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***Technical Support to MEMR to Formulate Jordan Energy
Sector Strategy JESS (2025 – 2035)***

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Abbreviations

Acronym	Definition
AAWDCP	Aqaba–Amman Water Desalination and Conveyance Project
BESS	Battery Energy Storage System
BOO	Build, Own, Operate
CBJ	Central Bank of Jordan
CCGT	Combined Cycle Gas Turbine
CNG	Compressed Natural Gas
CSP	Concentrated Solar Power
DSM	Demand Side Management
EBRD	European Bank for Reconstruction and Development
EDCO	Electricity Distribution Company
EE	Energy Efficiency
EMRC	Energy and Minerals Regulatory Commission
EMV	Economic Modernization Vision
ESCO	Energy Service Company
EV	Electric Vehicle
FEC	Final Energy Consumption
FSRU	Floating Storage Regasification Unit
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GHI	Global Horizontal Irradiance
GVA	Gross Value-Added
IDECO	Irbid District Electricity Company
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
JAEC	Jordan Atomic Energy Commission
JEF	Jordan Environment Fund
JEPCO	Jordanian Electric Power Company
JESS	Jordan Energy Sector Strategy
JICA	Japan International Cooperation Agency
JPR	Jordan Petroleum Refinery
JREEEF	Jordan Renewable Energy and Energy Efficiency Fund
LED	Light Emitting Diode
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MEMR	Ministry of Energy and Mineral Resources
MMSCFD	Million standard cubic feet per day
MoEnv	Ministry of Environment
MWI	Ministry of Water and Irrigation
NDC	Nationally Determined Contribution
NEEAP	National Energy Efficiency Action Plan
NREAP	National Renewable Energy Action Plan
NEPCO	National Electric Power Company
NREAP	National Renewable Energy Action Plan

NPC	National Petroleum Company
PESTEL	Political, Economic, Social, Technological, Environmental, Legal
PHES	Pumped Hydro Energy Storage
PHS	Pumped Hydro Storage
PPA	Power Purchase Agreement
PV	Photovoltaic
REEE	Renewable Energy Efficiency
REEE II	Renewable Energy & Energy Efficiency Program in Jordan
REEEL	Renewable Energy and Energy Efficiency Law
RES	Renewable Energy Sources
RoCoF	Rate of Change of Frequency
SCADA	Supervisory Control and Data Acquisition
SMR	Small Modular Reactor
SMEs	Small and Medium Enterprises
SWOT	Strengths, Weakness, Opportunities, Threats
ToU	Time-of-Use
UNFCCC	United Nations Framework Convention on Climate Change
VRE	Variable Renewable Energy

1 Executive Summary

The primary objective of the JESS 2025–2035 update is to evaluate the current trajectory, known as the Reference Pathway, and to develop a more ambitious alternative, the Optimistic Pathway, which aims to achieve 50% renewable electricity generation in the power sector.

1.1 Background

Between 2018 and 2019, the Ministry of Energy and Mineral Resources (MEMR), with support from EU Technical Assistance, developed the 2020–2030 Energy Strategy. The strategy envisions a more sustainable energy sector by maximizing the use of domestic resources and promoting synergies with other key sectors such as water, transport, oil and gas, and energy efficiency.

The strategy study explored six scenarios, one of which the “Increased Sustainability” scenario serves as a foundation for MEMR’s ongoing efforts, reflecting recent sectoral and regional developments. This scenario was designed and evaluated with reference to national policy frameworks, including the National Renewable Energy Action Plan (NREAP), the National Energy Efficiency Action Plan (NEEAP), and Jordan’s unconditional GHG emissions reduction target outlined in its Nationally Determined Contributions (NDC). The scenario strongly promotes increased penetration of renewable energy sources to support long-term sustainability goals.

The Increased Sustainability scenario is based on a set of key assumptions across economic, energy, and environmental parameters. These include:

- Baseline GDP growth trajectory, reflecting expected economic development;
- Implementation of planned RES projects, including the promotion of CSP with financial support;
- 9% reduction in final energy demand by 2030 through energy efficiency measures;
- Consideration of the existing and future capacity of the national refinery;
- Forecasted natural gas availability, including expected quantities, pricing trends, and import arrangements;
- Reduction of GHG emissions equal to 7% in 2030 with additional measures (NDC with measures);
- Conservative penetration of e-mobility in transport sector;
- Reduction of energy consumption in water sector equal to 15%.

Revision of the Increased Sustainability scenario was done in 2022 with the final report published in January 2023. The main focus of the assignment was on the following topics:

- Maximizing the integration of variable renewable energy sources (RES) to reach an indicative target of 50% by 2030;
- Evaluating potential reductions in greenhouse gas (GHG) emissions;
- Modernizing and upgrading the national electricity grid to support the transition toward a smart grid;
- Promoting the use of electric vehicles (EVs) across the transport sector;

- Strengthening energy efficiency (EE) measures across multiple end-use sectors;
- Incorporating the potential of green and possibly blue hydrogen into future planning;
- Consider regional power interconnections and cross-border electricity exchange;
- Assessing energy storage solutions, including their alignment with NEXUS-related projects such as the Aqaba-Amman Water Desalination and Conveyance Project;
- Promote greater utilization of natural gas in the industrial sector.

1.2 Strategic Framework

The overarching vision for Jordan's energy system is to establish a modern, resilient, and inclusive energy sector that meets the country's growing needs while aligning with national development and climate goals. This vision is built on the following key pillars:

- **Reliability:** Ensure continuous and stable supply of electricity to all sectors of the economy.
- **Accessibility:** Ensuring all people, including those in rural or remote areas, have physical access to electricity and clean fuels for cooking, heating and transportation.
- **Affordability:** Provide energy at competitive and fair prices for households, businesses, and industry.
- **Security:** Strengthen energy independence by reducing reliance on imported fuels and enhancing system resilience.
- **Sustainability:** Promote environmentally responsible energy practices in alignment with national policies and international climate commitments.
- **Maximization of Domestic Resources:** Prioritize the development and utilization of indigenous energy sources, including renewables, natural gas and oil shale.
- **Optimization of Renewable Energy:** Maximize the potential of solar and wind energy by ensuring their efficient, secure, and cost-effective integration into the national power system.



Figure 1 : Core principles guiding JESS

The JESS 2025–2035 is guided by the following strategic drivers:

- **Maximizing Utilization of Domestic Energy Resources:** Leveraging all available primary energy sources within Jordan to enhance energy security and reduce reliance on imports.
- **Accelerating Renewable Energy Development:** Expanding the share of solar and wind power in the national energy mix to support sustainability and decarbonization goals.
- **Exploiting the Risha Gas Field:** Increasing domestic natural gas production through the further development of the Risha field and construction of a connecting pipeline to the Arab Gas Pipeline.
- **Expanding Natural Gas Use in Industry and Transport:** Promoting natural gas as a cleaner alternative fuel in the industrial and transportation sectors.
- **Enhancing Energy Efficiency:** Improving energy performance across sectors to reduce consumption and optimize system operation.
- **Strengthening Energy-Water Nexus:** Deepening integration and coordination between the energy and water sectors to optimize resource use and planning.
- **Initiating Green Hydrogen Production:** Establishing the foundations for a green hydrogen economy to support decarbonization and create new export opportunities.

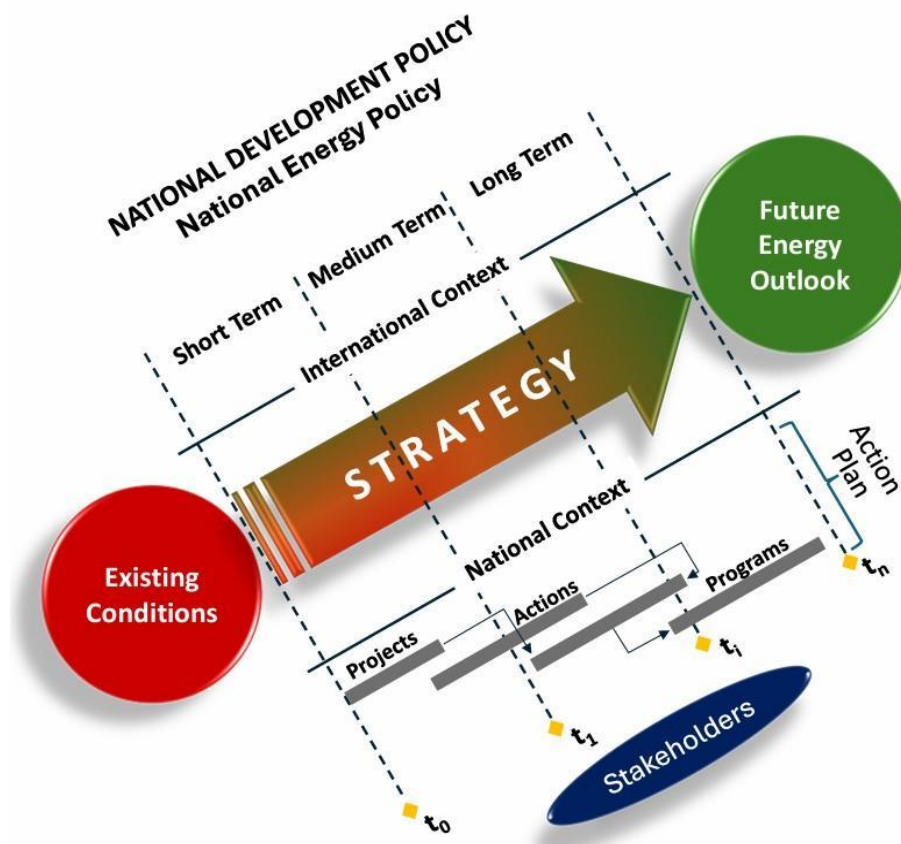


Figure 2: Energy strategy development

1.3 Reference Pathway and Optimistic Pathway

To assess the key challenges in shaping Jordan’s future energy system, two pathways are analyzed. These pathways reflect alternative combinations of assumptions regarding economic growth, the pace of implementing sustainability policies, improvements in energy efficiency, the expansion of renewable energy and the extent of reliance on energy imports. By comparing these pathways, it becomes possible to understand how different socioeconomic and policy choices influence future energy demand, the energy mix, import dependency and overall system sustainability.

Both pathways share common assumptions on population growth and household formation, but they diverge in their GDP growth projections. These socioeconomic drivers are central to shaping future energy demand: population growth influences residential consumption and infrastructure needs, while GDP growth affects industrial activity, transport demand and overall energy intensity. The interplay between these factors provides the foundation for understanding how Jordan’s energy system must adapt to ensure reliability, affordability and sustainability in the years ahead.

The Reference Pathway reflects a continuation of current trends, with gradual progress in energy efficiency and renewable energy integration, targeting 40% renewable electricity production by 2035. It is based on the reference GDP growth rate and leads to lower energy demand.

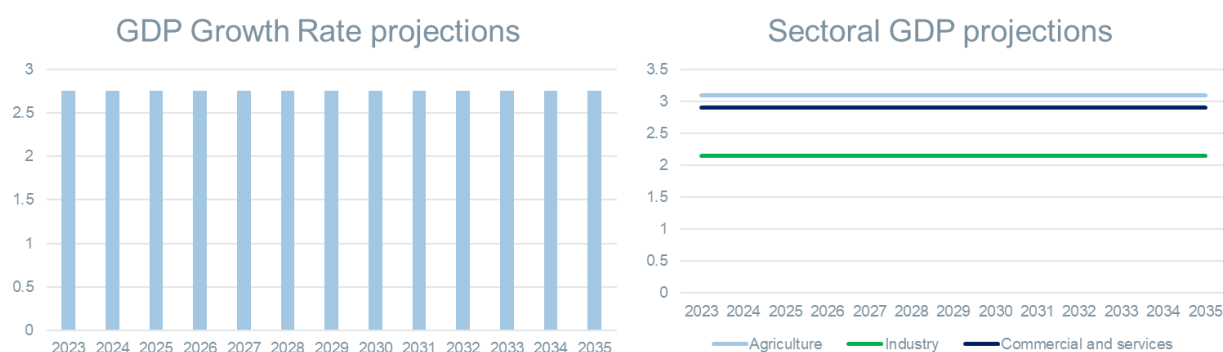


Figure 3: Reference GDP growth rates (Source: See GDP Assumption Note)

GDP Assumption Note:

During the execution of this project, representatives of the Ministry of Energy and Mineral Resources (MEMR) agreed that the GDP growth assumptions adopted should be consistent with those used in the NEPCO Master Plan. Accordingly, the GDP growth rates applied in this study initially followed NEPCO’s assumptions, namely an annual growth rate of 3.0% for the period 2025–2028 and 2.6% for the remainder of the study horizon.

Upon completion of the draft report, MEMR requested that this assumption be revised and expressed as a single average GDP growth rate applied uniformly over the entire analysis period. In response to this request and considering that GDP growth during the two years preceding the study period was close to 2.7%, as well as the fact that the equivalent average growth rate over the full horizon is 2.75%, the project team updated the relevant graphs and information accordingly.

It is important to note that a constant annual GDP growth rate of 2.75% results in the same cumulative GDP level at the end of the study period as that assumed in the NEPCO Master Plan. Consequently, the projected energy demand—across all energy sectors—and the associated investment and expenditure requirements remain effectively unchanged. Any interannual differences in GDP growth profiles are therefore considered to be diluted over the full period, leading to equivalent demand conditions and investment needs under both approaches.

The Optimistic Pathway represents an ambitious scenario, aiming for 50% electricity generation from renewable sources by 2033. It incorporates enhanced energy efficiency measures and increased electricity demand due to the high GDP growth rate target. This Pathway is aligned with the Economic Modernization Vision (EMV) and is based on EMV GDP growth, projected at an average annual rate of 5.6% between 2023 and 2033, with total GDP expected to reach 58.11 billion JD by 2033.

The international context for both pathways is primarily reflected through projections of global oil and gas prices, which are considered to be the same in both Pathways.

Table 1: Fuel prices projection¹

	2025	2030	2035
Crude Oil (\$/bbl)	69.2	79	78
LNG Imports (\$/MMBTU)	12	12	12
Chevron N. Gas (\$/MMBTU)	6.5	6.45	6.40
Risha Gas (\$/MMBTU)	4.50	6.62	6.57

1.4 Results and Policies Recommendations per Pathway

The differing GDP growth projections in the Reference and Optimistic Pathways lead to significant differences in future energy demand. In the Optimistic Pathway, higher economic growth drives increased industrial activity, transport demand, and residential consumption, whereas the Reference Pathway reflects a more moderate trajectory.

Beyond assumptions related to socioeconomic factors and different GDP growth projections, both the Reference Pathway and Optimistic Pathway are built upon a set of common input parameters, including the following:

- **Expansion of the Risha Gas Field:** Natural gas production is expected to reach 418 MMSCFD by 2029, extended to 812 MMSCFD by 2035 in the “Upside” scenario which is included in all the pathways. The Risha pipeline is operational in 2029.

¹ (Source: IEA WEO 2024, Electricity Sector Masterplan 2023-2025, import pricing formula and pricing assumptions for Risha gas)

Risha Gas Field Production Capacity

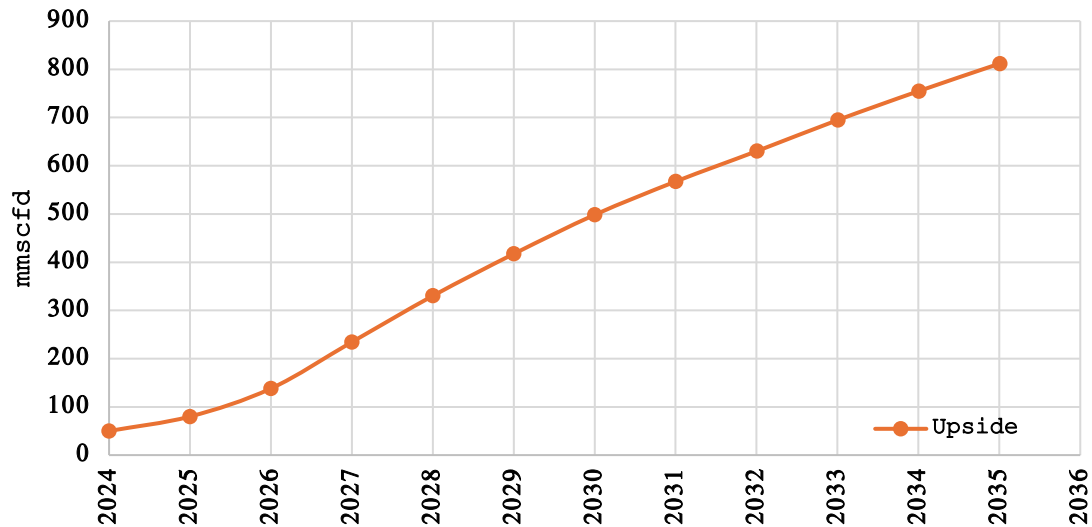


Figure 4: Projection of Risha gas field production²

- **Jordan Petroleum Refinery Update:** The national oil refinery will be updated by 2030, with a target refining capacity of 73,000 barrels per day.
- **Gasification of the Residential, Commercial, and Services Sector:** Natural gas is introduced in Amman and Zarqa starting in 2031, with consumption projected to reach 85 MMSCFD by 2035, with an additional 5MMSCFD used in road transportation. This is consistent with the projections in the 2022 study Strategic Options for City Gas Distribution Network in Jordan.
- **Gasification of Industry:** Continued gasification of large industries is assumed to reach 100 MMSCFD by 2029 and 173 MMSCFD by 2035, according to the latest projections provided by MEMR.

² Source: MEMR data provided on 07/10/2025

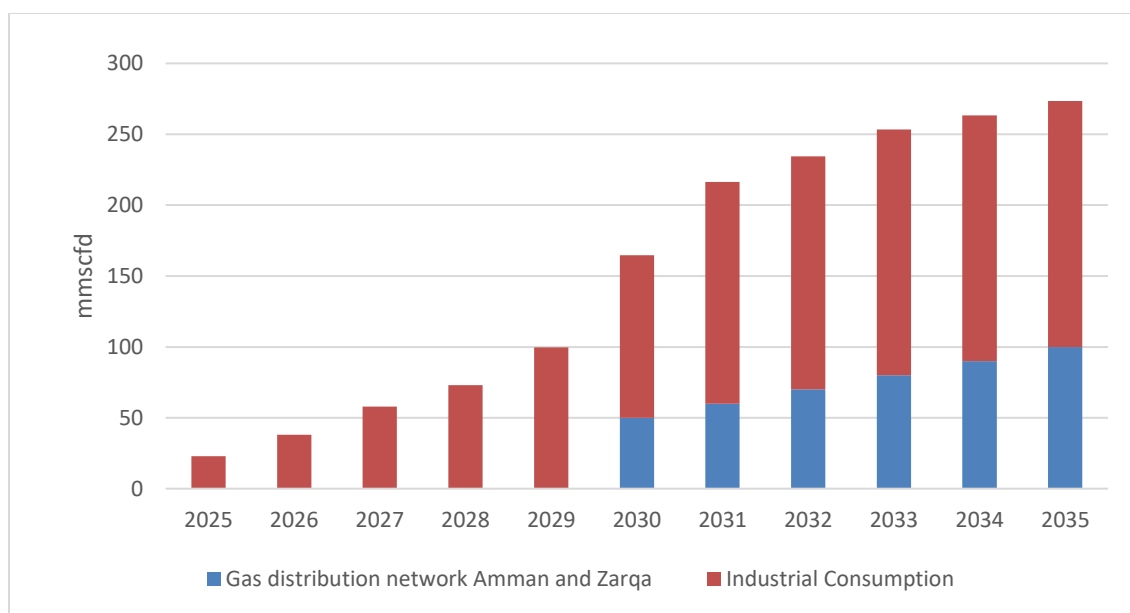
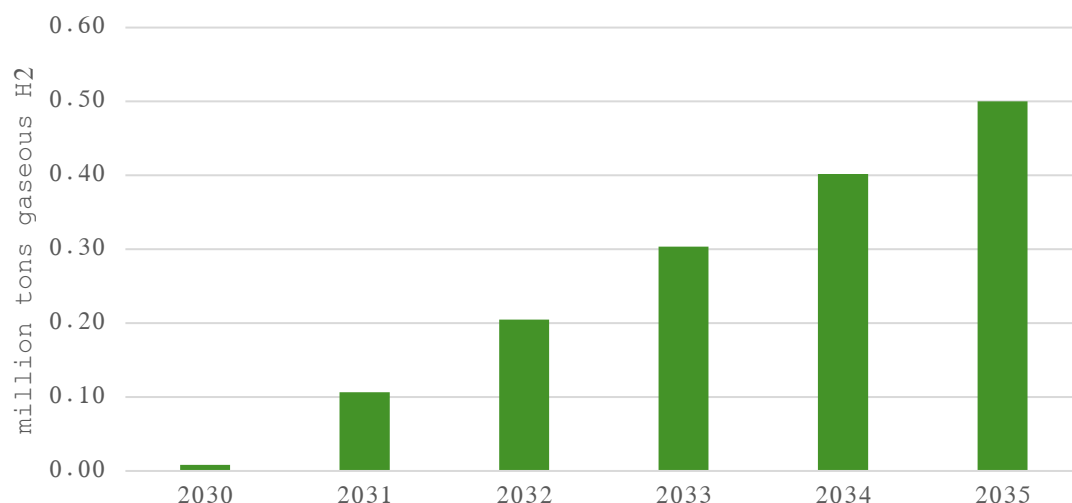


Figure 5: Projections of natural gas use in industry and the gas distribution network of Amman and Zarqa³

- **Electricity Demand for Water Pumping:** This includes projections for the Aqaba–Amman Water Desalination and Conveyance Project (AAWDGP), expected to be operational by 2030, with an assumption that 240 MW of solar PV capacity will be developed as wheeling projects to supply its electricity needs.
- **Energy Storage:** PHES Mujib (450 MW, 7-hour storage duration) is expected to become operational in 2030, while the first battery storage project is scheduled to start operation in 2028.
- **Green Hydrogen Strategy Implementation:** The national targets for green hydrogen exports are aligned to a revised timeline, with the 2030 targets expected to be achieved by 2035. This is consistent with the current expected timeline for the common infrastructure development.



³ Source: MEMR projections received on 08/10/2025

Figure 6: Green H2 export potential⁴

In addition to the common assumptions shared between pathways, the Reference Pathway includes the following specific assumptions:

- **Electricity Sector Expansion:** targeting a 33% share of renewable electricity generation by 2030 and 40% by 2035. Deployment of battery storage sized at 0.25 MW per 1 MW of new VRE after 2030.
- **Energy Efficiency:** Continued implementation of existing energy efficiency measures across key sectors, without introducing additional ambitious interventions.
- **Transport Sector:** Ongoing execution of the national EV Strategy, along with a limited introduction of compressed natural gas (CNG) vehicles, primarily targeting heavy-duty transport.

Beyond the common assumptions with the Reference Pathway, the Optimistic Pathway outlines the following further measures and projections:

- **Electricity Sector Expansion:** A more ambitious renewable energy trajectory, aiming for at least 50% of electricity generation from renewable sources by 2033. Deployment of battery storage sized at 0.25 MW per 1 MW of new VRE after 2027.
- **Enhanced Energy Efficiency:** Implementation of more advanced energy efficiency measures, particularly in buildings and transportation, including further improvements in public transport systems.
- **Transport Sector Initiatives:** Increased deployment of EVs assuming that 60% of new car sales will be electric vehicles, along with the introduction of CNG vehicles, particularly for heavy-duty transport.
- **Public Transport Measures:** A set of national and local public transport initiatives such as the Amman Bus Second Phase, the Jordan urban local bus reform project in Irbid and Zarqa, and the Low-Carbon Municipal Fleets Program are expected to shift travel demand from private vehicles to public transport. These measures are projected to achieve a 10% reduction in private car passenger-kilometers (pkm) by 2030, increasing to 17.5% by 2035. (Source: Green Growth National Action Plan – Transportation sector).
- **Freight Rail Operations:** The Jordan National Railway Project (Phase 1) is expected to begin operations for freight transport in 2031, in alignment with the Long-Term National Transport Strategy for Jordan to 2030.

The comparison results of Reference and Optimistic Pathways are presented in the following graphs.

The primary factor influencing energy import dependency in both pathways is the projected use of domestic natural gas from the Risha field. While the Optimistic Pathway includes greater deployment of renewables, the reduction in import dependency is more limited because strong economic growth drives much higher overall energy consumption.

In the Reference Pathway, energy import dependency declines to 11% by 2035, while in the Optimistic Pathway it falls to 21% by 2035.

⁴ Source: Draft National Green Hydrogen Strategy for Jordan, Oct. 2023

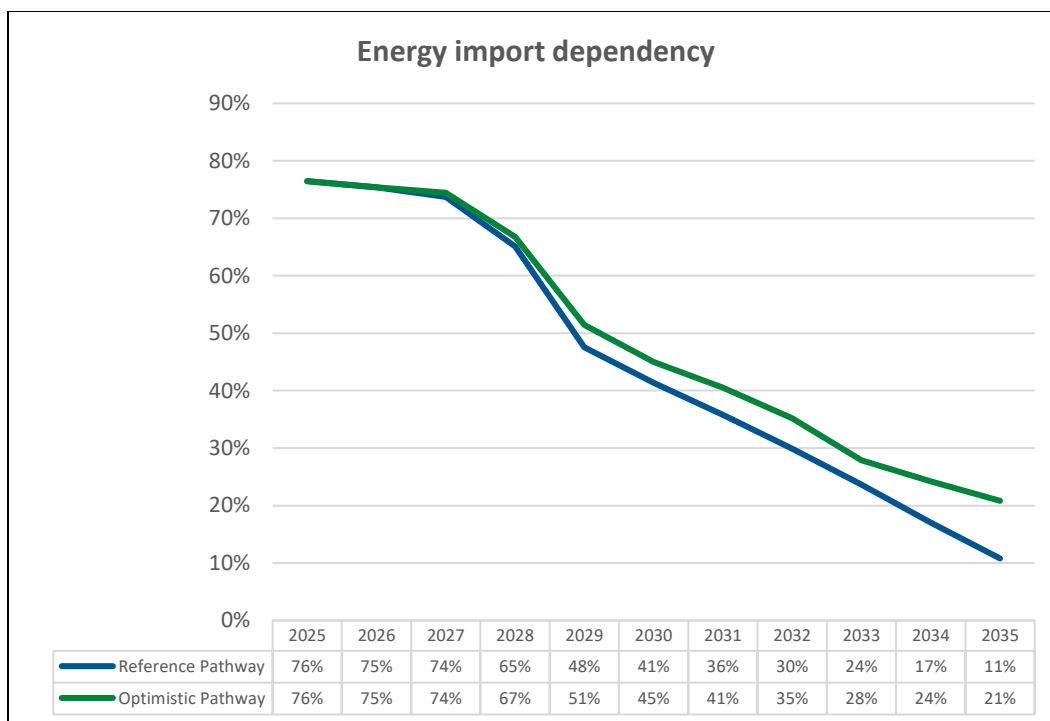


Figure 7: Energy import dependency in the period 2025-2035

The following graphs present **renewable electricity production, the share of electricity generation from renewables, primary energy generated from renewables, the share of renewables in the primary energy supply and the share of renewables in final energy consumption** for both pathways.

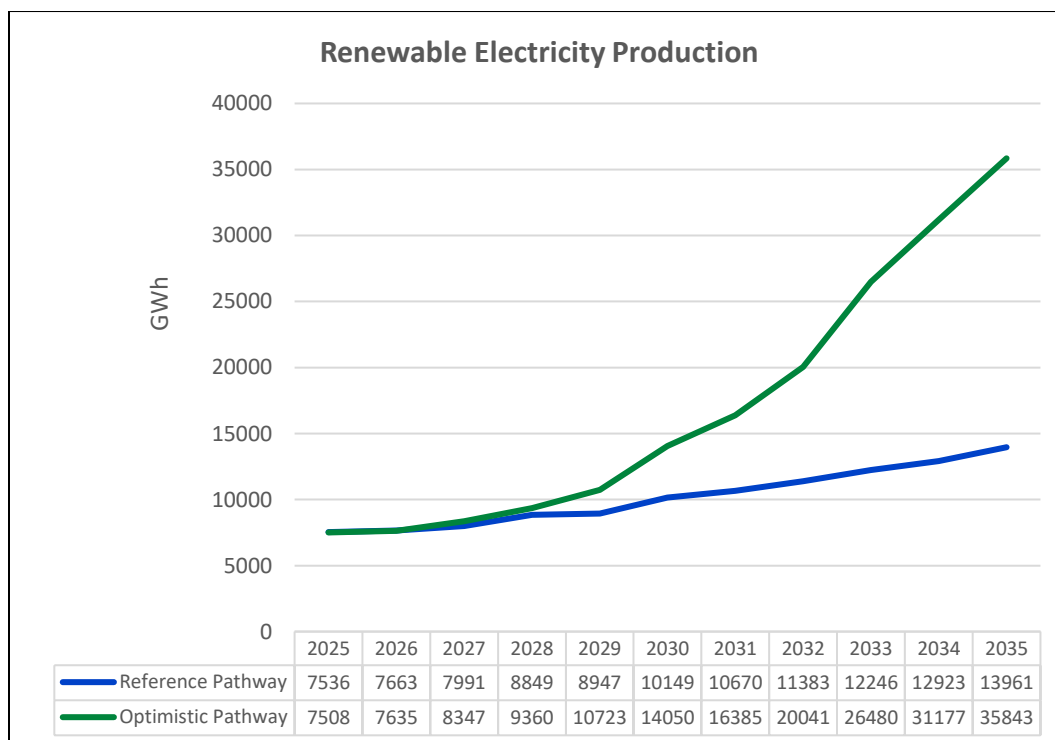


Figure 8: Renewable electricity production in the period 2025-2035

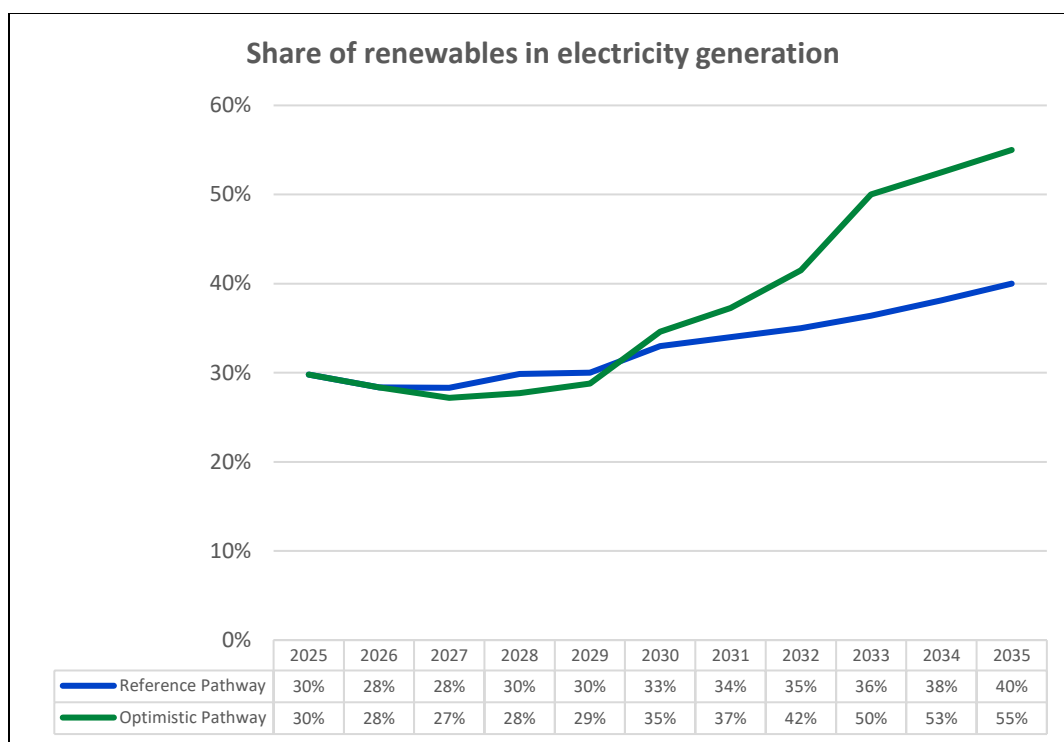


Figure 9: Share of electricity generation from renewables in the period 2025-2035

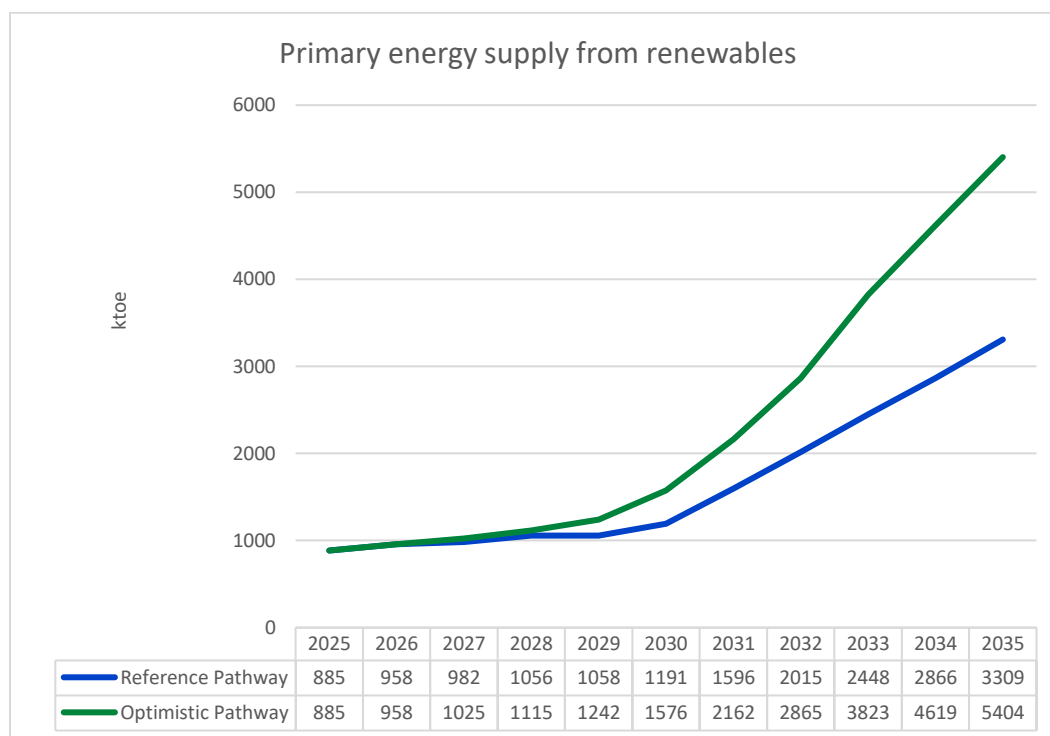


Figure 10: Primary energy supply from renewables in the period 2025-2035

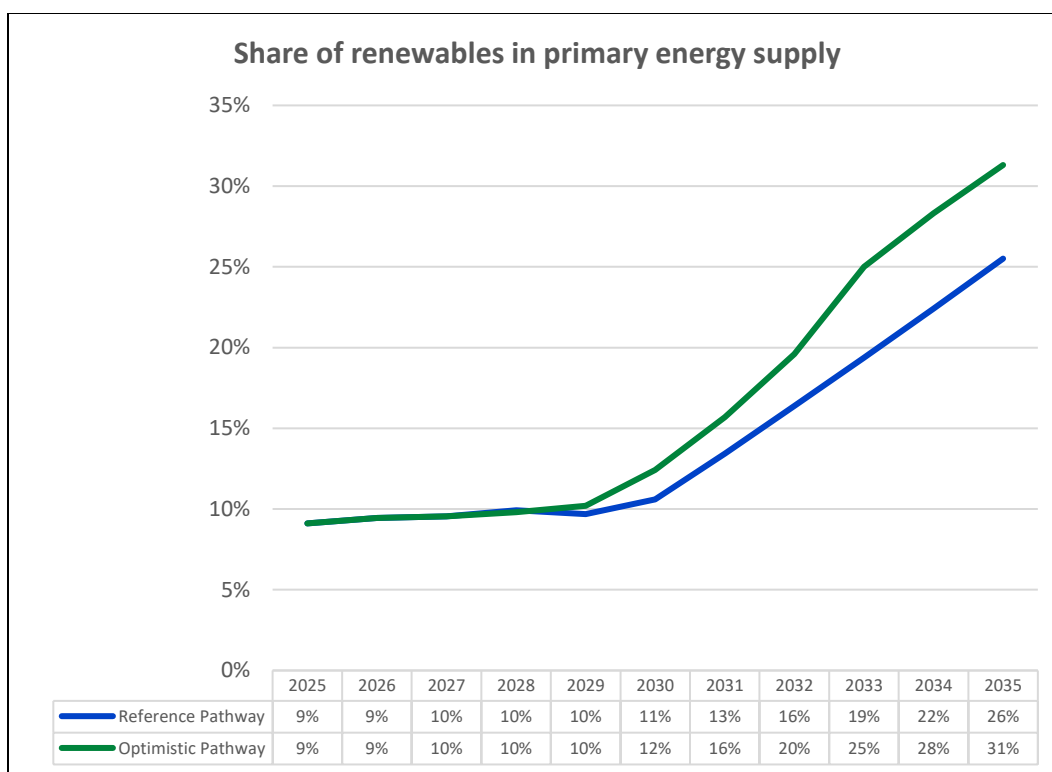


Figure 11: Share of primary energy supply from renewables in the period 2025-2035

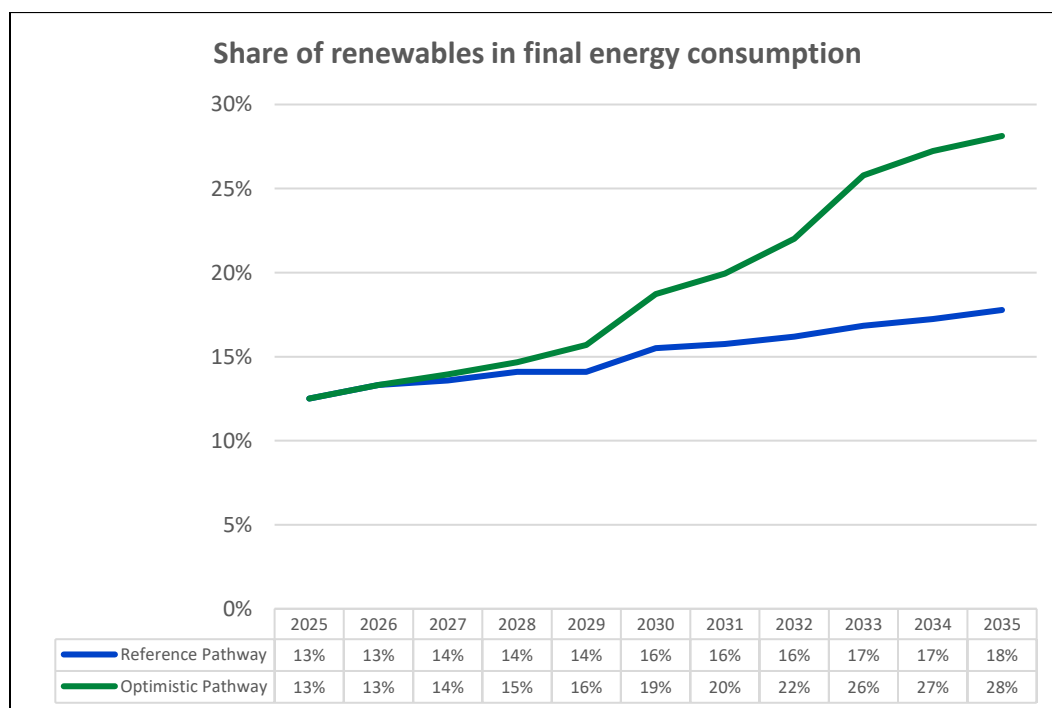


Figure 12: Share of renewables in final energy consumption in the period 2025-2035

Additional electricity generation is foreseen to supply **electrolysers for green hydrogen production**. This electricity will be sourced exclusively from renewable energy installations, primarily solar and wind that

are not connected to the national transmission grid. The projected volume of green hydrogen production is similar for both pathways, with slightly higher quantities in the Optimistic scenario that are used in the local industry.

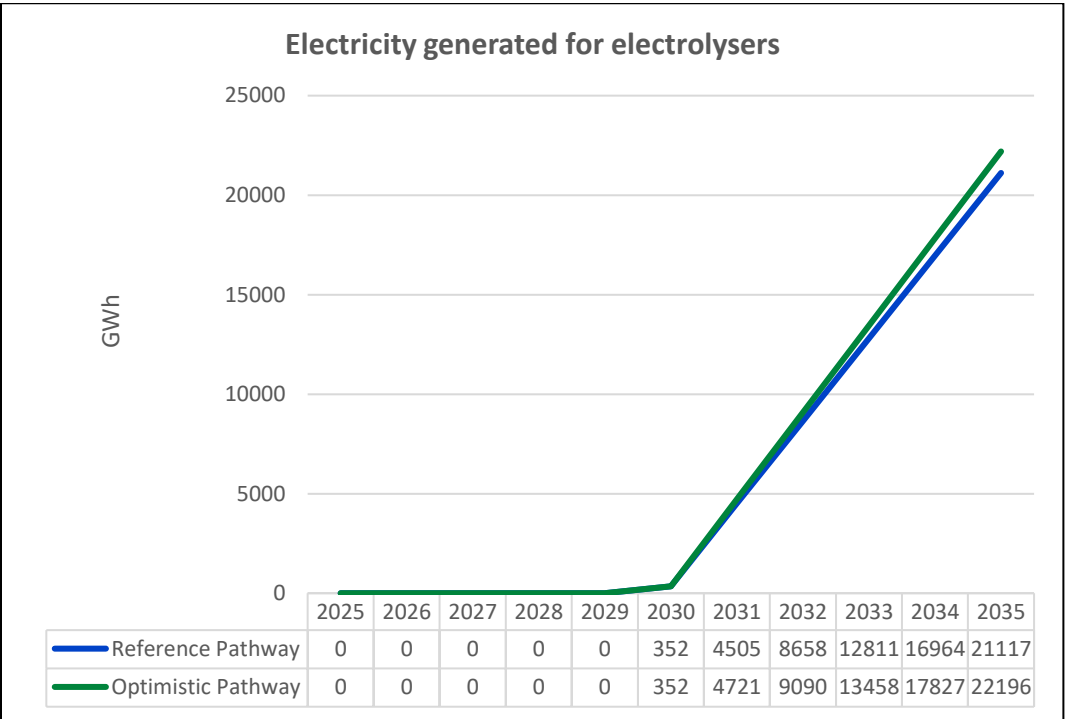


Figure 13: Electricity generated for electrolyzers in the period 2025-2035

The following graphs illustrate the required **overnight and total overnight investments in the power sector over the period 2025 - 2035**. Compared to the Reference Pathway, overnight investment costs in the power system are substantially higher under the Optimistic Pathway. This increase is primarily driven by higher electricity demand and a larger share of renewable generation, requiring greater deployment of renewable energy capacity as well as additional investments in storage systems to integrate the higher share of variable renewable sources.

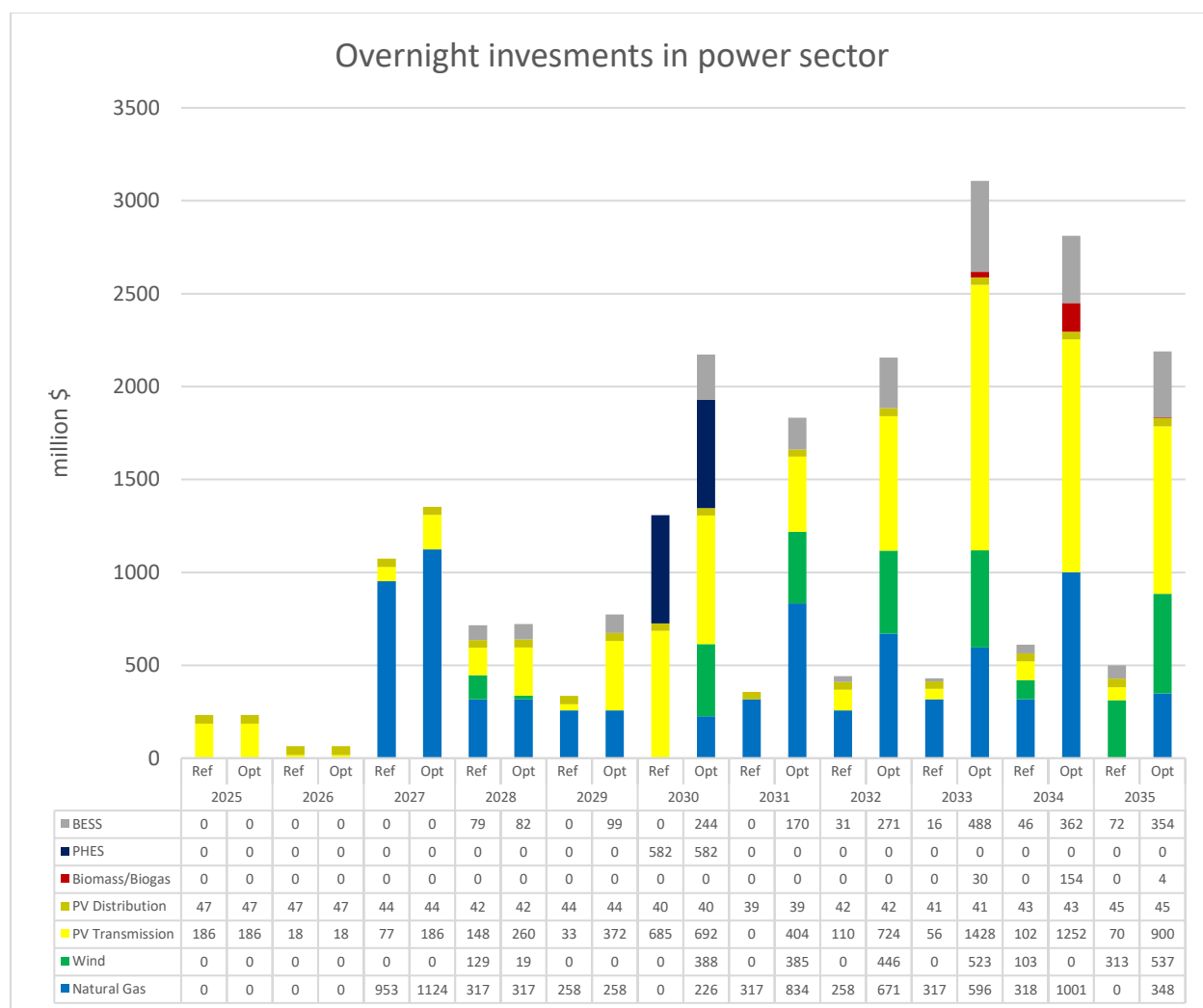


Figure 14: Overnight investment by generation type in the power system in the period 2025-2035 (Optimistic Pathway)

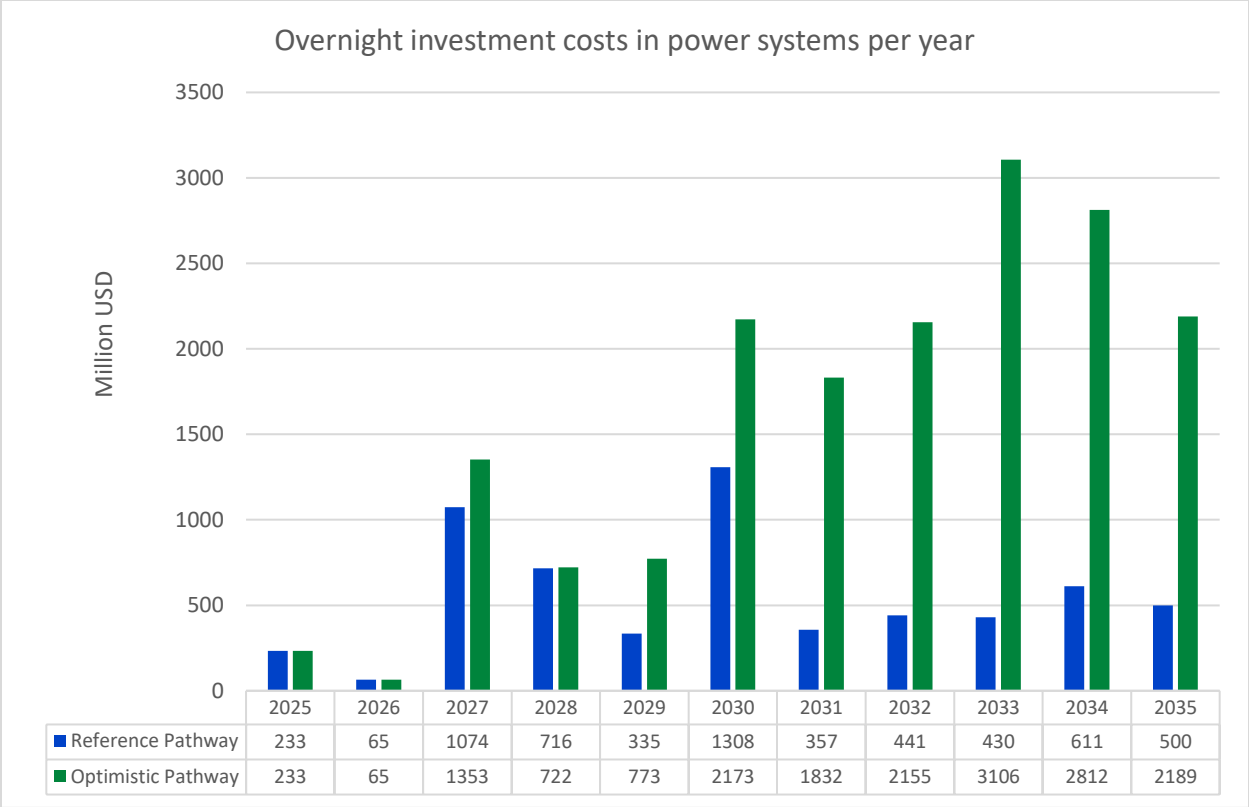


Figure 15: Overnight investment in the power system in the period 2025-2035

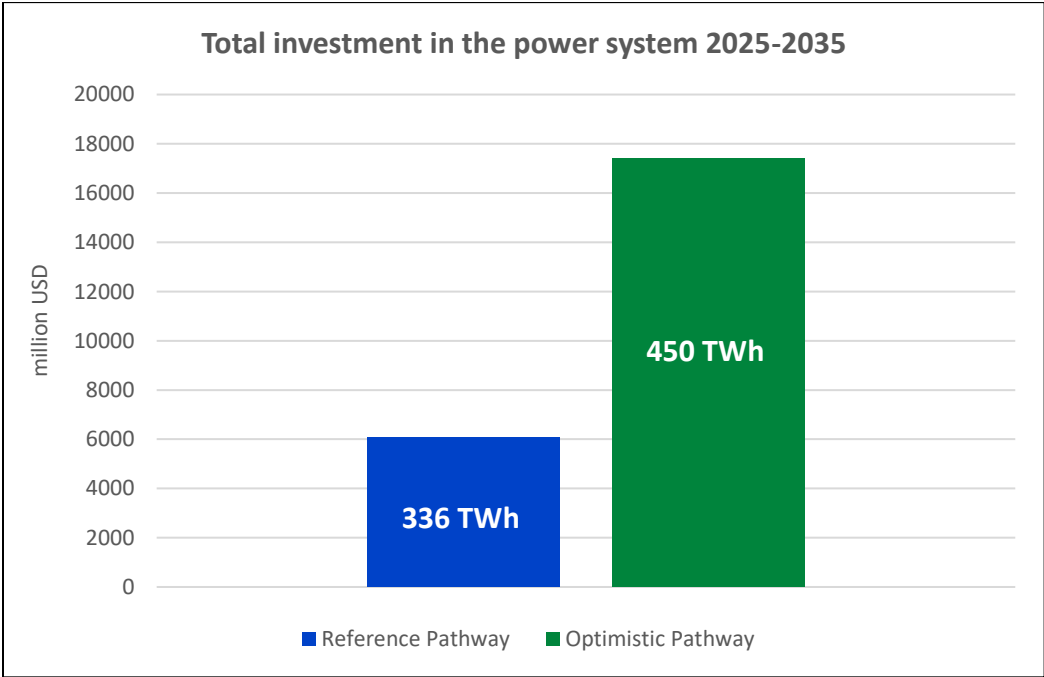


Figure 16: Total overnight investment costs in the power system in the period 2025-2035

Greenhouse gas emissions are expressed in CO₂ equivalent for both pathways and are presented in the following graph. In absolute terms (kilotons), greenhouse gas (GHG) emissions are higher in the Optimistic

Pathway, despite achieving 55% renewable electricity production by 2035 compared to 40% in the Reference Pathway, as a result of substantially greater energy demand.

