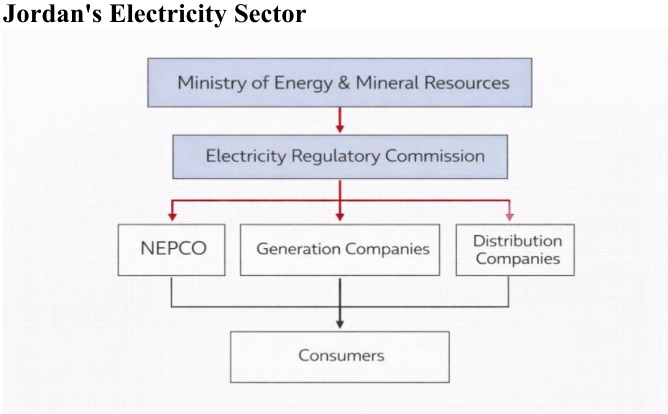


Figure 6: Hierarchy of the Regulatory Framework for Jordan's Electricity Secto

Legend: Organizational chart showing the relationships between the Ministry of Energy and Mineral Resources, Electricity Regulatory Commission, NEPCO, generation companies, distribution companies, and consumers.

5.2.2 Renewable Energy and Energy Efficiency Law (REEL)

The Renewable Energy and Energy Efficiency Law (No. 13 of 2012, amended 2014) provides the framework for renewable energy development.

Key Objectives:

- Promote utilization of renewable energy sources
- Increase renewable energy contribution to total energy mix
- Protect the environment
- Achieve sustainable development
- Enhance energy efficiency

Implementation Mechanisms:

- MEMR identifies suitable locations for renewable energy applications
- Renewable Energy and Energy Efficiency Fund (established 2013) provides financing
- Feed-in tariffs for renewable energy supplies
- Streamlined permitting for renewable projects

Funding Sources: The Renewable Energy and Energy Efficiency Fund receives contributions from:

- Jordanian government
- European Union
- PROPARCO (French development financial institution)
- Gulf Cooperation Council (GCC)

5.3 Policy Implementation Challenges

Despite comprehensive policy frameworks, implementation gaps persist:

Enforcement: Building codes and efficiency standards lack consistent enforcement mechanisms.

Awareness: Public awareness of energy efficiency benefits remains limited.

Data: Inaccessible databases and lack of clear information constrain planning and investment.

Funding: Insufficient financing for EE projects, particularly for low-income households.

Institutional Capacity: Implementing agencies require strengthened capacity for effective program delivery.

Coordination: Multiple stakeholders require enhanced coordination mechanisms.

6. DISCUSSION AND RECOMMENDATIONS

6.1 Synthesis of Findings

The analysis presented in this paper reveals a Jordanian electricity sector characterized by:

Structural Vulnerabilities:

- Heavy dependence on imported fossil fuels (94% of energy)
- Exposure to price volatility and supply disruptions
- System losses representing economic inefficiency
- Tariff-cost gap creating financial unsustainability

Significant Progress:

- Successful renewable energy deployment (20% of electricity)
- Regional interconnection enhancing grid stability
- Modern policy frameworks (REEL, General Electricity Law)
- Private sector participation through IPP model

Persistent Challenges:

- Demand growth (averaging 5% annually)
- Infrastructure aging requiring modernization
- Policy implementation gaps
- Financial sustainability of tariff structures
- Integration of variable renewable energy

Substantial Opportunities:

- Exceptional solar and wind resources
- Oil shale deposits for energy security
- Regional cooperation for energy exchange
- Energy efficiency potential
- Smart grid technologies

6.2 Strategic Recommendations

Based on this comprehensive analysis, the following strategic recommendations are proposed:

6.2.1 Accelerate Renewable Energy Deployment

Target Enhancement: Maintain 50% renewable electricity target for 2030 with clear implementation roadmap.

Technology Diversification: Expand beyond solar PV to include concentrated solar power (CSP) with storage, enhanced wind development, and biomass utilization.

Grid Integration: Invest in grid infrastructure to accommodate higher renewable penetration, including:

- Transmission capacity expansion
- Smart grid technologies

- Energy storage systems (battery, pumped hydro)
- Advanced forecasting and control systems

Distributed Generation: Promote rooftop solar and small-scale renewable systems through streamlined permitting, net metering, and targeted incentives.

6.2.2 Modernize Transmission and Distribution Infrastructure

Loss Reduction: Implement comprehensive loss reduction program targeting:

- Technical losses: Network upgrades, power factor correction, transformer efficiency
- Non-technical losses: Smart metering, enforcement against theft, improved billing

Grid Automation: Deploy advanced distribution management systems (ADMS), outage management systems (OMS), and distribution automation.

Asset Management: Implement condition-based maintenance and asset replacement programs for aging infrastructure.

6.2.3 Implement Tariff Reform

Cost-Reflective Pricing: Gradually align tariffs with costs while protecting vulnerable consumers through:

- Targeted direct subsidies (rather than across-the-board subsidies)
- Lifeline rates for essential consumption
- Time-of-use rates to reflect cost variations

Cross-Subsidy Reduction: Phase out inefficient cross-subsidies with clear timeline and social protection measures.

Financial Recovery: Address NEPCO accumulated losses through combination of tariff adjustment, efficiency improvements, and fiscal support.

6.2.4 Enhance Regional Cooperation

Interconnection Expansion: Complete planned interconnections with Turkey, Iraq, and Libya, and strengthen existing connections.

Market Development: Work toward regional electricity market with harmonized rules, coordinated dispatch, and transparent pricing.

Political Engagement: Sustain diplomatic efforts to maintain regional cooperation despite political challenges.