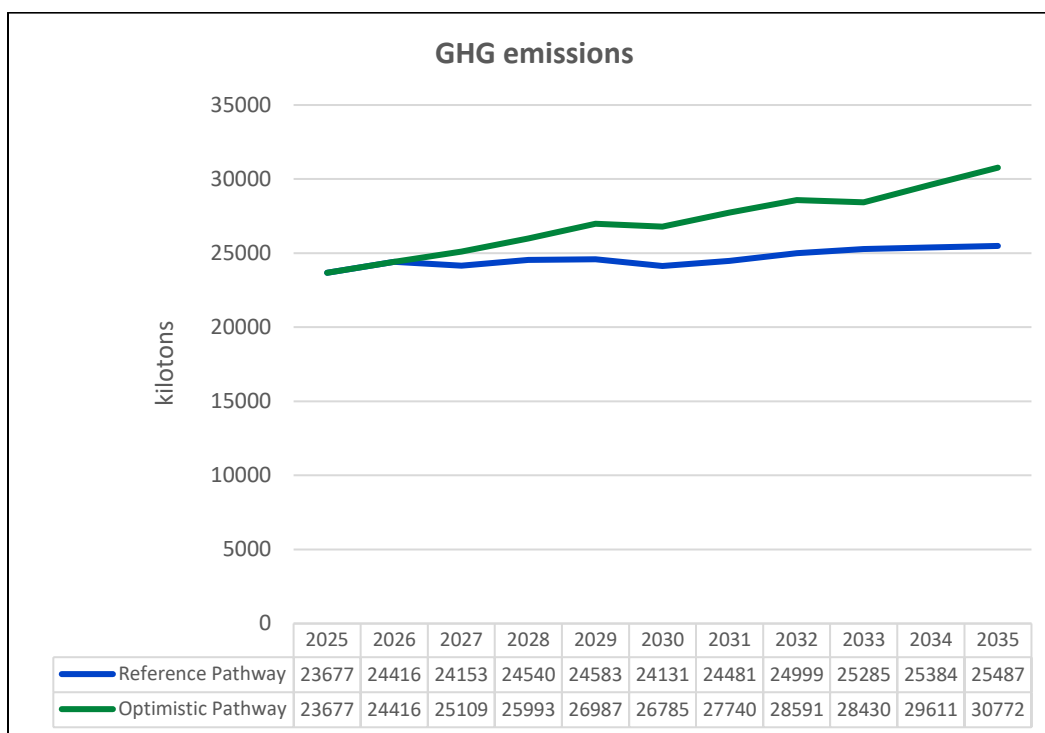


Figure 17: GHG emissions

Main energy policy conclusions for the Reference Pathway are defined for each sector.

Electricity Sector

- Future electricity generation is based on natural gas and renewables.
- Total RES capacity is projected to remain at around 3 GW in 2025, increase to 4.6 GW by 2030, and reach 5.6 GW by 2035.
- The battery storage project is expected to become operational in 2028 and PHES Mujib in 2030, both enhancing power system flexibility and supporting greater integration of renewable energy sources.
- The expansion of the generation and transmission network primarily follows the Electricity Sector Master Plan through 2030, with the power system assumed to continue operating under similar technical conditions.
- The final five years aim for 40% renewable electricity generation by 2035, which should be incorporated into the next Electricity Sector Master Plan revision, supported by comprehensive steady-state and dynamic studies.

Oil Sector

- Refinery update by 2030, with a target refining capacity of 73,000 barrels per day.

Natural Gas Sector

- Natural gas imports will continue under existing 'Take-or-Pay' contractual conditions until 2035.

- Exploitation of Risha gas field will provide domestic natural gas for electricity sector, industry and residential/commercial/services use.
- Gas pipeline connection of Risha gas field to Arab pipeline is expected to be in operation in 2029.
- The LNG import option will be retained to ensure security of supply.

Energy Demand Sector

- The industrial sector is expected to expand its use of natural gas as part of the shift toward cleaner energy sources.
- The use of natural gas in the residential and tertiary sectors is expected to expand, contributing to GHG emissions reduction through the replacement of oil products.
- AAWDCP is expected to become operational in 2030, with 240 MW of solar PV capacity envisaged as a wheeling project to supply its electricity needs.
- Continuation of energy efficiency measures to reduce energy consumption.
- Implementation of ToU tariffs to reduce electricity consumption in all sectors.
- Electricity demand from electric vehicles is expected to grow significantly, reflecting uptake aligned with a continuation of an ambitious EV strategy implementation.

Green Hydrogen Sector

- GH₂ production is expected to begin in 2030, with annual production gradually increasing in the following years.
- Electricity for electrolyzes will be supplied by dedicated solar and wind power plants that are not connected to the national transmission grid.
- The total renewable energy capacity required for GH₂ production is expected to reach 8.2 GW by 2035, comprising 7 GW of solar and 1.2 GW of wind installations.
- GH₂ production is predominantly projected for export.

Main energy policy conclusions for the Optimistic Pathway are defined for each sector.

Electricity Sector

- Future electricity generation is based on natural gas and renewables, with a significant increase in solar and wind contributions.
- The battery storage project is slated to start operation in 2028, with PHES Mujib following in 2030, both providing additional flexibility to the power system and enabling higher integration of renewable energy sources.
- Additional energy storage systems are required to ensure large integration of renewables.
- Total RES capacity is projected to remain at around 3 GW in 2025, rise to 5.6 GW by 2030, and reach as high as 13.9 GW by 2035.
- The power system is expected to face operational challenges related to balancing and stability, necessitating the deployment of additional assets such as power lines, energy storage systems and synchronous condensers to ensure an adequate level of security of supply.

- Revising the Electricity Sector Master Plan 2023–2035 is critical to ensure coherent transmission system development, as the pathways rely on markedly different economic drivers. Such a revision must be supported by rigorous steady-state and dynamic studies.
- High penetration of renewables, supported by energy storage systems, will significantly change operational conditions, potentially requiring updates to operational rules and procedures, which must be carefully addressed.

Oil Sector

- Refinery update is operational by 2030, with a target refining capacity of 73,000 barrels per day.

Natural Gas Sector

- Natural gas imports will continue under existing “take-or-pay” contractual conditions until 2035.
- Exploitation of Risha gas field will provide domestic natural gas for electricity sector, industry and residential use.
- Gas pipeline connection of Risha gas field to Arab pipeline is expected to be in operation in 2029.
- The LNG import option will be retained to ensure security of supply.

Energy Demand Sector

- The industrial sector is expected to increase its reliance on natural gas as part of the transition toward cleaner energy sources.
- The use of natural gas in the residential and tertiary sectors is expected to expand, contributing to GHG emissions reduction through the replacement of oil products.
- AAWDCP is expected to become operational in 2030, with 240 MW of solar PV capacity envisaged as a wheeling project to supply its electricity needs.
- Enhanced promotion of energy efficiency measures to reduce energy consumption.
- Implementation of Time of Use (ToU) tariffs to reduce electricity consumption in all sectors.
- A significant increase in electric vehicles is expected, along with the introduction of CNG vehicles for heavy-duty transport.

Green Hydrogen Sector

- GH₂ production is expected to begin in 2030, with annual production gradually increasing in the following years.
- Electricity for electrolyzes will be supplied by dedicated solar and wind power plants that are not connected to the national transmission grid.
- The total renewable energy capacity required for GH₂ production is expected to reach 8.6 GW by 2035, comprising 7 GW of solar and 1.6 GW of wind installations.
- GH₂ production is predominantly projected for export, with small quantities used in the local industry.

1.5 Overall Energy Policy Recommendations

Based on the analysis results across the examined Pathways, the following recommendations are identified as no-regret actions that remain advantageous under a range of possible developments in Jordan's energy sector.

- i. Future electricity generation up to 2035 is expected to rely on a combination of natural gas and renewable energy sources (RES). The integration of RES must be supported by energy storage systems such as pumped hydro energy storage (PHES) and battery energy storage systems (BESS) with the required capacity varying according to the selected pathway. The nuclear option is not anticipated before 2035, given the current immaturity of Small Modular Reactor (SMR) technology and its associated high costs.
- ii. To implement the renewable energy (RES) penetration targets in the power sector, the deployment of a Pumped Hydro Energy Storage (PHES) system becomes essential to provide the necessary flexibility to the power system. The requirement for energy storage is considerably higher under the Optimistic Pathway, driven by substantially greater electricity demand and increased integration of solar and wind power.
- iii. Strengthen the interconnectivity of the transmission system to enhance power system reliability through greater flexibility and to support expanded electricity trading opportunities.
- iv. The expansion of domestic natural gas production from the Risha gas field, coupled with the development of a pipeline connection to the Arab Gas Pipeline, is expected to significantly reduce energy import dependency and enhance overall energy sector security. Domestic natural gas production will progressively substitute imported gas currently secured under 'Take or Pay' contracts. LNG imports will remain an option to safeguard the security of supply.
- v. The use of natural gas will initially focus on the industrial sector and progressively expand to residential and commercial sectors, supported by the phased development of a natural gas distribution network.
- vi. Continued promotion of energy efficiency measures such as the utilization of solar energy for water heating in residential and commercial sectors, steam production in industrial installations, and the adoption of high-efficiency heat pumps for space heating and cooling in the tertiary sector to reduce overall energy consumption, combined with the implementation of ToU tariffs in all sectors.
- vii. Upgrade the oil refinery to increase production capacity and enhance storage facilities in line with international standards.
- viii. Ongoing promotion of electric mobility, alongside the introduction of CNG vehicles for the heavy-duty transport sector.
- ix. Improving public bus transport systems to reduce overall fuel consumption and promote more sustainable urban mobility.
- x. Proceed with freight rail operations to reduce road freight transport.
- xi. Start GH₂ production initially with a predominantly export orientation.
- xii. As the Jordanian power system moves toward 50% renewable production by 2033, operational conditions will be increasingly influenced by solar and wind generation,

potentially resulting in situations where 80–90% of electricity is produced from these sources. Therefore, it is strongly recommended that the implementation of 50% renewable pathways be accompanied by the following actions:

- Re-conduct comprehensive steady-state and dynamic studies to validate earlier findings and identify any additional measures needed to enhance overall system stability.
- Review and update the Electricity Sector Master Plan 2025–2035 considering the high renewable penetration targets.
- Explore opportunities to strengthen interconnections with neighboring countries to further improve system reliability and operational flexibility.

2 Situational Analysis and Strategic Framework

One of the innovative activities developed in this version of the Jordan Energy Sector Strategy (JESS) is the situational analysis of the national energy sector, aimed at defining the strategic pillars that will align the expectations and efforts of both the public and private sectors directly linked to this important industry. For this purpose, an analysis was conducted using one of the most widely applied tools in the strategic field: the SWOT analysis—Strengths, Weaknesses, Opportunities, and Threats. In this context, Strengths and Weaknesses correspond to the assessment of internal factors within the energy sector that could influence the implementation of any strategy, whereas Opportunities and Threats refer to external factors to the sector that may have a similar impact in the strategic domain. It is important to note that in all four areas of analysis, both international and national aspects are considered, with particular attention to the region in which the country’s energy development takes place. The next figure shows the contextual approach of the analysis performed.

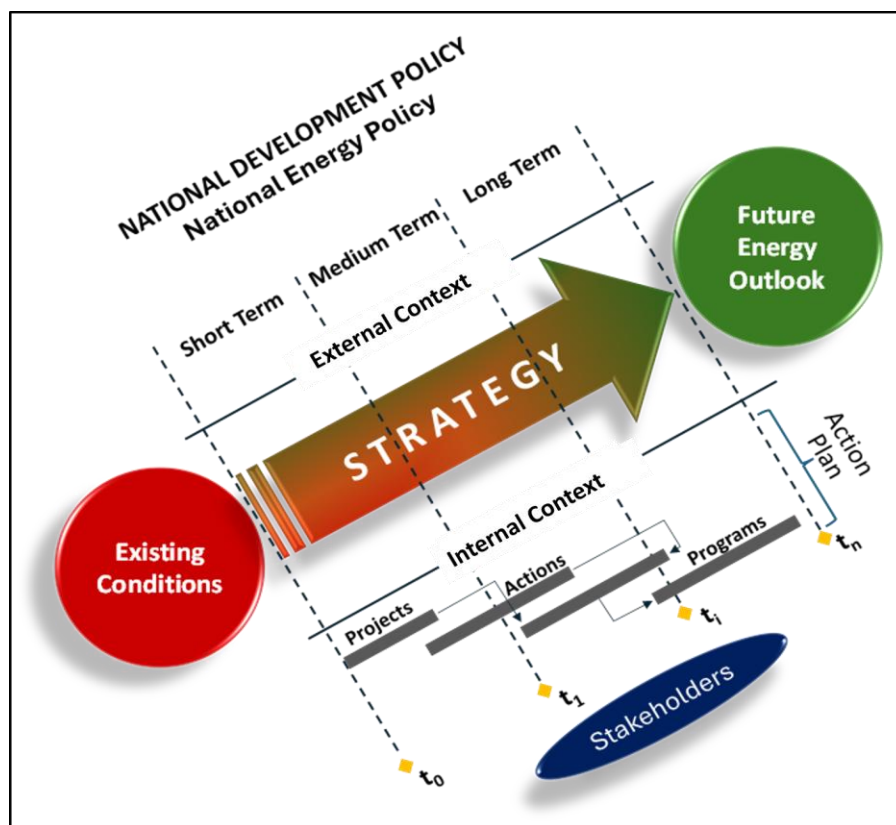


Figure 18: Strategic Framework

According to this framework, the purpose of the analysis is to define the strategy required to drive the transformation of Jordan’s energy sector from its current state to a future state as outlined in the national energy policy, in alignment with the country’s short-, medium-, and long-term development plans. The strategy, as conceived, must be operationalized by the entity responsible for steering national energy policy—the Ministry of Energy and Mineral Resources (MEMR). To this end, strategic axes have been defined to translate the overarching strategic objectives into practical terms, thereby enabling the precise identification of the set of strategic initiatives needed to achieve the intended goals.

The application of this methodology ensures a holistic view of the sector, enabling the identification of Jordan's strategic assets—such as its renewable energy potential—as well as the challenges linked to import dependency and regional geopolitical volatility. The SWOT approach served as the foundation for developing realistic and sustainable strategies aimed at strengthening the country's energy security and supporting its economic growth.

The SWOT analysis is a widely recognized strategic framework in energy planning (and in the public sector) due to its ability to synthesize internal and external factors that influence institutional performance. In the energy context, this approach makes it possible to identify, in an integrated manner, the sector's inherent strengths and weaknesses, as well as the external opportunities and threats that shape its development trajectory. By mapping these elements, the methodology facilitates informed decision-making, supports the prioritization of strategic actions, and ensures that policy directions are aligned with both national objectives and the dynamic conditions of the regional and global energy landscape, through:

- Identify internal strengths, such as available resources, institutional capacities, and technological advancements.
- Recognize structural weaknesses that hinder effective policy implementation.
- Detect emerging opportunities arising from global trends, technological innovations, or favorable regulatory frameworks.
- Assess threats, including geopolitical vulnerabilities, fiscal changes, and sector crises.

The selection of external factors was based on:

- Comprehensive document analysis, including the review of energy policies and global trends.
- Expert consultation through a survey directed at representatives from the MEMR, the private sector, and donor organizations, which enabled the validation of previously identified factors and the identification of new emerging variables

Although the consulting team had planned to conduct a thorough assessment of the internal perspective (strengths and weaknesses) following the recommendations outlined in the IRENA and World Bank Energy Sector Readiness Framework, time constraints and the inability to carry out detailed, focused interviews necessitated the design of a strategy that would allow for the indirect application of some of the methodology's recommendations. In this regard, the activities undertaken were:

- Review of previous strategies, institutional documents, and accumulated knowledge.
- Working meetings with key sector entities.
- Use of artificial intelligence tools to process large volumes of information and ensure a comprehensive evaluation.

The factors identified, both from the internal perspective (strengths and weaknesses) and the external perspective (opportunities and threats), were prioritized by the consulting team based on their strategic impact. From this process, a SWOT matrix was developed, whose cross-analysis enabled the formulation of specific strategies.

The use of the SWOT methodology has helped structure strategic thinking for the energy sector; however, it is important to acknowledge its limitations due to its static nature and the inherent risk of subjectivity

in the formulation of analysis elements by participants. To minimize these biases as much as possible, the consulting team combined the SWOT analysis with expert consultations, structured prioritization, and rigorous documentary support, thereby creating a hybrid approach aimed at making the analysis systematic, robust, and actionable.

2.1 Contextual Analysis

The PESTEL analysis was the tool used to identify and characterize both external and internal factors affecting the sector. Although its application is generally associated with the analysis of the external business environment, given that this is a public sector analysis, it was used in a mixed manner to identify factors impacting both the internal and external dimensions of the sector. The acronym refers to the identification of key factors across the Political, Economic, Social, Technological, Environmental, and Legal domains that could influence the country's energy development. This strategic analysis tool is widely used in both private and public sectors, and its implementation is considered more of an art than an exact science.

Due to the practical impossibility of conducting workshops with national energy sector experts, both inside and outside the MEMR, the methodological process employed in this study was carried out using a targeted survey technique directed at sector experts. To this end, the following activities were undertaken:

Data collection and cleansing: Inputs were gathered from official sources of the Government of Jordan, reports from multilateral organizations, previous studies of the national energy sector, earlier JESS reports, and interviews with key sector stakeholders.

- **Survey formulation:** Questionnaire was designed and sent to national energy sector stakeholders, including MEMR directors, private sector representatives, and donor organizations.
- **Internal analysis:** Assessment of strengths and weaknesses considering aspects such as existing infrastructure, generation capacity, source diversification, operational efficiency, and institutional framework.
- **External analysis:** Identification of opportunities and threats arising from variables such as international price volatility, global energy transition, regional cooperation, technological innovations, and regulatory changes.
- **Strategic synthesis:** Integration of results to define priority intervention areas, possible development scenarios, and energy policy recommendations

It is important to note that, since the survey allowed respondents to incorporate particular elements, they considered to have significant impact on the national energy sector and that may not have been included in the designed instrument, some of the identified factors corresponded more to the internal context than the external one, which enriched the analysis conducted.

As with the factors characterizing the external context, internal context factors were precisely and concretely drafted to clearly communicate the identified elements, facilitating their subsequent use in the cross-analysis and derivation of strategic axes.

Based on the information gathered from the surveys, a prioritization analysis was conducted to assess the importance of each element identified by participants within the energy sector context. On this basis, the

most relevant factors were drafted in a simple yet precise manner for later use in the cross-analysis of the SWOT matrix.

The most important identified factors are:

A. Political Factors

- i. Need for political stability in the entire region
- ii. Necessity to retain fruitful and smooth relationships with neighboring countries due to their dependence on energy imports
- iii. Regional tensions (Syria, Iraq, Lebanese-Israeli conflicts) that could disrupt gas and electricity flows, forcing the diversification of supply routes
- iv. National Energy Sovereignty: Reducing dependence on restrictive external financing and advancing domestic energy sources such as solar, wind, and green hydrogen
- v. Risk of Supply Cutoffs: Jordan's recent political history is defined by the severe consequences of energy supply disruptions, demonstrating that dependence on external pipelines represents an unacceptable political risk in the country's volatile location
- vi. Social License to Operate: The extent to which the government communicates the benefits of energy projects and secures community acceptance
- vii. Energy Security Governance: Assessing the reliability and diversification of energy sources to reduce reliance on imports
- viii. Inter-Ministerial Coordination: Effective collaboration among energy, environment, investment, and local government ministries to prevent procedural delays and accelerate implementation
- ix. Decisions on power generation technologies must be taken with proper systemic assessments considering their triggered impacts on infrastructure, costs and policy dependencies.

B. Economic Factors

- i. High national deficit and debts as a critical factor impacting the development of the national energy strategy
- ii. Need for a balanced budget due to the fuel subsidies provided by NEPCO for power generation to retain low electricity tariffs
- iii. Reciprocal relationship between energy projects and the broader economy, requiring low energy prices to sustain economic growth
- iv. Public Debt Burden: Government debt exceeds 92% of GDP and limits borrowing capacity for energy infrastructure
- v. Exposure to Oil Price Shocks: As a net importer, Jordan sees its fiscal and current account impacted when global crude oil prices rise unexpectedly
- vi. Global Supply Chain Disruptions: Delays and increased costs in project execution due to international supply chain volatility

- vii. Cost of Energy Production: Comparative assessment of production costs across various energy sources
- viii. Renewable Energy Finance Potential: Scaling up renewables to reduce import dependency, enhance energy security, and attract climate-related investments
- ix. FDI Volatility: The impact of fluctuating levels of foreign direct investment on the financing of major energy infrastructure
- x. Energy Market Demand: Analysis of current and projected energy demand trends across sectors
- xi. Technology Adoption and Localization Costs: Financial and technical challenges related to adopting renewable technologies and training a skilled local workforce
- xii. Financing Mechanisms and Incentives: Availability of investment financing, subsidies, and tax incentives for energy initiatives
- xiii. Private Sector Participation: The role of private investment in infrastructure development and technological innovation
- xiv. A Diversified Indigenous Energy Mix Anchored by Natural Gas: The national economic strategy must focus on expanding renewable energy, storage technologies and oil shale utilization, with immediate priority on accelerated development of the Risha gas field to reduce imports, increase GDP and secure a low-cost, reliable energy source
- xv. Transition to Natural Gas: Encouraging and incentivizing the industrial and transportation sectors to switch from imported petroleum derivatives to domestic natural gas will lower operational costs, reduce exposure to volatile oil prices and enhance competitiveness
- xvi. Resolving NEPCO's Debt: Implementing a sustainable solution to the massive debt accumulated by the National Electric Power Company will reduce costs, improve operational efficiency and strengthen financial viability.

C. Social Factors

- i. Most households have low income and are more vulnerable to the increase of energy prices
- ii. Electricity and fuel pricing is increasingly viewed as a socially sensitive issue that can affect public stability and perceptions of fairness
- iii. Urbanization and migration trends: A growing urban population (83% of total) and internal displacement are increasing the demand for reliable energy services in cities
- iv. Youth engagement and environmental activism: Rising participation of youth in climate and energy initiatives is accelerating the social acceptance of renewables and energy efficiency
- v. Digital Divide and Smart Grid Readiness: Gaps in digital access and skills may limit the deployment and use of smart meters, automation, and demand-side management technologies
- vi. Community Participation: Engagement of local communities in the planning and execution of energy projects to foster ownership and long-term support
- vii. Energy Equity: Ensuring the affordability of energy services across all socio-economic segments

- viii. Corporate Social Responsibility (CSR): Private sector support for energy access and compensatory initiatives for disadvantaged communities
- ix. Gender-Responsive Access: Mainstreaming gender considerations to empower women and promote inclusive energy access
- x. Stakeholder Engagement: Formal mechanisms for inclusive dialogue and participation in energy decision-making
- xi. Capacity Building and Education: Educational and training programs to enhance public awareness and technical expertise
- xii. Local Employment and Economic Development: Job creation and skills development linked to energy sector growth.

D. Technological Factors

- i. Advanced Demand Forecasting Tools: Strategic focus is placed on improving energy demand projections through enhanced modeling techniques and data accuracy
- ii. Smart-Grid Modernization (Dynamic Line Rating): Adoption of dynamic line rating and other smart-grid technologies enhance real-time monitoring and increase transmission capacity without new lines
- iii. Electric Vehicle (EV) Infrastructure Expansion: A 44% surge in EV registrations in 2023 has accelerated demand for nationwide charging networks and grid integration solutions
- iv. AI/ML-Driven Demand Forecasting: Recent studies demonstrate near-97% accuracy in next-hour demand forecasts using neural networks, enabling better load balancing and resource allocation
- v. IoT and Smart-Meter Roll-Out: Deployment of over 1.5 million smart meters by Itron enhances data collection, outage response times, and consumer engagement
- vi. Renewable-Powered Desalination Projects: Large-scale desalination plants powered by solar and wind require advanced control systems and robust cybersecurity to ensure reliable water and power supply
- vii. Distributed Energy Resource (DER) Integration: Smart system development to manage increased use of decentralized technologies such as home solar and battery storage
- viii. Technology Selection and Diversification: Evaluation of solar, wind, hydro, geothermal, and energy storage technologies for system viability
- ix. Advanced Energy Efficiency Technologies: Application of modern efficiency solutions across industrial, commercial, and residential sectors
- x. Smart Grid Implementation: Deployment of digital infrastructure to optimize electricity transmission, distribution, and consumption
- xi. R&D Capacity Enhancement: Strengthening domestic research capabilities to reduce technology imports and foster innovation
- xii. Innovation Partnerships: Investment in joint research and strategic collaboration with academic and private sector institutions

- xiii. Energy Efficiency and Demand Management: Technology-enabled solutions to reduce demand growth while maintaining service quality
- xiv. Gas Infrastructure as the Foundation for a Future Hydrogen Economy: Investing in a national gas pipeline network will create the backbone for transporting green and blue hydrogen in the coming decades
- xv. Virtual Pipeline Technology as an Agile Enabler for Fuel Switching: Deploying CNG and LNG virtual pipelines enables rapid delivery of Risha gas to industrial markets, accelerating displacement of expensive imported fuels before the main pipeline is completed

E. Environmental Factors

- i. Water Scarcity and Arid Conditions: Persistent drought and water shortages in Jordan pose major constraints on energy production, especially for thermal and water-intensive technologies
- ii. Efficient Water Resource Use in Energy Planning: Energy strategies must incorporate water-efficient technologies and prioritize low-consumption systems to address national water constraints
- iii. Desalination Integration: Solar- and gas-powered desalination is emerging as a strategic response to Jordan's water scarcity, requiring coordination with energy-sector development

F. Legal Factors

- iv. Need for Updated Environmental Legislation: New legal frameworks are required to manage the environmental risks associated with oil shale extraction and future nuclear energy development
- v. Water–Energy–Food Nexus Regulation: Mandatory targets in the 2015 Energy Efficiency and Renewable Energy Policy for the Water Sector require a 15% reduction in energy use for pumped water and a 10% increase in renewable share by 2030, shaping project design across sectors
- vi. Air-Quality Standards & Enforcement: Ambient air quality compliance dipped from 98.2% in 2021 to 96.4% in 2022, underlining the need to tighten emissions permits for power plants and dust-suppression requirements around solar farms
- vii. Biodiversity Impact Assessments: Desertification and endangered species habitats necessitate compulsory biodiversity surveys and habitat-offset requirements for large solar and wind farms under revised Environmental Protection Law guidelines
- viii. Mandatory Carbon Capture and Utilization (CCU) for CO₂-Emitting Projects: Establishment of a legal requirement for new energy and industrial projects to integrate carbon capture technologies and prioritize the conversion of captured CO₂ into valuable products, reframing emissions as a feedstock for a circular carbon economy.

It is worth mentioning that, although the analysis of internal factors was enriched with some contributions identified by respondents in the PESTEL analysis, a specific analysis was developed within the framework of the methodology supported by IRENA and the World Bank (Energy Sector Readiness Framework), which allowed for the identification of the main strengths and weaknesses of Jordan's energy sector that most impact strategy development.

As previously mentioned, this analysis was based on the review of prior strategies, institutional documents, and accumulated knowledge, meetings with representatives of key sector entities, and the use of artificial intelligence to process large volumes of information and ensure a thorough evaluation. This analysis enabled the direct identification of strengths and weaknesses, which were used for the formulation of the SWOT analysis presented below.

2.2 SWOT Analysis

Once the most relevant factors were identified, all analysis elements were formulated and classified within the categories of the SWOT matrix. The elements of the strategic analysis are presented below:

2.2.1 Strengths

- i. **Abundant Renewable Potential:** Jordan benefits from world-leading solar irradiance and designated wind corridors in southern and eastern regions, with renewables growing from 20% of generation in 2020 to nearly 27% by 2024 and a target of 50% by 2033.
- ii. **Diversified Energy Mix & Infrastructure:** Integration of LNG imports, solar, wind, and oil shale, combined with grid capacity expansion from 2,000 MW in 2005 to over 5,424 MW in 2020, reduces single-source dependency and enhances reliability.
- iii. **Regional Hub Potential:** Transmission interconnections with Egypt, Syria, Lebanon, and Palestine bolster security and export capacity, while planned routes like the Basra–Aqaba oil pipeline further diversify supply.
- iv. **Mature Regulatory & Investment Framework:** A robust IPP model, PPAs, net metering, wheeling policies, and clear licensing procedures under the 2012 Renewable Energy and Energy Efficiency Law attract local and foreign investment.
- v. **Human Capital & R&D Capacity:** Strong expertise within MEMR, NEPCO, and EMRC, supported by graduate programs and active research centers, ensures skilled workforce and innovation, with adequate funding for applied research.
- vi. **Clear Long-Term Strategy:** The National Energy Strategy 2020–2030 provides policy stability and ambitious targets for energy independence and renewable deployment.
- vii. **Risha Gas Field Prospects:** Domestic gas from the Risha field, projected to reach 150 MMSCFD by 2029 and 430 MMSCFD by 2034, offers a pathway to reduce import reliance and stabilize wholesale gas prices.
- viii. **Integrated Water-Energy Solutions:** Pilot projects in renewable-powered desalination and water–energy–food nexus regulation demonstrates innovative approaches to address chronic water scarcity.

2.2.2 Weaknesses

- i. **High Import Dependency:** Over 90% of primary energy is imported, representing 8–10% of GDP and exposing Jordan to global price volatility and geopolitical disruptions.

- ii. **Grid and Integration Constraints:** Limited transmission and distribution capacity cause renewable curtailments, while slow smart grid and demand-response rollout hampers system flexibility.
- iii. **Financial Strains & Debt Burden:** NEPCO's accumulated debt from subsidized tariffs and long-term LNG contracts burdens public finances and restricts sector investment.
- iv. **Regulatory & Policy Gaps:** Absence of dedicated frameworks and slow permitting for green hydrogen, power-to-X, large-scale storage, and desalination integration deter emerging technologies.
- v. **Water Scarcity Constraints:** Chronic drought and limited water resources restrict water-intensive energy projects, such as hydrogen production, solar cooling, and large desalination plants.
- vi. **Insufficient Storage & Demand-Side Management:** Limited energy storage infrastructure and nascent demand-response programs reduce the grid's ability to balance variable generation.
- vii. **Transport Sector Reliance:** High dependence on imported petroleum derivatives for transport, which accounts for nearly 50% of final energy demand, and low EV uptake impedes decarbonization.
- viii. **Sectoral Energy Intensity:** Industrial and agricultural sectors, including cement, phosphates, and pumped irrigation, consume high energy shares with limited efficiency and recovery measures.
- ix. **Tariff & Subsidy Challenges:** Electricity pricing structures and heavy subsidies for households and agriculture strain public finances and fail to incentivize efficient consumption.
- x. **Human Capital Shortages:** Gaps in deep technical knowledge of emerging renewable technologies and lack of professional certification for RE engineers' limit capacity to deploy and maintain advanced systems.
- xi. **Market Scale Limitations:** Jordan's small domestic market size constrains economies of scale for local RE manufacturing and limits commercial viability of certain technologies.

2.2.3 Opportunities and Threats

For the case of Threats and Opportunities, the identified factors were grouped, as much as possible and when deemed necessary, to simplify the cross-analysis and the definition of strategic axes. An additional assessment of their impact on the sector was also conducted for this grouping, discarding factors that, although important, did not have a significant impact on the sector's development.

Table 2: Opportunities and Threats

PESTEL Category	Factor	Opportunity / Threat	Impact
Political	Commitment of government to renewables (strategy 2020–2030)	Opportunity: Leverage clear policy signals to attract long-term green-energy partnerships (e.g. EU “Green Corridor”).	High
Political	Regional tensions & supply-cutoff risk	Threat: Geopolitical instability in neighboring states could abruptly disrupt fuel and power imports.	High
Economic	High import dependency & oil-price volatility	Threat: Global fuel-price shocks strain public budget and project viability—undermining tariff stability.	High
Economic	Renewable-energy finance potential & investor incentives	Opportunity: Expand climate-finance deals and green-bond issuances to fund large-scale solar, wind and green H ₂ projects.	High
Economic	NEPCO debt burden and subsidy structure	Threat: Heavy utility debt and subsidy obligations reduce fiscal space for new investments in clean technologies.	Medium
Social	Growing public & youth support for renewables	Opportunity: Mobilize social license and community co-investment in distributed solar, storage and efficiency programs.	Medium
Social	Digital divide & limited smart-grid readiness	Threat: Lack of connectivity and skills impedes demand-response rollout, slowing flexible load management.	Medium
Technological	Advanced grid capacity & smart-grid modernization plans	Opportunity: Implement dynamic line rating and digital grid controls to integrate higher shares of variable renewables.	High
Technological	Lack of storage & demand-side management	Threat: Insufficient storage and DR systems limit peak-shaving	High

		and flexibility, increasing risk of curtailment.	
Environmental	Abundant solar & wind resources	Opportunity: Export surplus green power to neighbors or Europe via planned interconnections, generating new revenue.	High
Environmental	Water scarcity & nexus pressures	Threat: Chronic water shortages constrain water-intensive projects (e.g., CSP, hydrogen, desalination) without storage.	Medium
Legal	Mature IPP/PPA framework & clear licensing	Opportunity: Streamline a “one-stop shop” for permits to accelerate project approvals and reduce investor risk.	Medium
Legal	Regulatory gaps for emerging tech (H ₂ , PtX, storage)	Threat: Slow or absent regulations for novel technologies hinder pilot scale-up and commercial deployment.	High

Below is a strategic analysis of the Jordan energy sector using the SWOT matrix, which cross-examines Strengths (S), Weaknesses (W), Opportunities (O), and Threats (T) to derive actionable strategies. The analysis is organized into four categories:

- Expansion Strategies (S+O): Leverage strengths to capitalize on opportunities.
- Protection Strategies (S+T): Use strengths to mitigate threats.
- Reorientation Strategies (W+O): Address weaknesses to exploit opportunities.
- Resilience Strategies (W+T): Minimize risks in critical scenarios.

SWOT Matrix Cross Analysis

Below is the result of the cross-analysis, presenting the considered elements, the proposed strategy, and the anticipated impact on the sector’s strategy.

Table 3: Results of the cross-analysis

CATEGORY	FODA COMBINATION	PROPOSED STRATEGY	IMPACT
Expansion (S+O)	Abundant solar/wind (S) + EU green corridor demand (O)	Develop large-scale solar/wind farms with export contracts to Europe via interconnections	High
	Mature IPP framework (S) + green finance potential (O)	Attract private investors for renewable projects through sovereign green bonds and climate-finance partnerships.	High
	Regional hub potential (S) + smart-grid modernization (O)	Upgrade grid infrastructure to enable cross-border energy trading and dynamic load management	Medium
Protection (S+T)	Diversified energy mix (S) + geopolitical instability (T)	Strengthening energy security by accelerating domestic gas (Risha field) and renewable deployment.	High
	Clear long-term strategy (S) + NEPCO debt burden (T)	Reform subsidy structures and introduce cost-reflective tariffs to reduce fiscal strain	High
	Human capital (S) + digital divide (T)	Launch training programs for smart-grid technologies to bridge the skills gap	Medium
Reorientation (W+O)	High import dependency (W) + renewable finance (O)	Secure concessional loans to fund local renewable manufacturing, reducing import reliance	High
	Grid constraints (W) + advanced grid tech (O)	Partner with tech firms to pilot battery storage and demand-response systems	High

Resilience (W+T)	Water scarcity (W) + water-energy nexus (O)	Scale up renewable- powered desalination projects with international funding	Medium
	Tariff subsidies (W) + oil-price volatility (T)	Phase out subsidies gradually while implementing social safeguards for vulnerable groups	High
	Lack of storage (W) + regulatory gaps (T)	Fast-track regulatory approvals for storage pilots to prevent renewable curtailment	High
	Small market size (W) + regional tensions (T)	Diversify export markets for renewable energy to reduce dependence on unstable neighbors	Medium

2.3 Strategic Axes

The strategy for the development of Jordan's energy sector is based on a rigorous SWOT analysis, which has enabled the precise identification of critical challenges and strategic opportunities to consolidate a sustainable and competitive energy sector. This analytical process led to the definition of seven strategic axes, carefully designed to guide the Ministry of Energy and Mineral Resources (MEMR) in implementing the national strategy.

These pillars address both the structural and situational challenges of the sector as well as emerging opportunities within the global energy transition context, promoting sustainability, technological innovation, energy security, and resilience. Through coordinated planning, efficient execution, and a results-based approach, these lines of action will position Jordan as a benchmark in energy development, aligned with national goals of economic growth, social inclusion, and environmental protection.

The strategic pillars represent priority action lines guiding the implementation of Jordan's energy sector strategy. Inspired by the strategic themes proposed by Norton and Kaplan within the Balanced Scorecard framework, they represent focal areas that integrate specific, measurable objectives aligned with the sector's strategic vision. Each pillar addresses a key dimension of energy development, including environmental sustainability, operational efficiency optimization, adoption of innovative technologies, governance strengthening, and enhancement of economic competitiveness.

This structure allows for translating SWOT analysis findings into concrete initiatives, ensuring a holistic approach that balances the internal needs of MEMR with the dynamics and demands of the global environment. Furthermore, the strategic pillars facilitate inter-institutional coordination, efficient resource allocation, and continuous monitoring of progress toward established objectives, ensuring effective and transparent management of the sectoral strategy.

To ensure the successful implementation of this strategy, it is recommended that the entity responsible for energy sector planning develop a management tool based on Norton and Kaplan's Balanced Scorecard. This tool could be complemented by the creation of a Strategic Map for Jordan's Energy Sector, which will visually and clearly articulate the objectives, indicators, and targets of the seven strategic pillars.

The strategic map will serve as a communication and alignment instrument, enabling the sector's vision to be shared at all levels within MEMR and with key stakeholders, including strategic partners, government institutions, investors, and civil society. This approach will strengthen coherence in strategy execution, promote accountability and cross-sector collaboration, maximize the impact of proposed initiatives, and ensure the achievement of Jordan's energy development objectives.

Below are the seven identified strategic axes:

I. ENERGY SECURITY, EFFICIENCY & SUPPLY DIVERSIFICATION

Purpose: Ensure the long-term availability, resilience, and sustainability of energy supply by combining diversified domestic production, regional integration, and enhanced energy efficiency across all sectors.

Scope: Expansion of renewable energy (solar, wind), development of the Risha gas field, oil shale utilization, enhancement of regional interconnections, cross-cutting enhancement of EE across the industrial, residential, commercial, institutional, and agricultural sectors, leveraging regulatory frameworks and implementation tools

Orientation: National sovereignty, reduced import dependency, and resilience against geopolitical shocks.

Key Stakeholders: MEMR, NEPCO, NPC, regional energy ministries.

II. SUSTAINABLE AND INCLUSIVE ENERGY TRANSITION

Purpose: Accelerate the shift to low-carbon energy systems while ensuring social equity and environmental integrity.

Scope: Decarbonization of the energy matrix, integration of green hydrogen, renewable-powered desalination, and phasing out of fossil fuel subsidies with social safeguards.

Orientation: Climate commitments (NDCs), social protection for vulnerable populations, water-energy nexus.

Key Stakeholders: MEMR, MoEnv, Ministry of Social Development, Donors (EU, GCF, GIZ).

III. GRID MODERNIZATION AND SYSTEM FLEXIBILITY

Purpose: Build a smart, adaptive and robust power system capable of integrating high shares of renewable energy.

Scope: Smart grid deployment, battery storage pilots, demand-side management, digital substations, dynamic line rating.

Orientation: Reliability, curtailment reduction, load balancing, and energy efficiency.

Key Stakeholders: NEPCO, EMRC, private tech companies, universities.

IV. MARKET LIBERALIZATION AND FINANCIAL SUSTAINABILITY

Purpose: Reform the energy market structure to promote transparency, attract investment and reduce fiscal burdens.

Scope: Tariff reform, debt restructuring of NEPCO, cost-reflective pricing, green finance mobilization (sovereign green bonds).

Orientation: Investment attractiveness, NEPCO viability, long-term affordability.

Key Stakeholders: Ministry of Finance, EMRC, private sector, multilateral banks (World Bank, EIB, AFD).

V. HUMAN CAPITAL AND INNOVATION ECOSYSTEM

Purpose: Strengthen institutional, technical, scientific, and data-driven capacities to support the energy transition, technological innovation, and evidence-based decision-making.

Scope: Technical training for smart grids, R&D in hydrogen and storage, RE certification schemes, university-industry partnerships, and integration of data-driven approaches within the national energy strategy to enhance public policy development and strategic decision-making.

Orientation: Workforce readiness, local innovation, knowledge-based and data-informed economy.

Key Stakeholders: MEMR, universities, vocational centers, international cooperation agencies, national data and digital transformation bodies.

VI. REGIONAL LEADERSHIP AND ENERGY DIPLOMACY

Purpose: Position Jordan as a regional hub for clean energy production, transit, and trade.

Scope: Cross-border energy trading, power-to-X exports (e-fuels), regional interconnectors, green corridors with EU and GCC.

Orientation: Economic diplomacy, export diversification, strategic alliances.

Key Stakeholders: MEMR, NEPCO, Ministry of Foreign Affairs, regional partners, EU.

VII. INSTITUTIONAL COORDINATION AND REGULATORY MODERNIZATION

Purpose: Strengthen governance and streamline regulatory processes to accelerate project implementation.

Scope: Harmonized licensing procedures, land use planning, fast-tracking permits for emerging technologies, multisectoral alignment.

Orientation: Procedural efficiency, investment facilitation, regulatory clarity.

Key Stakeholders: EMRC, MoEnv, MEMR, Ministry of Planning, local governments.

2.4 Strategic Roadmap

The proposed Strategic Roadmap defines twelve strategic actions that together provide a coherent roadmap to advance Jordan's energy transition, strengthen system reliability, and enhance regional integration. Each action includes its main activities, indicative duration, performance indicators, key institutional responsibilities, partners, and enabling conditions.

I. Development of Large-Scale Solar and Wind Farms with Export Contracts to Europe and Pan-Arab Region

Jordan will carry out feasibility studies in selected high-potential zones, tender Independent Power Producer (IPP) projects, and sign long-term Power Purchase Agreements (PPAs) with European and Arab partners. The plan also includes the development of regional grid interconnections to enable electricity export. This action will span approximately 5 to 8 years, with progress measured by the capacity installed (MW), number of PPAs signed, and total exported energy (GWh/year).

Main responsibility: MEMR, supported by NEPCO, the European Commission, GCC and private developers.

Prerequisites: Grid capacity upgrades, clear land allocation, and an updated regulatory framework for cross-border trading.

II. Attraction of Private Investors through Sovereign Green Bonds

The Ministry of Finance, in coordination with MEMR and the Central Bank, will issue sovereign green bonds to mobilize capital for renewable and energy efficiency projects. Complementary activities include investment forums and credit enhancement mechanisms to reduce investor risk. This action, estimated to be over 2 to 4 years, will be measured by the total bond issuance (US\$) and private investment attracted.

Key partners: MDBs such as the World Bank, EBRD, and the Green Climate Fund.

Prerequisites: Credit rating stability and a strong legal framework for green bond issuance.

III. Upgrading Grid Infrastructure

To support renewable integration, NEPCO will implement smart-grid pilot projects, expand interconnections, and install SCADA and Dynamic Line Rating (DLR) systems. The initiative, spanning 5 to 7 years, aims to increase interconnector capacity, reduce grid losses, and enable real-time system management.

Key partners: EMRC, the Arab Fund, and major technology providers such as Siemens and ABB.

Prerequisites: A comprehensive grid master plan and secured financing.

IV. Strengthening Energy Security through Domestic Gas and Renewables

This action targets the enhancement of energy self-sufficiency by developing upstream facilities in the Risha gas field and expanding renewable generation. Simplified licensing procedures will accelerate private participation. Over 4 to 6 years, the plan seeks measurable increases in domestic generation capacity and gas output, alongside a reduction in energy imports.

Main responsibility: National Petroleum Company (NPC), in partnership with MEMR and private operators.

Prerequisites: Updated upstream regulations and development financing.

V. Reforming Subsidy Structures and Implementing Cost-Reflective Tariffs

NEPCO will lead the design of a gradual tariff reform supported by public consultation and improved digital billing systems. Over a 2 to 4-year horizon, the reform will aim to reach cost-reflective tariffs while ensuring affordability through targeted social measures.

Key partners: EMRC, Ministry of Social Development, IMF, and World Bank.

Prerequisites: Political consensus and a supportive legal framework.

VI. Launch of Training Programs for Smart-Grid Technologies

NEPCO, in coordination with EMRC and national universities, will develop and deliver certification programs focused on smart-grid technologies and renewable integration. Over a 1 to 3-year period, the goal is to build a skilled workforce, measured by the number of certified professionals and training completion rates.

Partners: Donors

Prerequisites: Institutional partnerships and training infrastructure.

VII. Securing Concessional Loans for Local Renewable Manufacturing

JEDCO (Jordan Enterprise Development Corporation) will establish mechanisms to secure concessional financing and incentives to promote local renewable energy manufacturing. This 3 to 5-year action seeks to increase local content and establish manufacturing facilities for components such as solar panels, batteries, and cables.

Key partners: MEMR, UNIDO, and international technology firms from the EU, USA and China.

Prerequisites: Investment framework, incentive policy, and loan agreements.

VIII. Piloting Battery Storage and Demand-Response Systems

To improve grid flexibility, NEPCO will identify pilot sites and deploy utility-scale battery systems while launching demand-response trials with selected consumers. The 2 to 4-year initiative will be evaluated based on installed storage capacity (MWh) and renewable curtailment reduction.

Partners: EMRC, BESS manufacturers, and international donors.

Prerequisites: Regulatory approval for pilot programs and secured financing.

IX. Scaling Renewable-Powered Desalination Projects

The Ministry of Water and Irrigation will lead the design and execution of desalination plants powered by renewable sources. Over 3 to 6 years, the program aims to diversify water supply and enhance energy–water nexus resilience.

Partners: MEMR and the EU.

Prerequisites: Feasibility studies, environmental permits, and financing arrangements.

X. Phasing Out Subsidies with Social Safeguards

The Ministry of Social Development, in coordination with the Ministry of Finance and NEPCO, will implement a gradual phase-out of subsidies accompanied by a robust social protection mechanism. This 2 to 4-year program will leverage digital identity systems to ensure equitable support to vulnerable households.

KPI: Reduction in subsidies, number of households supported, and public acceptance rate.

Prerequisites: Functional social protection systems and stakeholder engagement.

XI. Fast-Tracking Regulatory Approvals for Storage Pilots

EMRC will establish an inter-ministerial task force to streamline the approval process for storage-related projects. Temporary regulations will be issued to enable timely pilot implementation. The 1 to 2-year measure aims to reduce the time required for regulatory approval and accelerate deployment.

Partners: MEMR, MoEnv, and private developers.

Prerequisites: Institutional coordination and legal provisions for pilot regulation.

XII. Diversification of Export Markets for Renewable Energy

MEMR will pursue new export opportunities through bilateral negotiations, memoranda of understanding, and joint infrastructure development. This 4 to 7-year initiative seeks to strengthen Jordan's position as a regional renewable energy hub, expanding exports to the EU and GCC markets.

Partners: NEPCO, the GCC Interconnection Authority, EU institutions, and the EIB.

Prerequisites: Bilateral agreements, financing, and regulatory harmonization.

3 Status and prospects of the energy sector in Jordan

3.1 Introduction

Over the past two decades, Jordan's energy sector has undergone a fundamental transformation driven by a combination of necessity, opportunity, and long-term strategic planning. The Kingdom's heavy reliance on energy imports, almost 95% of total primary energy supply ten years ago, made its economy vulnerable to global fuel price fluctuations and regional supply disruptions. In response, Jordan launched a series of ambitious reforms and investments aimed at diversifying its energy mix, improving energy efficiency, and enhancing the security and sustainability of its energy system.

A central feature of Jordan's transition has been the accelerated deployment of renewable energy. The significant solar and wind potential and clear regulatory frameworks led to an increase of the installed renewable capacity from near insignificance in 2010 to around 2.4 GW by 2023. This transformation is underpinned by policies enabling power purchase agreements, net metering, and wheeling arrangements.

3.2 Main characteristics of the energy sector

The current chapter presents all the significant elements, which contribute to the formulation of the socio-economic and energy context of Jordan. Moreover, statistical indicators are analyzed to facilitate both the development of the energy scenarios and the analysis of the results obtained. The analysis in the current section was based on the statistical data published by MEMR.

3.2.1 Socio-economic context

The increase of the population in the period 2010-2023 accounts to 72% (Figure 18). More specifically, the total population in 2023 was equal to 11.5 million inhabitants, while the average increase rate over the period was 6% on annual basis. Nevertheless, different population growth rates were identified in the periods 2010-2012, 2012-2018 and 2018-2023 (5%, 7% and 2% correspondingly). Until 2018, the increased growth rate was mainly due to the massive arrival of the refugees from neighboring countries (Syria, Iraq, etc.). The population increase and the tendency for urbanization are crucial factors affecting the final energy consumption.

The GDP calculated at constant 2016 prices increased by 34% in the period 2010-2023 with an average increase rate equal to 2% annually (Figure 19). Nevertheless, the evolution of economic growth rate was decelerated after 2010 and remained constant at the level of 2%-3% on annual basis until 2023 with the exemption of 2020 which was equal to -1% and 2021 which was equal to 4%, indicating the effect of the pandemic. Moreover, the GDP per capita was reduced by approximately 22% in the period 2010-2023, mainly due to the significant increase of the population as seen above.

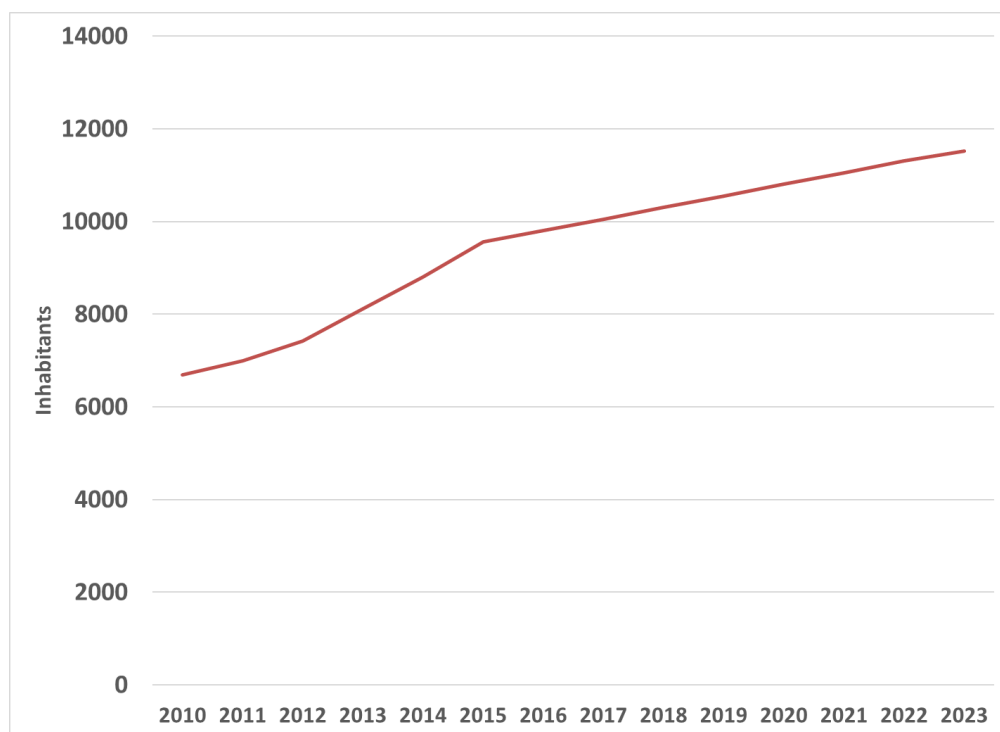


Figure 19: Evolution of the population in the period 2010-2023⁵

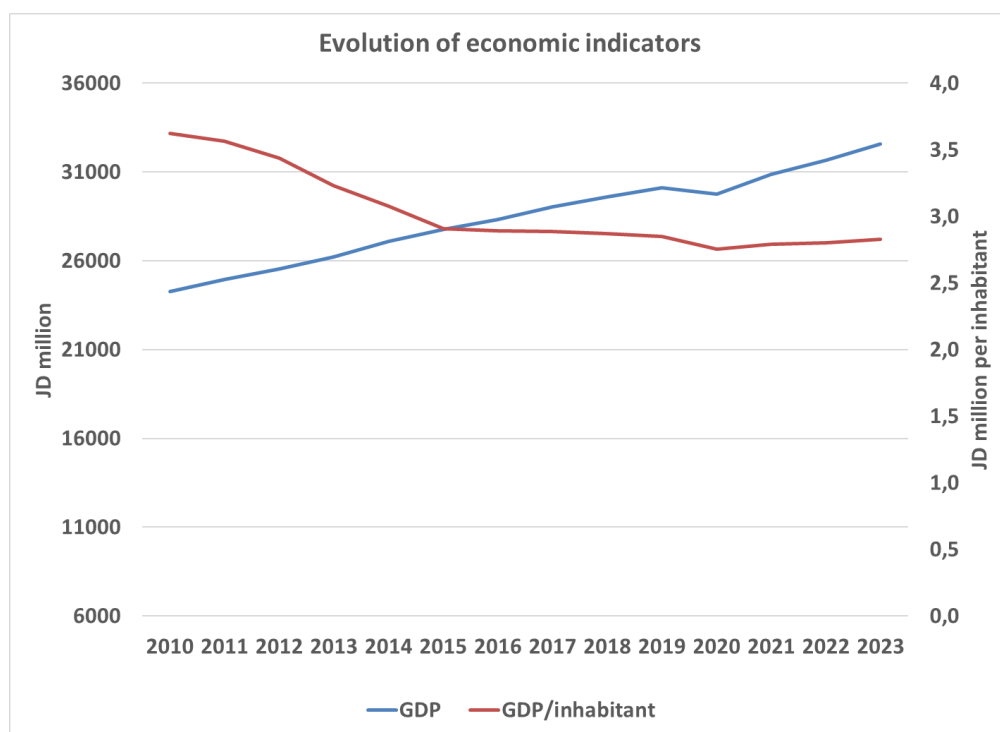


Figure 20: Evolution of the GDP (constant prices 2016) and the GDP/inhabitant for the period 2010-2023⁶

⁵ DOS, 2024

⁶ Central Bank of Jordan, 2024

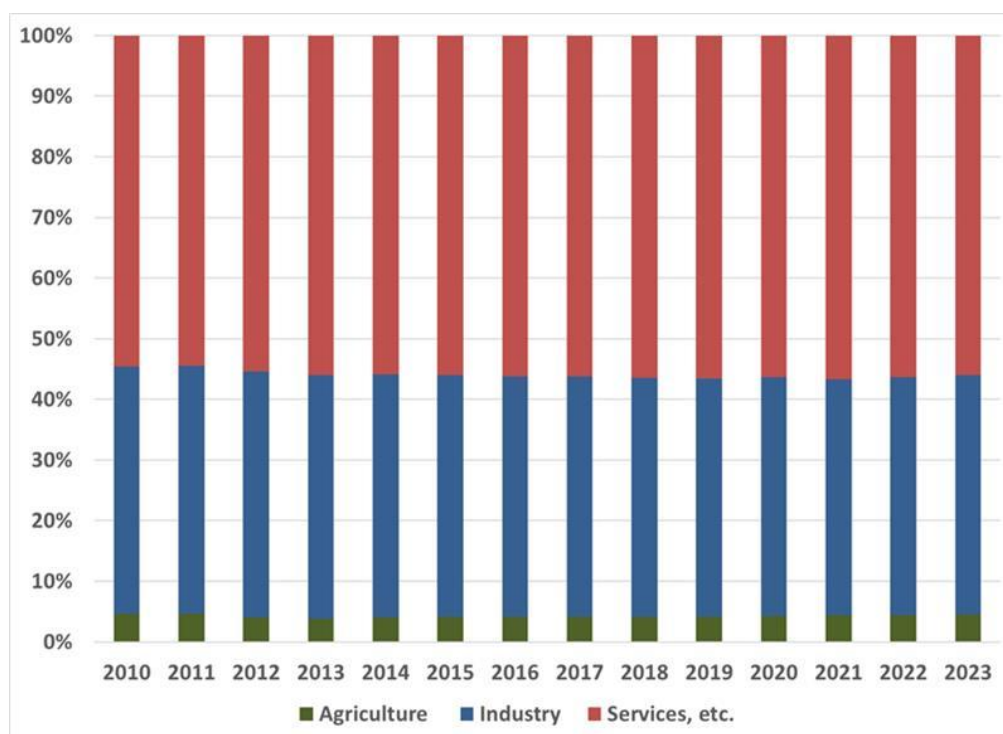


Figure 21: Gross Value-Added Contribution of the end-use sectors to the GDP in the period 2010-2023⁷

The structure of the economy of the country has changed gradually since 2010, with the contribution of the service sector (Figure 20) increasing slightly leading to the respective reduction of the contribution of industrial sector. The share of the agricultural sector remained constant during the same period. This indicates that no major structural changes have been observed in the economy of Jordan since 2010.

3.2.2 Primary Energy Supply

The indigenous primary energy production to natural gas (96.2% of the total energy production in 2023) and oil (3.8% of the total energy production in 2023) (Figure 21). The production of oil increased by 17% in the period 2010-2023, with a peak in 2021, but still the quantities are limited to about 6ktoe in 2023. The increase of local production of natural gas amounted to 1% with a continuously declining trend until 2019 (with an exemption of 2015). A reversal in the trend is observed since 2020, driven by intensified development of the Risha gas field, which is the country's only domestic source of natural gas.

⁷ World Bank Databank, 2025

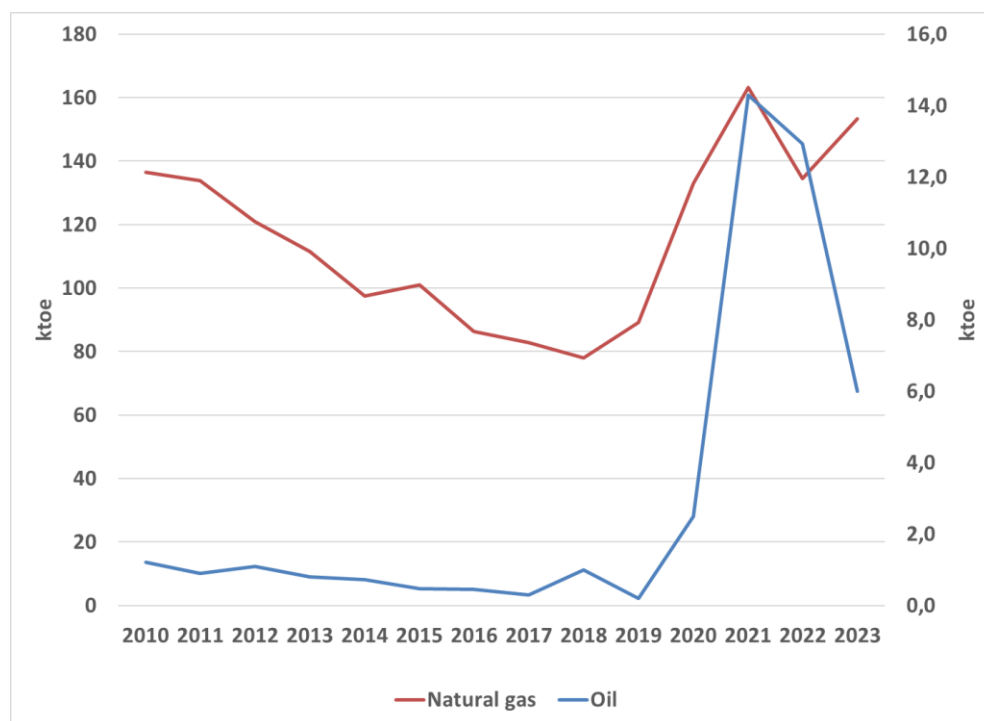


Figure 22: Indigenous energy production in the period 2010-2023⁸

The limited local fossil energy primary energy sources led to increased energy imports. Specifically, the total energy imports remain around 8Mtoe in the period 2010-2023, with a peak above 10Mtoe in 2017. In 2023 total imports amounted to 7,406 ktoe (Figure 22). Out of this amount, 58.9% of the total imported energy are crude oil and oil products, while the imported natural gas amounted to 39% of the total energy imports in 2023. Crude oil remains the most significant among the oil imports, while significant was the share of diesel (23.9%) and gasoline (21.9%) in 2023.

⁸ MEMR, 2023

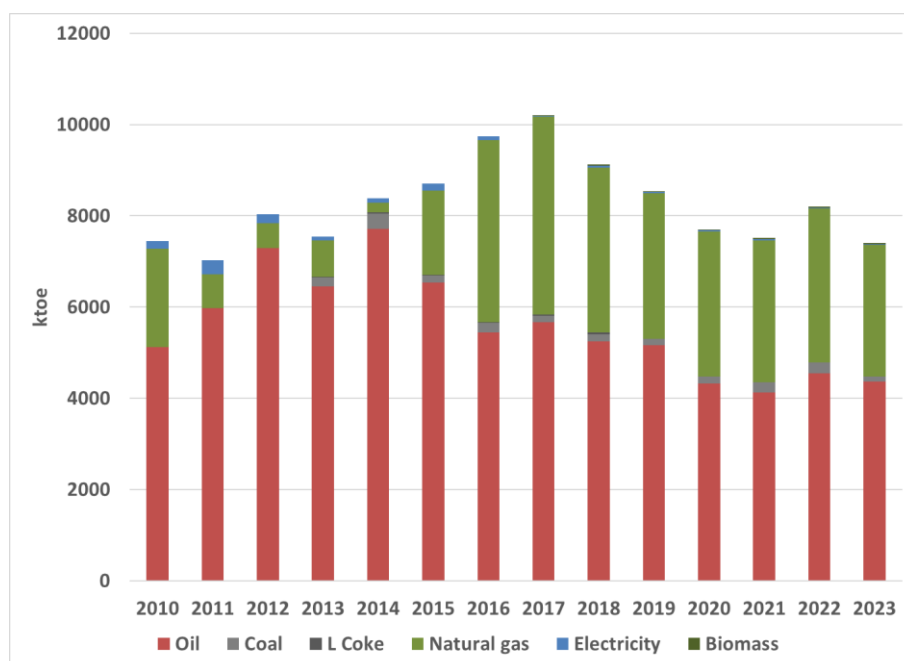


Figure 23: Energy imports in the period 2010-2023

The energy exports in the period 2010-2023 were limited to a small amount of electricity (amounted to 73.2 GWh in 2023), and a limited amount of natural gas that was re-exported from 2016 to 2018 (amounted to 249.1 ktOE in 2018) to cover the natural gas shortage in Egypt temporarily.

The primary energy supply increased by 22% in the period 2010-2023 with an average annual growth rate of 2% mainly due to the increase of the GDP and the significant penetration of RES (Figure 23). The supply of oil products decreased over the period 2010-2023 by 7%, and the respective share of natural gas increased by 33% respectively. The share of oil products to the primary energy supply in 2023 was 49%, while natural gas constituted the second most important fuel to primary energy supply (34%). In the period 2010-2014 imports were limited due to the shortage of gas in Egypt. This led to a temporary shift to the use of oil products for electricity generation and to a significant increase in the generation cost. The share of diesel, gasoline and LPG was significant during the period 2010-2023, and it grew by 62%, 156% and 114% over this period, respectively.

Renewable energy, and in particular electricity generation from renewables, increased with an average annual rate of 52% leading to a more than sixfold increase over the period from 2010 to 2023. Electricity generation from RES is the most significant contribution, covering 82% of the total renewable energy supply. The penetration of solar thermal energy, which represents 15% of the renewable energy supply in 2023, is growing constantly over the period examined, with a 70% increase from 2010 to 2023. Biomass reporting in the energy balance started in 2016, and it represents a share of 3% of the renewable energy supply in 2023.

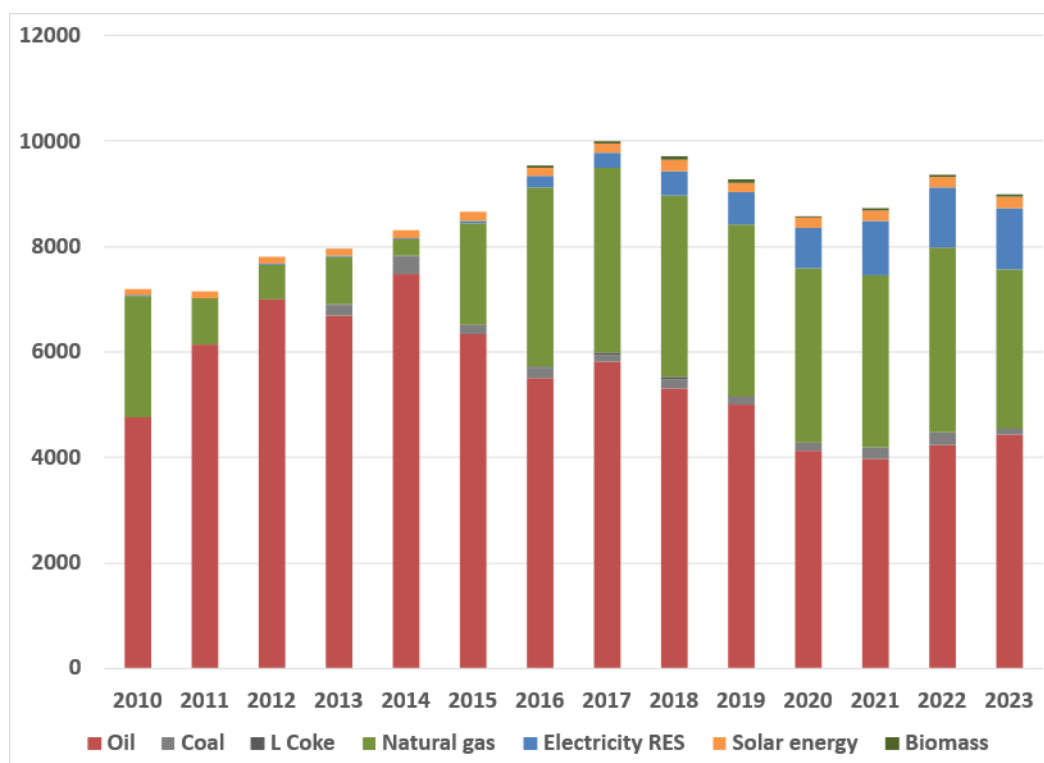


Figure 24: Primary energy supply in the period 2010-2023 (MEMR, 2023)

3.2.3 Transformation Sector-Refinery

Jordan's sole oil refinery is operated by the Jordan Petroleum Refinery Company (JPRC). Located in Zarqa, the refinery operates at a crude oil processing capacity of approximately 40000 barrels per day. The facility is responsible for producing a range of petroleum products, including gasoline, diesel, jet fuel, heavy fuel oil (HFO), and liquefied petroleum gas (LPG). Historically, JPRC has supplied a major share of Jordan's domestic fuel demand, although the country continues to import substantial volumes of refined products to meet consumption needs. JPRC's products are dominated by distillates, diesel and jet fuel account for nearly half of total output, alongside significant shares of gasoline, HFO, and LPG. In recent years, the refinery has faced operational and financial pressure due to aging infrastructure and limited complexity, prompting plans for a major upgrade to enhance efficiency, environmental performance, and product quality in line with international standards. As can be seen in Figure 24, the refining of oil products decreased by 47% between 2010 to 2023. Comparing the quantity of refined products with the respective demand in the period 2010-2023 it can be seen that a considerable share of the demand was covered by the refinery output for diesel (52%) and gasoline (45%) while for LPG this share was rather low at 18% (Figure 25).

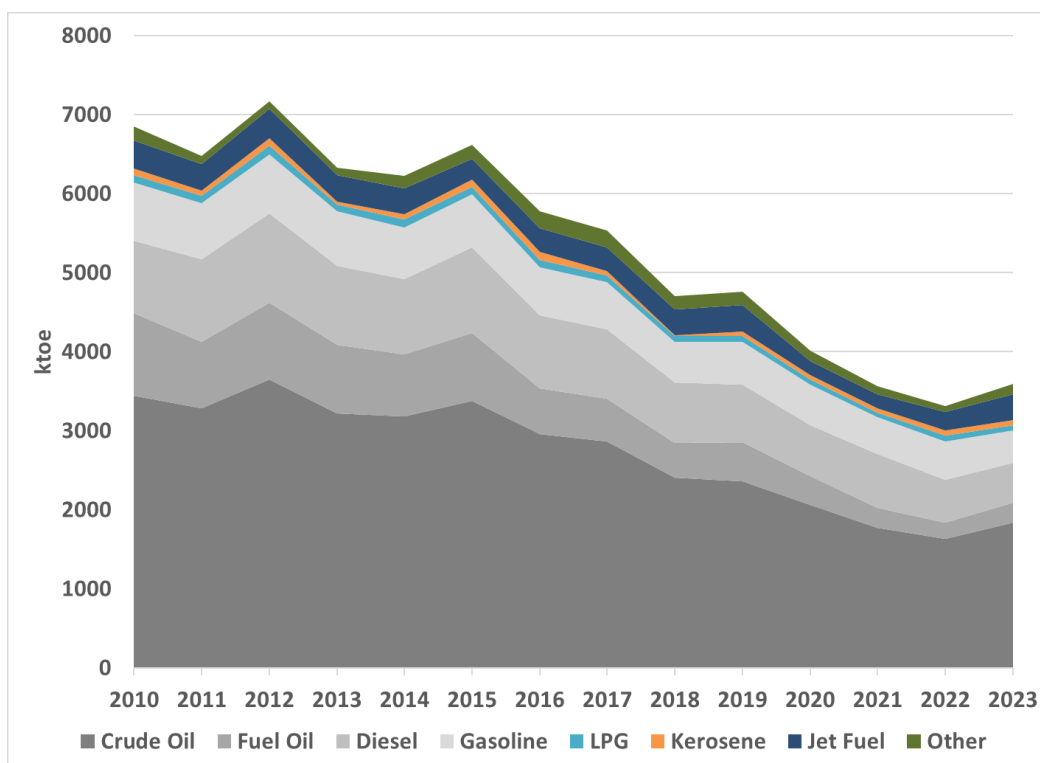


Figure 25: Energy content of crude oil versus refined products in the period 2010-2023 (MEMR, 2023)

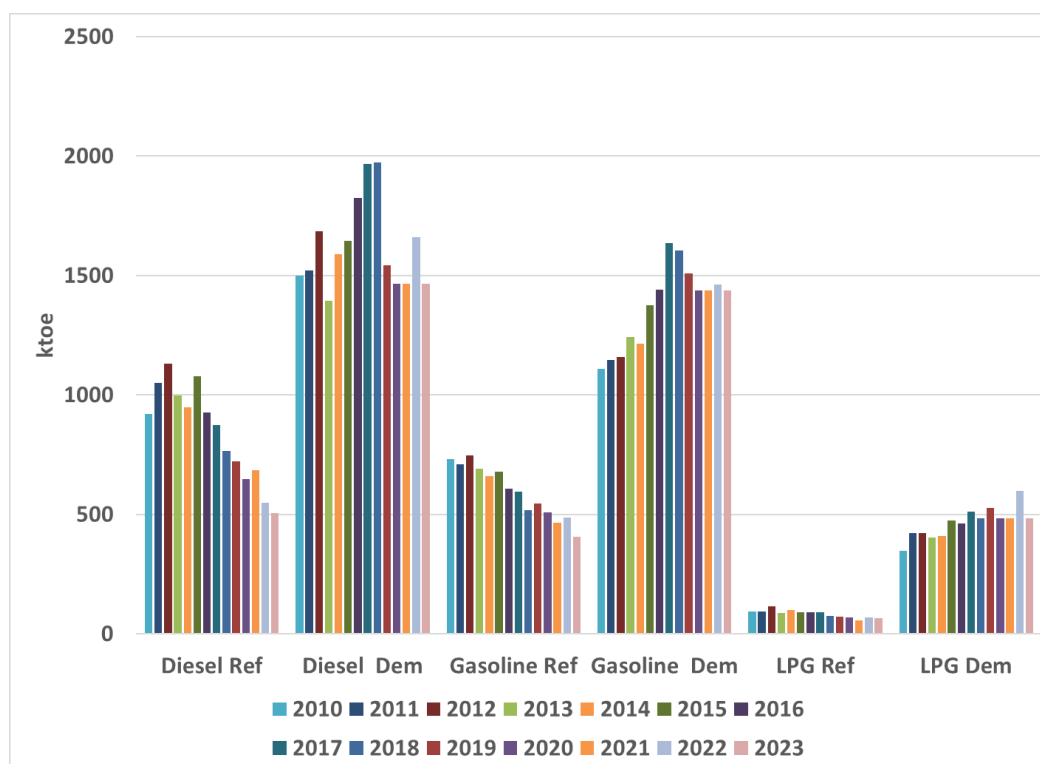


Figure 26: Comparison of refined oil products in the country to total oil products consumed in the period 2010-2023 (MEMR, 2023)

3.2.4 Transformation Sector-Electricity

The electricity generation from conventional fuels increased by 18% in the period 2010-2023 with an average annual growth rate equal to 1%. The share of electricity generated from renewables in the energy purchased (that is at the level of the transmission network) has grown from 0.5% in 2010 to 18% in 2023 (Figure 26). The corresponding total share of renewable electricity generation (including auto production and generation at the distribution level) reached almost 27% in 2023.

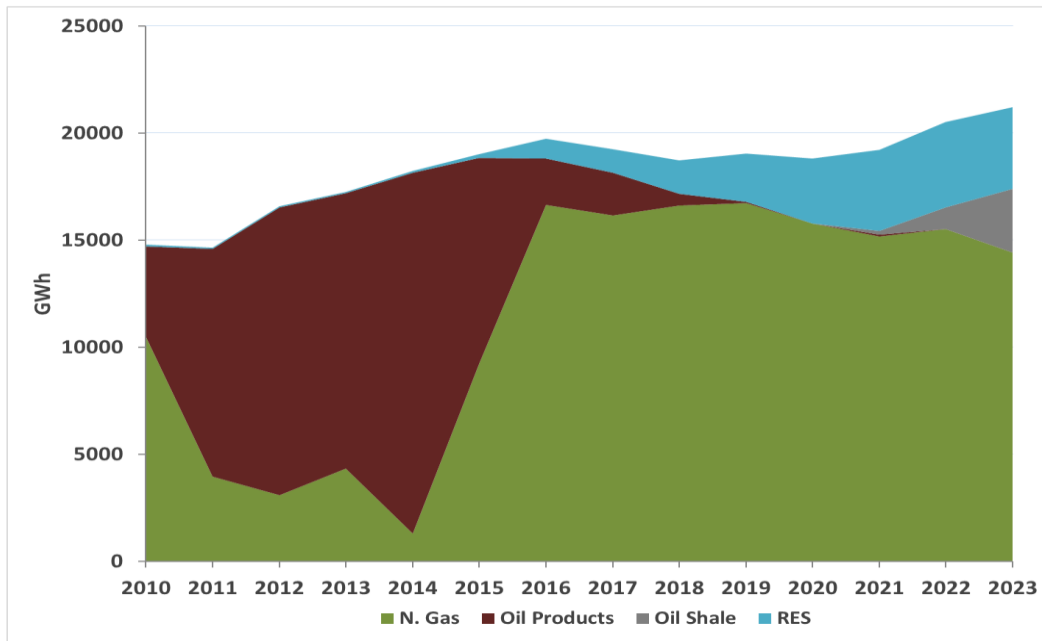


Figure 27: Electricity purchased by fuel in the period 2010-2023 (NEPCO, 2023)

Conventional electricity generation is mainly based on natural gas (83% in 2023) and oil shale (17% in 2023). Diesel was consumed mainly in the period 2010-2015 in order to substitute natural gas, due to the import shortage. In the period 2016-2018, natural gas became the dominant fuel for electricity generation with corresponding shares ranging from 84% in 2016 to 88% in 2018. The generation from oil shale started in 2022 and reached 14% of the electricity purchased by NEPCO in 2023.

The liberalization of the electricity sector started in 1996, while electricity generation and distribution sectors were privatized in 1999. The National Electric Power Company (NEPCO) is 100% state owned and owns the National Control Center and the transmission network, which consists of high voltage transmission lines of 132 kV and 400 kV. The Ministry of Energy and Mineral Resources (MEMR) develops the long-term strategy of the energy sector, while the Energy and Mineral Regulatory Commission (EMRC) was established to monitor and regulate the energy and minerals sectors. EMRC serves as the regulatory and monitoring body for the Electricity, Radiation Protection, Nuclear Safety & Security, and Mining Sectors, and therefore, ensures the application and enforcement of laws, by-laws, instructions, and directives specific to the regulation within these sectors.

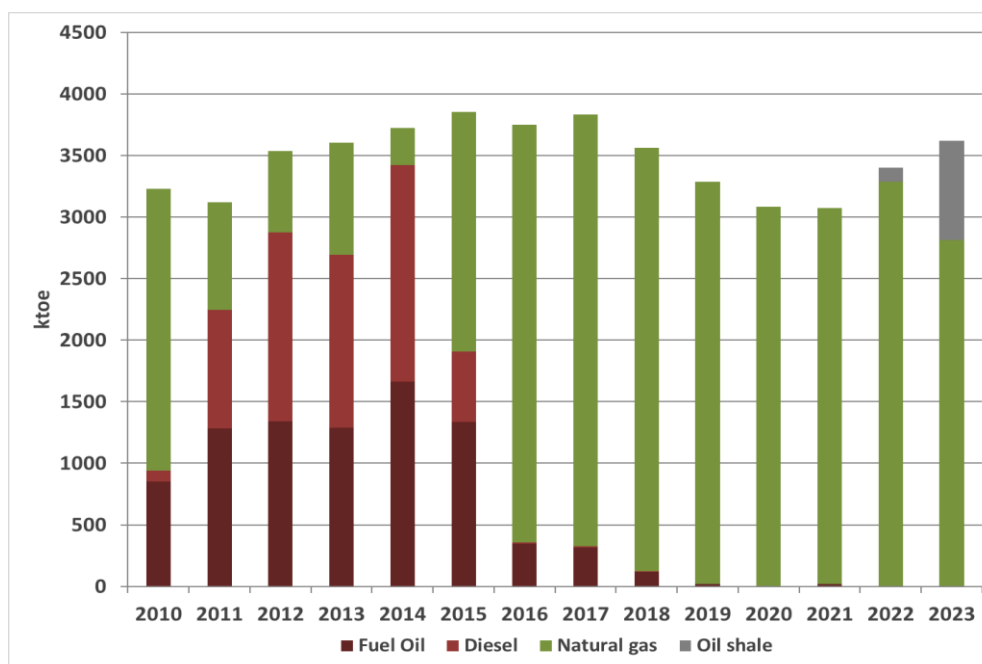


Figure 28: Input for electricity generation in the period 2010-2023 (Source: MEMR, 2023)

Indicative figures for the various characteristics of the electricity sector are presented in the next table. Between 2022 and 2023, peak load increased modestly from 4,010 MW to 4,240 MW, while the available generation capacity rose in parallel, both for conventional (from 4,208 MW to 4,443 MW) and renewable technologies (from 1,583 MW to 1,617 MW), indicating continued investment in system expansion and diversification. Electricity sales grew by 3.2%, reflecting rising demand. Operational performance improved as transmission losses fell from 1.92% to 1.81%, and all reliability indicators showed enhancements. The number of interruptions halved, while unsupplied energy dropped from 836 MWh to just 155 MWh. Average interruption duration declined from 3.5 to 1.3 minutes, and total annual outage hours dropped from 75 to 20.2. These trends demonstrate greater system resilience, better grid management, and improved service quality to consumers.

Table 4: Figures of the electricity sector in 2022 and 2023 (Source: National Electric Power Company, 2023)

Figures		2022	2023
Peak Load (MW)		4010	4240
Available Capacity for Interconnected System (MW)	Conventional	4208	4443
	Renewable	1583	1617
Sold Electrical Energy (GWh)		20446	21105
Transmission Losses (%)		1.92	1.81
Number of Interruptions		1.3	0.7
Unsupplied Energy (MWh)		836	155
Average Interruption Duration (Min/ Interruption)		3.5	1.3
Average Unsupplied Energy (MWh/ Interruption)		39	9.6
Interruption Duration (Hour)		75	20.2

The available capacity for electricity production on the transmission system level from different technology types is presented in the next table for the period 2019-2023.

Table 5: Available capacity (MW) for electricity generation on the transmission network in the period 2019-2023 (Source: National Electric Power Company, 2023)

Units		2019	2020	2021	2022	2023
Steam		605	360	360	595	830
Gas Turbines		83	83	60	60	60
Combined Cycle		2739	2739	2739	2739	2739
Diesel*		814	814	814	814	814
Wind Energy		369	518	622	621	621
Hydro		6	6	3.6	3.6	3.6
Solar		637	887	938	958	992
Total	Renewable	1012	1411	1564	1583	1617
	Conventional	4242	3996	3973	4208	4443

* HFO, Diesel, NG

The electricity generation from different types of technologies is presented in the next table for the period 2019-2023.

Table 6: Purchased electricity (GWh) in the period 2019-2023 (Source: National Electric Power Company, 2023)

Sector	Units	2019	2020	2021	2022	2023
Power Sector	Steam Units	140.4	71.6	323.3	1232.5	3036.2
	Combined Cycle	15313.3	14585.4	13924.8	13672.5	13322.4
	Simple Cycle	313.2	413	514.9	498.5	499.7
	Diesel Engines	1026.6	698	681.6	1107.5	535.6
	Hydro Units	18.4	18.3	18.7	19.1	22.4
	Wind Energy	874.9	1378.8	1595.5	1748.2	1647.1
	Solar Energy	1341.2	1645.2	2162.6	2222.3	2143
Imported energy (Egypt)		239.3	380.6	394.8	262.5	266.4
Others		5.4	3.3	2.6	0.1	0.6
Total		19272.7	19194.2	19618.8	20763.2	21473.4

Jordan has actively pursued regional electrical interconnection projects as a strategic component of its energy security and export diversification efforts (Table 5). These projects aim to strengthen grid resilience, facilitate electricity trade, and support regional cooperation. The Egyptian – Jordanian interconnection, operational via a 13 km 400 kV submarine cable with a current capacity of 550 MW, is being evaluated for expansion to 2,000 MW, with feasibility studies under preparation. The Jordanian – Syrian line (400 kV, 147 km) remains inactive. A Jordan–Lebanon exchange agreement, relying on transit through Syria, was signed but remains unimplemented due to regional instability. The Jericho interconnection is advancing, with the 132/33 kV Rama substation operational since July 2022 and the second phase under study. The Jordan–Saudi interconnection, designed for 500 MW in its first phase and 1,000 MW at a second stage are under technical study, has. Moreover, Jordan is part of a broader Gulf–Egypt interconnection scheme spanning 1,958 km with a projected capacity of 2,000 MW. Lastly, the Jordan–Iraq interconnection is set to supply 150–200 MW to Al-Qaim via a 336 km 400 kV line, with recent contractual amendments enabling future exports.

Table 7: Existing and planned electricity interconnection projects (Source: National Electric Power Company, 2023)

Project	Status	Voltage (kV)	Length (km)	Capacity (MW)
The Egyptian - Jordanian Electrical Interconnection (Submarine Cable)	The energy exchange contract was renewed for 2024 Both parties agreed to prepare the economic and technical feasibility study for the project to enhance the capacity of the interconnection line, aiming to reach 2000 MW, and to work on securing a funding source for this study The Egyptian side is waiting for the Arab Fund for Economic and Social Development to provide a grant for funding the study	400	13	550
The Jordanian - Syrian Electrical Interconnection	During 2023, there was no exchange of electrical energy	400	147	300-800
The Jordanian – Lebanese Electrical Interconnection	A contract for the exchange of electrical energy between the Jordanian and Lebanese sides, and an agreement to pass the energy through the Syrian Grid, were signed in early 2022, where it is hoped that (150) MW will be supplied to Lebanon during the period (6:00 - 24:00), and 250MW during the period (24:00 - 6:00), by the Jordanian Grid and through the Syrian Grid The above contracts haven't been implemented, related to the current situation in the region	132	Via the Syrian network	150-250
The Jordanian - Palestinian Electric Interconnection (Jericho)	The Rama Substation of 132 / 33 kV (first phase) has been operated in 3 rd of July 2022	132	30	80

Project	Status	Voltage (kV)	Length (km)	Capacity (MW)
	On 15/2/2024, the agreement for the second phase for the Rama transformer station has been signed			
The Jordanian – Saudi Electric Interconnection	The final forms of the interconnection agreements were prepared, and the work is currently underway of a commercial agreement. The technical details related to the project are not finally approved, therefore the agreements are not yet finalized.	400	112 in Jordanian territory + 52 in Saudi territory	500 in the first phase, 1000 in the second phase
The Jordanian – Gulf – Egyptian Electric Interconnection	The assumptions related to the commercial model for electricity exchange were agreed and feedback on the presented results was provided by the relevant stakeholders from the three countries	400	1958	2000
The Jordanian – Iraqi Electric Interconnection	On 11 th of February 2024 the contract between the two sides, has been modified, and the Jordanian side at the end of the project, will be able to export (150-200) MW to Al-Qaim Substation in Iraq side	400	330 in Iraqi territory + 6 in Jordanian territory	150-200

3.2.5 Final Energy Consumption

Final Energy Consumption (FEC) increased by 28% in the period 2010-2023 with an average annual growth rate equal to 2% mainly driven by the economic growth and population increase (the next Figure). In 2023, the transport sector was responsible for almost half (45%) of the final energy consumption. In the period 2010-2023 the transport sector increased by 39% with an annual growth rate of approximately 3%, and its relative share increased from 41% in 2010 to 45% in 2023.

The residential sector is the second most important contributor to the final energy consumption in 2023 with a share of 24%. The consumption of the residential sector increased by 60% in the period 2010-2023, while the respective share in the FEC increased to 24% in 2023, compared to 21% in 2010. The FEC of the industrial sector remained relatively stable with a slight increase of 3% in the period 2010-2023 leading to a reduction in its share in FEC, decreasing from 21% in 2010 to 16% in 2023. Finally, the FEC in the services sector increased by 51% in the period 2010-2023 retaining almost the same share in the total FEC with a slight increase from 8% in 2010 to 9% in 2023.

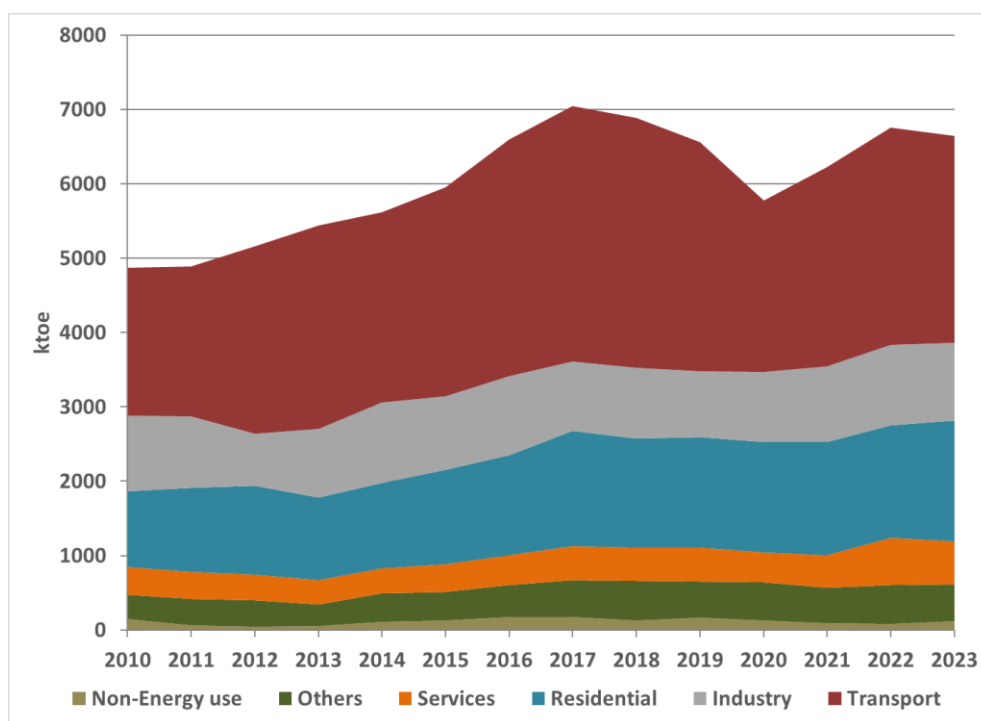


Figure 29: Final energy demand by sector in the period 2010-2023 (Source: MEMR, 2023)

Oil products have the highest share in the FEC since they cover 63% of the total in 2023 (Figure 29). The share of oil products in the final energy demand increased by 6% in the period 2010-2023 maintaining their dominant role, although the relative share reduced from the level of 75% in 2010. The increase in electricity consumption in the period 2010-2023 was equal to 50%, while the share of electricity in FEC increased from 23% in 2010 to 28% in 2023.

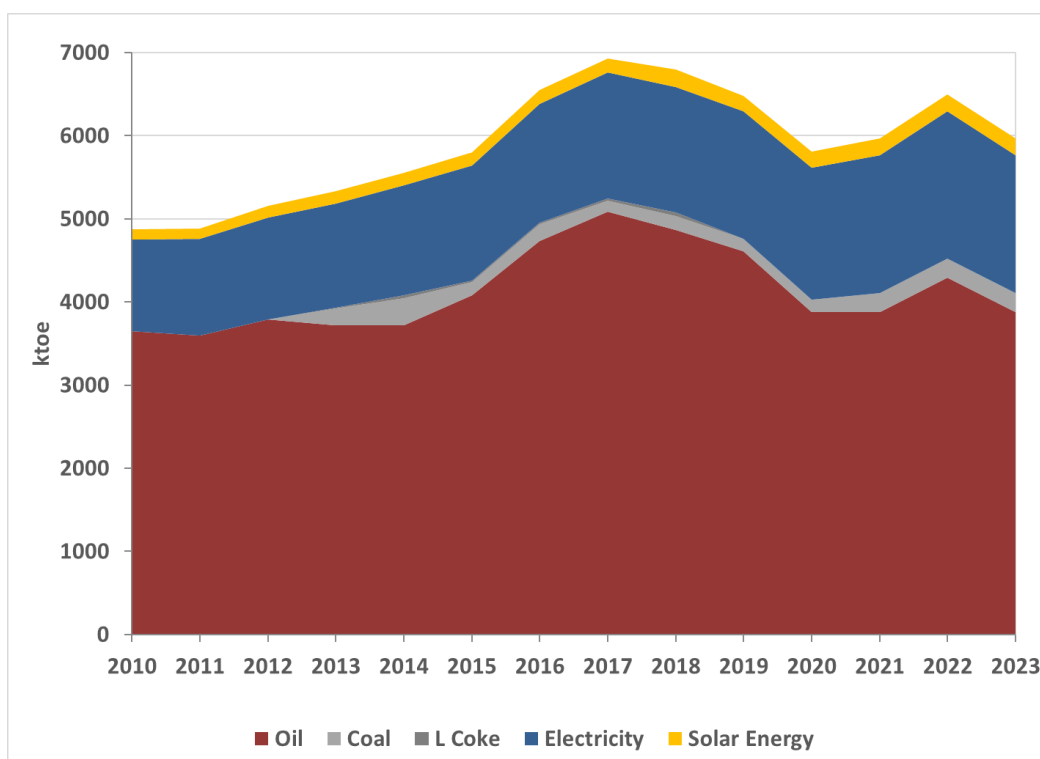


Figure 30: Final energy demand by fuel in the period 2010-2023 (Source: MEMR, 2023)

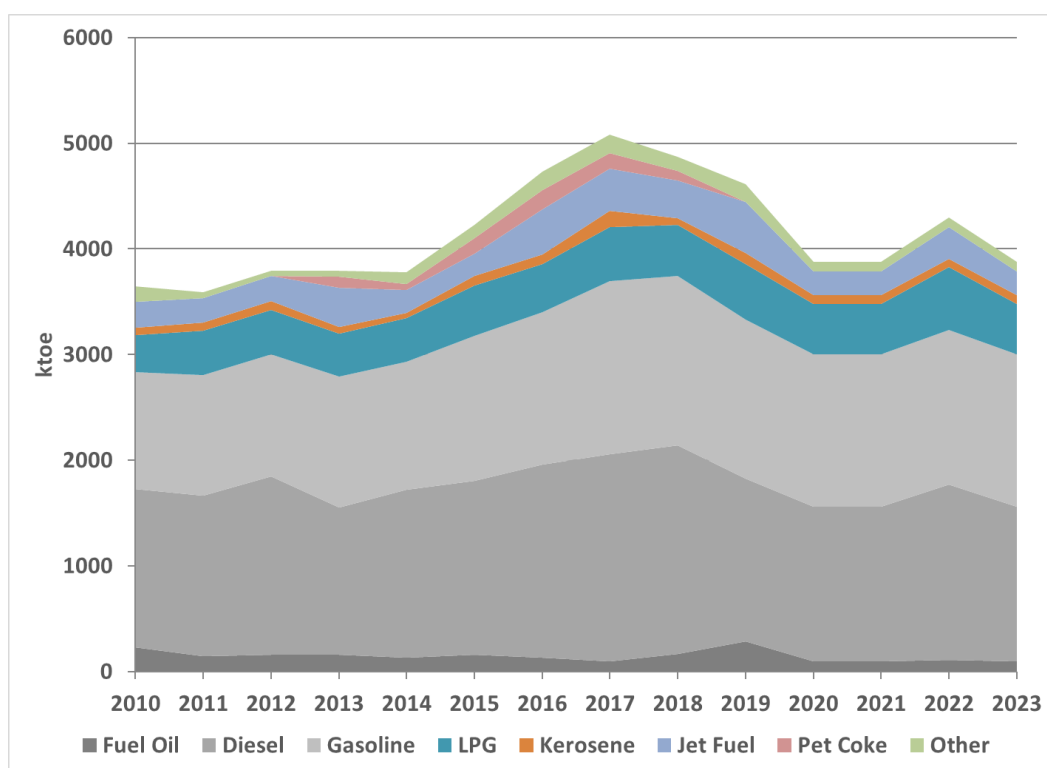


Figure 31: Final energy demand of each of the petroleum products in the period 2010-2023 (Source: MEMR, 2023)

The average annual growth rate of the demand for oil products in the period 2010 – 2023 was equal to 0.5%, while the corresponding growth rate for electricity was 3%. Nevertheless, oil products demand

remains almost stable during the period from 2010 to 2014, with an increase of around 26% in the period from 2015 to 2017, while after 2017 their share decreased significantly, with an exception of a peak in 2022, perhaps due to a post-pandemic rebound. In the period 2018-2023, the decrease of the oil products is due mainly to the decrease of fuel oil, diesel, jet fuel and gasoline (41%, 26%, 39% and 10% correspondingly). Diesel, gasoline and LPG are the most used fuels, with corresponding shares 37%, 34% and 13% of the total oil products in 2023 (Figure 30).

In the industrial sector, electricity consumption increased by 46% in the period 2010-2023 and its share reached 39% of the total industrial FEC in 2023 (Figure 31). The consumption of oil products decreased by 59% in the period 2010-2023 mainly due to the reduction of fuel oil and diesel (26% and 76% reduction from 2010 to 2023 respectively). Pet-coke was used as an alternative fossil fuel from 2013, having an upward trend up to 2017, but its use was discontinued in 2019. In 2023, the share of fuel oil and diesel in the final energy consumption in industry was equal to 15% and 12% respectively, while the contribution of the LPG was rather low at 1%. Coal consumption in the industrial sector has been reported since 2013, with a share of 11% of FEC in 2023. The consumption of natural gas appeared for the first time in 2019 and rapidly increased to levels around 22% in 2023.

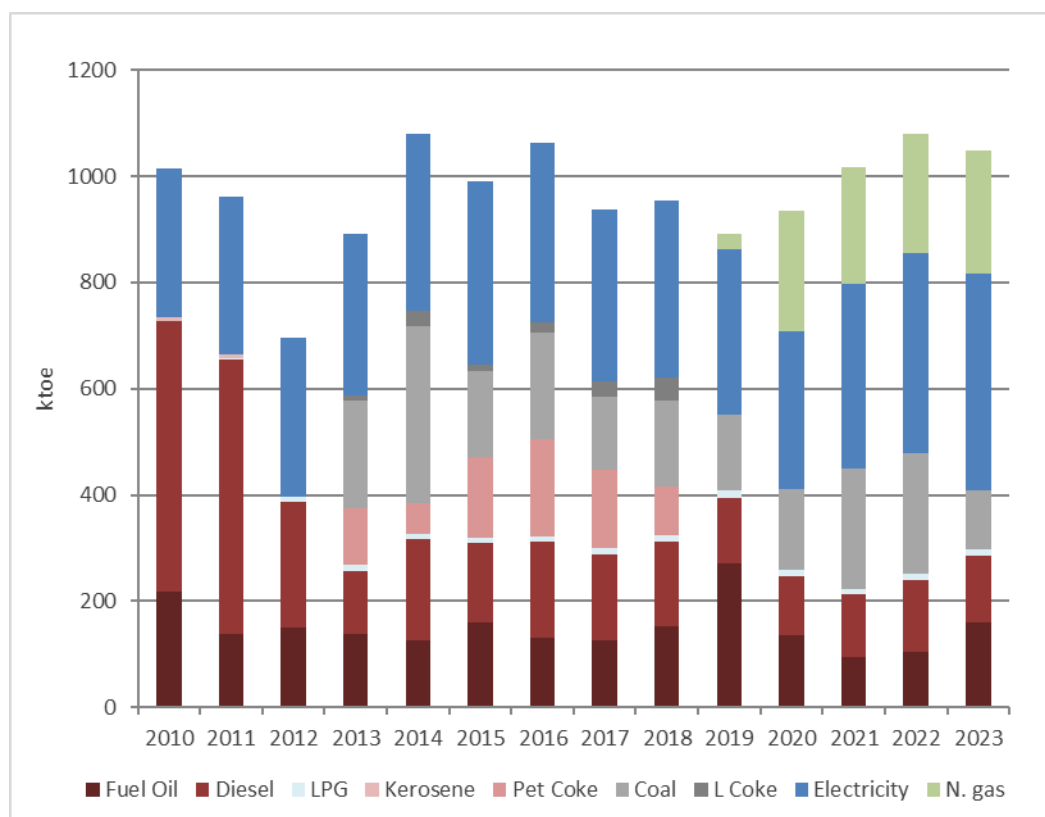


Figure 32: Final energy demand of the industrial sector by fuel in the period 2010-2023 (Source: MEMR, 2023)

The final energy intensity of industry has improved in the period 2010-2023, since it decreased by 23% resulting in 0.127 toe/1000JD in 2023 mainly due to the implementation of energy efficiency interventions (Figure 32). The final energy intensity is defined as the final energy consumption of the industrial sector

divided by the value added of the industry at constant prices (2016) providing an indication about the energy efficiency of the sector.

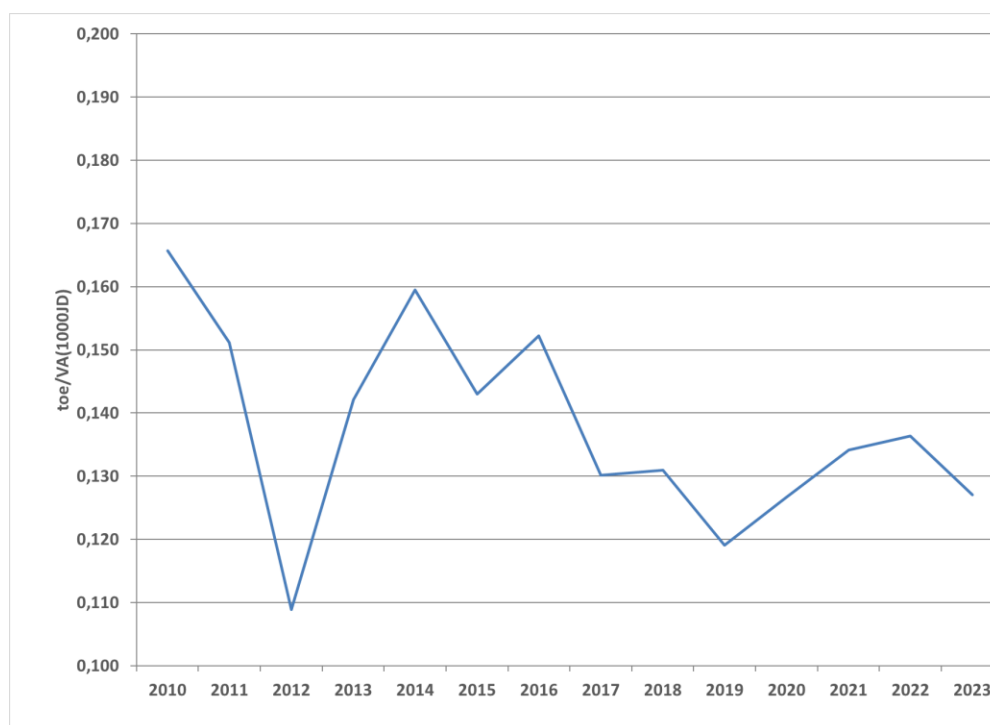


Figure 33: Final energy intensity of the industrial sector in the period 2010-2023⁹

In the transport sector, gasoline covers 50% of the sectoral FEC in 2023 (Figure 33), the contribution of diesel is 39% and jet fuel is equal to 10%, while the quantity of fuel oil is marginal. The use of diesel, gasoline and jet fuels increased significantly in the period 2010-2023 by 71%, 27% and 14% respectively. Electricity consumption for transportation as reported in the energy balance is minimal (16GWh), but the majority of EV charging happens in households, leading to a change in the electricity demand in the residential sector over the past five years. To address this issue EMRC imposed a license on electric vehicle charging meters, and the tariff for these meters is cheaper than the household tariff, as it is charged at a fixed-rate and does not depend on consumption segments, unlike the residential sector tariffs. EMRC also implemented time-of-use tariffs for charging stations in order to encourage electric vehicle owners to charge their vehicles outside peak hours, benefiting from a lower tariff.

The final energy intensity of transport sector has slightly increased by 4% from 2010 to 2023, resulting in 0.085 toe/1000JD in 2023 (Figure 34). The final energy intensity is defined as the final energy consumption of the transport sector divided by the GDP at constant prices (2016) providing an indication about the energy efficiency of the sector.