6.2.5 Strengthen Energy Efficiency

Building Codes: Enforce mandatory building codes for new construction, including thermal insulation, efficient lighting, and HVAC standards.

Appliance Standards: Implement minimum energy performance standards (MEPS) for key appliances with regular updates.

Industrial Efficiency: Promote energy management systems, energy audits, and efficiency investments in industry.

Public Awareness: Conduct sustained public awareness campaigns on energy conservation and efficiency.

6.2.6 Advance Oil Shale and Nuclear Prudently

Oil Shale: Progress Attarat project and exploration activities while ensuring environmental safeguards and water resource protection.

Nuclear: Continue SMR assessment with emphasis on safety, waste management, and international cooperation.

6.2.7 Strengthen Governance and Institutions

Regulatory Capacity: Enhance ERC capacity for effective regulation, tariff analysis, and market monitoring.

Implementation Accountability: Establish clear accountability mechanisms for policy implementation.

Stakeholder Engagement: Strengthen consultation processes with industry, civil society, and consumers.

Data Transparency: Improve energy data collection, analysis, and public accessibility.

6.3 Research Priorities

Future research should address:

- **Demand forecasting**: Refined models incorporating demographic, economic, and behavioral factors
- **Renewable integration**: Technical and economic studies of high-renewable systems
- **Energy storage**: Assessment of storage technologies for Jordan's grid
- **Tariff design**: Optimal tariff structures balancing efficiency and equity
- **Regional market design**: Frameworks for effective regional electricity trading
- **Climate impacts**: Assessment of climate change on energy demand and renewable resources

7. CONCLUSION

Jordan's electricity sector stands at a critical juncture where strategic decisions will shape the nation's energy future for decades. This comprehensive review has documented the sector's evolution, challenges, achievements, and opportunities.

7.1 Summary of Key Findings

Import Dependence: Jordan imports approximately 94% of its energy requirements, primarily oil and natural gas, creating substantial economic and strategic vulnerabilities. The cost of energy imports (approximately 2.5 billion JOD annually) represents a significant fiscal burden.

Demand Growth: Electricity consumption has grown from 6.1 billion kWh in 2000 to 17.0 billion kWh in 2021, driven by population growth (including refugee influxes), economic development, and changing consumption patterns. Peak demand reached approximately 3,300 MW in 2021.

Generation Mix: Natural gas dominates electricity generation (75-80%), with renewable energy contributing approximately 20% and oil products less than 5%. This mix represents substantial improvement in diversification compared to the pre-2015 period.

Renewable Achievement: Jordan has exceeded its renewable energy targets, with solar and wind capacity exceeding 2,400 MW and contributing 20% of consumed electricity. This achievement demonstrates effective policy implementation and private sector mobilization.

System Losses: Transmission losses average 2-3% and distribution losses 12-13%, representing significant economic inefficiency and revenue loss. Addressing these losses should be a priority.

Regional Interconnection: Jordan is connected to Egypt (550 MW) and Syria (1,000 MW), with broader eight-country interconnection projects advancing. These connections enhance grid stability and enable energy exchange.

Financial Sustainability: The gap between system costs (approximately 190 fils/kWh) and average tariffs (approximately 88 fils/kWh) creates substantial financial pressure. Tariff reform balanced with social protection is essential.

Policy Framework: Jordan has established comprehensive policy frameworks including the National Energy Strategy, General Electricity Law, and Renewable Energy and Energy Efficiency Law. Implementation gaps remain.

7.2 The Path Forward

The path toward a sustainable, secure, and affordable electricity future requires concerted action across multiple dimensions:

Accelerate Renewables: Maintain momentum in renewable energy deployment, targeting 50% of electricity by 2030. Invest in grid infrastructure and storage to accommodate higher renewable penetration.

Reduce Losses: Implement comprehensive loss reduction programs addressing both technical and non-technical losses through infrastructure upgrades, smart metering, and enforcement.

Reform Tariffs: Gradually align tariffs with costs while protecting vulnerable consumers through targeted subsidies rather than across-the-board underpricing.

Enhance Efficiency: Aggressively pursue energy efficiency through building codes, appliance standards, industrial programs, and public awareness.

Expand Regional Cooperation: Strengthen existing interconnections and complete planned connections to enhance grid stability and enable energy trade.

Strengthen Governance: Enhance regulatory capacity, implementation accountability, and stakeholder engagement.

7.3 Concluding Remarks

Jordan's electricity sector has demonstrated remarkable resilience in the face of substantial challenges—regional conflicts, supply disruptions, refugee influxes, and economic pressures. The successful mobilization of renewable energy, maintenance of grid reliability, and progress in regional interconnection represent significant achievements.

The path ahead requires continued commitment to the strategic vision of enhanced energy security through indigenous resource development, regional cooperation, and sustainable practices. The opportunities are substantial: exceptional renewable resources, strategic geographic location for regional energy trade, a skilled workforce, and supportive policy frameworks.

Realizing these opportunities requires sustained political will, effective implementation, appropriate investment, and continued international partnership. The payoff—enhanced energy security, reduced import dependence, environmental benefits, and economic development—justifies the effort.

Jordan's experience offers lessons for other resource-constrained nations pursuing energy transition: ambitious targets are achievable with appropriate policies, private sector mobilization is essential, regional cooperation enhances security, and the path from crisis to opportunity requires strategic vision and sustained commitment.

As Jordan pursues its vision of becoming a net energy exporter by 2030, the foundations laid through renewable energy development, regional interconnection, and policy reform will serve as the platform for continued progress. The journey from energy vulnerability to energy security and sustainability is well underway.

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