⁹ Source: Own elaboration based on energy balance data from MEMR 2023 and value-added data from World Bank Databank, 2023

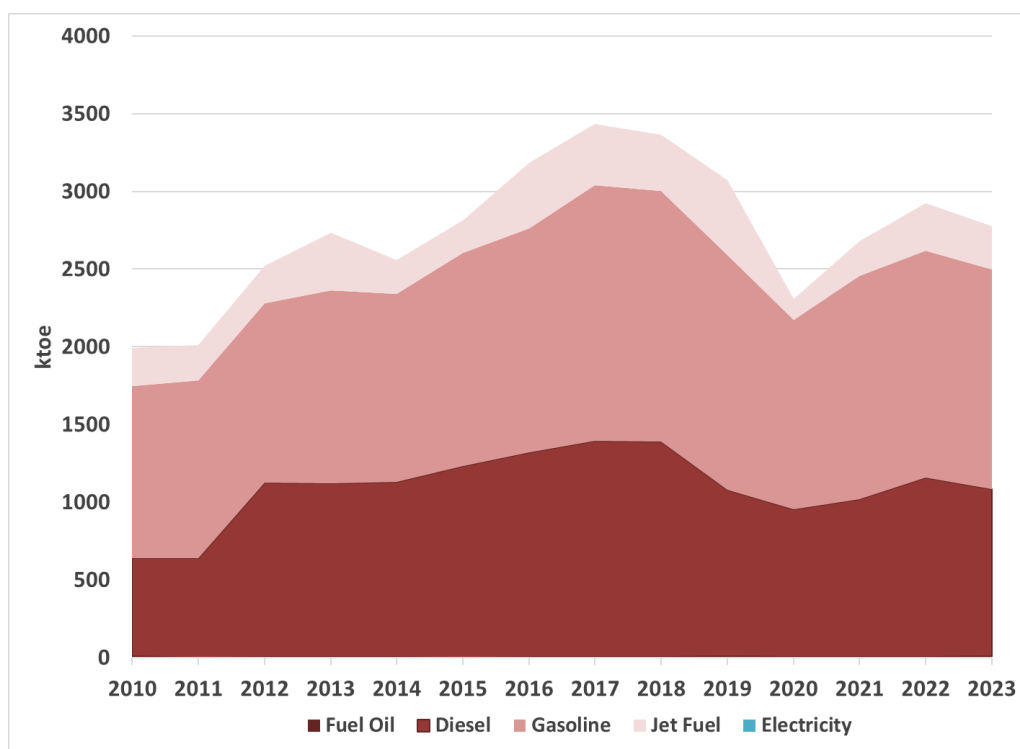


Figure 34: Final energy demand of transport sector by fuel in the period 2010-2023 (Source: MEMR, 2023)

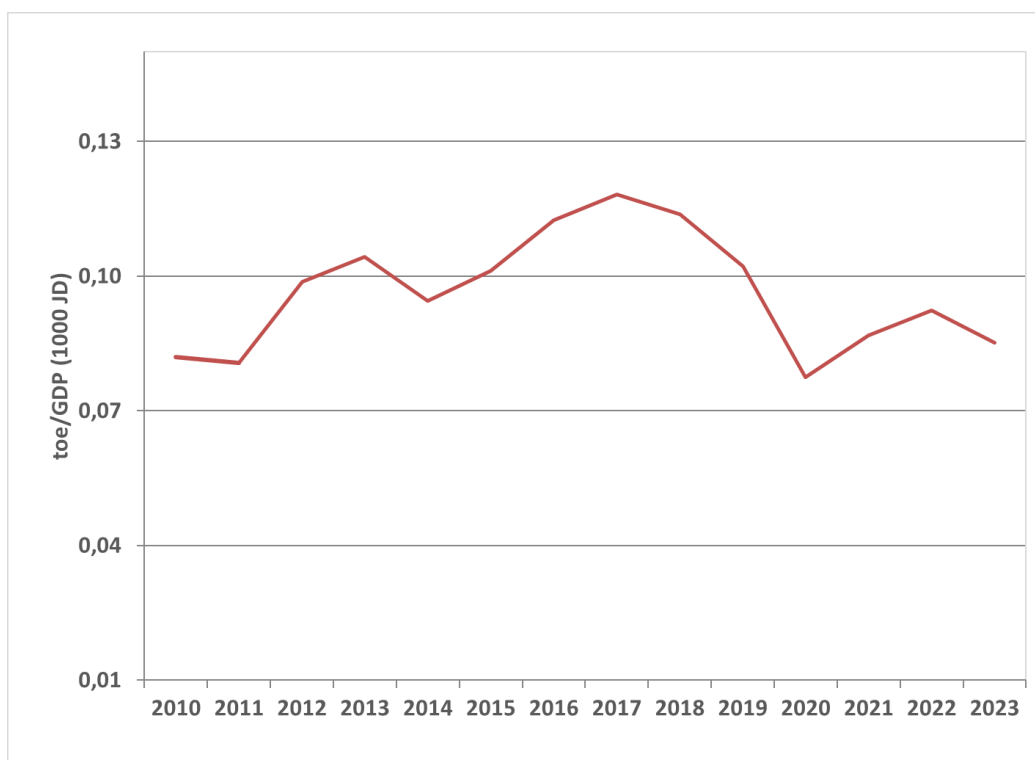


Figure 35: Final energy intensity of transport sector in the period 2010-2023¹⁰

¹⁰ Source: Own elaboration based on energy balance data from MEMR 2023 and value-added data from World Bank Databank, 2023

In the residential sector, electricity consumption increased by 83% in the period 2010-2023 and its share increased from 44% in 2010 to 50% in 2023 (Figure 35). The consumption of oil products increased by 35% in the same period (2010-2023) mainly due to the increase in the consumption of LPG (62% increase from 2010 to 2023). Moreover, the share of diesel was reduced to 6% in 2023 compared to 32% in 2010. The shares of LPG and kerosene remain stable between 2010 and 2023 at 26% and 6% respectively. The increase of solar thermal energy (solar water heaters) in the period 2010-2023 was equal to 52%, reaching a share of 10% of the final energy consumption in 2023. Finally, small amounts of biomass consumption are reported in the residential sector since 2016 with a share of 1% in 2023.

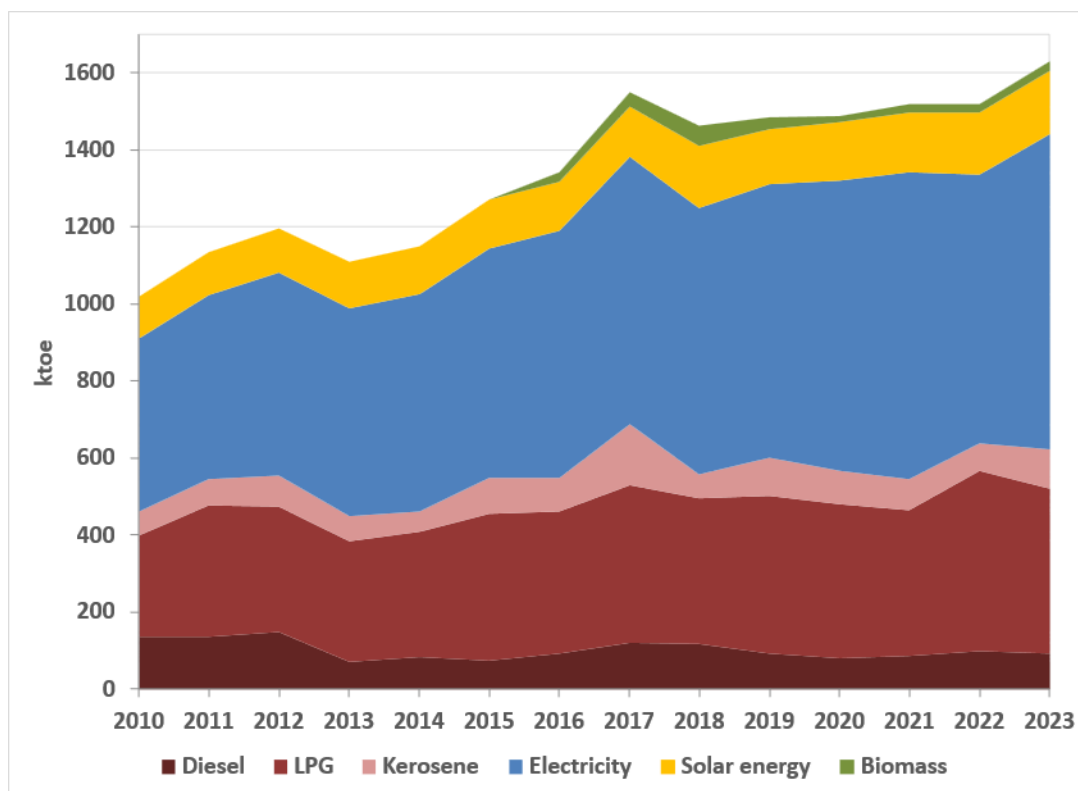


Figure 36: Final energy demand of the residential sector by fuel in the period 2010-2023 (Source: MEMR, 2023)

In the service sector, electricity increased by 89% in the period 2010-2023, increasing its share from 50% in 2010 to 62% in 2023 (Figure 36). The consumption of oil products decreased by 13% in the period 2010-2023 mainly due to the decrease of diesel by 42%, although LPG consumption increased by 58%. Moreover, the share of diesel to the final energy consumption was reduced from 32% in 2010 to 12% in 2023, while the share of LPG remained stable around 14%. The increase of the share of solar thermal energy (solar water heaters) in the period 2010-2023 was almost twofold contributing to a share of 8% of the sectoral final energy consumption in 2023. Finally, biomass consumption is reported in the services sector since 2016 reaching a share of 3% in 2023. The final energy intensity of the services sector increased from 2010 to 2023 by 8% reaching 0.029 toe/1000JD in 2023 (Figure 20). However, a decreasing trend has been observed from 2010 to 2014 by 28% and then from 2017 to 2020 by 19%, before the sharp increase in 2022 (Figure 37). The final energy intensity is defined as the final energy consumption of the service

sector divided by its value added at constant prices (2016), providing an indication about the energy efficiency of the sector.

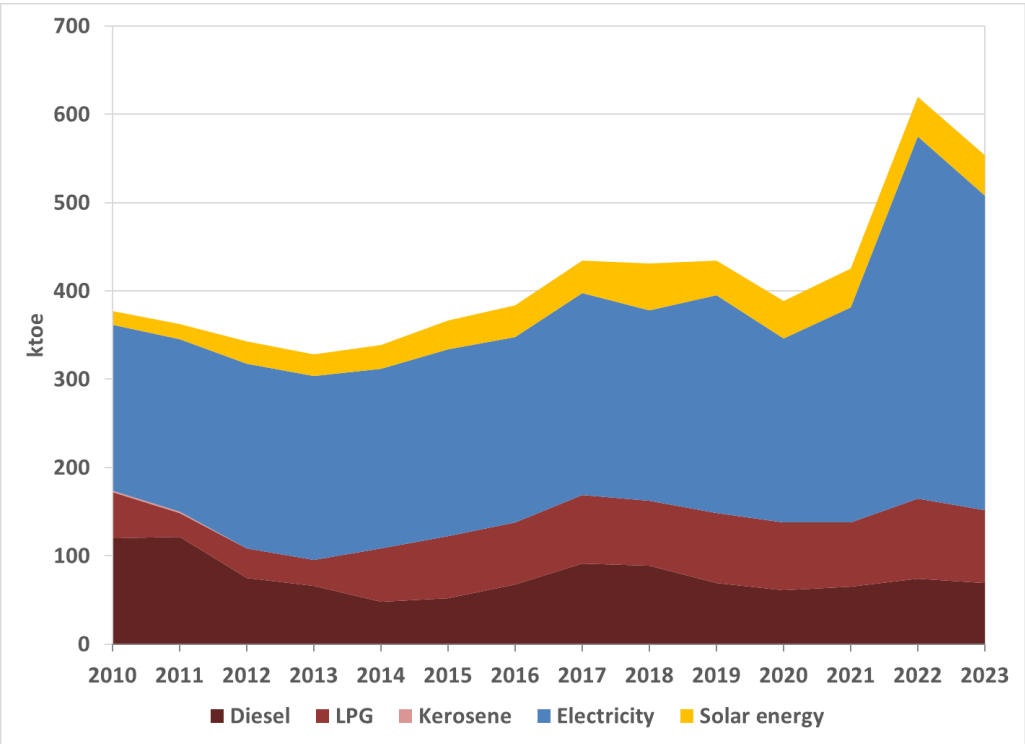


Figure 37: Final energy demand of the services sector by fuel in the period 2010-2023 (Source: MEMR, 2023)

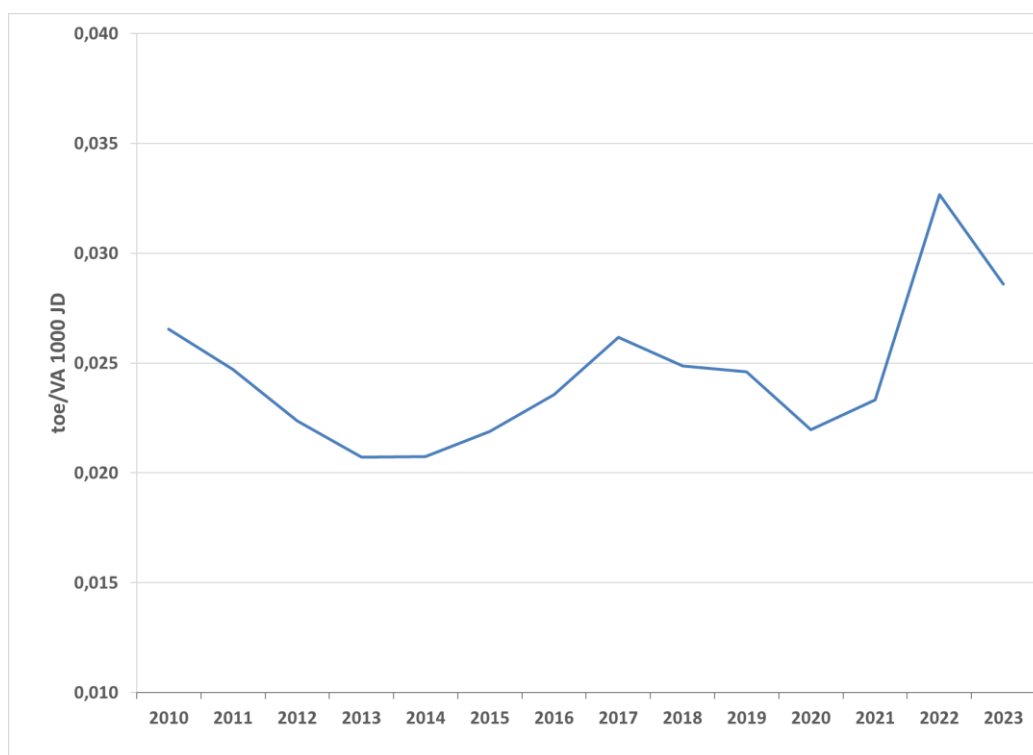


Figure 38: Final energy intensity of the services sector in the period 2010-2023¹¹

3.2.6 Overall Energy Indicators

Energy dependency has improved by 23% in the period 2010-2023. Specifically, the energy dependency was around 96% during the period 2010-2012, it increased to 97% for the following three years and afterwards it has been continuously decreasing, reaching 75% in 2023 (Figure 38). The improvement of energy dependency is a result of the increased penetration of RES and domestic oil shale for electricity production and the exploitation of solar thermal energy and biomass. The slight increase in the local production of natural gas from the Risha field is also contributing to this shift.

¹¹ Source: Own elaboration based on energy balance data from MEMR 2023 and value-added data from World Bank Databank, 2023

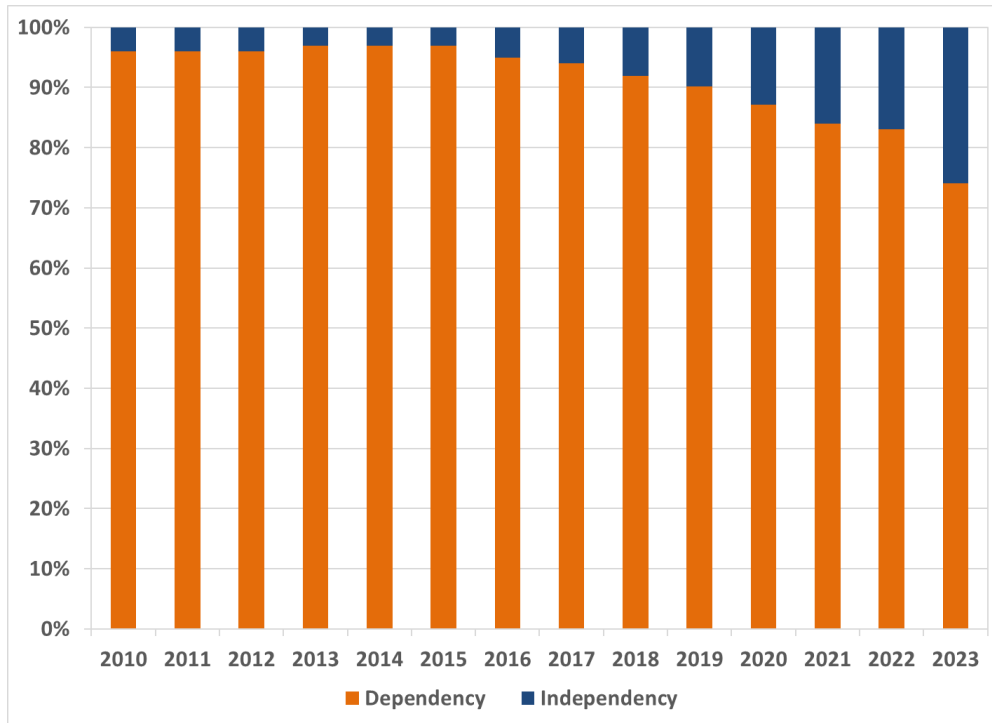


Figure 39: Energy security supply in the period 2010-2023 (Source: MEMR, 2023)

The primary energy intensity, which is calculated as the ratio of the primary energy consumption divided by the GDP at constant prices (2016), has improved by 9% over the period 2010-2023 (Figure 39). The primary energy intensity reached its lowest value in 2020 and 2023; however an increasing trend has been observed during 2010-2017.

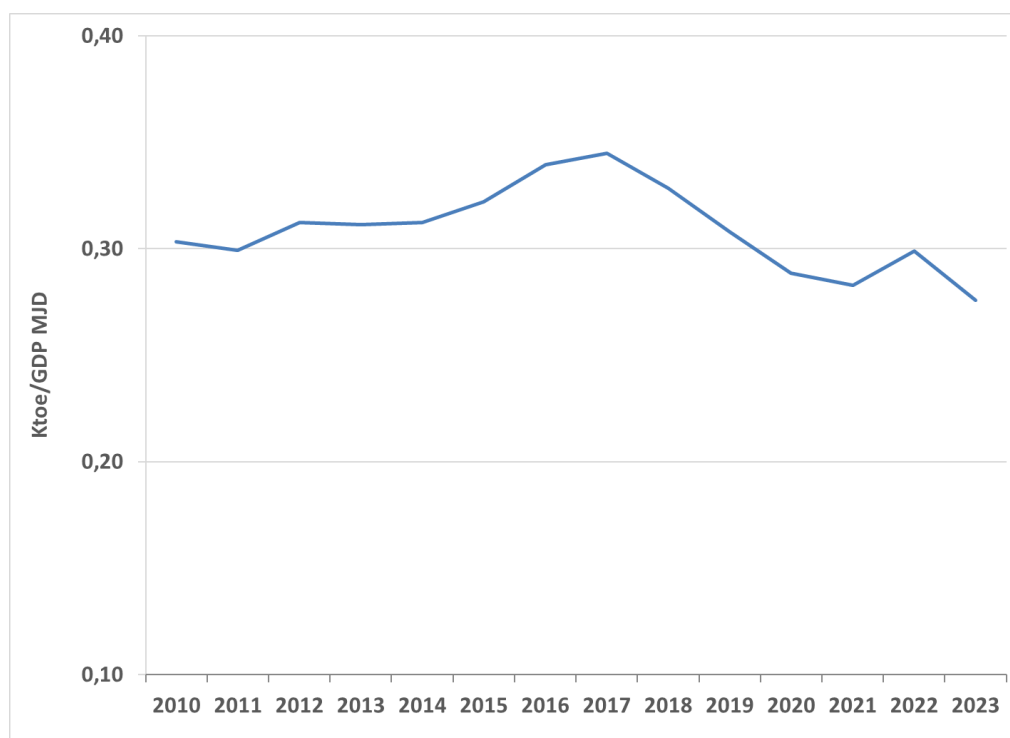


Figure 40: Primary energy intensity in the period 2010-2023¹²

The performance of the transformation sector, measured by the ratio of the final energy consumption to the primary energy consumption, has improved by 5% in period 2010-2023. The improvement trend is continuous, although the values of the ratio range between 66% in 2010 to 69% in 2023 (Figure 40). The specific consumption of electricity generation has also improved by 41% in the period 2010-2023, as it decreased from 223 toe/GWh in 2010 to 133 toe/GWh in 2023 (Figure 41), because of the increase of the share of RES in the electricity generation and the operation of efficient gas fired CCGTs.

Finally, the prices and tariffs for various energy products are presented in Table 6. In Jordan, electricity and oil product prices are adjusted by government authorities through structured pricing mechanisms. Electricity tariffs are set by the Energy and Minerals Regulatory Commission (EMRC) based on a cost-recovery model that incorporates generation, transmission, and distribution costs. Oil product prices are reviewed monthly by the government's Fuel Pricing Committee, which uses a formula based on international Platts prices, freight, insurance, exchange rates, and domestic logistics and tax components. This formula ensures that domestic prices reflect global market trends, while certain products such as LPG cylinders remain partially subsidized to protect low-income households.

¹² Source: Own elaboration based on energy balance data from MEMR 2023 and value-added data from World Bank Databank, 2023

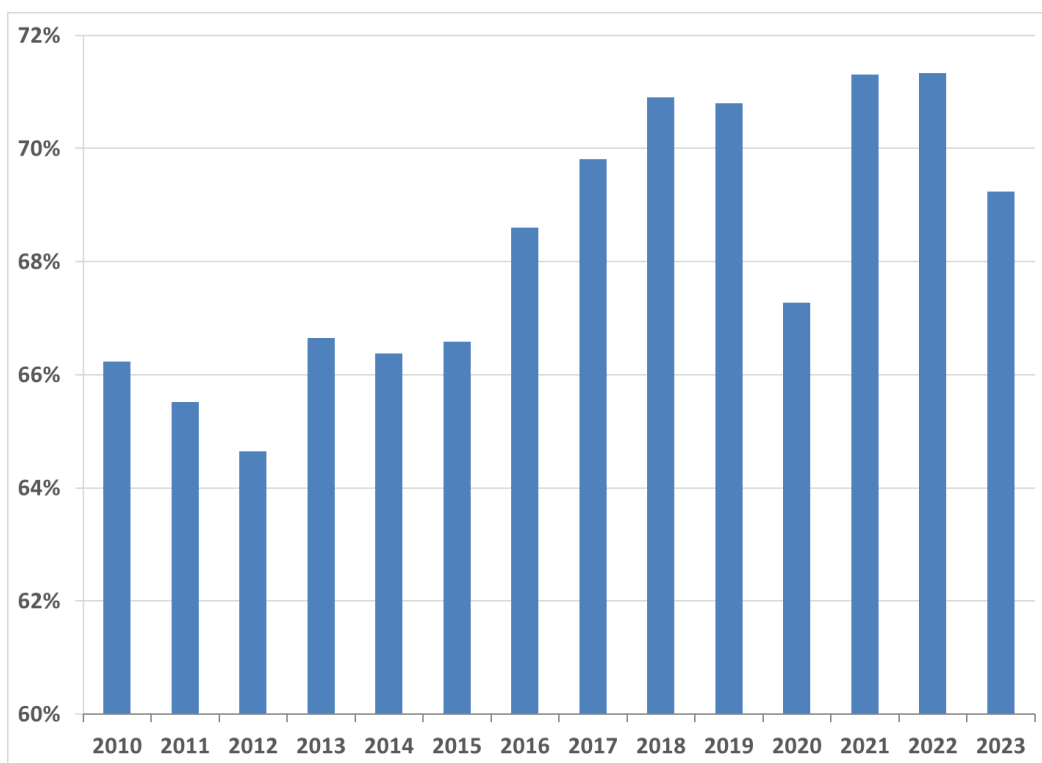


Figure 41: Efficiency of the transformation sector in the period 2010-2023¹³

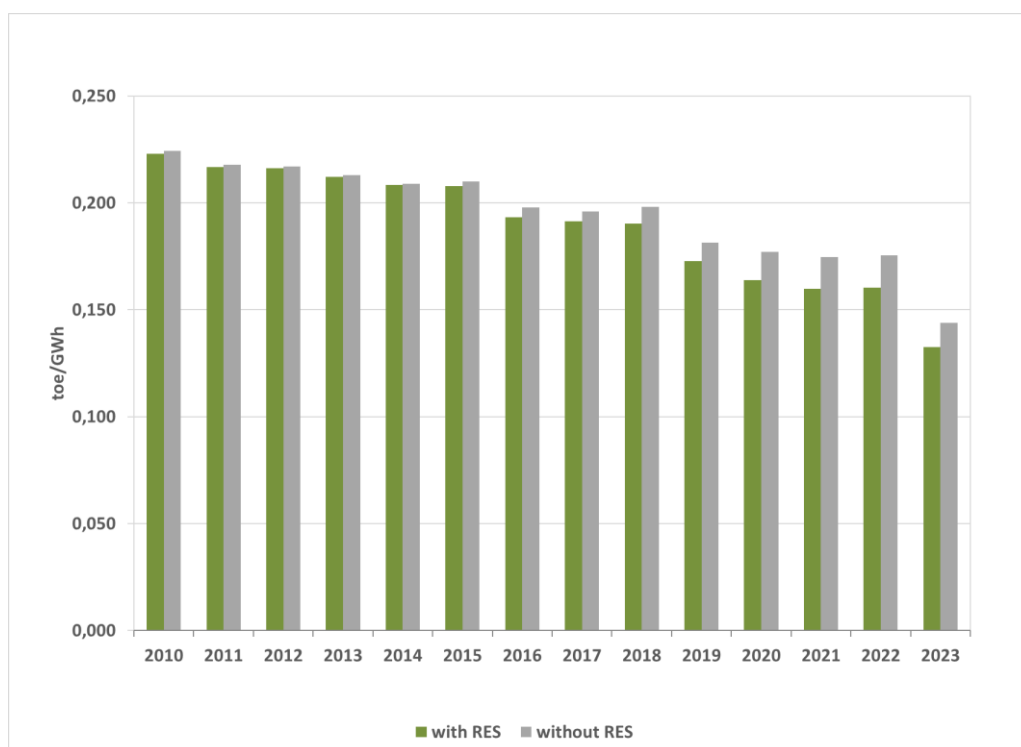


Figure 42: Specific consumption of electricity generation in the period 2010-2023 (Source MEMR, 2023)

¹³ Source: REEE II-TA (2018) and MEMR, 2023

Table 8: Energy products prices and tariffs (Source: National Electric Power Company 2023 and Global petrol prices 2025)

Energy product	Price-Tariff
Retail electricity (Source: National Electric Power Company, 2023)	
Household (Fils/kWh)	50-200
Domestic (Fils/kWh)	42-256
Flat Rate Tariff for TV & Broadcasting Stations (Fils/kWh)	152
Commercial Sector (Fils/kWh)	120-152
Flat Rate Tariff for Banking Sector (Fils/kWh)	285
Telecommunication Sector (Fils/kWh)	135-178
Flat Rate Tariff for Agriculture (Fils/kWh)	55
Agriculture (Fils/kWh)	49-55
Flat Rate Tariff for Water Pumping (Fils/kWh)	95
Flat Rate Tariff for Hotels (Fils/kWh)	82
Streets Lighting (Fils/kWh)	114
Army Forces (Fils/kWh)	146
Private hospitals (Fils/kWh)	140
Port Corporation (Fils/kWh)	159
Agriculture / Commercial (Fils/kWh)	98
Buildings operating on a charity basis (Fils/kWh)	42-256
Bulk supply electricity (Source: National Electric Power Company, 2023)	
Mining & Quarrying Industry (Fils/kWh)	170-237
Medium Industrial Consumers (Fils/kWh)	65-68
Other large Industries (Fils/kWh)	109-124
Small Industrial Consumers (Fils/kWh)	60-68
Other	
Gasoline (JD/lt) (Source: Global petrol prices) Apr 2025-July 2025	1.07-1.09
Diesel (JD/lt) (Source: Global petrol prices) Apr 2025-July 2025	0.65-0.68

3.2.7 Energy Balance for the year 2023

The complete energy balance for 2023 is presented in the next figure in order to demonstrate all the energy flows within the energy system.

Sector	Crude Oil	LPG	Gasoline	Kerosene	Jet Fuel	Diesel	Fuel Oil	Other	Total Oil Products	Coal	L. Coke	Oil Shale	N. Gas	Electricity	Solar Energy	Bio Mass	Thermal Renewable Energy	الطاقة الكلية
Indigenous Production	6								0			806	153	1139	210	13	223	2327
Imports	1775	521	956	23	43	1042	0	0	2585	111	0		2886	23		27	27	7406
Exports							-73	0	-73				0	0				-73
Bunkers				0	0	0			0									0
Stock Changes	56	6	15	10	-8	13	42	-1	76									132
Primary Energy Supply	1837	527	970	33	35	1055	-31	-1	2588	111	0		3039	1162	210	40		8986
Electricity						0	-3		-3			-806	-2808	1524				-2093
Power Plant Own Use														0				
Oil refinery	-1837	65	405	70	321	505	255	130	1753					0				-84
Oil Refinery Own Use					0	0	-120	0	-121					-5				-126
Trans. & Dist. Losses									0					-261				-261
InLand Demand	0	593	1376	103	356	1559	101	129		111	0	0	231	2419	210	40	250	
Final Energy Consumption	0	482	1436	81	222	1465	98	95	3878	226	0		219	1660	199	40		6222
Industrial		13				125	161		299	111	0		231	408				1048
Transport			1412		278	1079	6		2775					1				2776
Commercial & Services		82				69			152					356	46	16	63	570
HouseHolds		428		103		92			623					820	164	23	187	1630
Other Sectors		24				190			213					287				500
Non energy Use								118	118					0				118
Statistical Differences (%)	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0		0

Figure 43: Energy balance for the year 2023 (Source: MEMR, 2023)

3.3 Current policy measures and strategies - Potential of indigenous energy resources

3.3.1 Existing strategies

Jordan's Economic Modernization Vision (EMV) considers the energy sector as a strategic pillar for driving economic competitiveness, industrial transformation, and environmental sustainability. Within this context the Ministry of Energy and Mineral Resources (MEMR) has outlined several targeted energy priorities for the 2024–2025 implementation period, designed to accelerate the clean energy transition, reduce energy supply costs, and enhance overall system efficiency, while fostering investment and private sector engagement. A key priority is enhancing environmental sustainability and improving energy efficiency. This includes widespread deployment of solar water heating systems for households and low-income families, installation of municipal-scale photovoltaic systems, and the expansion of solar and wind energy capacity. A major area of focus is the transition to clean energy, underpinned by Jordan's ambitious green hydrogen program. A wide range of green hydrogen production projects are planned with the involvement of local, regional, and international developers. These include large-scale integrated projects aimed at supplying hydrogen for export markets and future domestic use in industries and transport. To address cost challenges in the electricity sector, a comprehensive financial reform plan has been introduced. Key measures include transitioning from a Floating Storage Regasification Unit (FSRU) to a more cost-effective Floating Storage Unit (FSU) for LNG imports and expanding natural gas supply to industrial zones such as Mowaqar, Zarqa, Al-Rawda, and Al-Qweira. These efforts aim to displace expensive liquid fuels and support industrial energy cost reductions. Infrastructure development plays a central role in the modernization plan. This includes accelerating the rollout of smart meters across electricity distribution networks, advancing development of domestic gas fields and strengthening interconnection capabilities with neighbouring countries. System efficiency is being further supported through the development of strategic electricity storage projects and high-efficiency generation facilities. These include the construction of combined-cycle power plants and a pumped-storage hydroelectric project near Wadi Mujib, aimed at increasing the grid's flexibility and its capacity to absorb renewable energy. Regulatory modernization is also a priority, with the introduction of a new Natural Gas Law to enhance the legal framework for midstream and downstream gas activities. Additional policy reviews are focused on introducing time-of-use electricity tariffs and expanding renewable energy storage solutions to reduce electricity system costs. Jordan's energy modernization vision includes a strong investment component, with new upstream exploration areas opened for private investment and incentives offered for clean energy deployment. This reflects a growing alignment between public policy and investor interest in both conventional and renewable energy resources.

The **Jordan Comprehensive Energy Sector Strategy 2020–2030**, which will be replaced by the current strategy, outlines the government's long-term vision to achieve sustainable energy security, diversify supply sources, and optimize the use of indigenous energy resources. The strategy serves as a blueprint for reducing dependency on imported fuels, lowering energy costs, and transitioning toward a cleaner, more resilient energy system. It builds upon achievements made through previous strategies while addressing persistent structural challenges. It is underpinned by four core pillars: energy security, affordability, sustainability, and resource optimization. The strategic planning process was informed by a PESTEL (Political, Economic, Social, Technological, Environmental, and Legal) analysis and a scenario-based energy planning methodology. Among four evaluated scenarios, the "high independency" scenario was selected as the most desirable development path. This scenario prioritizes increased domestic energy

production, greater integration of renewable energy, enhanced energy efficiency, and the development of supporting infrastructure and regulations. A major objective of the strategy is to raise the contribution of domestic energy sources to meet national demand. By 2030, renewable energy is targeted to account for 11% of primary energy consumption and 33% of electricity generation, while natural gas will continue to play a central role. These changes are expected to reduce the share of crude oil and petroleum products in the total energy mix.

Jordan's National Green Hydrogen Strategy sets out a comprehensive roadmap to position the Kingdom as a competitive regional hub for green hydrogen (GH2) production and export. Framed within Jordan's broader goals of achieving energy security, economic modernization, and climate resilience, the strategy outlines a phased development approach that leverages the country's abundant renewable energy potential, strategic geographic location, and investment-friendly environment. The vision is to establish Jordan as a green hydrogen exporter by 2030 while supporting domestic decarbonization across hard-to-abate sectors such as industry, transport, and power. Green hydrogen is seen not only as a clean energy vector but also as a catalyst for industrial transformation and green economic development. The strategy sets a dual focus first, to meet international demand for low-carbon hydrogen derivatives such as green ammonia, synthetic fuels, and methanol and second, to support national climate objectives under Jordan's updated Nationally Determined Contributions (NDCs). Jordan's comparative advantage lies in its high solar irradiance and significant wind resources, which enable the generation of low-cost renewable electricity, a critical input for green hydrogen via electrolysis. By 2030, the Green Hydrogen Strategy aims to allocate up to 8 GW of renewable capacity to green hydrogen production, scaling to over 22 GW by 2040. Electrolyser capacity is expected to reach between 1 and 5 GW by the early 2030s. The strategy is structured around five pillars: (1) Market Development, focusing on securing long-term export offtake agreements and stimulating domestic demand; (2) Infrastructure and Land Use, emphasizing the creation of GH2 hubs in designated zones with access to transmission grids and water sources; (3) Regulatory Framework, aimed at streamlining licensing, setting environmental and safety standards, and ensuring grid access; (4) Investment and Financing, with mechanisms to attract international project developers and de-risk private capital through public-private partnerships; and (5) Research, Development, and Innovation, which supports technology localization and workforce development.

On the regulatory front, the government has amended the Electricity Law and is in the process of issuing a Gas Law that will incorporate provisions related to hydrogen. Additionally, work is underway on developing a green hydrogen certification scheme. These legislative updates aim to clarify institutional responsibilities, define market access conditions, and streamline project approval timelines. The Ministry of Energy and Mineral Resources (MEMR) will serve as the main coordinating body, working alongside the Energy and Minerals Regulatory Commission (EMRC), the Ministry of Water and Irrigation (MWI), and the Jordan Investment Fund, according to their respective roles outlined in the regulatory framework.

. Pilot projects and Memoranda of Understanding (MoUs) with leading hydrogen developers are already underway, including feasibility assessments for integrated renewable-hydrogen facilities. Environmental sustainability is a core consideration and the strategy mandates life-cycle emissions tracking and prioritizes water-efficient electrolysis technologies such as PEM and AEM. Brackish water desalination co-located with renewable projects is planned to mitigate strain on Jordan's freshwater resources. Socio-economic co-benefits, including job creation, industrial diversification, and rural development, are central to the national value proposition. In the short term (2024–2026), the strategy focuses on regulatory setup,

pilot project execution, and stakeholder engagement. In the medium term (2027–2030), large-scale demonstration projects and export infrastructure are expected to materialize. In the long term (post-2030), Jordan envisions full market integration with regional and global value chains, particularly the EU and Gulf countries, and expansion into synthetic fuels and hydrogen-based heavy industry.

3.3.2 Oil derivatives

The security of supply of oil derivatives continues to be a strategic priority for Jordan. According to the latest statistics, the Jordan Petroleum Refinery Company (JPRC) in Zarqa, is currently operating at approximately 40,000 barrels per day, which is about 53% of the maximum operational capacity. The JPRC has long planned a major expansion project aimed at increasing operational refining capacity to 73000 barrels per day (MEMR 2025). However, the final investment decision remains pending, the key issue being securing the estimated USD 2 billion which is needed for the upgrade funding. JPRC retains ownership of key infrastructure, including the oil terminal and storage facilities in Aqaba, as well as three LPG bottling plants in Amman, Zarqa, and Irbid. Two other companies, Manaseer and Total Energies, now import most fuel products, increasing competition in the market. Regarding imports, approximately 65% of diesel, 70% of gasoline, and 90% of LPG are sourced from international markets, predominantly from Saudi Arabia and India. These imports are priced competitively and sold through a pricing formula regulated by MEMR¹⁴, which adds storage, distribution, and taxation costs to the import parity price.

In terms of policy direction, the government continues to pursue several core objectives: (i) the conversion of heavy fuel oil into lighter, cleaner products; (ii) the improvement of oil derivatives' quality specifications; (iii) the diversification of crude oil import sources (via Aqaba, overland, and the proposed Iraqi pipeline); and (iv) the development of the Hamza oil field and oil shale exploration. Furthermore, there is a clear strategic objective to raise the national storage capacity of oil products to meet international standards, improve domestic logistics, and ensure sufficient operational and strategic reserves.

The Strategic Stock for Crude Oil and Petroleum Derivatives Regulation No. 58 of 2020 establishes the legal and institutional framework for maintaining a national reserve of petroleum products in Jordan. The regulation is designed to ensure the Kingdom's energy security by mandating a minimum level of strategic stocks of crude oil and petroleum derivatives which can be mobilized during supply disruptions or emergencies. Responsibility for oversight and enforcement of the regulation lies with the Energy and Minerals Regulatory Commission (EMRC). The EMRC is authorized to define minimum stockholding levels, regulate the licensing of storage operators, and ensure compliance with reporting and safety requirements. The operational management of the strategic stock is delegated to the Jordan Oil Terminals Company (JOTC), which serves as the sole entity responsible for storage, inventory management, and emergency release of the national petroleum reserves. JOTC operates from a network of existing infrastructure that includes storage terminals in Aqaba and Zarqa, as well as LPG bottling and storage facilities in Amman, Zarqa, and Irbid. These facilities house both operational stocks, intended for routine market supply, and strategic stocks, which are reserved strictly for emergency deployment. The regulation stipulates that the strategic stock must be maintained at levels sufficient to meet domestic demand in times of crisis, which could include temporary power generation needs during supply crises, and to fulfil Jordan's obligations under international arrangements, including potential commitments to the

¹⁴ Petroleum Derivatives Pricing Regulation No. 122/2019

International Energy Agency (IEA) or regional energy security mechanisms. The regulation reflects Jordan's policy shift toward crisis preparedness, ensuring that the country maintains both physical reserves and institutional readiness in the event of global or regional disruptions.

3.3.3 Natural gas

Jordan's natural gas sector is undergoing a significant transformation, driven by a combination of expanding domestic production, strategic infrastructure development, and ongoing reliance on imports. Currently, Jordan secures most of its natural gas from international sources via pipeline import from the north connection through a contract with Chevron and from the south through the Arab pipeline from Egypt.

Jordan is preparing for a significant transition in its LNG infrastructure. MEMR, along with the Aqaba Development Corporation (ADC), is overseeing the development of the country's first onshore LNG regasification terminal, the Sheikh Sabah LNG Terminal, which is expected to be commissioned by late 2026. This new facility is being developed in partnership with GAS Entec and AG&P and is designed to handle a throughput capacity of up to 700 MMcf/d. Once operational, it is anticipated that the permanent onshore terminal will replace the floating FSRU, offering improved efficiency, higher regasification capacity, and greater operational stability for Jordan's natural gas imports.

The Energos Eskimo FSRU was previously stationed in Jordan at the Sheikh Sabah Al-Ahmad Port in Aqaba since 2015 and is currently operating in Egypt and is connected to the Arab gas pipeline between Jordan and Egypt in order to provide Jordan by natural gas whenever needed. In 2023, Jordan and Egypt formalized an energy cooperation agreement, allowing Egypt to utilize the FSRU for the remainder of its charter with Jordan's National Electric Power Co (NEPCO), which concludes in 2025. New Fortress Energy (NFE) has a 10-year charter agreement with EGAS for the Energos Eskimo, and it is expected to commence operations at EGAS's LNG import terminal in Ain Sokhna, Egypt, by mid-2025. In a related move, it was reported in mid-2025 that Jordan had sub-chartered an additional FSRU (*Energos Force*). This unit serves as a supplementary measure to ensure uninterrupted LNG supply during the transition to the onshore terminal or to meet increasing seasonal or industrial demand. This development reinforces Jordan's commitment to maintaining flexible and resilient LNG import capabilities.

The national single buyer, NEPCO, maintains long-term gas contracts with EGAS and Chevron, ensuring supply continuity up to the 2030s. However, domestic gas production remains a strategic priority, particularly as the country seeks to reduce import dependence and enhance energy security.

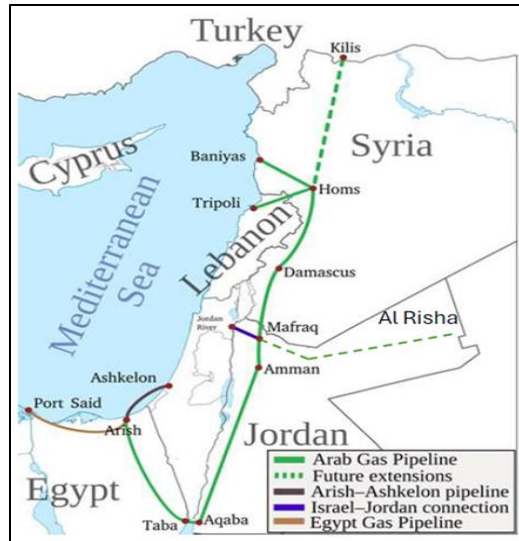


Figure 44: Existing and planned natural gas pipelines¹⁵

The Risha gas field, located in the eastern desert near the Iraqi border, is Jordan’s primary indigenous source of natural gas. Operated by the National Petroleum Company (NPC), Risha’s production capacity has increased in recent years, rising to 80 MMSCFD in 2025 after the resumption of drilling activities and the sales quantity reached 20MMSCFD . Under the current development plan, the NPC aims to ramp up production further in the period 2025–2029, with a target of 418 MMSCFD by 2029, when the Risha pipeline connecting the field with the Arab pipeline is expected to be operational. Beyond 2030 there are two possible production scenarios, an “upside” scenario reaching 812 MMSCFD by 2035 and a “Base” scenario reaching 570 MMSCFD by 2035. The “upside” scenario is used in all the pathways analysed in this document (in Chapters 5 and 6).

Risha Gas Field Production Capacity

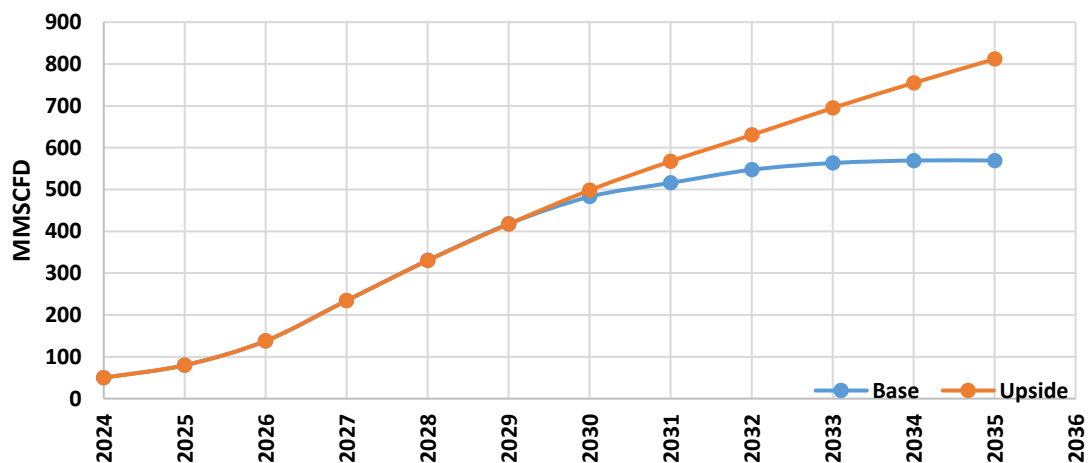


Figure 45: Projection of Risha gas field production potential¹⁶

¹⁵ Source National Petroleum Company (PLC)

¹⁶ Source: MEMR provided on 7/10/2025, National Petroleum Company (NPC)

To support this ambition, NPC has undertaken comprehensive geophysical reassessments and reservoir audits. The government has also engaged in coordinated planning to align the gas development strategy with broader economic objectives. These include delivering gas to industry to reduce energy costs, attracting gas-based investments, and promoting value-added applications such as gas-to-liquids and petrochemicals. Several supply agreements and memoranda of understanding have already been signed with industrial buyers including Jordan Chlorine, Unigaz, and others, reinforcing demand certainty for future production volumes. In parallel, the government aims to expand gas use in the residential and commercial sectors to reduce dependency on liquid fuels. The potential for natural gas use in Jordanian cities is also significant, particularly in urban centres like Amman and Zarqa and a relevant study highlighted that demand from sectors such as services, and residential buildings, especially for space heating, water heating, and cooking, could support the economic viability of city gas distribution networks. MEMR has issued an official document in 2025 titled "Opportunity to Develop Natural Gas Distribution Networks in Amman & Zarqa", under which interested parties are requested to submit a Letter of Intent with supporting documentation to MEMR as part of the preliminary process. Additionally, the project has been featured on Jordan's "Invest in Jordan" platform, underscoring its aim to attract investment for city gas pipelines spanning roughly 61 km, to serve residential, commercial, and light-industrial customers in both Amman and Zarqa.

3.3.4 Renewable Energy Sources

The legal foundation for promoting renewable energy in Jordan has evolved significantly. Initially introduced by the Renewable Energy and Energy Efficiency Law (REEEL) in 2012, the law aimed to stimulate investment through guidelines for renewable energy (RES) deployment and efficiency measures, with MEMR responsible for identifying suitable locations and coordinating land use per the law. In June 2024, this legislative framework was replaced by Law No. 12 of 2024, which retains and strengthens these provisions. The accompanying Bylaw No. 58 of 2024, titled "Regulating the Connection of Renewable Energy Source Facilities to the Electrical System," cancelled the previous 1 MW cap on *net metering* and introduced new connection options tailored for prosumers, including net billing, zero-to-grid, and buy-all/sell-all schemes

Grid-scale RES integration has accelerated and by the end of 2024, Jordan's total installed grid-connected solar PV capacity exceeded 2 GW, split almost evenly between distributed (1.08 GW) and transmission-level (0.99 GW) systems across operators. A 200 MW BOO solar tender was opened in May 2025, with commissioning expected by 2028, alongside lifting all project size limits as of September 2024

Under the updated Net Metering / Net Billing rules, developers can now choose from three connection models: net billing (excess daytime generation credits at US\$ 0.0705/kWh), zero-to-grid (self-consumption only), and buy-all/sell-all (selling all generation at the same rate). Tariffs vary by consumer type, and the 1 MW cap has been lifted, replaced by distributor assessments based on grid capacity.

NEPCO's Green Corridor project continues to support the expansion of RES by upgrading transmission lines and substations. Originally planned to be completed by 2023 at a cost of US\$160 million and financed in part by the EIB, this backbone, consisting of new 400 kV and 132 kV lines and substations, is central to integrating both current and future RES projects.

Financial incentives remain strong. The Jordan Renewable Energy and Energy Efficiency Fund (JREEEF), created under REEEL and the 2015 by-law, continues to offer subsidies, loans, guarantees, and technical grants. As of September 2024, the fund launched an US\$ 11.2 million rebate program covering up to 30%

of rooftop PV and solar thermal installation costs, targeting 9,000 installations. Connection tariff ceilings for excess electricity persist under Net Metering / Billing regulations at 120 fils/kWh (~US\$ 0.17) for solar, 95 fils (~US\$ 0.13) for hybrid, and 85 fils (~US\$ 0.12) for other RES. A +15% bonus applies for Jordan-made systems until total capacity surpasses 500 MW. Jordan has actively encouraged large-scale utility projects, as MEMR issued a major 200 MW solar tender in May 2025, aiming to add this capacity by 2028 with private sector investment.

3.3.5 The electricity sector

Under the General Electricity Law No. (10) of 2025, the Energy and Minerals Regulatory Commission (EMRC) remains the independent regulator of Jordan's electricity sector, with an expanded and clarified mandate consistent with a modernized market framework. EMRC is responsible for licensing all electricity sector activities, explicitly including generation, transmission, distribution, bulk supply, retail supply, and for the first time mentioned in legislation, energy storage as a distinct licensed activity. Storage is recognized on an equal legal footing with generation, transmission, and distribution, and requires a dedicated license from EMRC, either as a standalone activity or when integrated with generation or transmission assets. The law further integrates storage into the regulated electricity cost structure, explicitly including storage costs within system tariffs. This establishes a clear legal basis for utility-scale storage procurement, hybrid renewable-plus-storage projects, and future market-based storage services, while allowing storage to support system adequacy, flexibility, and reliability under centralized dispatch in the current market structure.

The Law explicitly preserves the single-buyer model in the short to medium term, confirming that the licensed transmission entity acts as the sole bulk supplier until a Cabinet decision authorizes a transition to a competitive wholesale electricity market. Within this framework, EMRC retains a central role in regulatory oversight, licensing compliance, and dispute resolution among licensees, as well as between licensees and consumers, thereby reinforcing regulatory certainty during the transition period. The law reaffirms that electricity transmission remains a licensed activity, while allowing private investment in transmission infrastructure through licensed entities, including "future transmission licensees.". Strategically, the law mandates MEMR to continuously monitor sector development and prepare the transition from a single-buyer model to a competitive wholesale electricity market, creating a clear legal pathway for future market liberalization, under which generation, storage, and ancillary services could progressively be unbundled and competitively traded.

Electricity tariffs approved under EMRC's authority explicitly reflect the full costs of the electricity system, including generation, transmission, distribution, energy storage, capacity, and network services. Electricity produced by licensed generators is sold to the bulk supplier under PPAs, while large consumers may continue to be supplied directly by the bulk supplier under licensed arrangements. Distribution companies remain responsible for retail supply within their concession areas, tariff application, grid connection approvals, impact studies, and the implementation of net metering and related schemes, subject to EMRC regulation.

As a conclusion the 2025 General Electricity Law institutionalizes renewable energy and storage as core components of Jordan's electricity system, strengthens legal certainty for private generation and transmission investments, and establishes a forward-looking framework capable of supporting large-scale renewable integration, storage deployment, and eventual market opening.

3.3.6 Oil-shale

The vision of utilizing indigenous oil shale for electricity generation, crystallized with the launch of the Attarat Oil Shale Power Plant, Jordan's first power facility using direct combustion of oil shale. Developed by the Attarat Power Company (APCO), a consortium led by YTL Power, Guangdong Energy, and Eesti Energia, the project features two 235 MW units. The first unit began commercial operation in October 2022, followed by the second in May 2023. It operates under a 30-year take-or-pay PPA with NEPCO, supplying baseload power and including state guarantees for electricity purchase. MEMR has since paused the development of new direct-burning oil shale plants due to the inflexible nature of such units and Jordan's long-term gas commitments, meaning no new oil-shale-fired plants are expected before 2030.

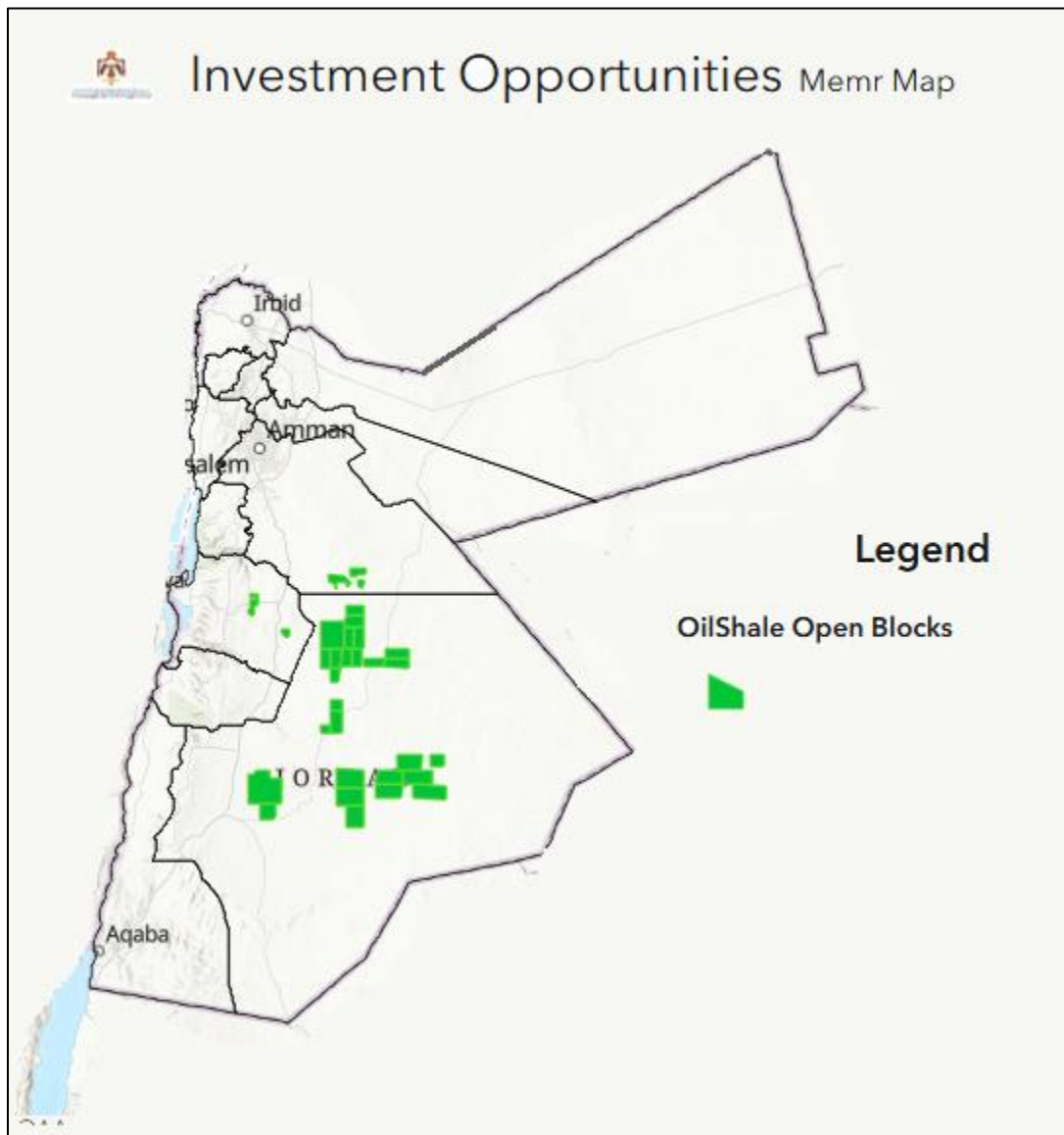


Figure 46: Oil shale deposits in Jordan¹⁷

¹⁷ Source: <https://memr-jordan.maps.arcgis.com/apps/dashboards/22d32daf9f704dbf9e640a018f8c2386>

On the synthetic oil production front, MEMR has signed a memorandum of understanding (MOU) in 2023 with Al Majjarah Oil Shale and natural resources company to execute exploration program in Al Iajjun area. Also MEMR has offered the Oil Shale investment opportunities as shown on Figure 46 and on the interactive map that found on MEMR website, While proposals once envisioned significant synthetic oil outputs, these remain contingent on securing full project financing; also, the synthetic oil requires further processing before entering any conventional refinery. As such, it is generally expected to expand the Jordan Petroleum Refinery by adding a desulfurization unit to receive oil produced from oil shale retorting.

3.3.7 Pumped Hydro Energy Storage

Pumped Hydroelectric Energy Storage (PHES) projects can play a crucial role in facilitating Jordan's energy transition towards higher shares of renewable generation. Pumped hydro technology is based on synchronous generation, enabling it to deliver a full range of ancillary services, including the provision of inertia, frequency and voltage support, and adequate fault level contribution to the grid. Implementation of Pumped hydro projects is long as development activities include finding a proper location, geological investigations, optimization of the technical solution, environmental and social assessments and complexities in constructing upper and lower reservoirs.

The implementation of pumped hydro projects requires a long time and must be planned well in advance, as the development process involves selecting an appropriate site, conducting geological investigations, optimizing the technical design, performing environmental and social assessments, and addressing the engineering complexities associated with constructing the upper and lower reservoirs. Pumped hydro projects have an exceptionally long operational lifetime compared to many other energy storage technologies. When properly designed and maintained, these facilities can operate reliably for 50–100 years, providing a durable and cost-effective solution for large-scale energy storage and grid stability over multiple generations.

A comprehensive feasibility study and business model for a hydropower storage project was conducted, identifying the Al-Mujib Dam as the site with the highest potential for a pumped storage facility, offering the lowest projected specific energy storage costs. The Mujib PHES project will be implemented with an installed capacity of 450 MW and a storage duration of 6 hours. Its implementation will significantly support the further integration of renewable energy projects into the Jordanian grid.

Other sites have been analysed as potential candidates for new PHES projects, including the Wadi Al-Arab and King Talal Dam locations that have to be further analysed and considered for possible implementation.

3.3.8 Battery Energy Storage

A wide range of battery technologies are available for large-scale energy storage applications, each with its own characteristics and benefits.

Lithium-ion batteries are the dominant technology in today's energy storage market, accounting for over 90% of global grid-scale battery installations. They offer high energy density, fast response times, and long cycle life, making them well suited for both grid-scale and distributed applications. Compared to other battery technologies, lithium-ion systems are lightweight, efficient, and capable of providing a wide range of services to the power system. They are particularly effective for short-term energy storage applications.

Other technologies, such as flow batteries, utilize liquid electrolytes to enable longer discharge durations and extended lifespans, making them well suited for long-duration energy storage. Meanwhile, emerging technologies including solid-state batteries, sodium-ion, and metal-air systems are under development, with the potential to further reduce costs, improve efficiency and enable more flexible and resilient energy storage solutions for the future grid.

Battery inverter technologies can contribute to system frequency and voltage regulation. They can provide ‘synthetic inertia’ or fast frequency response, although their ability to support fault levels remains limited. The lifespan of a battery energy storage system is primarily determined by its charge and discharge cycles but is also influenced by the operation mode. In general, batteries operated in constant power mode degrade more quickly, leading to a shorter service life. The implementation timeline for BESS projects is relatively short and cost relatively low, making them well suited for integration with wind and solar installations. Accordingly, in the TIMES model, all wind and solar projects commissioned after 2027 in the Optimistic Pathway and after 2030 in the Reference Pathway are accompanied by battery systems with a capacity equal to 25% of the associated renewable plant and a storage duration of four hours. The relatively short implementation timeline of BESS projects makes them well suited for integration with wind and solar installations.

3.3.9 Nuclear power

Nuclear energy plays a crucial role in achieving global net-zero greenhouse gas emissions by 2050, serving as a reliable, low-carbon, and baseload source that can effectively complement variable renewable energies such as wind and solar. Its benefits include:

- Providing a stable, low-carbon backbone: Nuclear plants operate reliably around the clock, making them ideal for supplying baseload electricity and supporting grid stability as the share of variable renewables increases.
- Displacing fossil fuels: By replacing coal and gas generation, nuclear energy can sharply reduce CO₂ emissions and other pollutants.
- Enhancing energy security: Nuclear generation reduces reliance on imported fossil fuels, making the energy supply more resilient to price volatility and geopolitical risks.
- Complementing renewables: In high-renewables scenarios, nuclear can balance the grid and reduce the cost and scale of long-duration storage required to manage fluctuations in wind and solar output.

Jordan has been pursuing a nuclear program as part of its long-term energy strategy to diversify its generation mix, reduce reliance on imported fossil fuels, and build a more resilient and sustainable energy sector. The initiative, led by the Jordan Atomic Energy Commission (JAEC), includes the establishment of a 5 MW Research and Training Reactor at the Jordan University for Science and Technology, which supports education, research, and the production of medical isotopes.

In alignment with global net-zero goals and Jordan’s own energy security objectives, JAEC emphasizes the strategic role of nuclear energy in supporting a balanced, low-carbon power system. In official planning documents, JAEC notes that nuclear power can contribute significantly to long-term stability in electricity supply while enabling higher penetration of intermittent renewables such as wind and solar. This vision aligns with broader national commitments to reduce greenhouse gas emissions and accelerate the transition to sustainable sources of energy.

A key focus for Jordan's nuclear future is Small Modular Reactors (SMRs), which JAEC is actively exploring for deployment. SMRs offer several advantages in the Jordanian context: lower cooling water requirements than traditional large reactors (important given Jordan's arid climate), modular factory construction that can reduce project risk and financing hurdles, suitability for inland siting closer to load centers and the potential to support energy-intensive sectors such as data centers and artificial intelligence infrastructure. A reliable and domestically supported baseload generation source is also viewed as vital for reinforcing Jordan's energy and water security, particularly as the country seeks to attract high-technology investment and sustainably scale its economy.

In Jordan, the deployment of the first SMR is not anticipated before 2035, as JAEC aims to gain more operational experience from early international installations and to carefully tailor technology selection, regulatory frameworks, and local workforce development to national needs.

In support of implementing nuclear energy in Jordan, it is important to highlight the country's significant uranium reserves and ongoing exploration efforts as part of its long-term nuclear energy strategy. The main uranium resources are in central and southern Jordan, including:

- Central Jordan: The Central Jordan Uranium Project in the Swaqa area, featuring shallow-depth mineralization suitable for open-pit mining.
- Other Areas: Additional uranium mineralization identified in locations such as Khan Azzabib and Wadi Balaama.

The Jordan Uranium Mining Company (JUMCO), a subsidiary of the Jordan Atomic Energy Commission (JAEC), is responsible for uranium exploration, resource characterization, and future mining and processing activities. Preliminary studies and feasibility assessments have confirmed the potential for domestic uranium extraction, offering a secure, long-term fuel supply for future nuclear energy generation and reducing reliance on imported fuel.

SMRs are generally considered to have lower upfront capital costs per unit compared to traditional large-scale nuclear plants, thanks to their smaller size and potential for modular, factory-built construction. However, their cost per kilowatt (around USD 4,000–8,000) can still be relatively high in early deployments due to limited economies of scale. Advantages of SMRs include reduced financing and construction risk, shorter building times (3-5 years versus 5-10 for large units), and the ability to locate closer to load centers, minimizing grid expansion needs.

The introduction of nuclear generation into the Jordanian power system would further diversify the country's energy mix and reduce its dependence on imports. As must-run units, nuclear plants can also support system stability and potentially reduce the need for additional synchronous condensers.

However, given the relatively small size of the Jordanian power system and its limited connections to neighboring countries, nuclear approach may restrict the ability to integrate variable renewable generation, potentially increasing curtailment, especially in scenarios where renewables comprise 50% of the generation mix.

3.3.10 Electricity Demand

In 2024, NEPCO finalized and endorsed its Generation Master Plan, which serves as the foundational roadmap for power supply expansion and system resilience in Jordan. It sets a national target of achieving

at least 31% renewable energy in the electricity supply mix by 2030, incorporating both transmission- and distribution-connected projects. This master plan underpins decision-making for new generation and storage capacity, ensuring that all future investments are aligned with competitive procurement principles outlined under the World Bank's Electricity Sector Efficiency and Supply Reliability Program and consistent with Jordan's PPP and Public Procurement framework. NEPCO's plan also includes grid reinforcement, including development of the Northern Green Substation and associated overhead transmission lines, financed in partnership with the EBRD. These upgrades strengthen network capacity in northern and central regions, enhance the system's ability to absorb renewable generation, and support NEPCO's goal of increasing transmission availability to 99.96% by 2026. Overall, the master plan represents a critical step in Jordan's energy transition, driving growth in distributed and utility-scale renewables, strengthening infrastructure resilience, and aligning NEPCO's operations with international standards in cost-efficiency, competition, and sustainability.

Jordan is actively positioning itself as a regional digital gateway, with data centre development emerging as a strategic priority under its Digital Transformation Strategy 2021–2025 and the broader Reach 25 National Vision. Building on strong ICT fundamentals, such as over 88% internet penetration, a fast-growing tech-savvy workforce, and government-led initiatives to digitize public services, Jordan has attracted interest from both regional and global operators exploring data infrastructure investment. Industry reports project the Middle East & Africa data centre market to grow rapidly, and Jordan is seen as a potential corridor for undersea cable traffic and AI-driven cloud services. The Arab Fund's Country Partnership Strategy 2025–2029 explicitly supports developing energy and data infrastructure for the Aqaba Digital Hub, offering financing for related technical studies and fiber cable-linked expansions such as the Blue-Raman line.

Jordan is preparing to introduce Time-of-Use (ToU) tariffs for the electricity consumption in all sectors, as part of its ongoing electricity market reforms aimed at enhancing efficiency, demand-side management, and grid flexibility. The Energy and Minerals Regulatory Commission confirmed that pilot programs are underway, supported by technical studies from international donors, to assess consumer responsiveness and system readiness. The new tariff structure will segment electricity prices by periods of peak, shoulder, and off-peak hours, encouraging consumers to shift usage away from high-demand periods. This is particularly important in the context of growing rooftop solar adoption and increasing use of electric vehicles (EVs), both of which contribute to load variability. To enable the rollout, smart meter deployment is being expanded in coordination with distribution companies (JEPCO, IDECO, EDCO), and a regulatory framework for dynamic pricing is expected to be finalized by September 2026. The government sees ToU tariffs as a crucial tool to reduce peak loads, avoid costly generation capacity additions, and better integrate renewable energy into the grid. A brief impact analysis was performed using the hourly demand variation to estimate how electricity demand would respond to the implementation of ToU tariffs. The core assumption is that demand is responsive to time-differentiated pricing, particularly during peak periods. The analysis projected that ToU implementation starting in 2027 will lead to a 8.9% reduction in the system peak demand and a 1.8% reduction in energy use. International benchmarks from California, Spain, Italy, South Korea, and others were used to validate assumptions and calibrate expectations, with results aligned to global experiences showing 5–15% peak demand shifts and 3–12% energy reshaping across residential ToU programs. Analysis of the existing literature indicates a critical distinction between the short-term and long-term effects of ToU tariffs, since early gains from ToU pricing tend to stabilize or

decrease over time, as consumer responsiveness declines due to behavioural adaptation, economic shifts, or changes in appliance ownership and efficiency.

A literature review conducted to examine the experiences of other countries (summarized in the table below), in addition to those mentioned, revealed that:

- The most consistent impact of TOU tariffs is peak demand reduction, generally between 5% and 12%, depending on adoption levels.
- The total system energy reduction is more modest, typically 2%–5%, and strongly dependent on behavioral change and demand elasticity.
- Uzbekistan achieved the largest absolute reduction in total energy consumption, driven by TOU combined with social limits and aggressive tariff reforms.
- Philippines and India show steady results in lowering peaks and improving infrastructure efficiency, with greater operational benefits than outright reductions in total MWh consumed.

Country	GDP PPP per capita (2024 USD)	Population 2024 (M)	TOU Tariff Status	Impact on System Peak Demand	Impact on System Energy
Jordan	9,52	11.7	Partial/Pilot	Not broad/pilot results only	Not broad/pilot results only
Bolivia	9,844	11.3	Not generalized	Up to 5% reduction (in pilots)	<2% reduction (in pilots)
Tunisia	12,714	12.0	Urban pilots	Up to 5% reduction (in pilots)	Marginal (<2%) reduction (in pilots)
Philippines	10,376	117	Urban/industrial, broadening	5–12% reduction (peak hours)	2–5% reduction (mainly shift, not total)
Uzbekistan	10,45	36	Industrial/broad segment	Strong: largest users drop sharply	10.6% national residential reduction*
Jamaica	10,26	2.8	Residential pilots	Up to 5% reduction (in pilots)	<2% reduction (in pilots)
Namibia	10,281	2.6	Pilots only	Up to 5% reduction (in pilots)	<2% reduction (in pilots)
India	9,817	1,428	Urban/industrial, segmented	5–10% reduction (peak hours)	<3% reduction (mainly shift, not total)
Morocco	9,066	38	Pilots	Up to 5% reduction (in pilots)	<2% reduction (in pilots)

Figure 47: ToU Literature Review

3.3.11 Renewable Energy Sources potential

Jordan possesses a significant potential of solar and wind energy, that positions it as a regional leader in the transition to a low-carbon, sustainable energy system. The country's energy planning documents, along with international technical assessments, emphasize both the richness of renewable resources and the structural, regulatory, and infrastructural challenges that must be addressed to unlock their full contribution to national development.

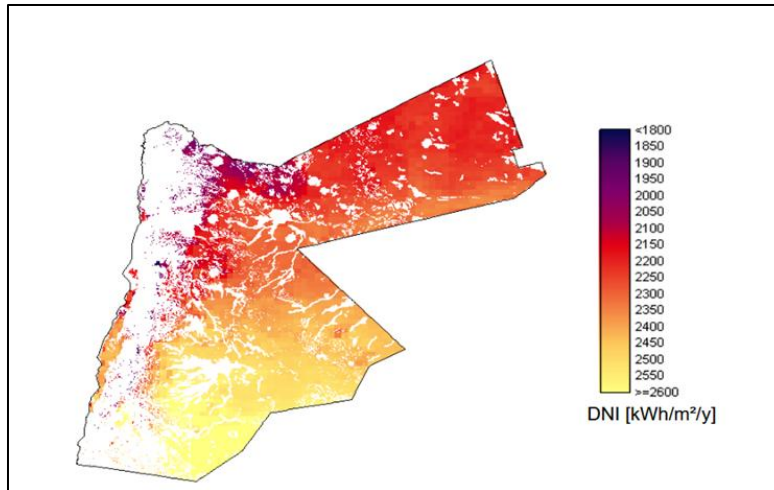


Figure 48: Direct Normal Irradiance levels in Jordan¹⁸

Solar energy stands out as Jordan's most abundant and technically mature renewable resource. Situated within the global solar belt and blessed with more than 300 days of sunshine per year, the country receives a high level of solar irradiance throughout its territory. In particular, the Global Horizontal Irradiance (GHI) in the southern region reaches 2,336 kWh/m² annually, placing Jordan among the top-performing solar locations worldwide (REEE II-TA, 2017). Solar resource assessments conducted in areas such as Mafraq and Aqaba report Direct Normal Irradiance levels exceeding 7.5 kWh/m² during peak summer months. These conditions provide a favourable environment for the expansion of both photovoltaic and concentrated solar power systems.

Wind energy potential is also considerable, particularly in elevated and sparsely populated areas such as the Jordanian Highlands, Wadi Araba, Tafila, and parts of Irbid. These regions consistently record average wind speeds ranging between 7 and 11 m/s at turbine hub heights, and detailed statistical analyses confirm capacity factors and energy yields that meet international benchmarks (REEE II-TA, 2017).

¹⁸ Source MEMR (https://www.memr.gov.jo/EBV4.0/Root_Storage/AR/FAQ/documents6.pdf)

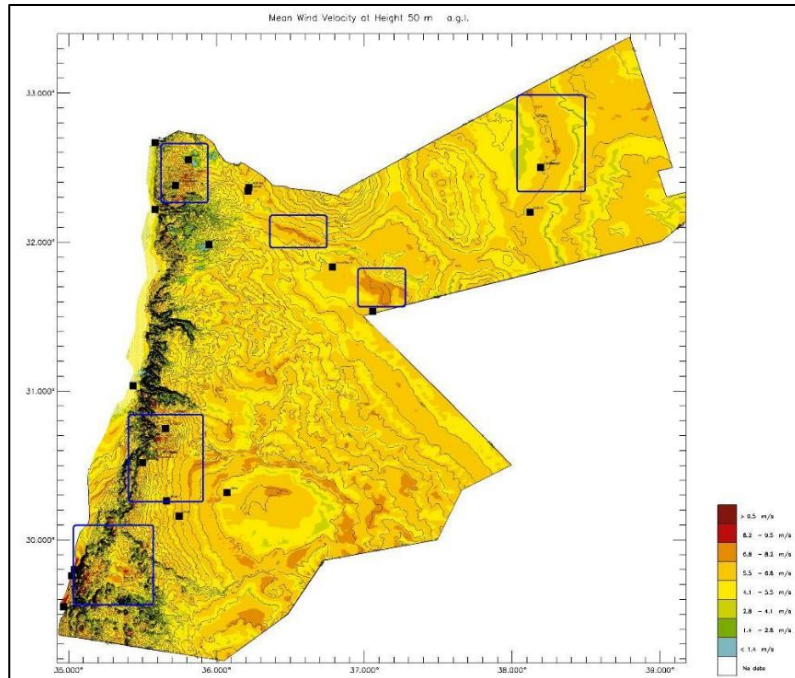


Figure 49: Mean wind speed at 50m height in Jordan¹⁹

Geothermal energy in Jordan is classified as moderate in potential and is generally constrained by relatively low reservoir temperatures, often below 100°C, particularly in fields identified along the eastern flank of the Jordan Valley and the plateau east of Madaba (REEE II-TA, 2017). While these conditions are insufficient for electricity generation, they are suitable for direct-use applications such as hot water spas, greenhouse heating, and other thermal services. The promotion of such applications could contribute to localized energy solutions and reduce fossil fuel dependency in niche sectors.

Biomass and biogas represent another component of Jordan's renewable portfolio. The country produces approximately 2 million tons of municipal solid waste annually, equivalent to about 0.95 kg per capita per day. Additional sources of organic waste include sewage sludge, olive mill waste, industrial effluents, and animal manure. Collectively, these feedstocks support the feasibility of developing waste-to-energy systems, particularly in large landfill sites such as Ghabawi and Al Ekaider, which process 1,500 and 1,000 tons of waste per day respectively. These landfills alone have the potential to support electricity generation projects producing an estimated 20 to 30 MW, depending on waste stabilization and methane recovery efficiencies (REEE II-TA, 2017). The development of biogas systems would also align with national waste management priorities and provide co-benefits such as organic fertilizer production and emissions reductions.

Hydropower, is limited due to Jordan's arid climate and absence of perennial rivers, nonetheless offers some localized potential. Recent technical assessments estimate that approximately 33.2 MW of small hydropower capacity can be installed in existing dams, while proposed new dams could add an additional 14.95 MW, totaling nearly 48.15 MW of technically viable hydropower capacity (REEE II-TA, 2017). Dams such as Mujib (8,000 kW), Kafraïn (5,650 kW), and Waleh (4,350 kW) are among the most promising sites for generation.

Despite the strength of its resource base, Jordan's renewable energy transition is not without challenges. Grid constraints continue to limit renewable integration, particularly in remote southern and eastern

¹⁹ Source MEMR (https://www.memr.gov.jo/ebv4.0/root_storage/en/eb_list_page/wind_map_of_jordan.pdf)

regions where solar and wind potential is highest. The delayed rollout of enabling technologies such as smart meters, the absence of dynamic electricity tariffs, and lengthy permitting processes have also impeded the speed of deployment. Financial access remains an issue, especially for households, municipalities, and small industries. Institutional fragmentation and limited enforcement of energy efficiency standards further reduce the effectiveness of policy instruments. Moreover, water scarcity places constraints on the development of solar thermal technologies and green hydrogen electrolysis, both of which require substantial water inputs.

3.3.12 Energy efficiency

Jordan has established a robust and evolving energy efficiency (EE) policy framework centred on national strategies, sectoral action plans, legislative instruments, and dedicated financing mechanisms. The country's efforts, coordinated by MEMR, are part of a long-term vision to enhance energy security, reduce dependence on energy imports, and meet climate commitments under the Paris Agreement.

Strategic and Policy Framework

Jordan's energy efficiency governance is underpinned by a layered suite of policies:

- **Jordan Energy Strategy 2020–2030:** The Strategy calls for a 9% energy savings by 2030. It outlines targeted efficiency improvements across the electricity, water, transport, and building sectors. The strategy is updated by the current document which extends the targets towards 2035.
- **Jordan Energy Strategy Action Plan (2020–2030):** This operationalizes the above strategy through a set of coordinated programs, emphasizing stakeholder collaboration and feasibility-driven implementation. It reaffirms EE priorities across all major consumption sectors. The action plan is updated to follow the current updated energy strategy.

- **National Energy Efficiency Action Plans (NEEAPs):**

Jordan's commitment to enhancing energy efficiency has been systematically implemented through its series of National Energy Efficiency Action Plans (NEEAPs), each building on the experiences and outcomes of its predecessor. The **First NEEAP**, covering the period from 2012 to 2014, set a target of achieving 806 GWh in electricity savings, primarily through 11 sector-specific measures across residential, industrial, commercial, and water sectors. By the end of the implementation period, approximately 324 GWh had been saved, representing 40% of the target—an important foundational achievement that highlighted both the potential and challenges of energy efficiency programming in Jordan. The **Second NEEAP**, implemented between 2018 and 2020, was significantly more ambitious, with a target of 1,975 GWh in cumulative savings. It featured 35 energy efficiency measures, including 26 sector-specific and 9 cross-sectoral actions. Despite facing challenges related to financing and institutional readiness, the plan succeeded in delivering 914 GWh in savings, amounting to 46.3% of its intended goal. The current and most comprehensive plan, the **Third NEEAP** for 2024–2026, aims to improve energy efficiency by 6.02%—equivalent to 1,055 GWh of electricity savings compared to the 2018 baseline. This plan introduces a total of 50 targeted measures supported by 61 subordinate actions, covering all key consumption sectors. It is grounded in the strategic objectives of the Jordan Energy Strategy 2020–2030 and incorporates valuable insights and best practices derived from the previous NEEAPs, ensuring a more integrated, data-driven, and results-oriented approach to energy efficiency across the Kingdom.

Legal and Regulatory Framework

Jordan's EE legislation and regulatory instruments are comprehensive and include:

- **Jordanian National Building Law (1993):** Mandates thermal insulation and efficient heating/cooling systems, enforced via the Thermal Insulation Code (1998, revised 2009) and the Energy Efficient Building Code (2010).
- **Renewable Energy and Energy Efficiency Law (2012, Law No. 13) and Amendment (2014, Law No. 33):** Establishes legal grounds for EE activities, including tax exemptions, the creation of JREEEF, and mandatory licensing/audit systems.
- **By-law No. 73 of 2012:** A pivotal regulation mandating:
 - Energy audits and licensing for auditors.
 - Energy labelling and MEPS.
 - Consumer reporting and database creation.
 - MEMR's oversight of audits, investment promotion, awareness, and emergency response.
- **By-law No. 13 of 2015 & No. 50 of 2018:** Offer sales tax and customs exemptions for EE equipment.
- **By-law No. 49 of 2015:** Establishes the Jordan Renewable Energy and Energy Efficiency Fund (JREEEF) under MEMR.
- **General Electricity Law (2003, Law No. 64):** EMRC is mandated to promote rational electricity use.
- **JS 2243 Energy Audit Standards (2019):** Applied to all entities consuming >50 toe/year, with enforcement and compliance overseen by MEMR.
- **Energy Efficiency Standards and Labels:** Enforced by JSMO under By-law 73/2012, with testing supported by the accredited Energy Labelling Laboratory at NERC.

Financing and Institutional Support

Jordan has institutionalized energy efficiency financing through public funds, concessional loans, and donor-backed programs.

The Jordan Renewable Energy and Energy Efficiency Fund (JREEEF), established in 2012, serves as the country's central institution for financing energy efficiency and renewable energy initiatives. It plays a pivotal role in enabling the implementation of energy-saving projects by offering a structured financial package that typically includes 30% in non-repayable grants, 50% in concessional loans, and 20% in commercial finance. JREEEF's support spans a wide range of beneficiaries, including households, small and medium-sized enterprises (SMEs), municipalities, and industrial entities. By 2023, the fund had successfully contributed to annual energy savings of 75.3 GWh, translating into cost reductions of approximately JD 16.8 million. Looking ahead, JREEEF aims to mobilize between JD 50 million and JD 100 million annually in energy efficiency investments by 2025. In addition to its financial offerings, the fund provides critical technical assistance, supports the enforcement of energy efficiency standards such as Minimum Energy Performance Standards (MEPS), and conducts nationwide public awareness and education campaigns to promote the adoption of efficient energy practices.

The Central Bank of Jordan (CBJ) has taken a significant step toward promoting sustainable economic development through the launch of its Green Finance Strategy for the period 2023–2028. This strategy is designed to transform the financial sector into a key enabler of the country’s green transition by encouraging investment in environmentally sustainable projects. In line with this objective, the CBJ works in close coordination with commercial banks across Jordan to develop and offer tailored financial products that support energy efficiency (EE) and renewable energy (RE) initiatives. These products include concessional loans and credit lines that are specifically structured to reduce the financial barriers faced by businesses and households seeking to implement clean energy solutions. Through this strategy, the CBJ aims not only to facilitate access to green finance but also to strengthen Jordan’s resilience to climate and environmental risks, align the financial sector with national sustainability targets, and position the country as a regional leader in sustainable finance.

In addition to the core financing mechanisms described above, several other initiatives contribute to expanding the availability of funding for energy efficiency and renewable energy projects across different sectors. One such initiative is the Green Economy Financing Facility (GEFF) Jordan, led by the European Bank for Reconstruction and Development (EBRD), which provides dedicated credit lines through local partner banks to support private sector investments in green technologies, including energy efficiency upgrades and renewable energy installations. Another key program is the Energy Efficiency in Public Buildings (EEPB) initiative, funded by the German development bank KfW, which targets improvements in energy performance across government-owned buildings through retrofitting and modernization projects. The Cities and Villages Development Bank (CVDB), in partnership with the European Investment Bank (EIB), also plays an essential role through a framework loan designed to support energy efficiency improvements in municipal infrastructure, benefiting over 100 municipalities across Jordan. Furthermore, the Jordan Kuwait Bank offers a specialized Energy Efficiency Product, developed in collaboration with the Central Bank of Jordan, which provides tailored commercial financing for companies aiming to reduce their energy consumption through efficiency measures. Collectively, these initiatives diversify the financial landscape for green investments in Jordan and reinforce the country’s transition toward a more energy-efficient and low-carbon economy.

Sector-Specific Integration and Green Growth

Jordan’s energy efficiency actions are closely aligned with its Green Growth National Action Plan (GG-NAP) 2021–2025 and Vision 2025. These policies embed EE into six core sectors, namely energy, water, transport, agriculture, waste, and tourism, and aim for a sustainable and resilient economic transformation. The transport GG-NAP specifically targets modal shifts, public transport investment, and e-mobility.

3.3.13 Water sector

Jordan’s National Water Strategy 2023–2040 lays out a long-term, integrated vision to ensure lasting water security, environmental sustainability, and socio-economic resilience in one of the world’s most water-scarce countries. Aligned with the nation’s Economic Modernization Vision and Public Sector Modernization Roadmap, the strategy addresses deep-rooted structural challenges in water supply, governance, finance, and climate adaptation. It establishes actionable goals through 2040 to rebalance supply and demand, optimize utility performance, harness non-conventional water resources, and modernize institutional structures.

Jordan's renewable water availability, just 61 m³ per capita annually, is far below the international water scarcity threshold of 500 m³. With rapid population growth, climate change, and groundwater over-abstraction, water availability is projected to further decline by 15% by 2040. The strategy prioritizes the National Conveyance Project, and the expansion of reclaimed wastewater use to stabilize municipal and irrigation supplies.

The strategy outlines an urgent financial restructuring plan. With annual deficits of JD 200–300 million and electricity accounting for over half of operational costs, water utilities currently recover only a fraction of their service costs. The plan aims to achieve full cost recovery for operations and maintenance (O&M) and build-operate-transfer charges by 2040, while maintaining affordability for low-income users through targeted subsidies.

This will be achieved by restructuring tariffs, reducing energy consumption, improving cash collection, and mobilizing investment for maintenance. A phased approach is envisioned where recovery of O&M costs will be achieved by 2030 and full cost (including capital charges) by 2040.

Recognizing that the water sector consumes about 9% of the country's total electricity, the strategy identifies energy efficiency as a priority for financial and environmental sustainability. Pumping water across Jordan's elevation gradients and treating wastewater imposes high energy demands, now exceeding total water bill revenues. The goal is to reduce the energy consumed per cubic meter of water processed and to reach 40% renewable energy integration in water sector operations by 2040. This will involve implementing energy management systems, modernizing infrastructure, and coordinating with MEMR on joint projects.

The agricultural sector, responsible for nearly half of total water use, faces immediate reform. On-farm water use efficiency is just 60%, with freshwater used disproportionately in low-value crop production. By 2030, the strategy aims to replace 60% of freshwater used in irrigation with reclaimed or harvested water. Non-conventional sources will be prioritized for agriculture, especially in the Jordan Valley, while highlands irrigation will be subjected to stricter controls.

Reforming the legal and institutional framework is critical. The strategy seeks to establish a transparent, independent regulatory body; update outdated laws; and implement data-driven performance systems. At the same time, it aims to modernize the workforce by strengthening career pathways, enhancing training, and increasing representation of women and youth across water institutions.

Recognizing the importance of digital transformation, the strategy emphasizes adoption of smart technologies, SCADA systems, and advanced data analytics to improve operations and transparency. The role of the private sector will be expanded in wastewater treatment, infrastructure development, and service delivery through well-regulated partnerships. An innovation center is envisioned to incubate and pilot modern water technologies in collaboration with academia.

Jordan's water sector is identified as the most climate-vulnerable in the country. Rising temperatures, declining precipitation, and extreme weather events threaten infrastructure, water quality, and agricultural output. The strategy integrates climate adaptation into every objective, including drought and flood management, water reuse, and circular economy practices. Additionally, it institutionalizes the Water-Energy-Food-Environment Nexus through the creation of a Nexus Council to ensure policy coherence and integrated project development across sectors.

3.3.14 Climate Change - Greenhouse Gases Emissions

Jordan has developed a comprehensive climate governance framework composed of the updated *National Climate Change Policy 2022–2050* (NCCP), the *Fourth National Communication to the UNFCCC* (4NC), and the *Long-Term Low Emission Development Strategy* (LTS). These documents collectively articulate Jordan’s commitment to climate resilience, emissions reduction, and sustainable development, aligned with its Nationally Determined Contributions (NDCs).

The **National Climate Change Policy 2022–2050 (NCCP)** sets a clear policy vision that by 2050, Jordan will be more resilient to climate change impacts and will maintain progress toward carbon neutrality through low-carbon investments and clean energy deployment. The policy emphasizes inclusiveness, fairness, and the principle of common-but-differentiated responsibilities. The core objective is to integrate climate adaptation and mitigation across all sectors, making climate action a central pillar of national development. The policy uses a “Theory of Change” framework to link systemic barriers, low social awareness, and inadequate finance, with enablers like policy coherence, capacity development, and gender-sensitive planning.

Key features of the NCCP include:

- A dual-track approach to adaptation and mitigation, with cross-cutting measures.
- Emphasis on institutional reform, technology transfer, and financing.
- Integration of gender, youth, and vulnerable groups.
- Alignment with national priorities such as Jordan Vision 2025 and the Economic Modernization Vision.

Jordan’s **Fourth National Communication** (4NC) to the UNFCCC provides a detailed update on greenhouse gas emissions, sectoral vulnerabilities, and national mitigation actions. Total GHG emissions in 2019 stood at approximately 30.7 MtCO₂eq, dominated by the energy sector (74%), followed by agriculture, industrial processes, and waste. Emissions trends have remained relatively stable due to renewable energy deployment and fuel switching from oil products to natural gas.

Key vulnerabilities identified in the 4NC include:

- Water stress, intensified by climate variability and demographic pressures.
- Agricultural losses, due to temperature increases and changing precipitation patterns.
- Health threats, particularly the rise in vector-borne and water-related diseases.
- Urban and coastal risks, from heatwaves, flash floods, and saline intrusion.

The report details ongoing and planned adaptation projects in water infrastructure, sustainable agriculture, and early warning systems. Mitigation policies focus on:

- Renewable energy scale-up, now contributing around 28% of electricity generation.
- Energy efficiency programs across residential, industrial, and municipal sectors.
- Public transport investments and vehicle electrification.
- Carbon pricing discussions and MRV systems are under development.

Jordan's Long-Term Low Emission Development Strategy (LTS) presents an economy-wide roadmap to achieve a net-zero emissions target by 2050, structured around three-time horizons (short: to 2030; medium: 2031–2040; long: 2041–2050). The strategy adopts a scenario-based approach, evaluating decarbonization trajectories against business-as-usual (BAU) baselines and socio-economic constraints.

The LTS identifies five transformative pathways:

1. Power Sector Decarbonization – Targeting 50–60% renewable penetration by 2040 and full decarbonization by 2050 through grid modernization, storage, and flexible baseload systems.
2. Sustainable Transport – Expanding public transport infrastructure, transitioning to electric and hydrogen vehicles, and deploying low-carbon fuels.
3. Green Buildings and Industry – Enhancing building codes, introducing minimum energy performance standards (MEPS), and promoting clean industrial processes.
4. Circular Economy and Waste Management – Scaling up waste-to-energy initiatives, improved recycling, and methane capture.
5. Agriculture, Forestry, and Land Use (AFOLU) – Implementing climate-smart agriculture, improving land use practices, and afforestation.

The strategy emphasizes the importance of international climate finance, carbon markets, and just transition mechanisms. It also includes co-benefits assessments, such as job creation, public health improvements, and biodiversity preservation.

These three documents reflect an increasingly harmonized climate governance system:

- The NCCP sets the long-term framework and guiding principles for climate action.
- The 4NC operationalizes international reporting and tracks GHG trends, vulnerabilities, and sectoral progress.
- The LTS provides a quantified, sectoral roadmap for net-zero emissions aligned with NDC and NCCP targets.

Institutional mandates are reinforced by the Ministry of Environment's leadership, with sector-specific responsibilities assigned to line ministries. The Climate Change Directorate and the National Climate Change Committee (NCCC) are centrally coordinating bodies across all documents. Overall, Jordan stands out in the MENA region for articulating a clear, integrated, and forward-looking response to climate change—one that prioritizes resilience, inclusivity, and low-carbon development.

3.3.15 Transport sector

Jordan's national transport policy landscape is defined by a strategic convergence of economic modernization, environmental sustainability, and climate mitigation goals. The core of this policy framework is structured around three interlinked documents: the *Long-Term National Transport Strategy (LTNTS)*, the *Sustainable Urban Transport Master Plan (SUTMP)*, and the *National E-Mobility Strategy (2024)*. Together, these instruments offer a coherent vision to transform Jordan's transport system into an integrated, low-emission, and socially inclusive sector by mid-century.

The Long-Term National Transport Strategy (2023–2040) establishes the country’s overarching vision for a safe, efficient, and sustainable transport system. It emphasizes a shift from fragmented, car-dependent infrastructure to a multimodal system grounded in interconnectivity, logistics efficiency, and institutional modernization. At the core of this strategy is a commitment to strengthening governance structures within the sector. The strategy calls for the empowerment of the Land Transport Regulatory Commission (LTRC), modernization of institutional roles, and enhanced coordination among the Ministry of Transport and other regulatory and planning bodies. This institutional reform is seen as foundational to delivering long-term improvements in infrastructure delivery, service regulation, and performance oversight. Moreover, the strategy highlights the need to expand Jordan’s freight and passenger networks beyond road transport, advocating for investments in rail corridors, dry ports, and intermodal hubs to optimize regional trade logistics and reduce over-reliance on fossil-fuel-intensive trucking.

In parallel, the Sustainable Urban Transport Master Plan for Jordan (2022) addresses the growing challenges of urban congestion, air pollution, and mobility exclusion in Jordan’s major cities. The plan focuses primarily on metropolitan areas such as Amman, Zarqa, and Irbid, proposing a comprehensive framework to promote more compact, connected, and equitable urban mobility. Central to the master plan is the principle of transit-oriented development (TOD), which promotes densification around high-capacity transit lines to reduce average trip lengths and increase public transport utilization. The plan also encourages pedestrianization and active mobility infrastructure, such as safe sidewalks and bike lanes, particularly in densely populated or underserved neighborhoods. Importantly, the SUTMP calls for the deployment of Intelligent Transport Systems (ITS) to integrate public and private transport services, streamline fare structures, and enhance user accessibility. A critical concern addressed in the plan is the limited coverage and quality of public transport, particularly in eastern Amman and peripheral cities, where nearly 37% of the population lacks access to reliable transport services. This gap disproportionately affects low-income households, youth, and women, thereby undermining the broader objectives of social equity and economic inclusion.

The third and most targeted of the three strategies, the National E-Mobility Strategy (2025), introduces a focused set of policy interventions aimed at transitioning Jordan’s vehicle fleet toward electrification. The strategy is driven by three primary policy motivations: reducing national greenhouse gas (GHG) emissions, improving local air quality, and reducing the country’s dependency on imported fossil fuels. As of 2023, Jordan had registered over 42,000 electric vehicles (EVs), driven largely by generous import tax exemptions. However, the strategy acknowledges that fiscal incentives alone are insufficient for long-term transformation. It therefore outlines a broader policy package that includes reforming EV charging tariffs, introducing time-of-use electricity pricing to manage grid loads, and investing in national charging infrastructure. Specifically, it estimates that at least 510 additional public charging stations will be required by 2030 to keep pace with projected EV uptake. It also highlights the need for JD 400 million in power sector investments, comprising JD 190 million in new generation capacity and JD 210 million in grid upgrades, to accommodate transport electrification without destabilizing the national electricity supply.

Importantly, the E-Mobility Strategy does not limit its scope to private vehicle adoption. It includes targeted interventions for electrifying public transport fleets, particularly city buses. For example, the Greater Amman Municipality has launched an e-bus pilot, but scaling such efforts remains hindered by financing gaps, lack of technical capacity, and infrastructure constraints. The strategy therefore proposes new public-private partnership models, innovative procurement frameworks, and integrated depot and charging solutions to support city-level electrification. From an economic perspective, the full

implementation of the proposed policy measures could yield a net present value of USD 255.6 million, driven by fuel savings, improved air quality, and new employment opportunities in maintenance, charging infrastructure deployment, and electric vehicle services.

When examined collectively, these three strategies demonstrate a shift in Jordanian transport policy from reactive infrastructure investment to proactive, systems-based planning. The Long-Term National Transport Strategy provides strategic architecture and institutional roadmap. The Sustainable Urban Transport Master Plan operationalizes this vision through localized, inclusive mobility interventions. The E-Mobility Strategy targets a critical technical transformation with tangible emissions and energy benefits. Together, these policies reflect Jordan's commitment to sustainable mobility, climate resilience, and economic modernization. They also reinforce the country's Nationally Determined Contributions (NDCs) under the Paris Agreement and its broader goals under the Economic Modernization Vision 2023–2033.

3.3.16 Green and Sustainable Policies

Jordan has developed a comprehensive and evolving framework of green and sustainable policies that reflect its strategic ambition to transition toward a low-carbon, resource-efficient, and climate-resilient economy. These policies are rooted in national development plans and climate commitments, most notably the Economic Modernization Vision 2023–2033, Jordan's updated Nationally Determined Contributions (NDCs), and a suite of sectoral strategies spanning energy, transport, water, and industry as discussed in the previous sections. Together, they outline a coherent and cross-sectoral pathway toward sustainable development, with climate change mitigation, adaptation, and green growth at the core.

The energy sector serves as the cornerstone of Jordan's green transformation. The Comprehensive Energy Sector Strategy 2020–2030 charts a course for energy diversification, security, and affordability by expanding renewable energy to contribute 31% of electricity generation by 2030. Parallel to this, the 2024–2025 energy sector priorities under the Economic Modernisation Vision accelerate implementation through targeted investments in solar, wind, green hydrogen, and grid modernization. The National Energy Efficiency Action Plans (NEEAPs) have institutionalized short-term planning and implementation of efficiency measures, with the third NEEAP (2024–2026) alone aiming to reduce electricity consumption by over 1,000 GWh. Jordan's green hydrogen strategy positions the country as a regional production and export hub, leveraging its vast renewable potential and geographic proximity to European and Gulf markets. The strategy outlines a phased approach to project deployment, infrastructure planning, and regulatory development. Complementing these sectoral efforts is the Jordan Renewable Energy and Energy Efficiency Fund (JREEEF), which operationalizes green finance through grants, concessional loans, and partnerships with donors and commercial banks. JREEEF's programs support households, municipalities, and SMEs, with initiatives that span solar heating, PV deployment, efficient appliances, and public awareness campaigns. The Central Bank of Jordan also plays a role in green finance, launching a Green Finance Strategy to direct capital toward climate-aligned investments and support energy transition projects.

In the water sector, the National Water Strategy 2023–2040 introduces sustainability principles across resource planning, infrastructure development, and utility operations. It aims to reduce non-revenue water, expand renewable energy use in water pumping, increase the share of non-conventional water, and achieve full cost recovery for water services by 2040.

On the climate policy front, Jordan's updated National Climate Change Policy 2022–2050 and Fourth National Communication provide a comprehensive vision for resilience and emissions reduction. The policy integrates climate across planning, budgeting, and institutional frameworks, emphasizing the role

of adaptation in water, agriculture, health, and urban development. The Fourth National Communication highlights the country's vulnerability to climate extremes and details its sector-specific mitigation efforts, including renewable energy, energy efficiency, sustainable transport, and carbon pricing. Jordan's Long-Term Low Emission Development Strategy (LTS) adds a forward-looking decarbonization roadmap, targeting net-zero emissions by 2050, emphasizing clean energy, electrification of transport, circular economy measures, and afforestation.

3.4 Barriers and challenges for penetration of RES and EE

Despite significant progress, Jordan faces several challenges that hinder the full penetration of renewable energy sources (RES) and the widespread adoption of energy efficiency (EE) measures.

A key challenge regarding the share of RES in electricity generation is the structural limitation in grid capacity and flexibility, leading to curtailment and increased system balancing needs. These constraints are highlighted in the *Comprehensive Energy Strategy 2020–2030*, which calls for greater investments in storage and grid modernization to support higher renewable shares. Regulatory bottlenecks, such as delays in licensing, grid connection approvals, are cited in the *E-Mobility Strategy* as obstacles that deter investor confidence (Jordan E-Mobility Strategy, 2025). Time-of-use (ToU) tariffs currently exist for electric vehicle charging, telecommunications, medium and large industries, extractive industries, and water pumping, while the introduction of ToU in the residential sector is planned for 2026.

Financial challenges are relevant particularly for small-scale consumers and municipalities, who often face difficulties accessing affordable capital for EE retrofits and decentralized solar systems. Although institutions like JREEF have introduced concessional financing and grant mechanisms, gaps remain in market penetration due to limited project bankability and credit constraints (JREEF Booklet 2015–2023). In the EE domain, the *Third National Energy Efficiency Action Plan (NEEAP 2024–2026)* identifies barriers such as low compliance with audit requirements, insufficient enforcement of energy performance standards, and limited institutional capacity to implement cross-sectoral efficiency measures.

Infrastructure limitations, such as the need for expanded smart metering, grid storage, and localized substations, are emphasized in the *Economic Modernisation Vision Energy Sector Priorities 2024–2025* and the *Presidency Annual Report for the Energy Sector (2025)*, where slower-than-expected smart meter deployment (63.9% achieved versus 72% targeted) illustrates the practical difficulties in rolling out enabling technologies.

Finally, water scarcity presents a cross-sectoral barrier, particularly relevant for solar thermal and green hydrogen projects that rely on water-intensive processes. This challenge is addressed in the *National Water Strategy 2023–2040*, which emphasizes the critical water-energy nexus and the need for co-located water and energy planning. Addressing these interlinked barriers will require a combination of infrastructure investment, regulatory modernization, targeted financial instruments, and institutional reform to unlock the full potential of RES and EE in Jordan's energy transition.

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4 Pathways and Methodology

4.1 Introduction

Developing a national energy strategy requires an analytical approach that includes complexity and uncertainty about future developments. One of the most effective tools to navigate this landscape is scenario building, a methodology that allows policymakers to explore multiple plausible futures rather than attempting to predict a single outcome. A scenario is a pathway of a structured narrative that describes how the future might unfold, based on different assumptions about key driving forces. These narratives are not forecasts, but explorative tools that reveal potential choices and their consequences. In energy planning, this analysis helps stakeholders assess policy options, manage uncertainty, and identify robust pathways for sustainable and resilient energy systems. Robust scenario analysis is an approach to strategic planning that goes beyond producing a single “forecast” or “best guess” of the future. The emphasis is not on predicting the future, but on preparing for uncertainty, variability, and shocks. The key Features of Robust Scenario Analysis include an exploration of uncertainty since the approach recognizes that the future cannot be predicted with precision and therefore alternative pathways are used to capture a wide range of possible outcomes including economic, technological, political, environmental topics. Through evaluating how strategies perform across pathways, for example with rapid renewable uptake of geopolitical instability, the approach identifies vulnerabilities and trade-offs. It focuses on robustness and not optimality, in the sense that a strategy is “robust” if it performs reasonably well across many pathways, even if it is not the absolute optimal in any single one. Furthermore, the analysis is iterative and adaptive since pathways are updated as new data, technologies, or policies emerge allowing decision-makers to adapt policies over time rather than being locked into one path.

4.2 The Pathways

4.2.1 About pathway analysis

Alternative pathways analysis facilitates decision-making by illuminating uncertainties, trade-offs, and potential implications of different strategic choices, rather than offering forecasts. Typically, national planning exercises define a baseline pathway which represents a continuation of current policies and alternative pathways which explore different options including aggressive renewables uptake, hydrogen introduction into the energy mix, increased energy efficiency measures etc. As an example, Egypt's Integrated Sustainable Energy Strategy to 2035 (ISES) employs a normative, back-casting policy pathway to guide its long-term energy transition. Rather than projecting future outcomes based on existing trends, this approach begins by defining a clear set of national targets and then systematically works backward to identify the specific policies, institutional reforms, investment needs, and infrastructure developments required to reach those goals. This includes outlining the pace and scale of renewable energy deployment, such as annual capacity additions for solar and wind. The ISES also considers the regulatory and financial frameworks necessary to attract private investment and ensure long-term power sector sustainability. This approach also helps manage competing policy priorities, such as reducing fossil fuel dependency and maintaining fiscal balance, while staying on course toward its strategic sustainability vision.

4.2.2 Pathways for the present study

The Jordan Energy Sector Strategy 2025–2035 is structured around two principal pathways: a Reference Pathway and an Optimistic Pathway, each designed to explore alternative energy system evolution in alignment with Jordan’s strategic objectives and planning axes.

The present study analysed several pathways with different levels of expected economic growth and ambition related to the energy efficiency improvement and utilisation of renewable energy sources (Figure 50).

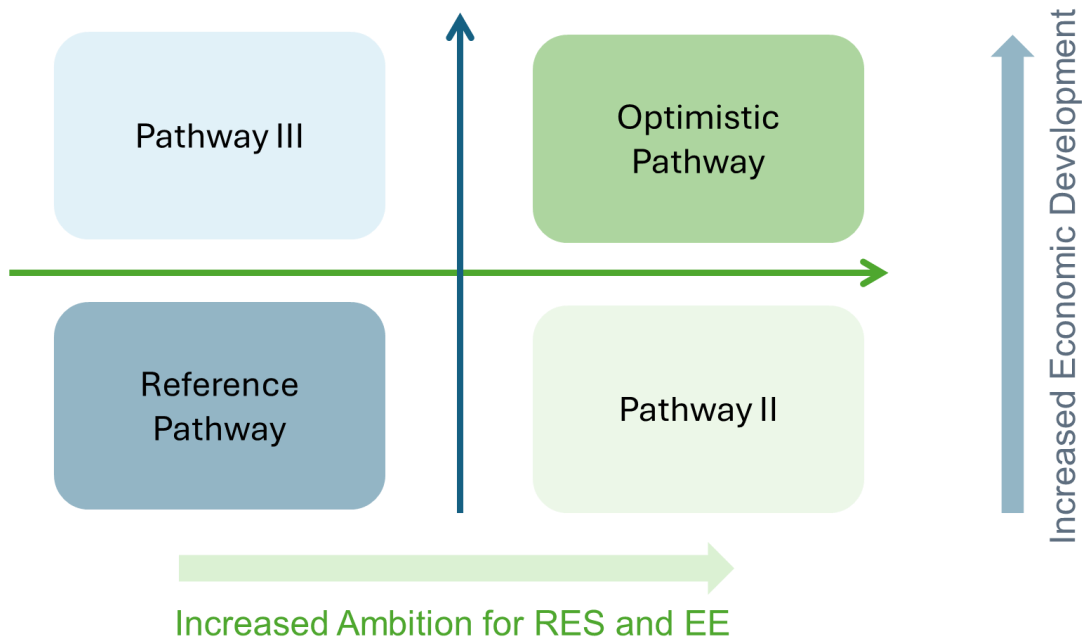


Figure 50: Overview of analysed pathways

Table 9: Key attributes of analysed pathways

Nº	Pathway	GDP	RES Electricity	Energy Efficiency
I	Reference	Reference GDP (3% until 2028, 2.6% after that)	33% by 2030 40% by 2035	Current trend
II	Pathway II	Reference GDP (3% until 2028, 2.6% after that)	50% by 2033	Increased EE
III	Pathway III	EMV GDP (5.6% average)	33% by 2030 40% by 2035	Current trend
IV	Optimistic	EMV GDP (5.6% average)	50% by 2033	Increased EE

The Reference and the Optimistic Pathways are considered in more detail in the following analysis, representing the two extremes of the analysis space, while Pathways II and III are presented in the Annexes.

The **Reference Pathway** reflects a continuation of existing policies, investment patterns, and moderate improvements in energy efficiency and renewable deployment. In the electricity sector the Reference Pathway follows a conservative penetration of renewable energy sources, achieving the national target for 2030 and increasing after this. This pathway serves as a reference case for assessing system costs, energy security, and emissions under current trends.

The Optimistic Pathway reflects rapid economic growth and an accelerated energy transition, characterized by stronger policies, higher renewable energy integration, rapid electrification of transport, and full implementation of energy efficiency measures across the residential, tertiary, transport, and water sectors. It anticipates deeper market reforms, and a proactive investment program to maximize the use of domestic energy resources, particularly solar and wind, and optimize renewable energy integration in the power sector supported by storage and grid modernization.

These Pathways are assessed across the strategic axes of **Reliability, Affordability, Security, Sustainability, Accessibility, Maximizing the Use of Domestic Resources, and Optimizing Renewable Energy**. These axes mirror the core strategic objectives that were outlined in the Jordan's 2015–2025 energy strategy, namely: ensuring secure and sustainable energy supply for development, increasing the contribution of local resources to the energy mix, and reducing the economic burden of energy costs.

Security of supply remains a core concern in Jordan's energy planning, particularly in the electricity sector, which continues to rely heavily on natural gas. The latest disruption in natural gas supply in 2025, exemplified the negative effect that this could have on the cost of electricity generation. In 2023, over 80% of electricity generation was fueled by natural gas, although the operation of the oil shale plant and the growing share of renewable energy has begun to diversify the fuel mix. Nonetheless, the need for further diversification of generation technologies and fuel sources remains critical to strengthen resilience and reduce dependency on gas imports. The recent developments of the Risha gas field and the exploitation of this domestic resource can be a real game changer in the energy sector of Jordan. The Attarat oil shale plant (470 MW), commissioned in mid-2023, marked a major development in domestic energy resource utilization and contributes to both energy security and base-load capacity, albeit with environmental trade-offs. As for nuclear power, particular SMR, it remains a candidate technology in long-term planning, to be assessed after 2035 in light of evolving techno-economic and geopolitical considerations. On the oil supply side, Jordan's dependence on imports continues, although the Zarqa Petroleum Refinery meets around 60% of domestic demand for refined products. No acute risks have been identified concerning access to crude oil and petroleum products, as Jordan has sufficient access to global markets, and oil products are widely traded.

Minimizing the overall cost of energy remains a central objective of Jordan's energy strategy. The energy modelling framework embedded in JESS assesses different future pathways under multiple parameters, such as economic growth, fuel and technology prices, and policy enforcement levels, while optimizing for system-wide costs. Particular attention is given to the cost implications of energy diversification, renewables integration, grid upgrades, and fuel switching, ensuring that affordability remains a cornerstone alongside sustainability and security.

The modelling of emissions is directly linked to Jordan's commitments under its Updated Nationally Determined Contributions (NDCs), which aim to achieve economy-wide emission reductions relative to business-as-usual projections. The emissions impact of each Pathway is explicitly quantified, taking into account fuel mix evolution, technology choices, and the role of clean energy interventions. The pathways will test the effectiveness of policy packages in reducing CO₂ intensity across sectors and meeting Jordan's long-term decarbonization pledges.

Energy efficiency remains one of the most cost-effective strategies to improve system performance. JESS incorporates a suite of energy efficiency policies across key sectors, particularly residential and tertiary buildings, transport, and the water sector. The planned measures include thermal insulation, efficient lighting and appliances, EV and hybrid vehicle promotion, modal shift in urban transport and introduction of rail for freight transportation. Each policy is characterized by implementation timing, savings potential, and expected enforcement rates, especially in the medium to long term.

4.2.2.1 The Reference Pathway

The Reference Pathway represents a scenario with **reference GDP growth**, consistent with the projections utilised in the latest Electricity Masterplan, in which current energy and climate policies are fully implemented without additional measures beyond those already planned or announced. It assumes that existing national targets, including renewable energy integration goals, are met through incremental progress and institutional continuity. This pathway serves as a reference case to evaluate the energy system's performance under a trajectory of policy stability and moderate ambition, rather than transformational change.

Under this Pathway, the Kingdom prioritizes the optimal use of all available primary energy resources, including both domestic fossil fuels and renewable sources. This means continued exploitation of oil shale for electricity generation, the sustained use of natural gas, both domestically produced and imported, and a moderate expansion of renewables such as solar PV and wind. Jordan continues to maintain its LNG import infrastructure in Aqaba to provide a backup mechanism for energy security, particularly in periods of high demand or supply disruption.

The Reference Pathway also integrates the strategic decision to capitalize on recent natural gas discoveries, in the Risha field, which are expected to be scaled up gradually for national supply. The inclusion of Risha gas at a competitive price set at 90% of the imported gas price (including the transportation costs) supports its increasing role in the domestic supply mix, while pipeline gas imports from Egypt and Israel continue, in line with current contracts through 2035 and LNG remains available as a backup source.

To enhance fuel diversification and reduce the cost and environmental impact of oil product consumption, the pathway incorporates the promotion of natural gas and compressed natural gas (CNG) in the industrial and transport sectors. This includes gradual fuel switching from diesel and heavy fuel oil to natural gas, particularly in urban freight, public transportation, and industrial heating applications. A key infrastructure component included in this pathway is the development of natural gas distribution networks in major cities such as Amman and Zarqa, with operation starting from 2031, aligned with recent feasibility studies and investor calls from MEMR.

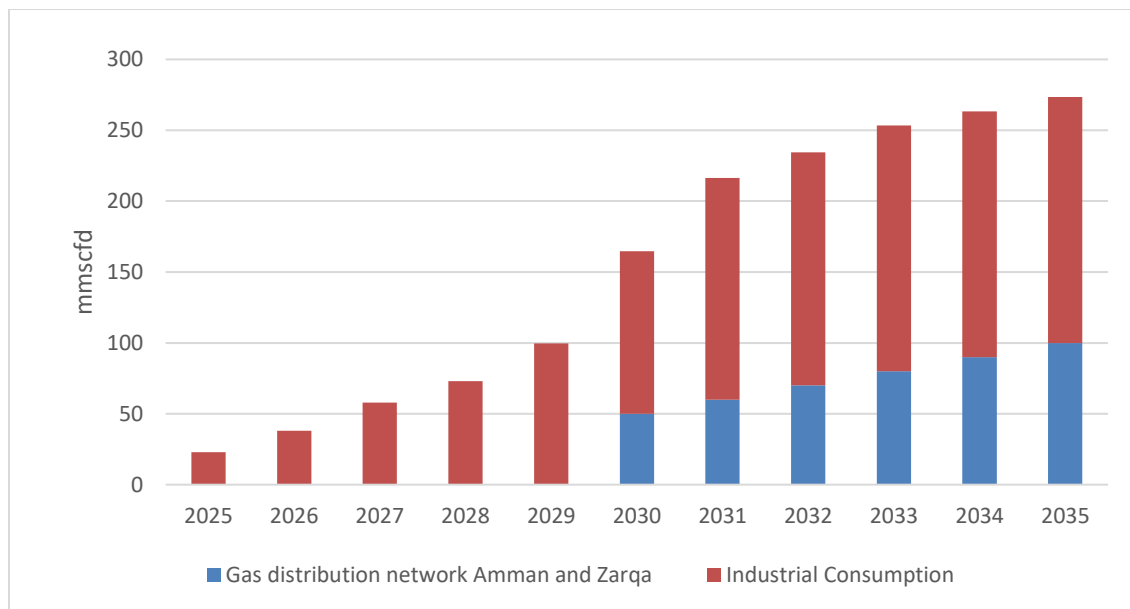


Figure 51: Projections of natural gas use in industry and the gas distribution network of Amman and Zarqa (Source: MEMR 2025)

The Reference Pathway is designed to meet the existing target of RES in electricity generation of 33% by 2030, increasing further to 40% by 2035. Renewable energy contributions grow steadily up to 2030, mainly through utility-scale solar PV and onshore wind, benefiting from global cost reductions and available land in southern and eastern Jordan. The growth of variable renewable generation after 2030 is enabled by strategically deploying Battery Energy Storage Systems (BESS) at a capacity equivalent to 25% of all new vRE installations. The storage systems support grid flexibility by providing short-term balancing and shifting energy to match demand patterns. Modeled as grid-connected assets, they are crucial for managing intra-day fluctuations and ensuring supply security in a decarbonizing system.

Explicit cost adjustments for grid infrastructure requirements are included in the analysis, to ensure a realistic and robust simulation of future system expansion. To reflect the additional investment required for integrating new generation into the transmission network, an incremental cost of \$94 per kW of new capacity is added to all generation capacity investments. This accounts for the reinforcement and expansion of the transmission system, particularly important under high renewable energy penetration scenarios and the inclusion of the synchronous condensers mentioned above. Similarly, as electricity demand increases, particularly due to electrification of transport, buildings, and water pumping, the need for distribution network upgrades becomes critical. Therefore, an additional \$547/kW is added for each kW increase in electricity demand, capturing the capital expenditures associated with expanding medium- and low-voltage grids, transformers, and consumer-level infrastructure.

The Pathway maintains a balanced view of energy security, relying on multiple import routes for fuels, resilient generation technologies including dual-fuel power plants, and diversification across fossil and renewable sources. It assumes the continued operation of the Attarat oil shale plant (470 MW). Nuclear power and in particular Small Modular Reactors (SMR) remain a candidate technology but does not appear as part of the solution within the planning horizon, with its assessment deferred beyond 2035 for potential long-term integration.

A key consideration in Jordan’s future electricity demand profile is the anticipated increase in energy consumption from water sector operations, particularly with the implementation of the Aqaba-Amman Water Desalination and Conveyance Project (AAWDCP). Scheduled to become operational in 2030, this project will involve large-scale desalination at the Red Sea and long-distance pumping of water northward to supply Amman and other central regions. Given the high elevation difference and long conveyance route, the project is expected to impose a significant electricity demand, primarily for high-pressure pumping. In the Reference pathway, this new demand is explicitly modelled as part of the water sector’s electricity load, and it is assumed that the AAWDCP will be powered by 240 MW of dedicated solar PV capacity, developed under wheeling arrangements to supply the Ministry of Water and Irrigation (MWI) or its operating agencies. This design reflects Jordan’s policy to decarbonize the water–energy nexus and minimize the financial burden of utility-scale water supply projects.

The development of green hydrogen is acknowledged as a strategic opportunity but is assumed to remain at a nascent stage within the planning horizon. While Jordan has initiated policy frameworks and international cooperation (including MoUs and feasibility studies) to explore its potential as a regional hub for green hydrogen production and export, especially leveraging its high solar and wind resource availability, the Reference Pathway assumes the development of facilities for exporting by 2035 (Figure 52). Hydrogen is not included as an energy vector in domestic demand or supply balances. However, basic infrastructure requirements such as grid integration points, land allocation for hydrogen zones, and regulatory groundwork will be initiated, setting the foundation for post-2035 scaling. The option of exporting green hydrogen is actively pursued, with the Green Hydrogen Strategy’s export targets expected to be achieved within five years of the original schedule, reaching the 2030 goals by 2035, in line with the expected development of the common infrastructure.

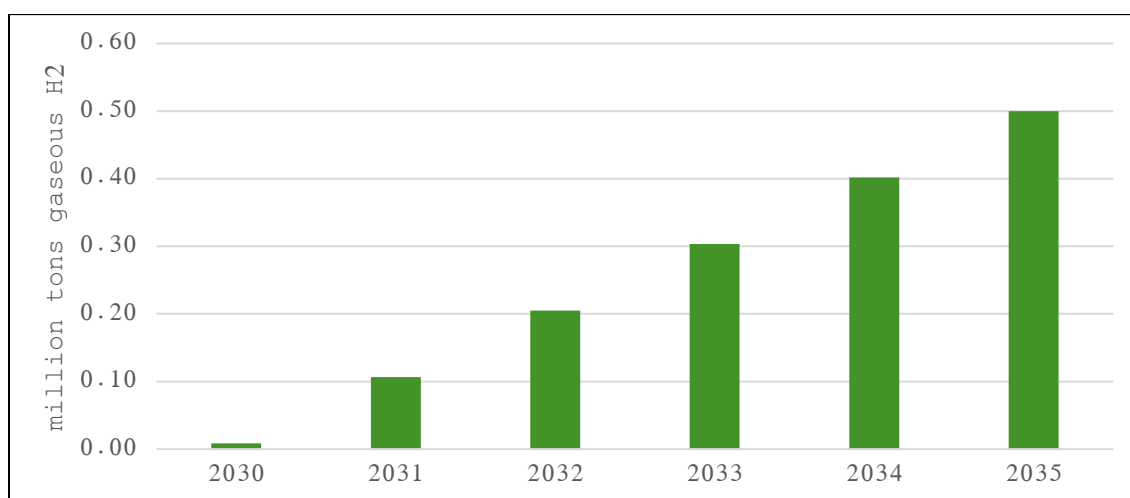


Figure 52: Green H2 export assumptions²⁰

The Jordan Petroleum Refinery upgrade has been incorporated into the analysis of both pathways as a strategic project. It is assumed to be finalized by 2030, with a refining capacity of 73,000 barrels per day and a total investment requirement of 2.0 billion USD. Its inclusion reflects the ongoing importance of the domestic refining sector in meeting national oil products demand with fuels according to the highest international standards, while also reducing reliance on imports and improving energy security. By considering this investment under both pathways, the analysis ensures consistency in the treatment of

²⁰ Source: Data from Draft National Green Hydrogen Strategy for Jordan, Oct. 2023, transposed by five years

critical infrastructure that will remain part of Jordan’s energy system beyond 2030, regardless of the transition trajectory.

In terms of demand drivers, the Reference Pathway is underpinned by demographic projections consistent with national sources, foreseeing an average annual increase of the population of 2.239% until 2035, reaching 15 million people by that year. The economic projections are considered with a constant annual GDP growth rate of 2.75%.

International energy price projections, critical for modelling cost competitiveness, are incorporated directly into the Reference Pathway using inputs from the IEA World Energy Outlook 2024, pricing formulae for natural gas and basic assumptions for the Risha gas pricing as described in detail in section 4.3.2 below.

The implementation of ToU tariffs is included in the Reference Pathway, starting in 2027, which is projected to lead to a 8.9% reduction in the peak demand and a 1.8% reduction in energy consumption by 2030 (see Section 3.3.10 when the full effect of the tariffs will be consolidated).

A series of transport sector policies already under implementation or formally adopted by the Government of Jordan are included with a focus on clean vehicle deployment, and infrastructure development. According to the latest statistical data a total of 198 thousand Electric Vehicles (EV) are currently registered in Jordan. In 2023 and 2024 the sales of EVs corresponded to 56% and 50% of new sales respectively. The pathway assumes a continuation of the increase of EVs consistent with the assumptions in the electricity sector Masterplan and the Optimistic scenario of the EVs strategy, leading to a projection of EVs according to the next table.

Table 10: Projection of the EVs²¹

	2025	2030	2035
Battery EV (000 vehicles)	198	320	445

Additionally, the introduction of Compressed Natural Gas (CNG) vehicles, particularly for heavy-duty applications such as freight and municipal fleets, is incorporated as a minor but strategic policy element to reduce diesel use and improve local air quality.

In summary, the Reference Pathway represents a continuity-oriented pathway, grounded in current policies, moderate technological progress, and gradual diversification. It offers a realistic reference for assessing the robustness of Jordan’s energy system under known policy commitments, while allowing comparison with more ambitious pathways in terms of cost, emissions, system flexibility, and investment needs.

4.2.2.2 The Optimistic Pathway

The Optimistic Pathway represents an ambitious vision for transforming Jordan’s energy system, with rapid economic growth as its primary driver. The average GDP growth rate is consistent with the 5.6% foreseen in the Economic Modernization Vision (EMV) of the Kingdom. The pathway reflects a future where policy ambition is strengthened, technological change is accelerated, and climate and sustainability

²¹ Source: own elaboration based on the latest statistics on new registrations by the Department of Statistics and assumptions on the annual share of EVs in the new registrations

goals are prioritized. This pathway explores the potential of a high-renewable, lower-emission energy system, supported by market reforms, advanced infrastructure, and comprehensive demand-side measures.

The same inputs as in the Reference Pathway are considered for the availability of fossil fuel imports, prices, refinery update and the exploitation of the local gas resources in the Risha gas field.

Energy demand in the Optimistic Pathway is significantly higher than in the Reference Pathway, driven by strong GDP growth of 5.6% annually over the next decade.

A central pillar of the Optimistic Pathway is the accelerated decarbonization of the electricity sector. The share of renewable energy sources (RES) in electricity generation is projected to reach 50% by 2033, significantly beyond the targets of the Reference Pathway. This transition is driven by rapid deployment of utility-scale solar PV and wind power, supported by the introduction of energy storage solutions to maintain system stability. The increase of variable renewable generation is supported by the strategic deployment of Battery Energy Storage Systems (BESS). A key planning assumption in this Pathway is the installation of BESS capacity equivalent to 25% of the capacity of all new VRE installations. The storage systems are assumed to provide both short-term balancing and peak shifting, enabling more efficient use of solar energy during evening demand peaks and reducing reliance on gas-fired peaking units. These BESS units are considered to be grid-connected assets, dispatched according to a least-cost optimization logic. Their contribution is essential for absorbing intra-day fluctuations and maintaining the security of supply in a decarbonizing system. Furthermore, to maintain system stability in a grid with high shares of inverter-based renewable generation, the analysis integrates the installation of four Synchronous Condensers of 125 MW each, based on recommendations from the study for the *Establishment of a Grid Development Strategy for the Jordanian Electricity System* (2022). These devices enhance inertia, voltage regulation, and fault current support, which are critical for grid reliability. Explicit cost adjustments for grid infrastructure requirements are included in the analysis. To reflect the additional investment required for integrating new generation into the transmission network, an incremental cost of \$94 per kW of new capacity is added to all generation capacity investments. This accounts for the reinforcement and expansion of the transmission system, particularly important under high renewable energy penetration scenarios and the inclusion of the synchronous condensers mentioned above. Similarly, as electricity demand increases, the need for distribution network upgrades becomes critical and an additional \$547/kW is added for each kW increase in electricity demand, capturing the capital expenditures associated with expanding medium- and low-voltage grids, transformers, and consumer-level infrastructure.

The implementation of ToU tariffs is included in the Optimistic Pathway, starting in 2027, which is projected to lead to 8.9% reduction in the peak demand and a 1.8% reduction in energy consumption by 2030 (see Section when the full effect of the tariffs will be consolidated).

The development of green hydrogen is included with the same assumptions as in the Reference Pathway for exports, but small quantities of green H₂ are also available for use in industrial applications, mainly in the chemicals and fertilizers sectors.

In the transport sector the pathway assumes the continuation of Jordan's national Electric Vehicle (EV) Strategy. In 2023 and 2024 the sales of EVs corresponded to 56% and 50% of new sales respectively. The pathway assumes the continuation of this trend with 60% of new registrations being EVs in the time horizon until 2035, as an effect of the continuation of Jordan's national Electric Vehicle (EV) Strategy,

promoting EV penetration, with incentives such as vehicle registration discounts, and public charging infrastructure investments. This leads to a projection of EVs according to the next table.

Table 11: Projection of the EVs²²

	2025	2030	2035
Battery EV (000 vehicles)	198	728	1,258

The introduction of Compressed Natural Gas (CNG) vehicles, particularly for heavy-duty applications such as freight and municipal fleets, is incorporated as a strategic policy element to reduce diesel use and improve local air quality.

Strong emphasis is placed on the modal shift from private vehicles to public transport, recognizing its dual role in reducing both energy consumption and greenhouse gas emissions. According to the Green Growth National Action Plan – Transportation Sector (2020) a suite of public transport improvement measures is projected to achieve a 10% reduction in passenger-kilometers (pkm) from private cars by 2030, increasing to 17.5% by 2035. Key initiatives supporting this shift include the Amman Bus Second Phase, the Jordan Urban Local Bus Reform Project in Irbid and Zarqa, and the expansion of low-carbon municipal fleets. These efforts aim to improve service reliability, expand geographic coverage, and upgrade vehicle efficiency, making public transport a more attractive and sustainable alternative. The pathway assumes an increase in the pkm travelled by public transportation through better integration of routes, ticketing systems, and the introduction of cleaner buses, thereby reducing urban congestion, lowering per capita fuel use, and contributing to improved air quality and equity in mobility access.

Looking beyond road transport, the Optimistic pathway includes the commencement of freight rail operations from 2031, in alignment with the Jordan National Railway Project – Phase I and the Long-Term National Transport Strategy (to 2030). This new rail corridor is expected to support modal shift in freight logistics, reducing heavy truck traffic and associated emissions, particularly along key trade and transit routes. This projection assumes that 3% of the freight load (in tnkms) is shifted from road transport to rail transport by 2035 gradually after the start of the operation in 2031.

Distribution losses, are targeted for a gradual reduction with the long-term objective being to reach 110 percent by 2035, aligning Jordan's system with global benchmarks and supporting overall energy efficiency and financial sustainability in the electricity sector

Enhanced energy efficiency measures are implemented in buildings, to reduce overall energy demand, improve system cost-efficiency, and lower emissions. In the buildings sector, policies support the widespread adoption of thermal insulation, efficient lighting and appliances, high efficiency heat pumps and geothermal heat pump systems for space heating and cooling, especially in new urban developments and large public and commercial buildings (a more detailed description is presented in section 6.2 where the results on energy efficiency are also analysed).

²² Source: own elaboration based on the latest statistics on new registrations by the Department of Statistics and assumptions on the annual share of EVs in the new registrations

4.2.3 Modelling methodology

The modelling framework implemented for the pathway analysis of the Jordan Energy Sector Strategy (2025–2035) is the TIMES (The Integrated MARKAL-EFOM System) model, a widely recognized, bottom-up, technology-rich optimization tool developed under the International Energy Agency’s ETSAP (Energy Technology Systems Analysis Program). TIMES is designed to identify least-cost energy system pathways by minimizing total system costs over a defined planning horizon, while meeting specified energy service demands and policy constraints such as emissions targets or renewable energy shares. TIMES covers the entire energy system, from primary energy supply and imports, through transformation and conversion processes, to end-use consumption across all sectors, including residential, commercial, industry, transport, and agriculture, enabling a fully integrated assessment of energy flows, technology choices, and policy impacts. (Figure 51). It integrates detailed techno-economic data on energy technologies, fuels, and end-use sectors, allowing for scenario-based analysis of investment, operation, and policy impacts across the energy system. The model uses linear programming techniques to solve for the optimal mix of technologies and fuels under each scenario. TIMES supports both national and regional modelling applications and is extensively used in long-term energy and climate policy planning worldwide. A comprehensive description of the TIMES framework, its mathematical structure, and data requirements is provided in Appendix II of this report.

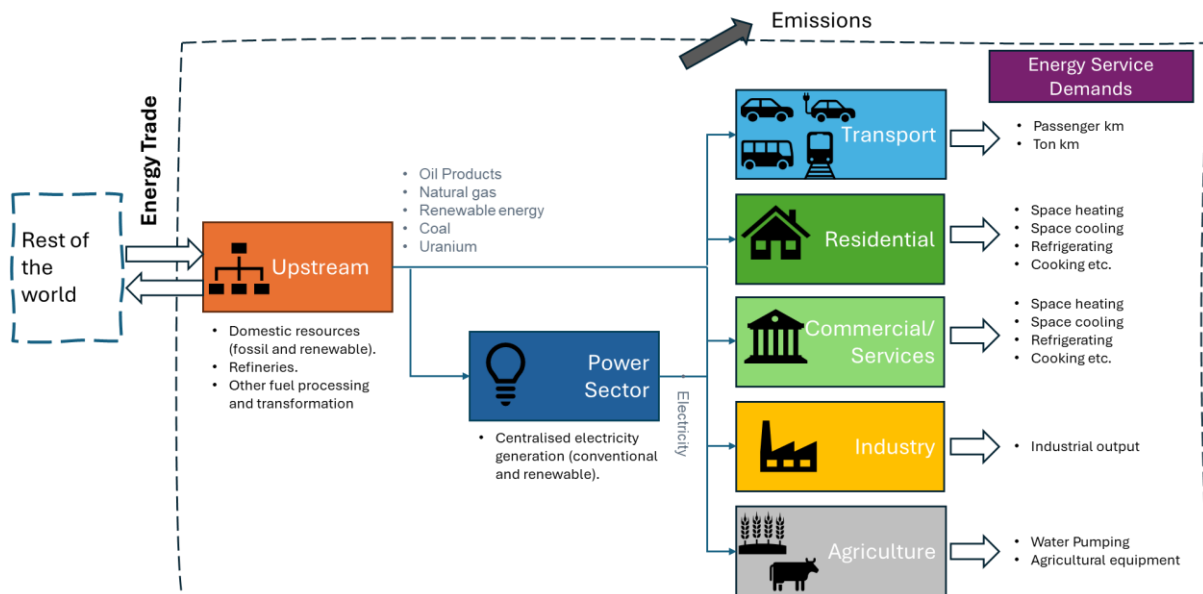


Figure 53: Energy System representation in TIMES

To complement the long-term optimization of the energy system using TIMES, the SDDP (Stochastic Dual Dynamic Programming) model is applied to analyze the hourly dispatch of the power system in selected milestone years, when the share of variable renewable electricity generation is high. SDDP is a state-of-the-art tool widely used for modelling the operation of hydrothermal and renewable-based power systems under uncertainty. It optimizes short-term and medium-term dispatch decisions by simulating hourly electricity demand, generation availability, including variability in solar and wind output, and operational constraints such as ramping limits, reserve requirements, and interconnection flows. This detailed temporal resolution allows for a realistic assessment of system flexibility, curtailment risks, storage requirements, and backup needs under different generation mixes. By focusing on key years,

typically those corresponding to strategic policy targets or significant technology transitions, the SDDP simulations provide critical insights into system reliability and the feasibility of integrating high shares of variable renewable energy. The results from SDDP are used to validate and refine the TIMES outputs, ensuring that investment pathways derived from least-cost planning also satisfy operational feasibility under realistic dispatch conditions.

4.3 Drivers and Assumptions for Modelling Purposes

The following modelling inputs are common across both pathways which are analysed within the modelling framework and are therefore presented here. A detailed presentation of the model inputs is included in Appendix I.

4.3.1 Demand Drivers

In energy system modelling, demand drivers are critical exogenous inputs that shape the evolution of energy service needs across sectors. These include population growth, GDP growth, and sectoral economic activity, all of which influence the scale and structure of energy demand. By projecting these drivers across the planning horizon, the modelling framework allocates energy consumption across sectors and end-uses based on service demand, technological performance, and economic optimization.

The population of the Kingdom is projected to increase steadily from 11.5 million in 2023 to 15 million in 2035, reflecting a compound annual growth rate of 2.239%, based on Department of Statistics (DOS) estimates²³ (the next figure). This demographic expansion will lead to an increase of energy service demands mainly in the residential and transportation sectors.

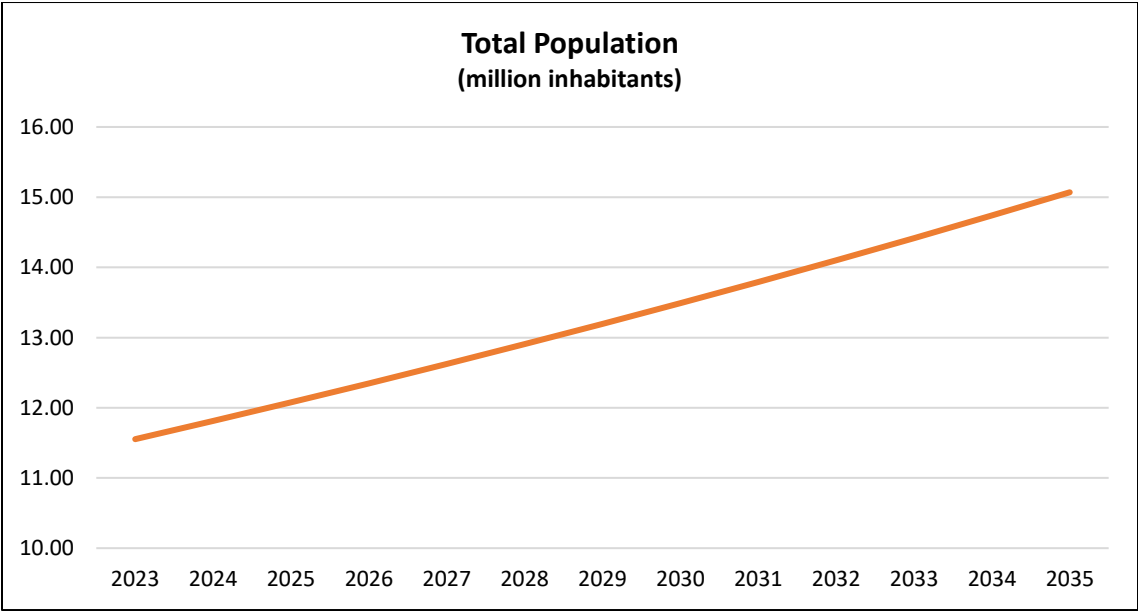


Figure 54: Population projection

²³ This projection was used in the Electricity Masterplan 2024 for the electricity demand projections.

The Reference Pathway is based on the baseline GDP growth rate assumed in the development of the 2023–2035 Electricity Sector Master Plan. According to this projection the growth rate is 3% until 2028 and 2.6% after that until 2035.

The GDP growth rate used in the Optimistic Pathway analysis is consistent with the Economic Modernization Vision (2023) targeting an average growth rate of 5.6% between 2023 and 2033, achieving the target of 58.11 billion JD by that year. In the modelling framework, these projections will define the scale of energy service demands across residential, commercial, industrial, and transport sectors, serving as the basis for evaluating final energy demand, system cost, emissions, and fuel mix.

4.3.2 Fossil fuel Prices

International fossil fuel price projections are among the most uncertain and influential parameters in long-term energy system modelling. These prices affect technology dispatch decisions, investment pathways, and overall system costs, particularly in countries like Jordan, which relies heavily on imported fuels. The volatility of global oil and gas markets, driven by geopolitical tensions, supply chain disruptions, and energy transition dynamics, makes it difficult to predict future price trajectories with high confidence.

In the modelling framework for Jordan’s energy strategy, the TIMES model incorporates fossil fuel price assumptions based on authoritative sources. Crude oil prices follow the Stated Policies Scenario (STEPS) of the IEA World Energy Outlook 2024 projections, starting at \$82/bbl in 2023 and declining gradually to \$77/bbl by 2040, reflecting a long-term easing of oil demand globally. LNG import prices are \$12/MMBTU, while imported gas prices are calculated based on the pricing formulae in connection with the crude oil price and the local Risha gas pricing is set at 90% of the import price plus the transportation tariff once the pipeline is operational in 2030.

Table 12: Projections of fossil fuel prices²⁴

	2025	2030	2035
Crude Oil (\$/bbl)	80.71	79.00	78.00
LNG (\$/MMBTU)	12	12	12
Egypt gas (\$/MMBTU)	6.27	6.23	6.20
Chevron Gas (\$/MMBTU)	6.53	6.45	6.40
Transportation tariff (\$/MMBTU)	0.90	0.90	0.90
Final price for Chevron Gas (\$/MMBTU)	7.43	7.35	7.30
Final price from Risha Gas (\$/MMBTU)	4.50	6.62	6.57

4.3.3 Power Sector Data

Technology cost projections are a fundamental input in least-cost optimization models such as TIMES, as they directly influence the competitiveness, deployment rate, and system role of various energy technologies. In TIMES, the model seeks to minimize total system cost while meeting energy service demands and policy constraints. Therefore, assumptions about future investment costs, operating and maintenance expenses, efficiencies, and lifetimes of technologies, particularly for renewables (e.g. solar PV, wind), storage systems, electric vehicles, and emerging technologies like green hydrogen, play a

²⁴ Source: Crude oil price according to the Stated Policies Scenario (STEPS) of IEA World Energy Outlook (2024). N. Gas prices calculated according to the pricing formula. Risha Gas price set at 90% of the import gas plus the transportation tariff.

decisive role in determining the optimal technology mix. Lower projected costs for solar PV or batteries, for example, can accelerate their adoption in model results, displacing fossil-based generation and altering the structure of the electricity and transport sectors. Conversely, overestimating costs can delay decarbonization pathways or misrepresent transition risks. As such, using reliable, periodically updated cost trajectories is essential to ensure realistic modelling outcomes and robust scenario comparisons. In this analysis the cost data for the power sector technologies that have been used in the Electricity Masterplan (2024) are implemented as can be seen in Table 10. Annex I includes detailed tables of technology costs across all sectors.

Table 13: Overnight Capital Costs of Electricity Generation Technologies

TECHNOLOGY	Life (years)	Overnight Investment Costs (\$/kW)			
		2025	2030	2035	2040
CCGT	25	1000	1000	1000	1000
Steam Turbine	25	1300	1300	1300	1300
Gas Turbine	25	675	675	675	675
Oil Shale Steam Turbine	30	4700	4700	4700	4700
Nuclear	60	-	6000	6000	6000
Nuclear SMR	60	-	4000	4000	4000
Wind	20	1200	1200	1170	1100
PV	20	650	650	600	550
Roof top PV	20	1110	1110	900	825
CSP 8h storage	25	3090	2458	2034	2034
CSP 12h storage	25	4060	3100	2570	2570
Biogas	25	4430	3960	3960	3960
Hydro Pump storage	60	1200	1200	1200	1200
BESS 4h storage	15	701	700	726	726

Source: Electricity sector masterplan (2024). PV and Wind prices reduced according to the projections by IEA World Energy Outlook (2024)

4.4 References

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5 The Reference Pathway

This chapter presents the results of the Reference Pathway, which reflects the continuation of the current trends in the energy system development under reference GDP growth.

5.1 Final Energy Consumption

Final energy consumption refers to the total energy consumed by end users such as households, industry, transport, services, and agriculture after energy has been delivered and converted from its primary sources (like crude oil, coal, natural gas or renewables). Expressed in kilotons of oil equivalent (ktoe), it serves as a fundamental input for determining the required primary energy sources. Driven by reference GDP growth and the increase in population, the final energy consumption rises steadily from 6,893 ktoe in 2025 to 8,525 ktoe in 2035, a total increase of 23.7 % (Figure 55).

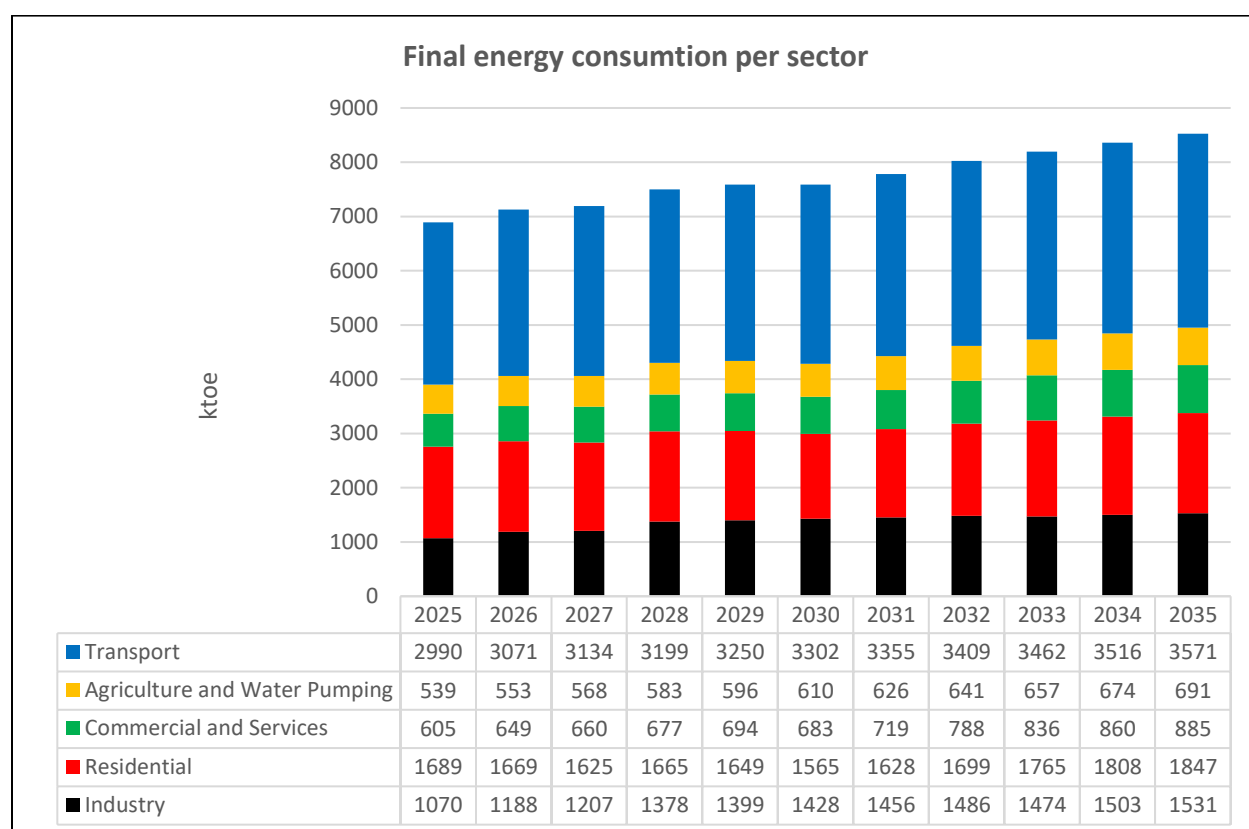


Figure 55: Final energy consumption per sector for the period 2025-2035

In 2025, transport dominates national consumption with 43.4 %, followed by the residential sector at 24.5%, industry 15.5 %, commercial and services 8.8 %, and agriculture and water pumping 7.8 %. By 2030, total FEC reaches 7,589 ktoe and transport still represents the largest share at 43.5 %, industry increases its weight slightly to 18.8 %, the residential sector's share declines to 20.6 %, while commercial/services and agriculture represent 9.0 % and 8.0 %, respectively. In 2035, transport consumption reaches 3,571 ktoe, maintaining a 41.9 % share. The residential sector rises modestly to 1,847 ktoe (21.7 %), industry to 1,531 ktoe (18.0 %), services to 885 ktoe (10.4 %), and agriculture to 691 ktoe (8.1 %). Overall, the sectoral composition of final energy demand remains transport-dominated but with a gradual structural shift

toward industry and services, consistent with Jordan’s current economic diversification plans and energy efficiency policies.

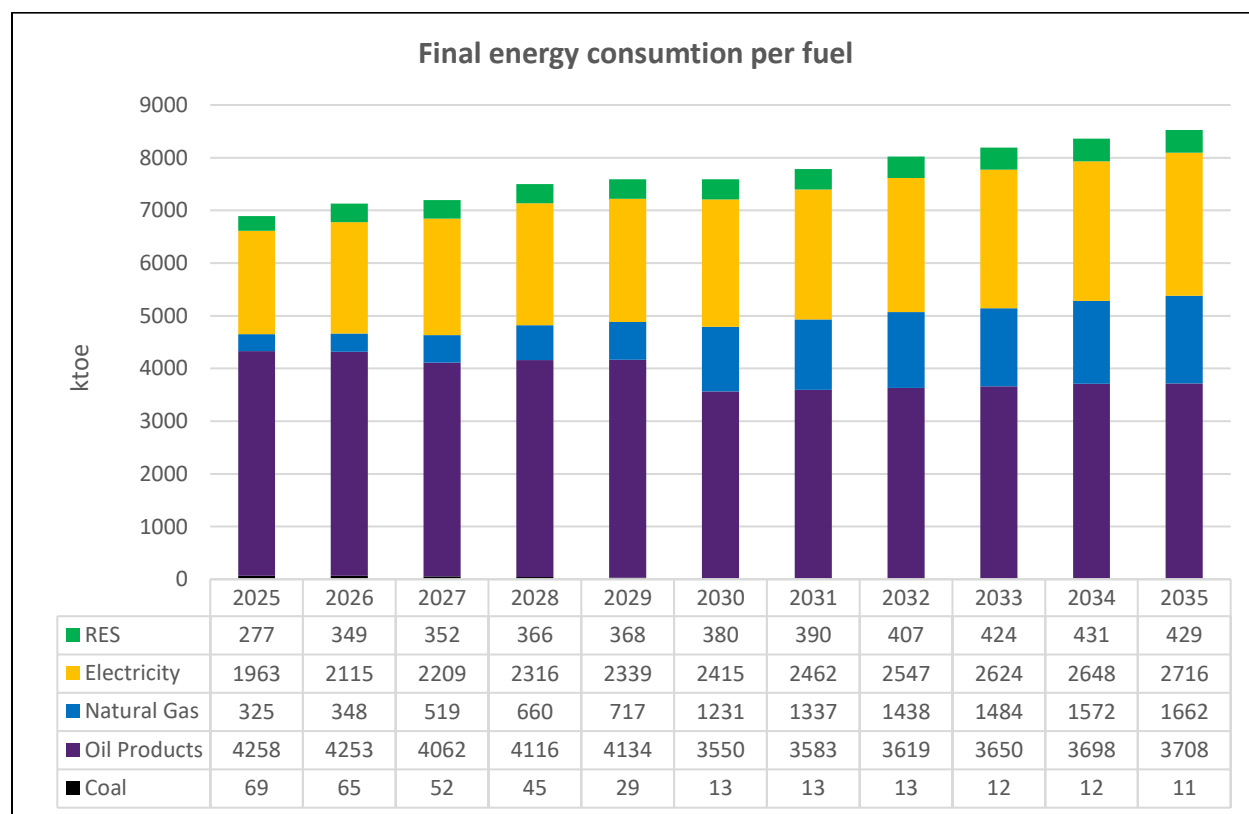


Figure 56: Final energy consumption per fuel for the period 2025-2035

Final energy consumption by fuel shows a gradual decarbonization trend between 2025 and 2035, with a decline in coal and oil use and strong growth in electricity and natural gas (Figure 56). In 2025, oil products are the dominant energy source with 4,258 ktoe (61.8%) of total consumption, followed by electricity (28.5%), natural gas (4.7%), renewables (4.0%), and coal (1.0%). By 2030, total final energy consumption shifts structurally as oil products decline to 3,550 ktoe (46.8%), while electricity rises to 2,415 ktoe (31.8%), natural gas surges to 1,231 ktoe (16.2%), renewables contribute 380 ktoe (5.0%), and coal drops sharply below 0.2%. In 2035, oil products still account for 43.5% (3,708 ktoe), electricity increases to 2,716 ktoe (35.5%), natural gas reaches 1,662 ktoe (21%), renewables stabilize around 429 ktoe (5.6%), and coal almost disappears (11 ktoe, 0.1%). Between 2025 and 2035, the share of oil products and coal declines from 67.5% to 64.6%, while cleaner energy carriers, electricity, gas, and renewables expand steadily.

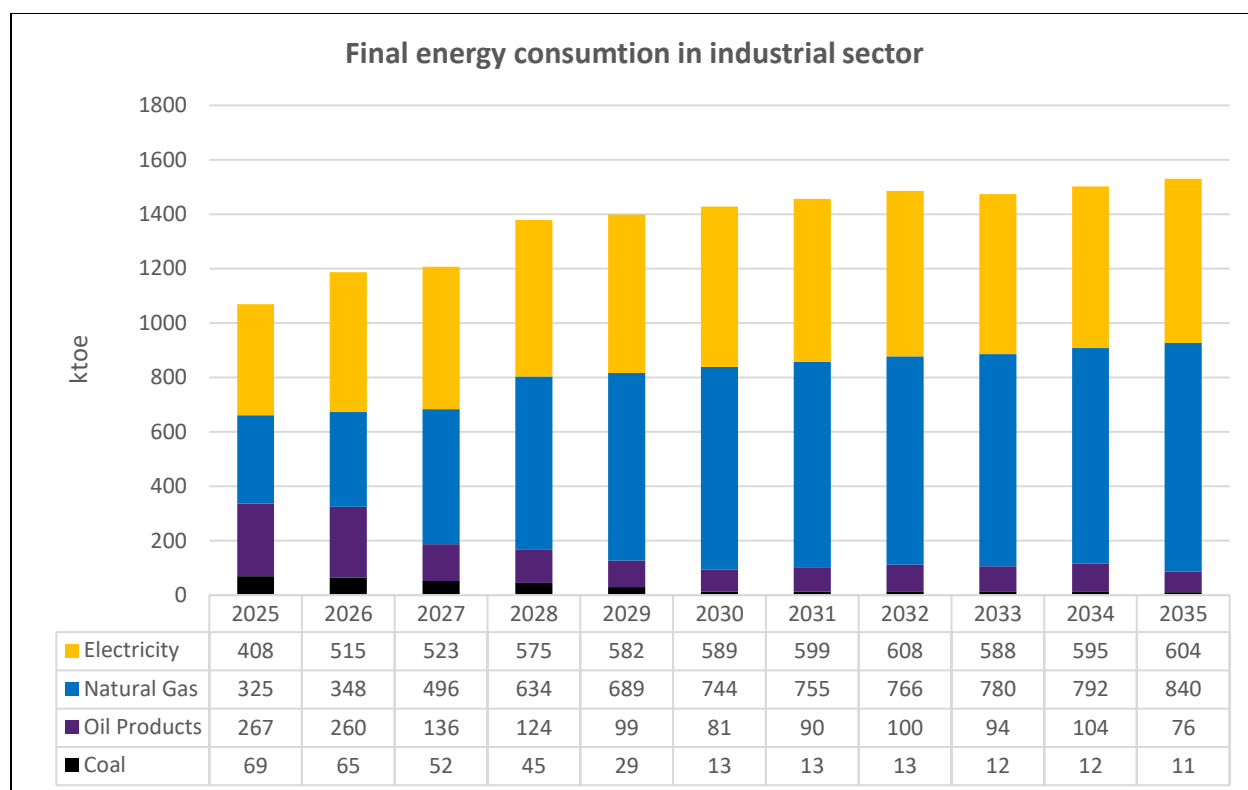


Figure 57: Final energy consumption in the industrial sector for the period 2025-2035

Final energy consumption in the industry sector shows a transition away from oil and coal toward natural gas and electricity between 2025 and 2035 (Figure 57). In 2025, total industrial consumption amounts to about 1,070 ktoe, composed of coal 69 ktoe (6.5%), oil products 267 ktoe (25%), natural gas 325 ktoe (30%), and electricity 408 ktoe (38%). By 2030, total industrial FEC rises to roughly 1,428 ktoe, with natural gas becoming the dominant fuel with 744 ktoe (52%), electricity accounting for 589 ktoe (41%), while oil products drop sharply to 81 ktoe (6%), and coal drops below 1%. In 2035, industrial FEC reaches about 1,531 ktoe, with natural gas (55%) and electricity (39%) almost fully replacing traditional fossil fuels. Over the decade 2025–2035, total industrial energy demand rises by 43%, while its composition shifts decisively as natural gas use more than doubles whereas oil products and coal fall significantly.

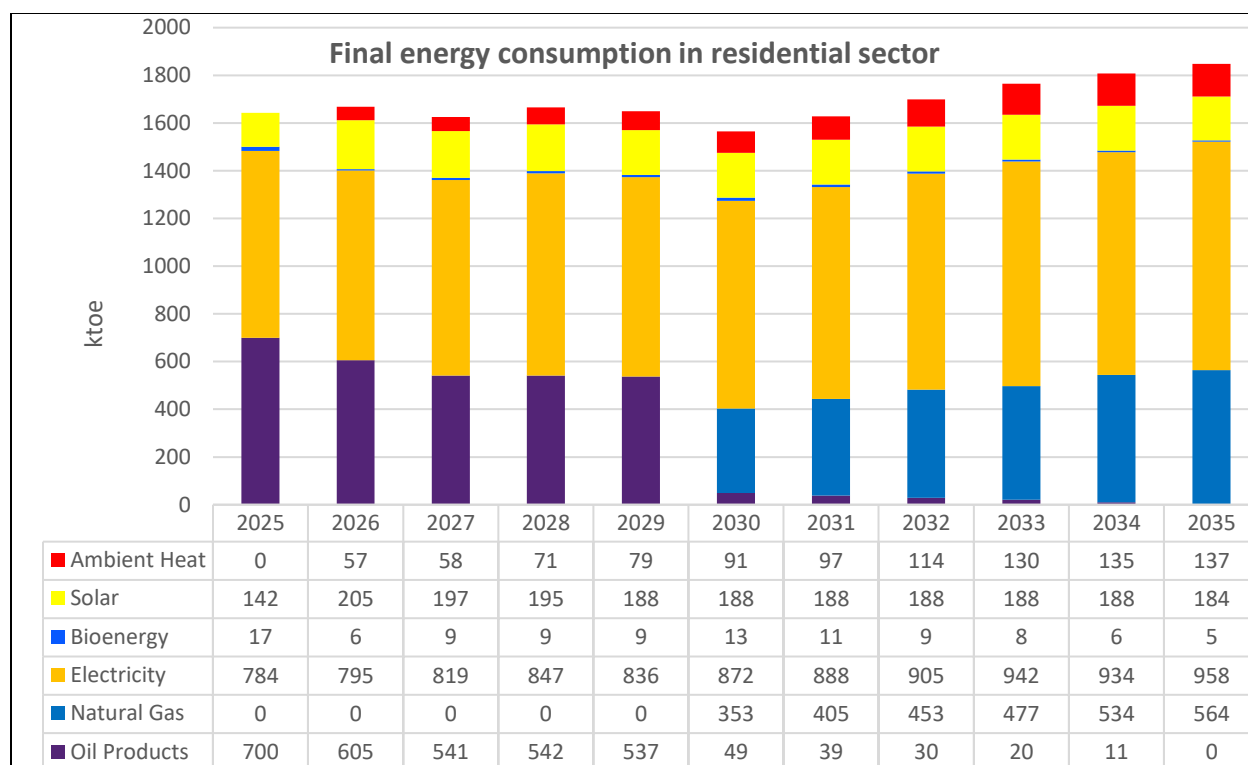


Figure 58: Final energy consumption in the residential sector for the period 2025-2035

Final energy consumption in the residential sector undergoes a significant transformation between 2025 and 2035, characterized by the phase-out of oil products, the rapid penetration of natural gas, and the steady electrification of end-uses (Figure 58). In 2025, total residential final energy consumption stands near 1,643 ktoe, largely dominated by electricity (784 ktoe, 48%) and oil products (700 ktoe, 43%), with smaller shares from solar (142 ktoe, 9%) and bioenergy (17 ktoe, 1%). By 2030, total consumption is structurally altered as oil products reduce to 49 ktoe (3%), while natural gas rises to 353 ktoe (26%), driven by gas network expansion in Amman and Zarqa. Electricity consumption increases to 872 ktoe (63%), solar remains constant at around 188 ktoe (14%), and ambient heat, reflecting the growing diffusion of heat pumps, contributes 91 ktoe (7%). In 2035, electricity becomes the dominant carrier at 958 ktoe (52%), natural gas reaches 564 ktoe (31%), solar 184 ktoe (10%), and ambient heat 137 ktoe (7%), while oil products and bioenergy reduce below 1%.

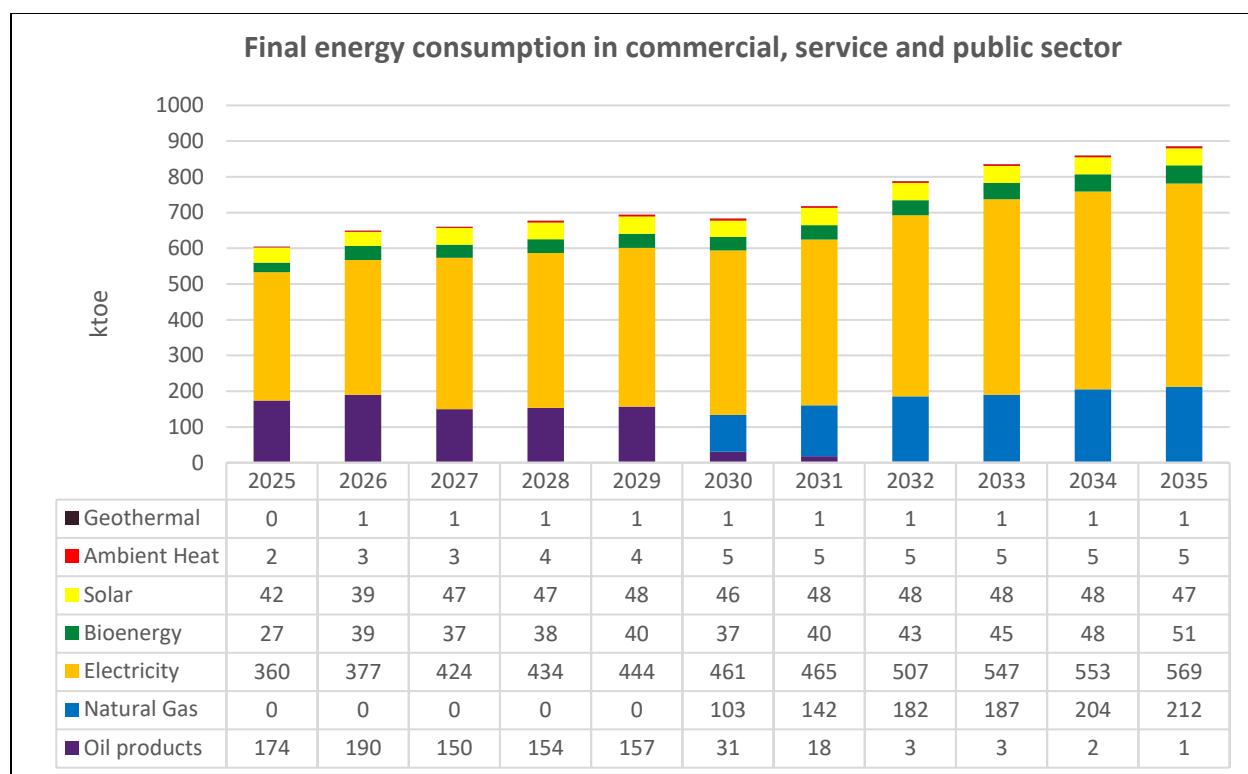


Figure 59: Final energy consumption in the commercial, service and public sector for the period 2025-2035

The commercial and services sector in Jordan demonstrates steady electrification and the gradual introduction of natural gas between 2025 and 2035, alongside a decline in oil products (Figure 59). In 2025, total final energy consumption in the sector is around 602 ktOE, mainly composed of electricity (360 ktOE, 60%), oil products (174 ktOE, 29%), bioenergy (27 ktOE, 4%), and solar (42 ktOE, 7%). By 2030, total consumption rises to roughly 683 ktOE. Electricity remains dominant (461 ktOE, 67%), natural gas enters the mix with 103 ktOE (15%), and oil products reduce to 31 ktOE (5%). Renewables continue to provide a stable contribution of about 90 ktOE (13%), primarily from solar for solar water heating. In 2035, total energy use grows moderately to about 886 ktOE, with electricity increasing to 569 ktOE (64%), natural gas reaching 212 ktOE (24%), and renewables accounting for 100 ktOE (11%). Oil products nearly disappeared, falling below 1 ktOE. Between 2025 and 2035, sectoral FEC rises by about 47%, while the energy mix shifts decisively from oil products to cleaner carriers as natural gas grows from zero to 212 ktOE.

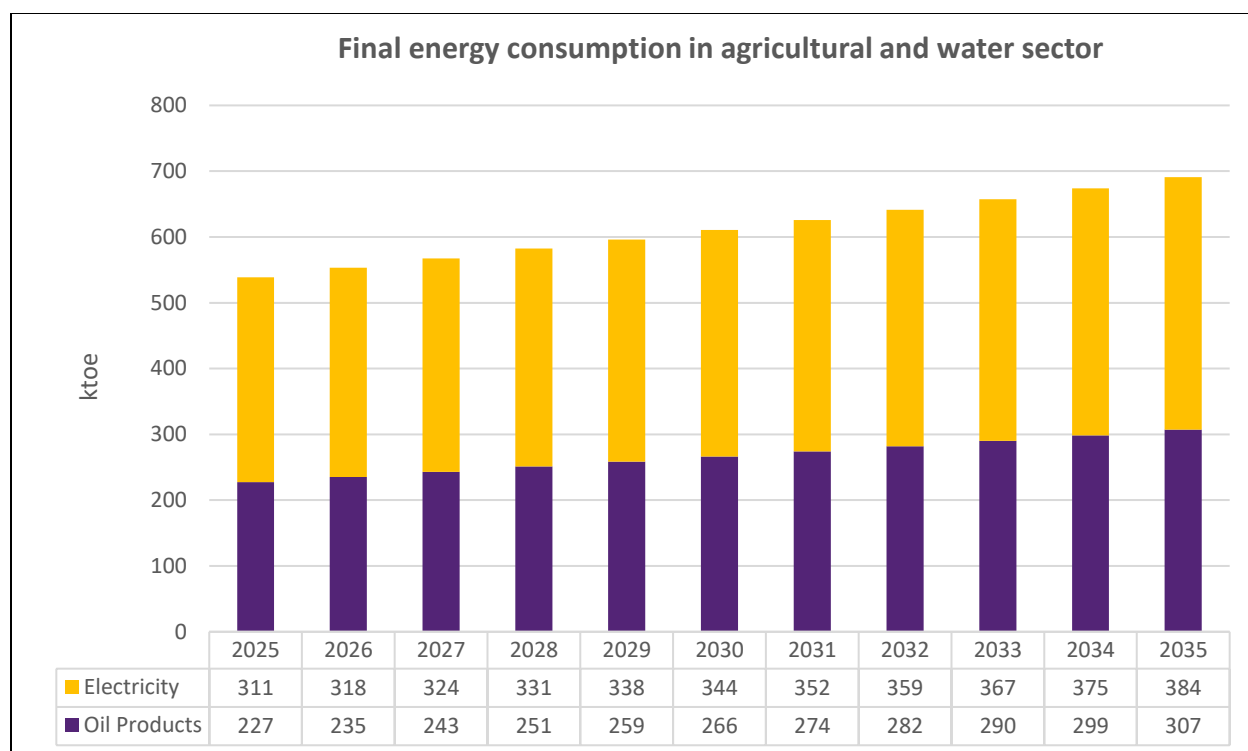


Figure 60: Final energy consumption in the agricultural and water sector for the period 2025-2035

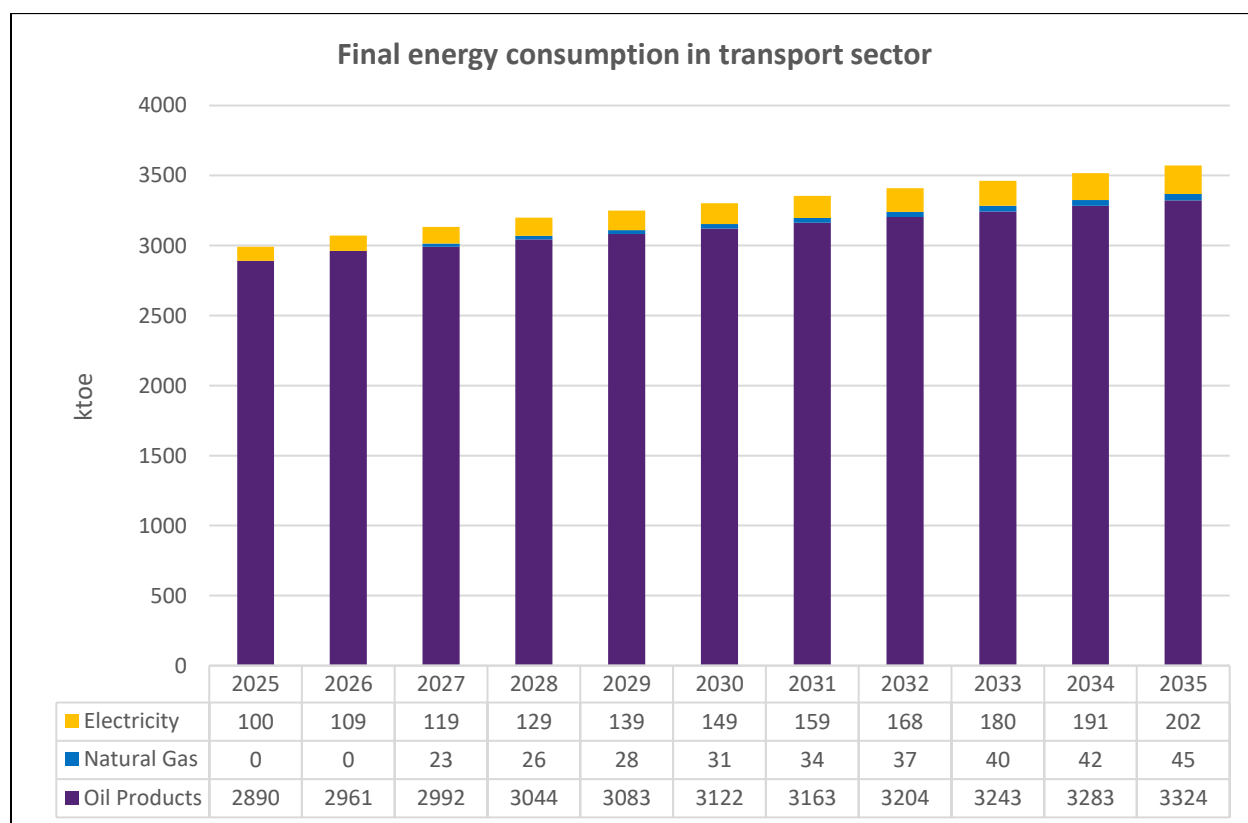


Figure 61: Final energy consumption in transport sector for the period 2025-2035

Final energy consumption in the transport sector shows a gradual but clear diversification between 2025 and 2035, with modest electrification and the initial introduction of natural gas, while oil products remain. In 2025, total transport energy use reaches approximately 2,990 ktoe, of which oil products account for 2,890 ktoe (96.6%) and electricity 100 ktoe (3.4%). By 2030, total consumption increases to 3,122 ktoe, with oil products still providing 97%, but electricity rising to 149 ktoe (4.8%) and natural gas entering the mix with 31 ktoe (1.0%), signaling the adoption of gas-fueled heavy vehicles and the continuation of the successful electric mobility policy. In 2035, total transport demand climbs further to 3,571 ktoe, still dominated by oil products (3,324 ktoe, 93%), though electricity reaches 202 ktoe (5.7%) and natural gas 45 ktoe (1.3%), confirming gradual diversification. This evolution reflects slow decarbonization in the sector compared to others, constrained by the dominance of conventional vehicle fleets for freight and international aviation fuels.

5.2 Primary Energy

Primary energy refers to energy contained in natural resources before it undergoes any conversion or transformation by human activity. It represents the raw, unprocessed form of energy directly extracted or harnessed from nature, including resources such as crude oil, natural gas, coal, biomass, solar radiation, wind, hydropower and geothermal energy. Primary energy production is expected to rise significantly over the next decade, driven by increased natural gas output from the Risha field. Additionally, the large-scale integration of renewable energy into the power system as well as its use in green hydrogen and ammonia production will further contribute to the overall growth in primary energy output.

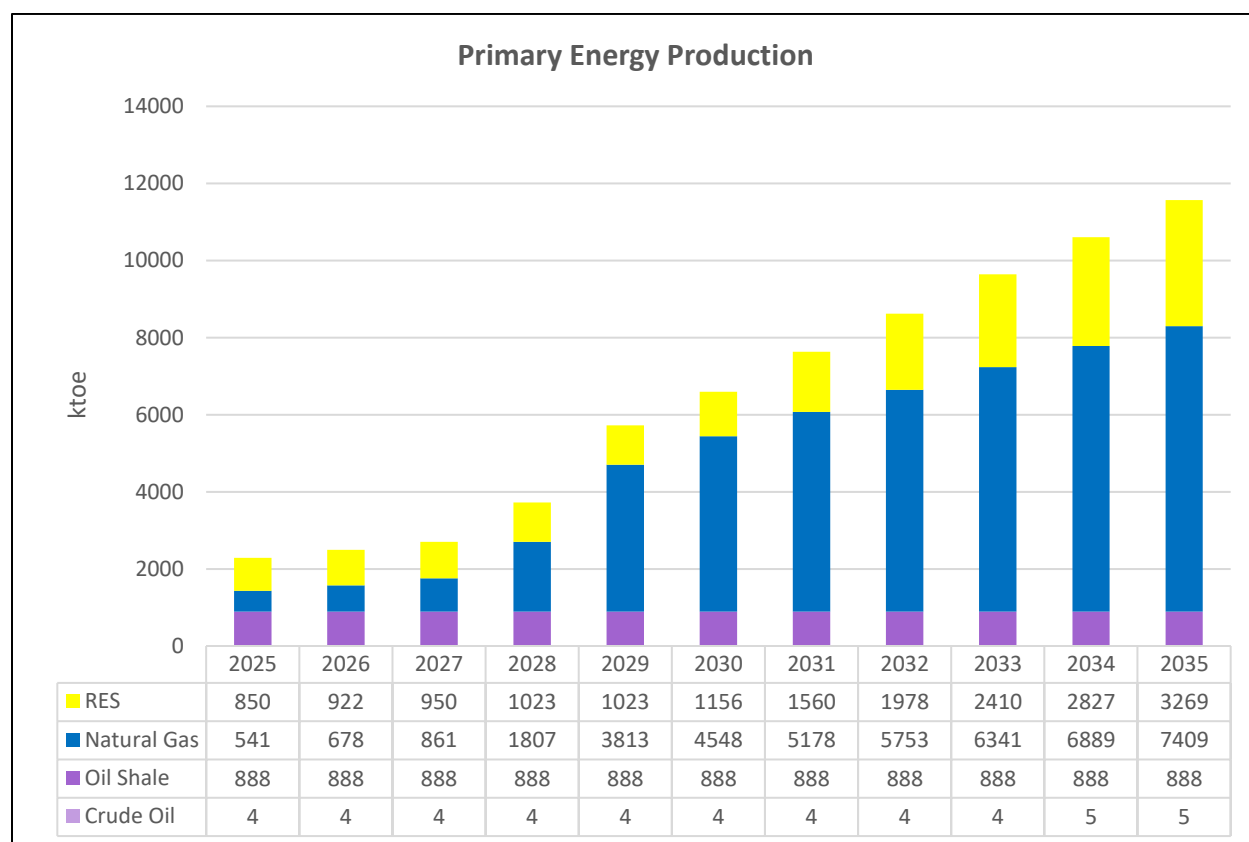


Figure 62: Primary energy production for the period 2025-2035

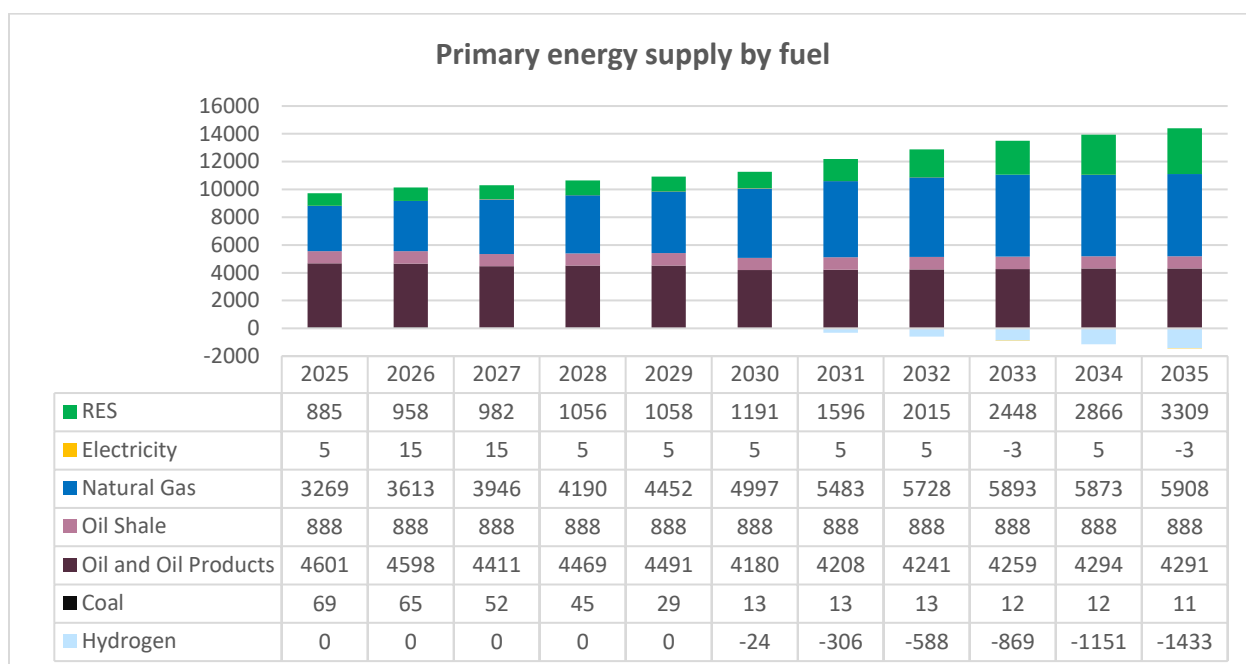


Figure 63: Primary energy supply by fuel for the period 2025-2035

Primary energy supply increases moderately between 2025 and 2035, while the energy mix undergoes a structural shift toward natural gas and renewables, with a gradual decline in oil dependence. In 2025, total primary supply stands at roughly 9,718 ktoe, dominated by oil and oil products (48%) and natural gas (33%), with oil shale (9%) and renewables (9%) providing smaller shares. Coal and electricity imports remain marginal. By 2030, the total supply rises to nearly 11,273 ktoe, driven by an increase of natural gas to 4,997 ktoe (44%) and renewables to 1,191 ktoe (11%), while oil and oil products decline to 4,180 ktoe (37%). Oil shale remains constant, covering around 8%, and the first hydrogen exports appear. In 2035, total supply reaches 12,970 ktoe, with a clear decarbonization pattern: natural gas becomes the leading source (45%), renewables expand to 3,309 ktoe (26%), and oil and oil products fall to 33%. Oil shale remains at 7%, while hydrogen exports increase significantly (–1,433 ktoe), marking Jordan’s entry as a hydrogen exporter.

5.3 Energy import and export

Given the rise in domestic energy demand, imports increase until 2028 but then as the production from the Risha gas field scales up and the renewable energy gradually increases, imports stabilise at the level of 6.3Mtoe. This corresponds to the take-or-pay quantities of natural gas and the crude oil and some oil products that continue to be imported. At the same time, energy exports are expected to rise, due to the projected export of hydrogen and ammonia and the projected export of surplus gas from the Risha field. Overall, energy import dependency is projected to decline significantly, from 76% in 2025 to 10% by 2035, driven by increased Risha gas production, renewable production and the expansion of hydrogen and ammonia output.

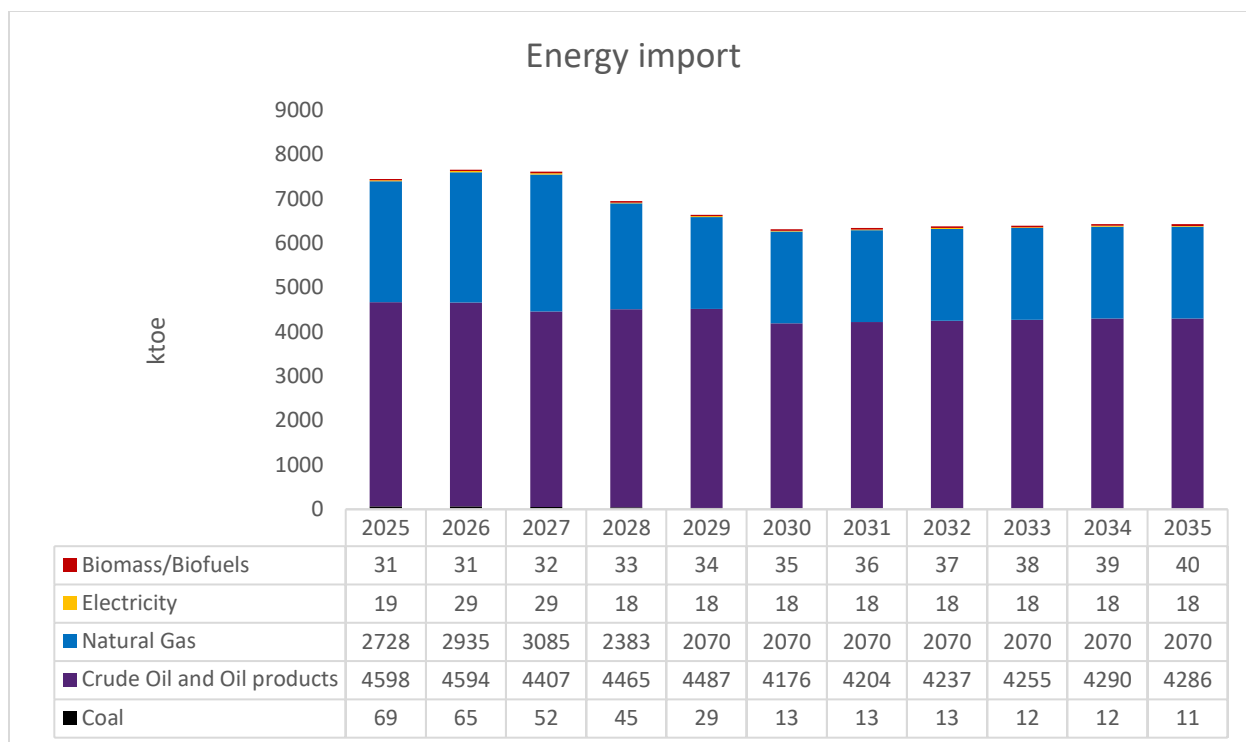


Figure 64: Energy import for the period 2025-2035

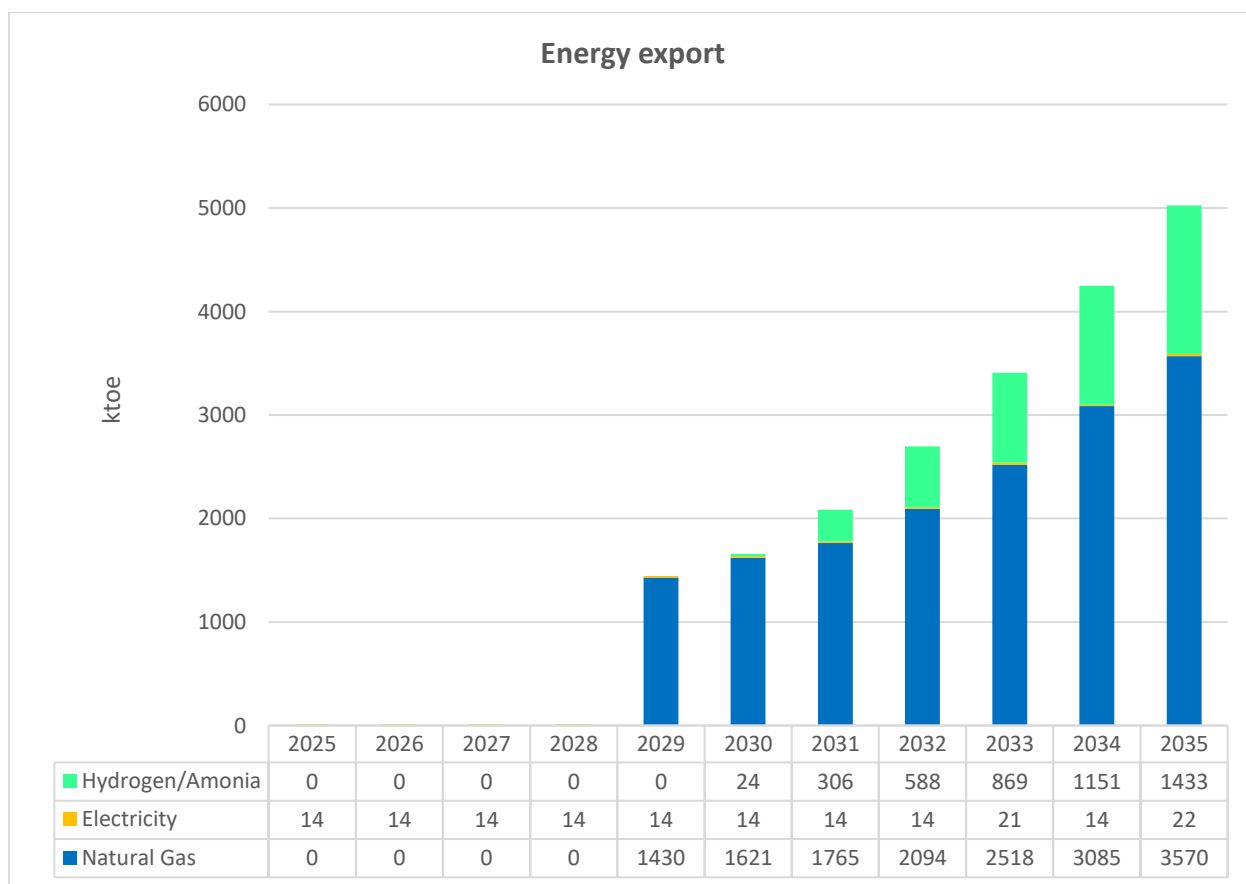


Figure 65: Energy export for the period 2025-2035

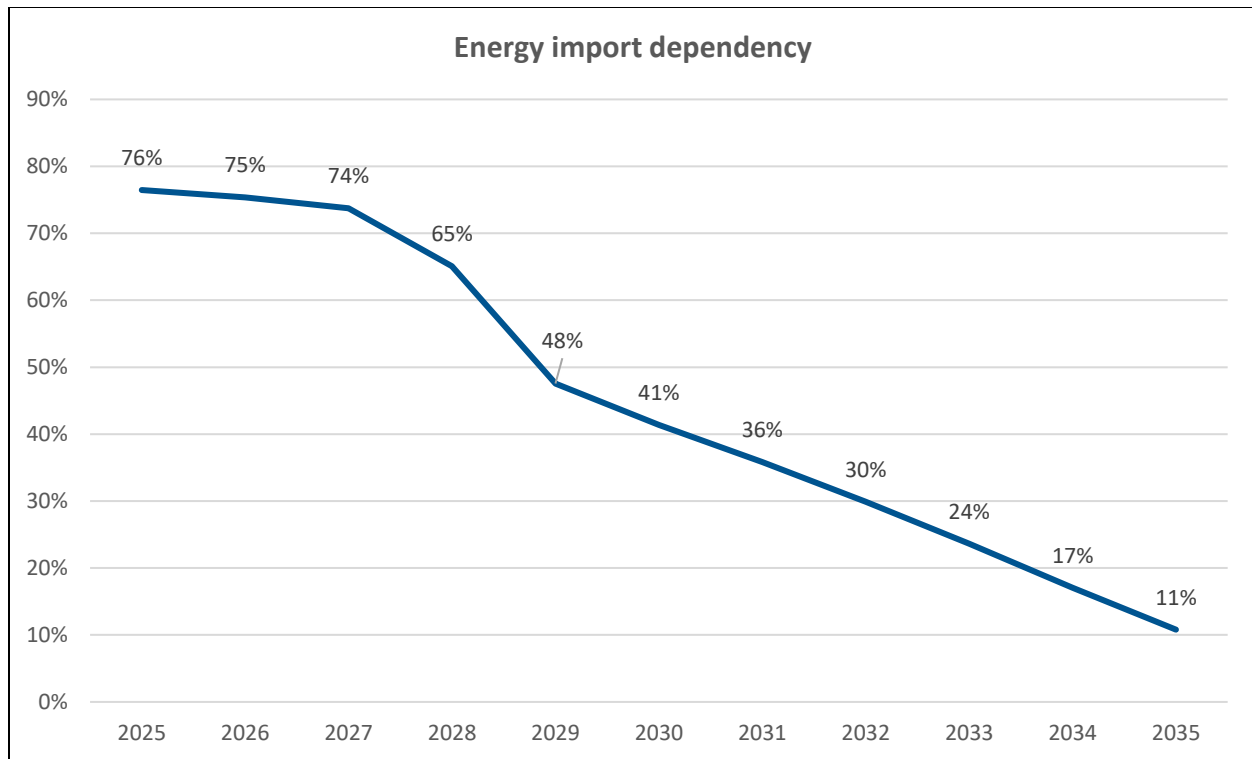


Figure 66: Energy import dependency

5.4 Electricity sector

The electricity sector is characterized by a diversified energy mix for power generation. Under the Reference Pathway, electricity production will continue to be primarily based on natural gas, with a gradually increasing contribution from renewable energy, particularly solar power plants. Renewable electricity generation is projected to reach around 33% of total production by 2030 and 40% by 2035.

Overnight investment costs reflect a balanced allocation between natural gas power plants and renewables, predominantly solar, with substantial investment in the PHES Mujib project. PHES Mujib is regarded as a key enabler of system flexibility and renewable integration, while further renewable deployment after 2030 is supported by additional battery storage systems.

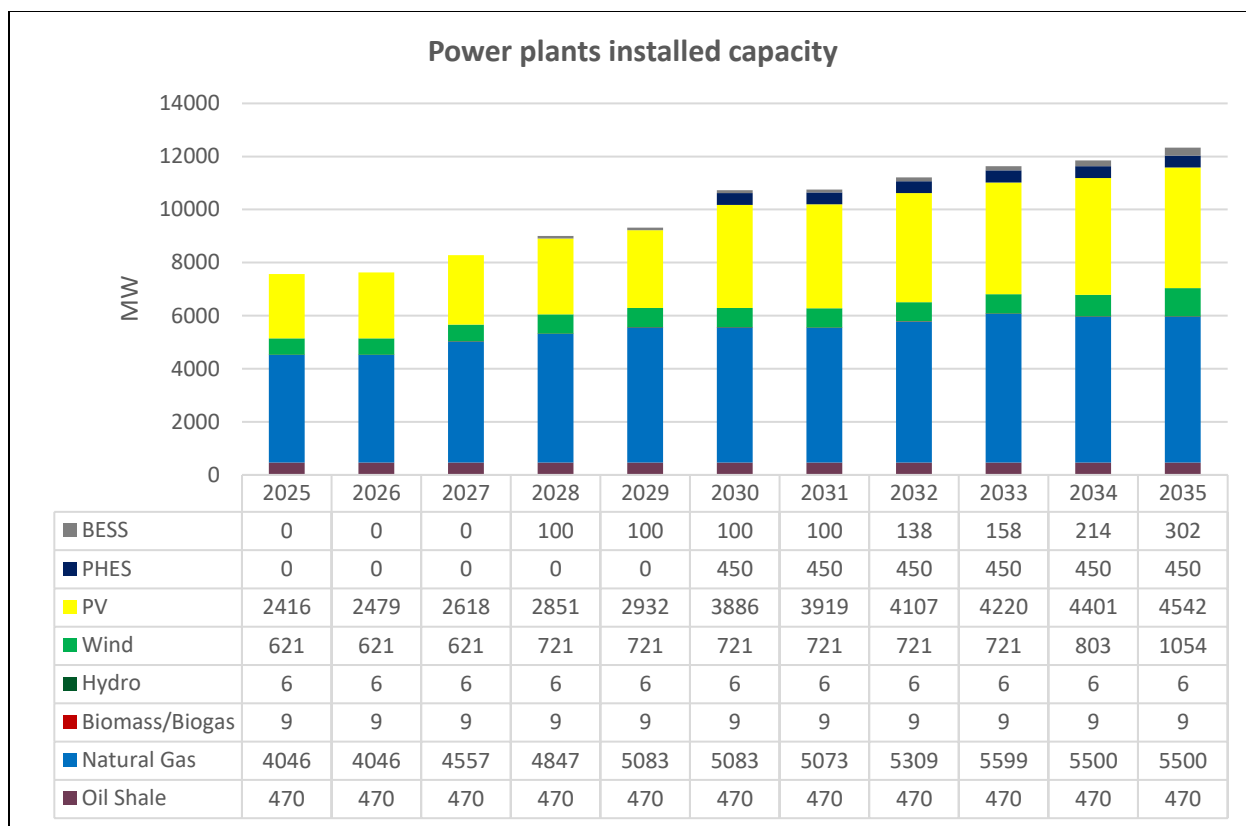


Figure 67: Installed capacity per type of power plants in the period 2025-2035

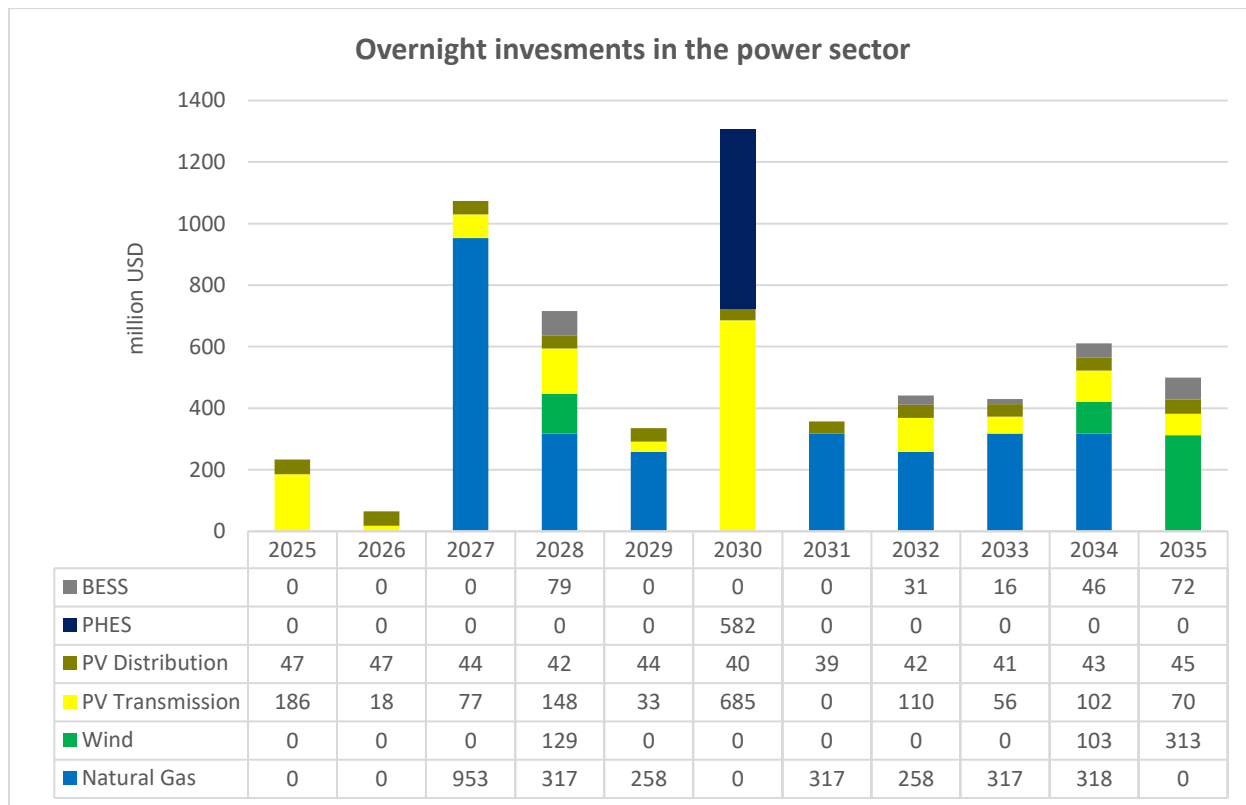


Figure 68: Overnight investment costs in the power system in the period 2025-2035

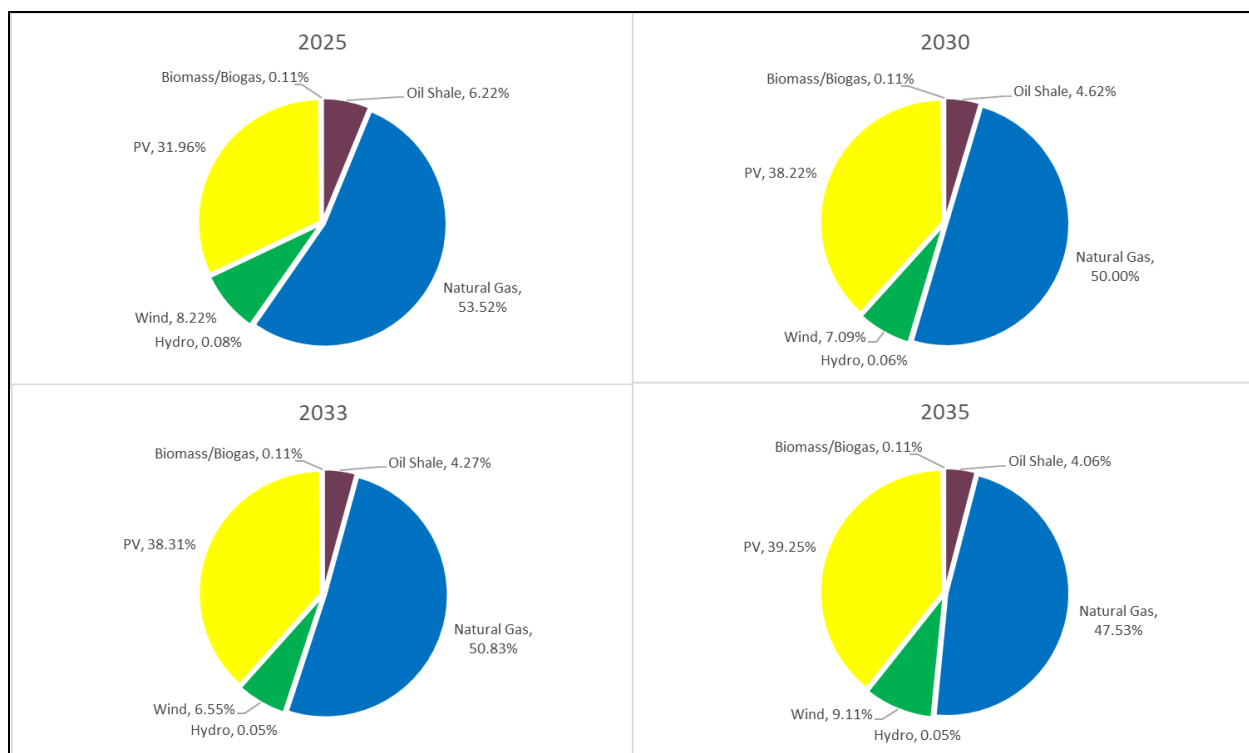


Figure 69: Share of the installed capacity per type of power plants in 2025, 2030, 2033 and 2035

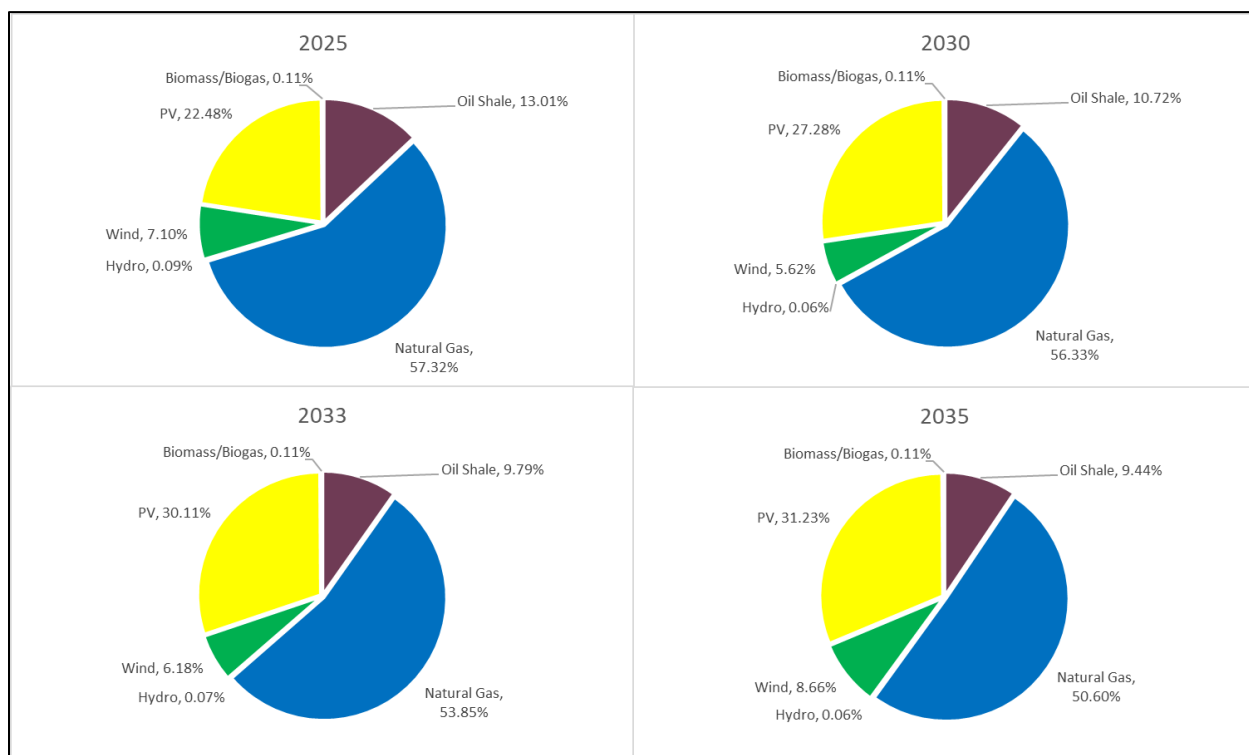


Figure 70: Share of the produced electricity per type of power plants in 2025, 2030, 2033 and 2035

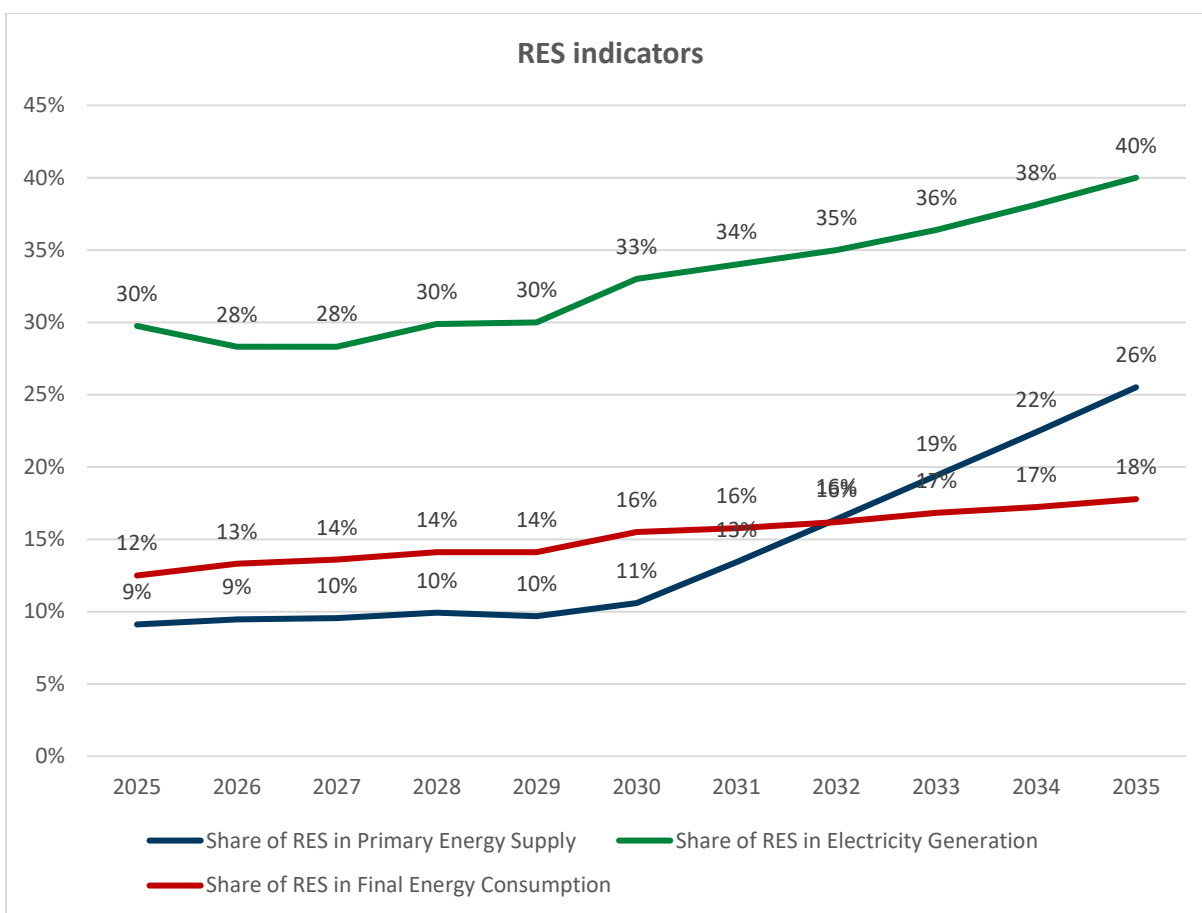


Figure 71: Indicators for RES penetration in the period 2025-2035

5.4.1 Disbursement Plan for Reference Pathway

Based on the results obtained for each of the Pathways analyzed, an evaluation was carried out of the annual disbursement schedule required to cover the investments associated with the expansion of the power generation and transmission system. For this purpose, it is important to recall that, up to this stage of the analysis, the unit investment costs of the generation technologies have been considered as overnight values; that is, they reflect the total construction cost as if the project were executed instantaneously, without any temporal distribution of expenditures.

In order to realistically represent the sequence of outlays throughout the implementation cycle of each project, these costs were transformed into typical annual disbursement schedules, differentiated according to the nature of the investment and the execution practices commonly adopted in the industry. In particular, standard expenditure profiles were applied, reflecting the progressive distribution of costs from the initial stages of studies and preparatory works, through the peak disbursements during the construction phase, and up to the completion of the project and its commercial operation.

The scheduling of these disbursements, disaggregated by project type and planning horizon, is presented in the next table, and constitutes the basis for the financial analysis and comparative assessment of the expansion Pathways.

Table 14: Disbursement Schedule

ELEMENT	Construction Period	1	2	3	4	5	6
CCGT	3	5%	25%	45%	25%	-	-
BIOGAS	3	5%	25%	45%	25%	-	-
SOLAR PV	2	5%	60%	35%	-	-	-
WIND	3	5%	50%	35%	10%	-	-
HPS	5	5%	15%	20%	25%	30%	5%
TRANSMISSION	4	5%	15%	25%	45%	10%	-
BESS	2	30%	65%	5%	-	-	-

The maximum development period of the works contemplated in the plan has been estimated at six years, consistent with the expected duration of the Al-Mujib Hydro Power Storage (HPS) project. As an example, and as shown in the reference table, gas-fired Combined Cycle Gas Turbine (CCGT) generation projects have an approximate construction period of three years, while their financial disbursements extend over four years, distributed according to the indicated percentages.

For transmission projects, it was assumed that the physical development of the works requires on average four years, with a disbursement schedule extending up to five years, reflecting the typical execution timelines and financial closure periods associated with this type of infrastructure.

Based on these technology-specific schedules, a consolidated projection of disbursements was prepared for the period 2025–2035, excluding any potential financial commitments that may materialize beyond this time horizon.

For the Reference Pathway, the next figure presents the planned disbursement schedule for generation investments, broken down by technology type.

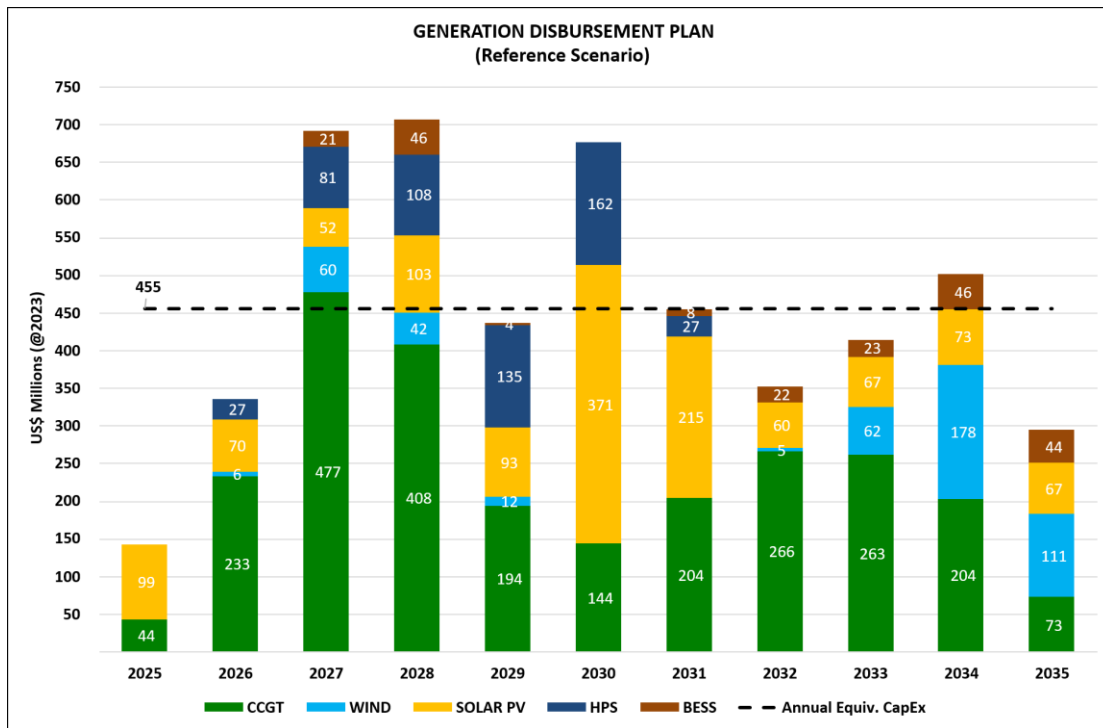


Figure 72: Generation Disbursement Plan (Reference Pathway)

As shown in the figure, the disbursement plan begins with USD 142 million in 2025 and increases annually to nearly USD 700 million in 2028, before declining to USD 294 million at the end of the study period. The capital requirements to finance generation expansion average around USD 455 million per year over the analysis period, representing a significant demand for investment resources, the vast majority of which is expected to be covered by private investment opportunities.

For this same Pathway and study period, the next figure presents the total planned disbursement for both generation and transmission. The figure shows that transmission investments start at USD 28 million in 2025, peak at USD 74 million in 2030, and then progressively decline to USD 23 million in 2035, with an average annual transmission investment of approximately USD 46 million.

Considering the combined investments in both transmission and generation, total capital requirements average USD 501 million per year. Annual investment needs start at USD 170 million in 2025, reach a maximum of approximately USD 771 million in 2028, and decline to USD 318 million by the end of the study period.

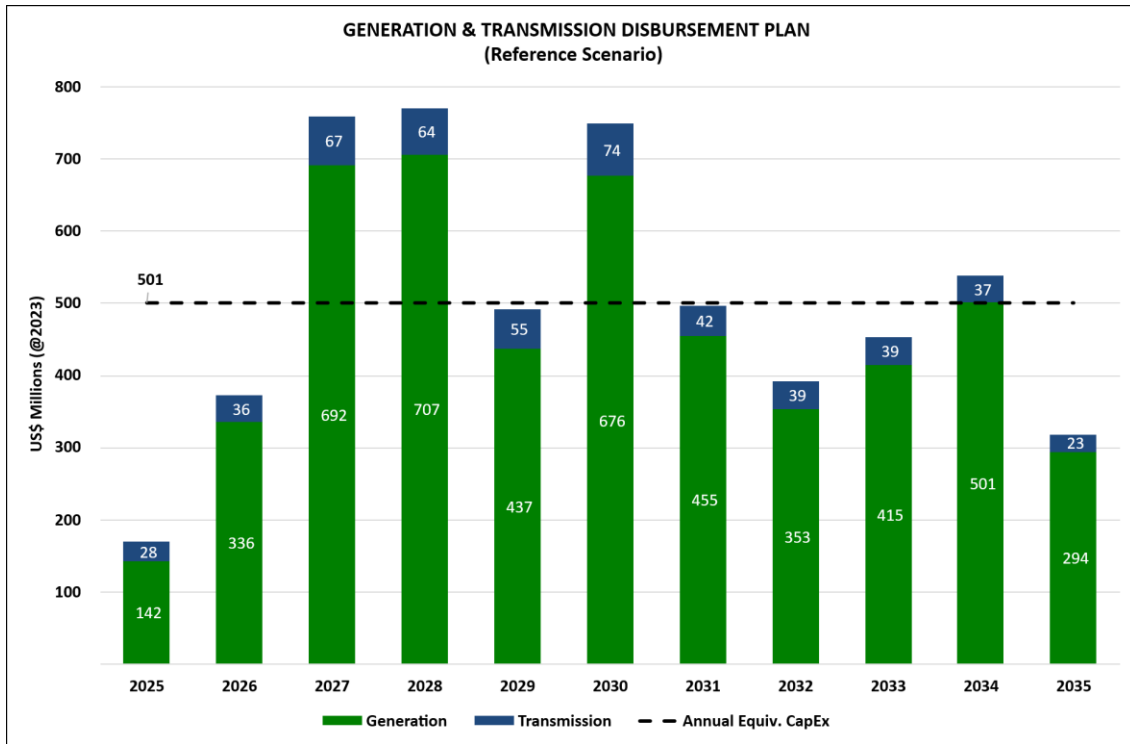


Figure 73: Generation & Transmission Disbursement Plan (Reference Pathway)

5.5 GHG emissions

Detailed sectoral and aggregate GHG emission results are shown in the subsequent graphs and tables. Electricity production and transport sectors are the primary contributors to GHG emissions.

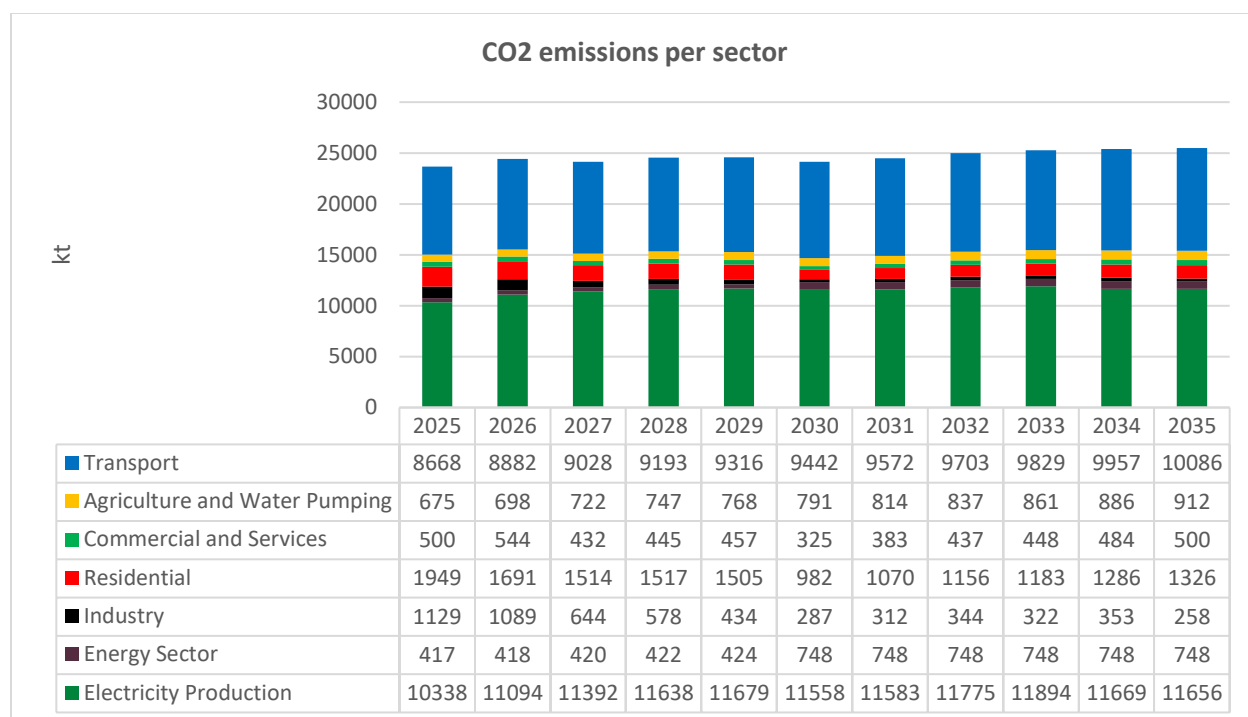


Figure 74: CO2 emissions by sector in the period 2025-2035

Total CO₂ emissions remain relatively stable over the period 2025–2035, but the sectoral composition shifts gradually in line with fuel diversification and electrification trends. In 2025, CO₂ emissions are dominated by electricity generation (43%) and transport (37%), followed by residential (8%), industry (5%), and smaller shares from agriculture (3%) and commerce (2%). By 2030 the contribution of transport is 39%, while electricity generation slightly increases to 48% due to expansion of gas generation, despite renewable expansion. Emissions from industry drop significantly due to the significant reduction of coal and the switch to natural gas for a large share of industrial installations. In 2035 electricity at 45% and transport at 40% together account for nearly nine-tenths of national emissions. Overall, transport and electricity production remain the main CO₂ emission sources, while emissions from industry and buildings decline due to electrification, gasification, and efficiency gains.

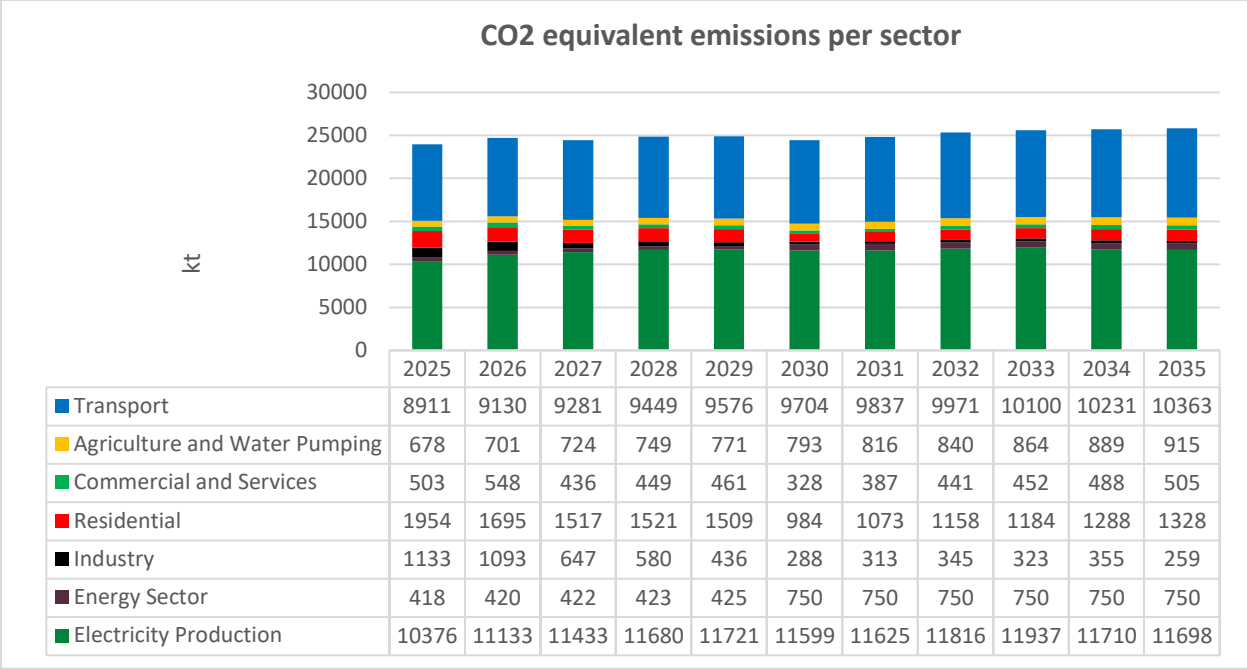


Figure 75: CO₂ equivalent emissions by sector in the period 2025-2035

6 The Optimistic Pathway

This chapter presents the results of the Optimistic Pathway, an ambitious scenario driven by high GDP growth and rapid economic development, aiming for 50% of electricity production from renewable sources.

6.1 Final Energy Consumption

The following graphs and tables present the estimated final energy consumption by sector and fuel type for the period 2025-2035, further illustrating the distribution of fuel use across various sectors under the Optimistic Pathway.

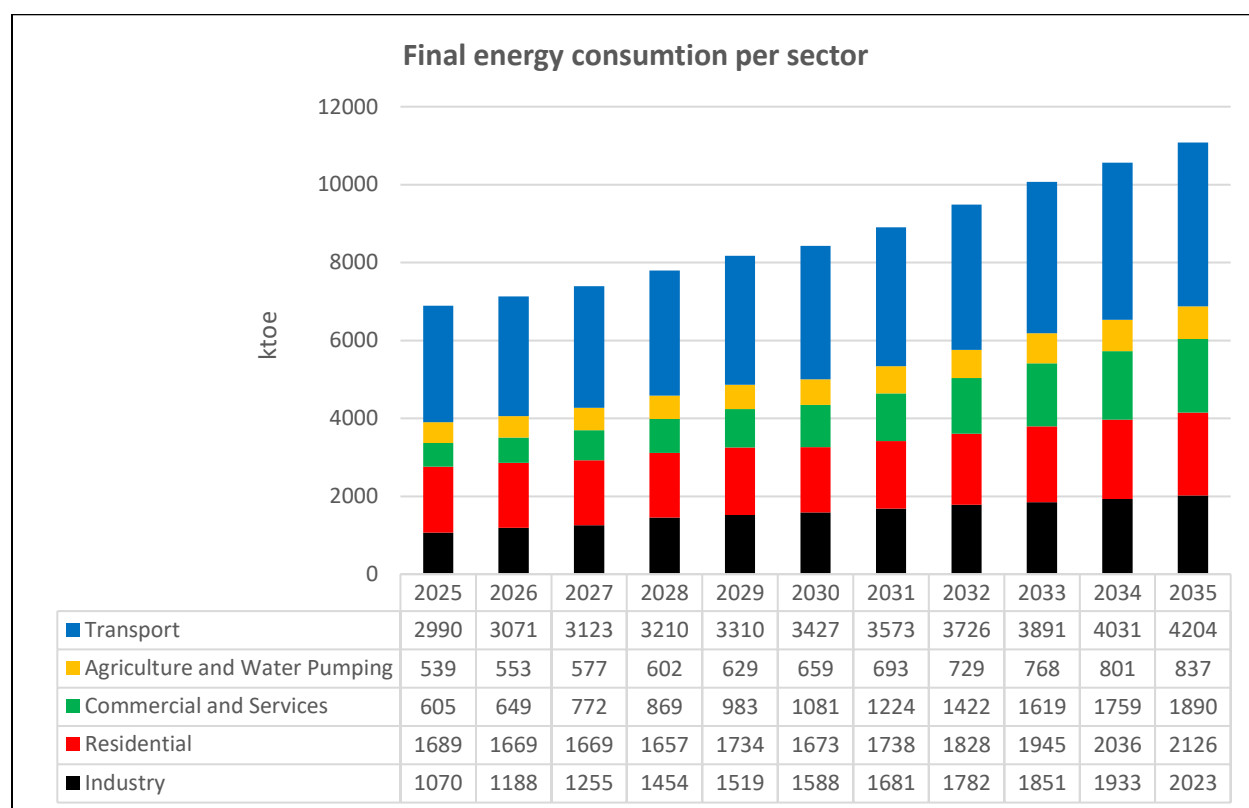


Figure 76: Final energy consumption per sector for the period 2025-2035

Final energy consumption rises consistently from 6,893 ktoe in 2025 to 11,079 ktoe in 2035, showing a strong upward trend linked to economic growth, industrial expansion, and rising demand in the residential and transport sectors. In 2025, FEC is dominated by transport (43%) and residential (25%) consumption. Industry follows with 16%, commercial and services account for 9%, and agriculture and water pumping for 8%. By 2030, total FEC reaches about 8,428 ktoe, with transport (41%) remaining the largest consumer, followed by industry (19%), residential (20%), services (13%), and agriculture (8%). The share of the commercial and services sector grows rapidly, reflecting the expansion of tertiary activities, including data centres, and increased building energy demand. In 2035, total FEC nearly doubles to 11,080 ktoe, marking a 60% increase from 2025. Transport (38%) remains the main consumer, but its share gradually declines as other sectors expand faster. Industry grows substantially to 2,023 ktoe (18%). Residential demand rises steadily to 2,126 ktoe (19%), while commercial and services consumption more than triples, reaching

1,890 ktoe (17%), emerging as the fastest-growing sector, connected with the expansion foreseen in the Economic Modernisation Vision. Overall, between 2025 and 2035, Jordan's FEC grows by 61%, led by a threefold rise in services energy use, followed by industrial (+89%), transport (+41%), and residential (+26%). This evolution indicates a shift from transport-dominated demand toward a more balanced structure, driven by the expansion of the industrial and services sectors under the Economic Modernisation Vision.

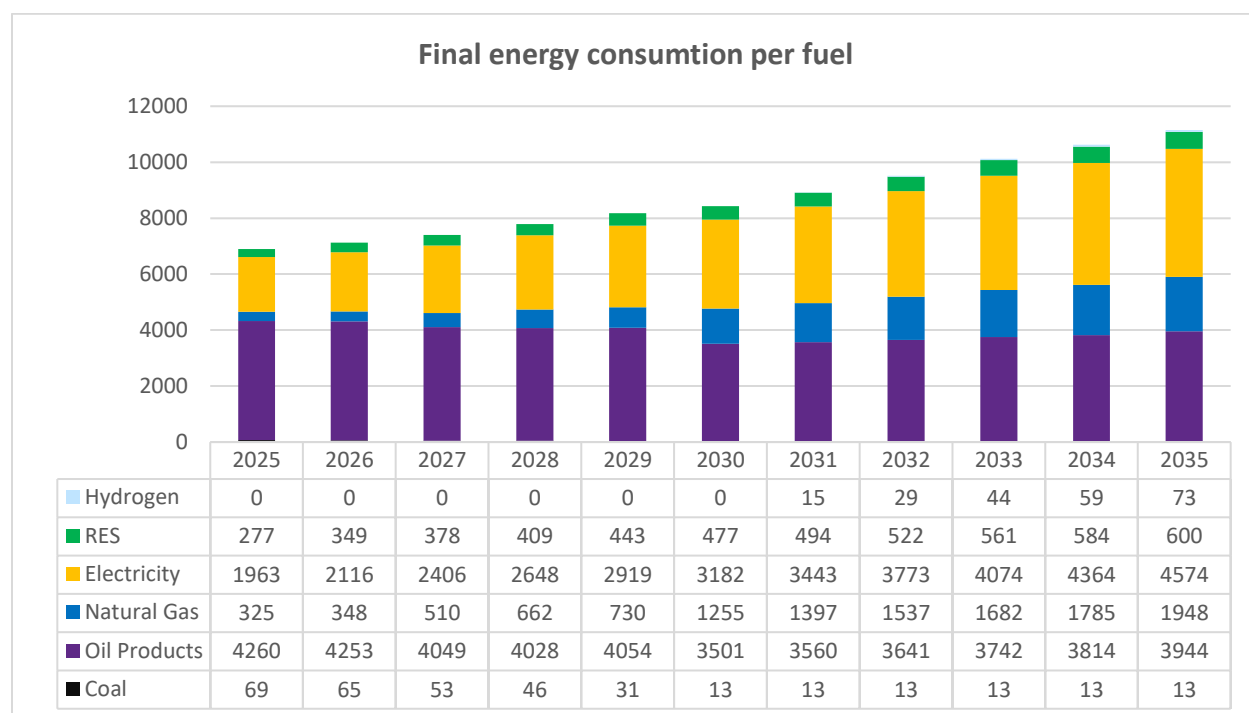


Figure 77: Final energy consumption per fuel for the period 2025-2035

Final energy consumption by fuel shows a steady shift toward cleaner energy sources and electrification between 2025 and 2035, driven by the phase-out of coal, reduced oil dependency, and strong growth in electricity and natural gas. In 2025, total FEC is dominated by oil products (62%) and electricity (28%), followed by natural gas (5%), renewables (4%), and a small share of coal (1%). By 2030, total consumption shows a clear structural transformation. Oil products decline to 42%, electricity rises to 38%, and natural gas reaches 15%, marking its emergence as a major end-use fuel. In 2035, total FEC reaches about 11,080 ktoe, with electricity becoming the largest energy carrier (41%), oil products' share falls to 36%, and natural gas increases further to 18%, reflecting industrial gasification and fuel switching. Renewables (6%) continue expanding through solar, bioenergy, and ambient heat, while coal is fully phased out. Between 2025 and 2035, total FEC grows by 61%, but the fossil fuel share drops to 54%, as electricity and renewables account for most of the increase.

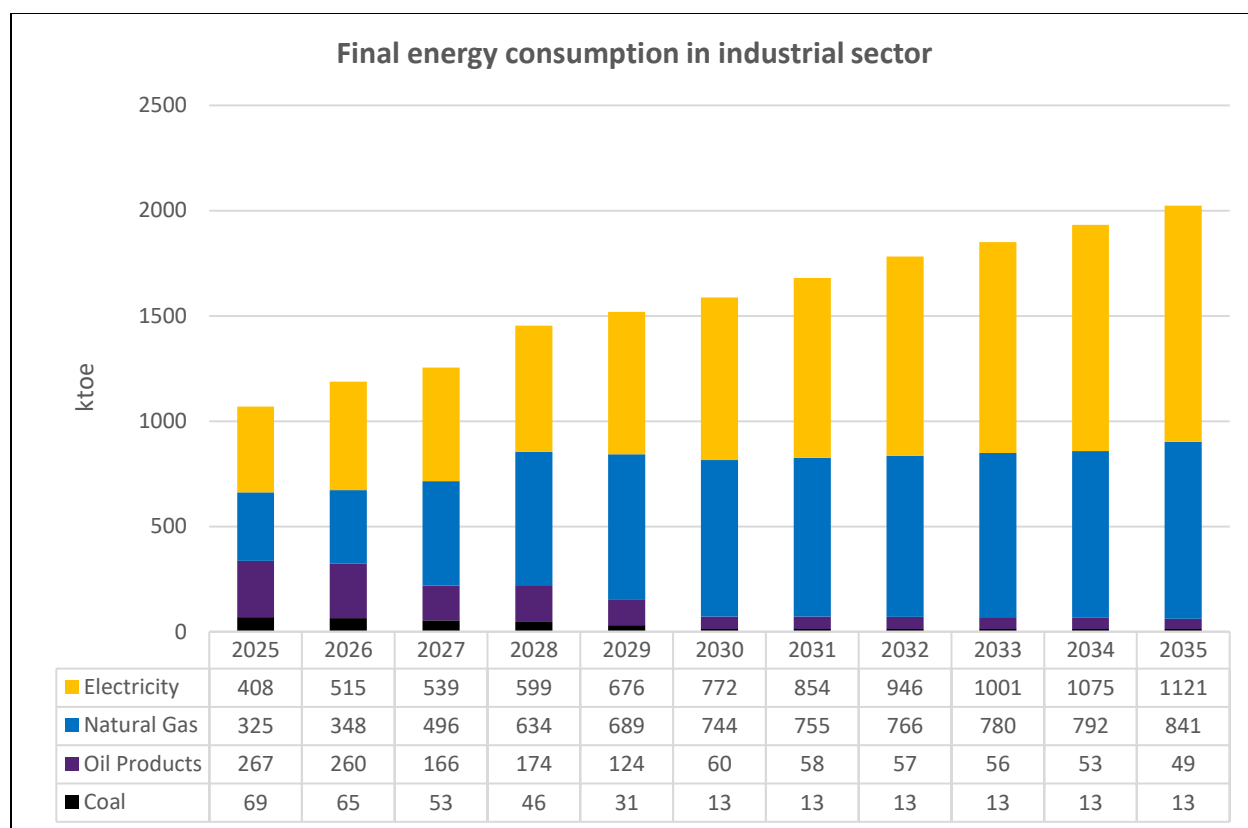


Figure 78: Final energy consumption in the industrial sector for the period 2025-2035

The industrial final energy consumption rises steadily from 1,070 ktoe in 2025 to 2,023 ktoe in 2035, reflecting robust growth driven by industrial expansion and progressive fuel switching toward cleaner energy sources. In 2025, the industrial sector's energy mix is dominated by electricity (38%), oil products (25%), and natural gas (30%), with a minor share of coal (6%). By 2030, total industrial FEC reaches about 1,588 ktoe, while the composition shifts significantly: natural gas becomes the main fuel (47%), electricity increases to 49%, and oil products and coal together drop below 5%, highlighting the sector's transition away from traditional fossil fuels. In 2035, industrial FEC exceeds 2,023 ktoe, with electricity (55%) and natural gas (42%) jointly accounting for nearly all energy use. Oil products fall to just 2%, and coal is almost phased out to less than 1%. Between 2025 and 2035, industrial energy demand grows by 89%, but CO₂-intensive fuels (coal and oil) decline by over 90%, replaced by electricity and gas. This structural change demonstrates a decarbonization effort, consistent with national goals to expand natural gas infrastructure, electrify industrial processes, and enhance energy efficiency.

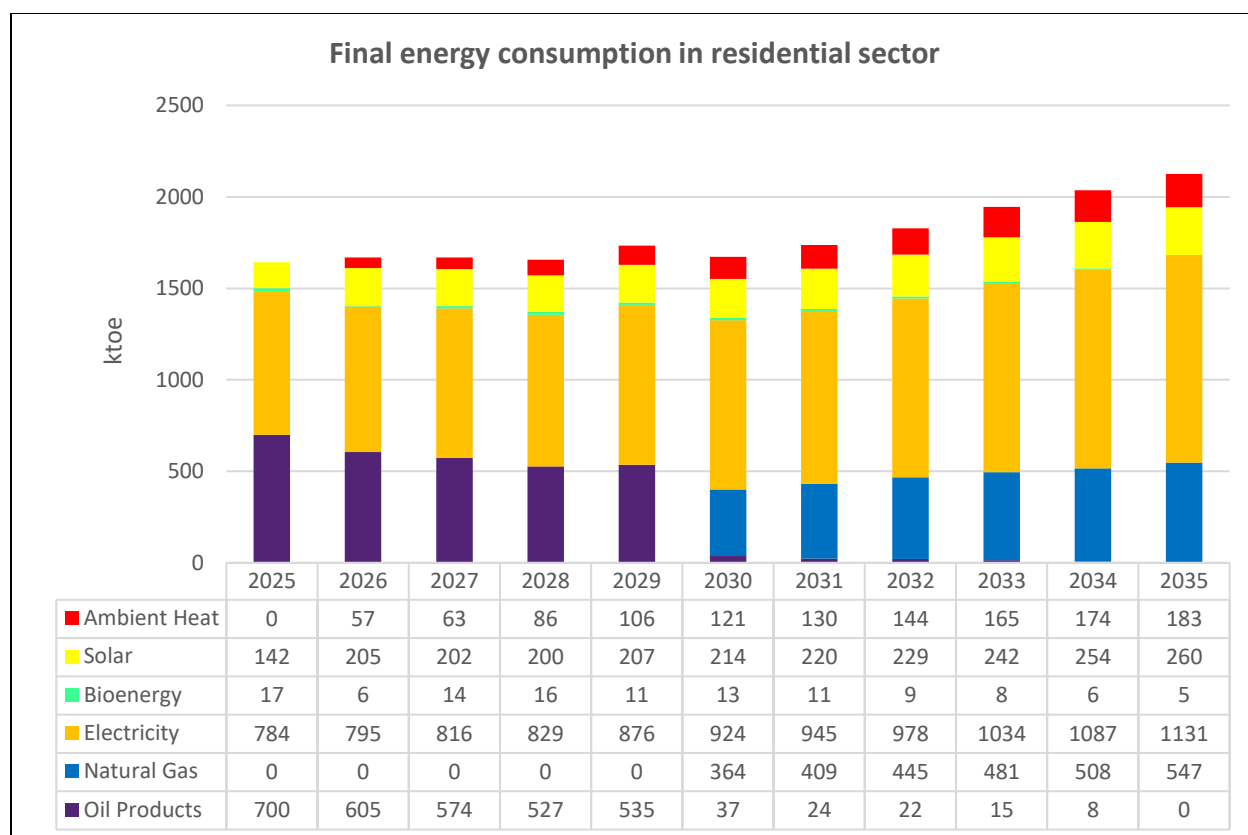


Figure 79: Final energy consumption in the residential sector for the period 2025-2035

Final energy consumption in the residential sector shows a deep transformation between 2025 and 2035, characterized by significant reduction of oil products, electrification, and the emergence of natural gas as a major contributor. In 2025, total residential demand is around 1,640 ktoe, with electricity (46%) and oil products (41%) as the main energy sources, followed by solar (8%), and minor contributions from bioenergy (1%). By 2030, total consumption shifts dramatically in composition as oil products decline sharply to 2%, replaced by natural gas (364 ktoe, 21%), while electricity rises to 924 ktoe (52%). Solar and ambient heat together reach around 335 ktoe (19%), confirming rapid diffusion of solar water heaters and heat pumps. In 2035, residential FEC totals roughly 2,126 ktoe, marking a 26% increase from 2025. The mix becomes electricity 53%, natural gas 26%, solar 12%, ambient heat 9%, and only traces of oil products (<1%) remain. This structural change over the decade demonstrates a decisive decarbonization pathway for the residential sector, emphasizing the use of cleaner heating technologies, natural gas network expansion, and widespread adoption of solar water heaters and efficient appliances.

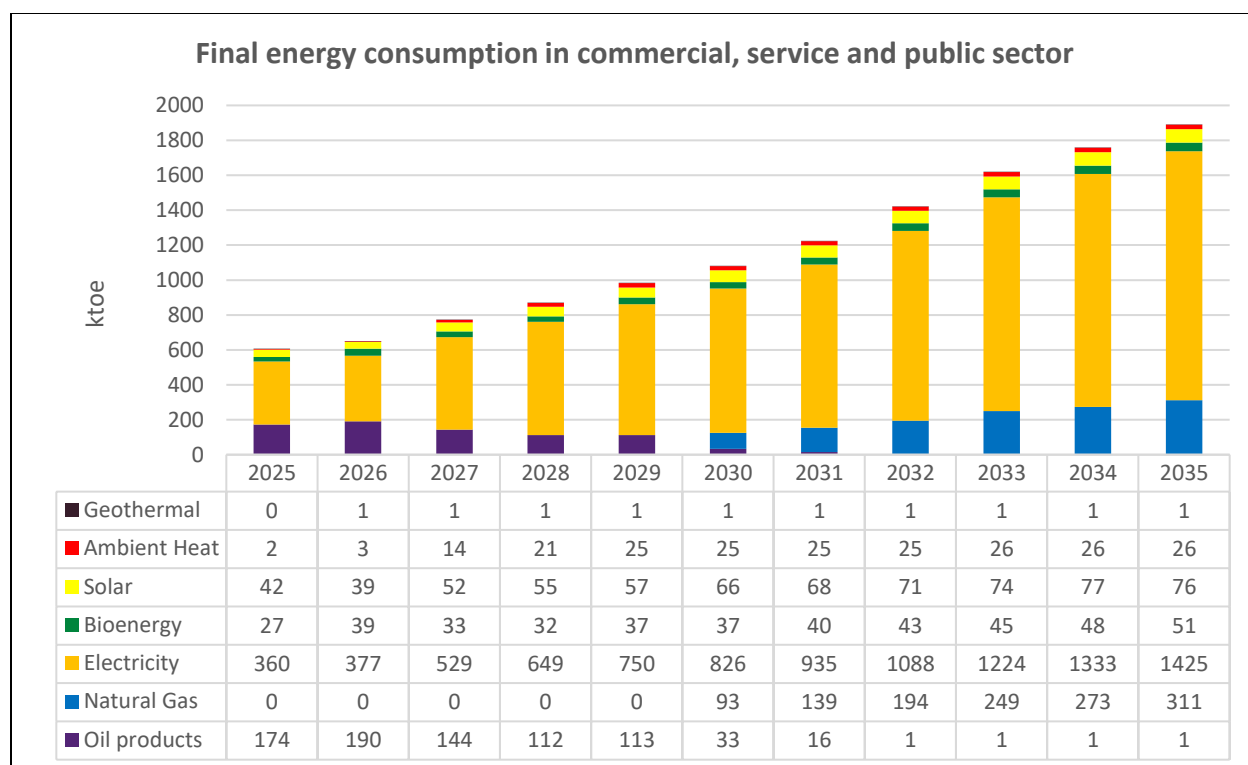


Figure 80: Final energy consumption in the commercial, service and public sector for the period 2025-2035

The commercial and services sector shows strong growth in final energy consumption from 605 ktOE in 2025 to 1,890 ktOE in 2035, driven primarily by increased electrification and the introduction of natural gas, while traditional fossil fuel use nearly disappears. This increase is consistent with the achievement of the GDP growth targets of the EMV, since services and in particular data centres play a significant role in the achievement of the national targets. In 2025, the sector's total consumption is around 605 ktOE, dominated by electricity (360 ktOE, 60%), followed by oil products (29%), bioenergy (4%), and solar (7%). By 2030, total demand rises to about 1,080 ktOE. Electricity becomes the leading source, reaching 826 ktOE (76%), while natural gas begins to penetrate with 93 ktOE (9%). Oil products decline to only 33 ktOE (3%), replaced by natural gas and electricity, while renewables (solar, bioenergy, and ambient heat combined) contribute about 12%. In 2035, energy use nearly doubles to 1,890 ktOE, with a fully transformed mix, since electricity dominates (1,425 ktOE, 75%), natural gas reaches 311 ktOE (16%), and renewables (solar, bioenergy, ambient, and geothermal heat collectively provide 9%. Oil products become negligible (<0.1%), marking a full shift away from liquid fuels.

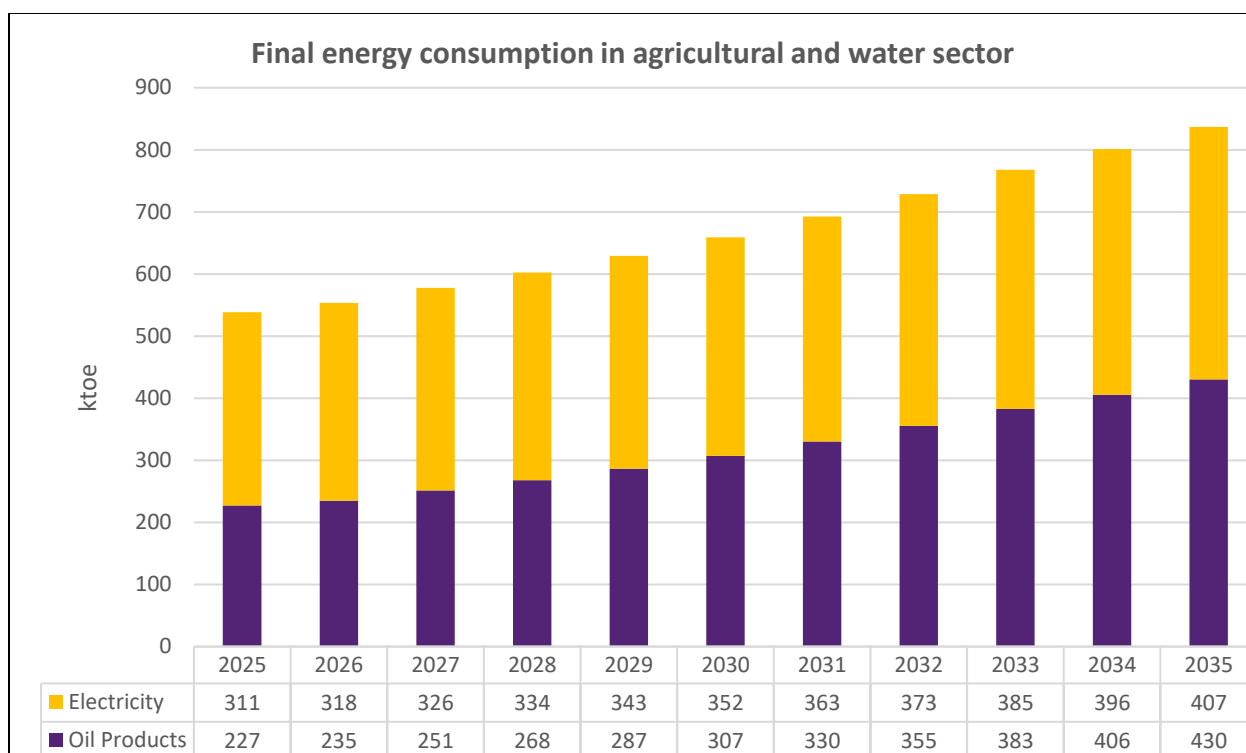


Figure 81: Final energy consumption in the agricultural and water sector for the period 2025-2035

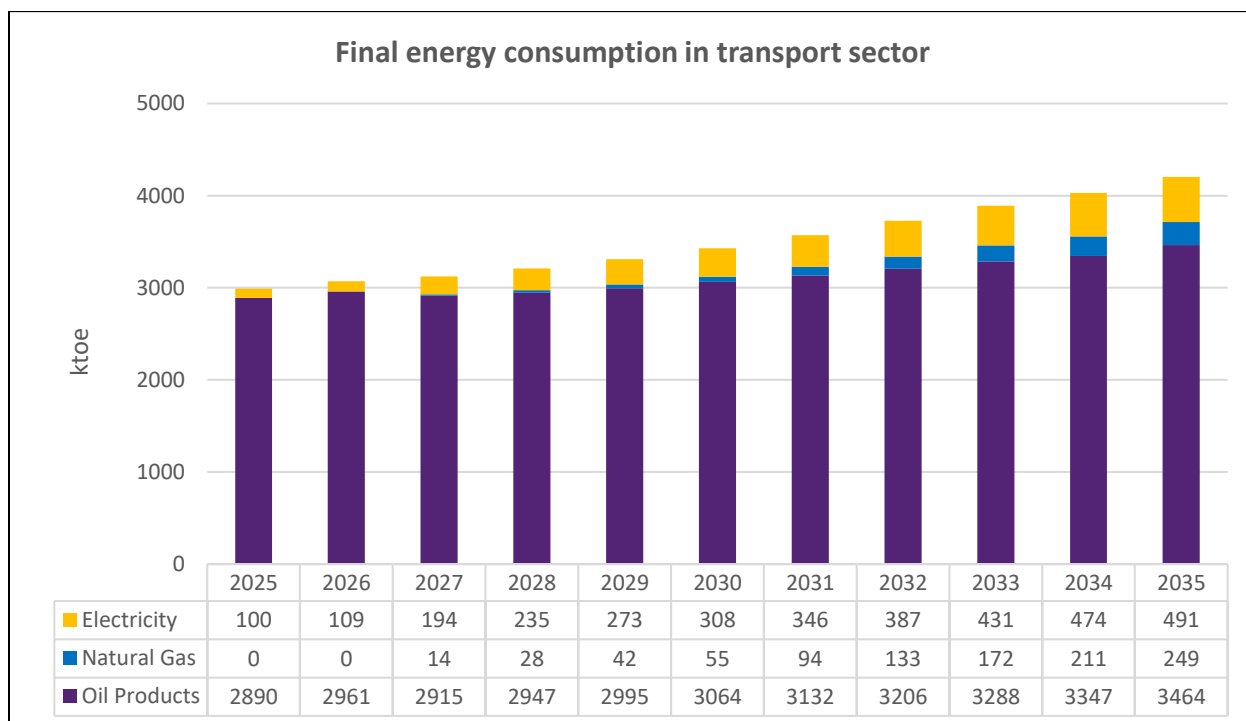


Figure 82: Final energy consumption in transport sector for the period 2025-2035

Final energy consumption in the transport sector remains dominated by oil products throughout the period 2025–2035, though a gradual diversification begins through the introduction of natural gas and

electricity. In 2025, total transport energy use is around 2,990 ktoe, composed almost entirely of oil products (97%), with electricity representing 3% and no measurable contribution yet from CNG. By 2030, total demand increases to 3,428 ktoe mainly in freight transportation driven by the economic growth, with oil products providing 89%, while electricity use expands to 308 ktoe (9%), and natural gas enters the mix with 55 ktoe (2%), used in trucks and busses, marking the first penetration of cleaner fuels in the vehicle fleet. In 2035, total transport energy consumption reaches 4,204 ktoe, showing a 41% increase from 2025. Oil products remain dominant (82%), but their share continues to decline as electricity rises to 491 ktoe (12%) and natural gas grows to 249 ktoe (6%). Over the decade, oil product use rises modestly (+20%), while electricity consumption increases nearly fivefold, and natural gas expands rapidly, reflecting deployment of EVs, CNG vehicles, and supporting infrastructure.

6.2 Energy Efficiency

To measure the energy efficiency achievements of the Optimistic pathway, the final energy consumption is compared with the level of FEC in Pathway III, which corresponds to the same GDP growth and therefore the same demand in energy services, but with lower energy efficiency ambition. An overview of the related differences and measures is presented in the following table.

Table 15: Energy efficiency related inputs

	Pathway III	Optimistic Pathway
Industrial sector	Introduction of Natural Gas according to the current plans replacing oil products.	Introduction of Natural Gas according to the current plans replacing oil products.
		Energy Management systems and EE in industry leading to savings of 5% in 2030 and 10% in 2035 compared to the Baseline
Transportation	EVs reaching 728 thousand by 2030 and 1258 thousand by 2035	EVs reaching 728 thousand by 2030 and 1258 thousand by 2035
	Share of CNG trucks 3% by 2030 and 4% by 2035 of the total fleet of trucks	Share of CNG trucks reaching 5% by 2030 and 20% by 2035 of the total fleet of trucks
		Modal Shift: Reduce the demand of passenger kilometres by private cars by 10% in 2030 and 17.5% by 2035 (25% by 2040) with a corresponding increase of pkm in public transport
		Modal shift: Reduce the demand of ton kilometres covered by trucks by 3% by 2035 (starting from 2031) shifting the tnm to rail transport of cargo.
Residential Sector	Introduction of natural gas according to the study of gasification of Amman and Zarqa	Introduction of natural gas according to the study of gasification of Amman and Zarqa
	Solar water heaters cover 40% of the hot water demand in households by 2035	Solar water heaters cover 50% of the hot water demand in households by 2035

	Efficient Heat pumps covering up to 10% of space heating demand by 2030 and 20% by 2035	Efficient Heat pumps covering up to 50% of space heating demand by 2035
	Condensing boilers up to 10% of the demand by 2030 and 20% by 2035	Condensing boilers up to 30% of the demand by 2030 and 40% by 2035
		Savings from the implementation of building shell improvements (replacement of windows and insulation). Savings of 3% by 2030 and 7% by 2035.
Commercial/Services/Public sector	Introduction of natural gas according to the study of gasification of Amman and Zarqa	Introduction of natural gas according to the study of gasification of Amman and Zarqa
	Solar water heaters cover 95% of demand in hotels and 50% of the hot water demand in hospitals by 2035	Solar water heaters cover 100% of demand in hotels and hospitals all sectors by 2030
	Limited used of ground source heat pumps covering up to 1% of heating demand by 2035	Ground source heat pumps up to 40% of the heating demand by 2035
	Efficient heat pumps covering 5% of heating demand by 2030 and 7.5% of the heating demand by 2035	Efficient heat pumps covering up to 35% of the heating demand by 2030 and 40% by 2035.
	Condensing gas boilers up to 10% of the heating demand by 2035 in hotels, hospitals, and office buildings.	Condensing boilers up to 20% of the heating demand by 2035 in hotels, hospitals, and office buildings.
	100% LED lighting in all buildings by 2035	100% LED lighting in all buildings by 2035
		Reduction of heating and cooling demand by 5% in 2030 and 8.5% in 2025 due to the building shell improvements (replacement of windows and insulation) in all non-residential buildings)

The implementation of these measures in the Optimistic pathway achieves energy savings compared to Pathway III. While Final Energy Consumption in Pathway III reaches 11.92Mtoe by 2035, the Optimistic pathway limits this to 11.08 Mtoe, resulting in an absolute saving of 0.84 Mtoe. In relative terms, the Optimistic Pathway begins with modest savings of 1% in 2027, but accelerates to 4% in 2030, and reaches 7% savings by 2035.

In the residential sector, savings appear gradually, reaching 1% by 2030 and 3% by 2035, reflecting efficiency improvements from building envelope refurbishment and household appliance upgrades. The commercial, services, and public sector follows a similar path, with incremental savings of 3–4% from 2027 onward. The transport sector stands out with a strong trajectory as savings start at 1% in 2027 and climb

steadily, peaking at 10% in 2035, underlining the structural impact of fleet renewal and modal shift to public transport. The industrial sector also delivers sustained improvements, growing from 2.5% in 2027 to 10% by 2035, showing the gradual but significant effect of energy-efficient technologies, energy audits and energy management systems. Overall, this analysis shows a steady pattern of progress, with transport and industry providing significant long-term savings, while residential and services make smaller contributions.

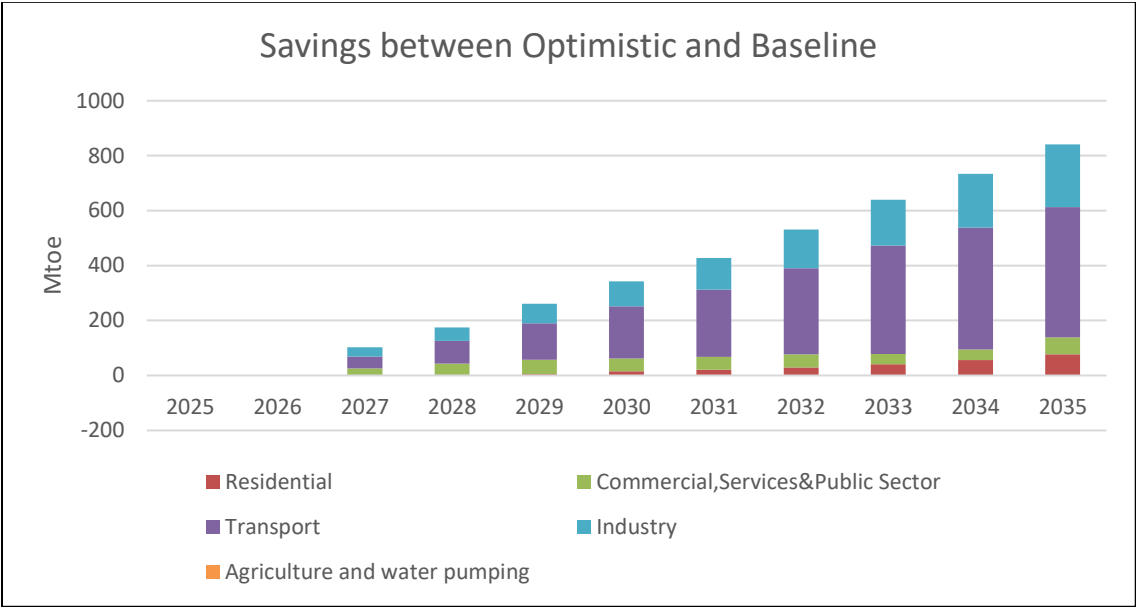


Figure 83: Final energy consumption savings in Optimistic with respect to Pathway III

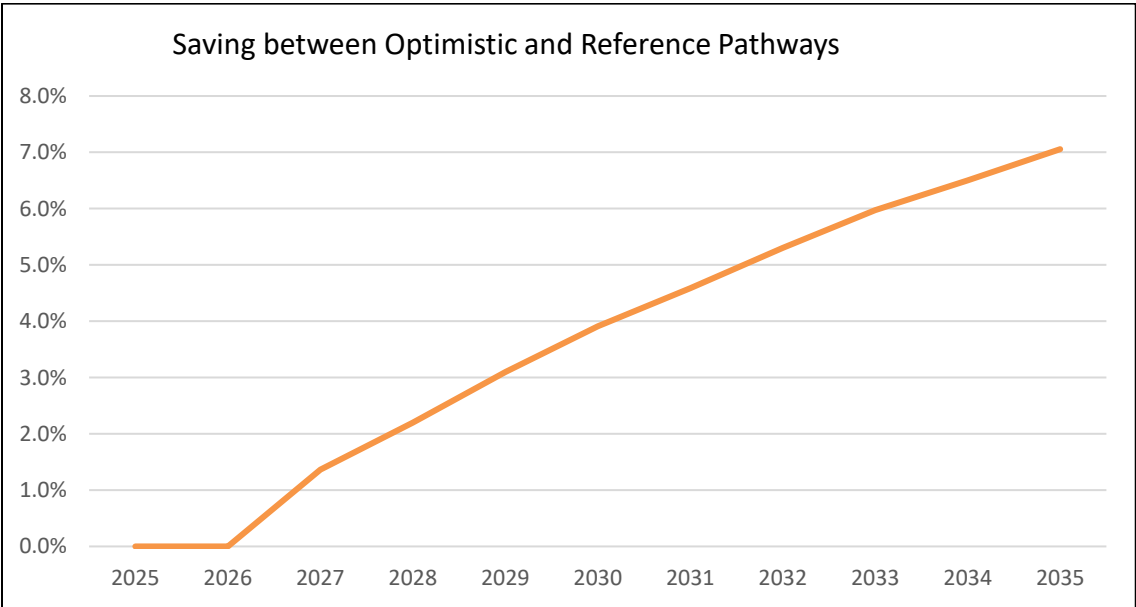


Figure 84: Percent energy saving in Optimistic with respect to Reference Pathway

6.3 Primary Energy

As in the Reference Pathway, the increased domestic natural gas production from the Risha gas field, together with the expansion of renewable energy for electricity generation and for hydrogen and ammonia production, is expected to significantly reshape Jordan's energy landscape.

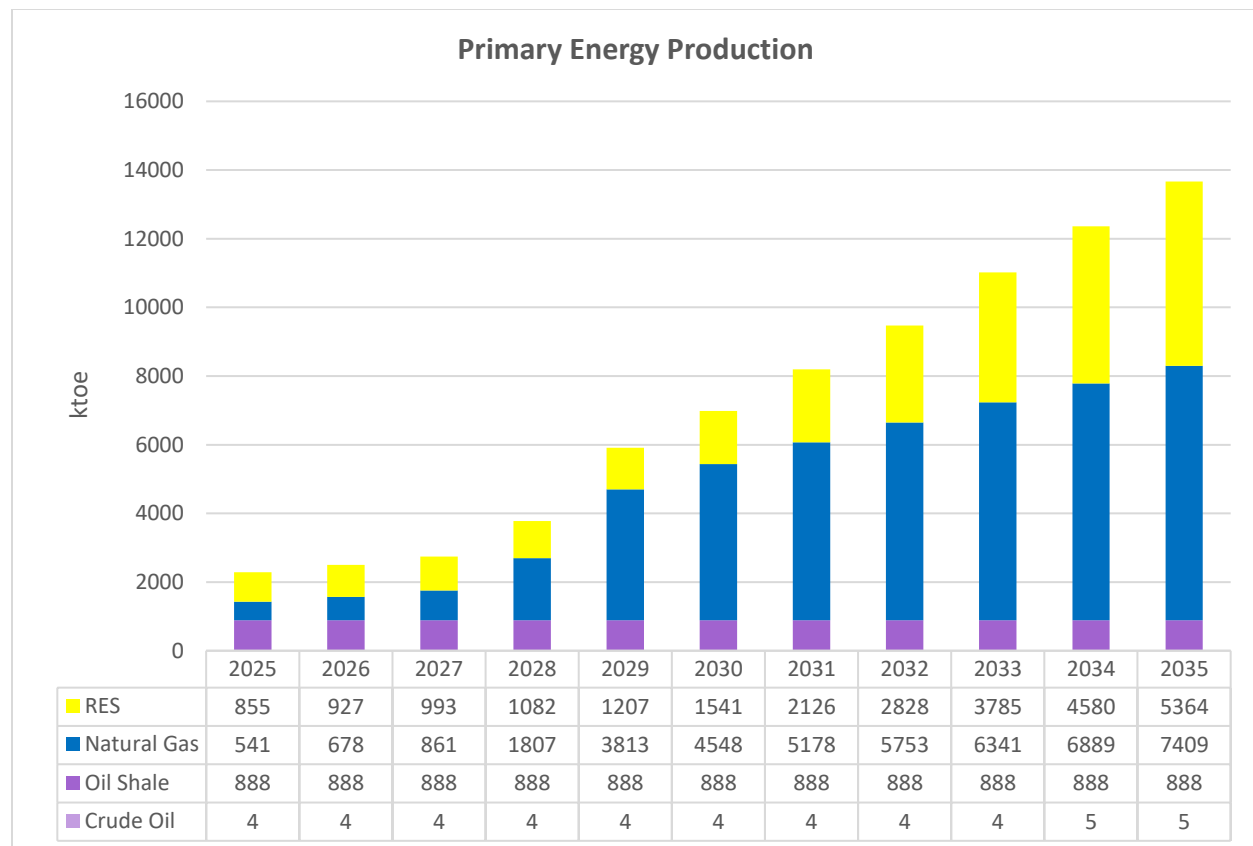


Figure 85: Primary energy production for the period 2025-2035

Primary energy production grows significantly between 2025 and 2035, increasing from 2,283 ktOE to 13,664 ktOE, driven by the rapid expansion in natural gas extraction and renewable energy generation. In 2025, total domestic production is modest at 2,283 ktOE, composed mainly of oil shale (39%) and renewables (37%), while natural gas contributes 24%. By 2030, total production reaches 6,981 ktOE, with a marked shift toward natural gas (55%) as the exploitation of the Risha field expands, followed by renewables (22%) and oil shale (13%). In 2035, domestic production rises dramatically to 13,664 ktOE, nearly covering Jordan's total primary energy supply. Natural gas becomes the dominant source (54%), renewables expand to 39%, and oil shale's contribution declines to 7% in relative terms. This transformation underpins Jordan's progress toward energy independence, which targets higher reliance on domestic gas and renewables to reduce imports and enhance energy security.

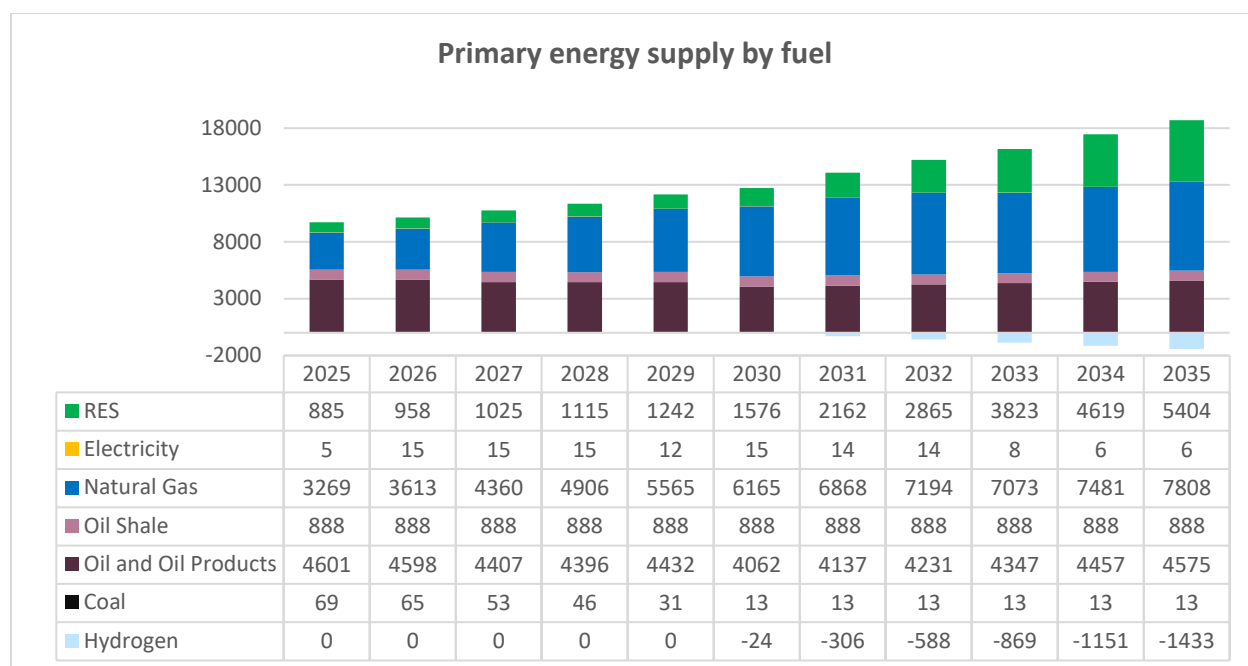


Figure 86: Primary energy supply by fuel for the period 2025-2035

Primary energy supply (PES) increases significantly between 2025 and 2035, while the energy mix undergoes a marked transformation driven by the expansion of natural gas and renewables, alongside a gradual decline in oil products and coal. In 2025, total primary energy supply amounts to around 9,640 ktoe, with oil and oil products (48%) and natural gas (33%) dominating the mix. Renewables account for 9%, while oil shale contributes at 9% and coal at 1%. By 2030, PES rises to approximately 12630 ktoe, with the structure shifting notably toward natural gas (48%), which becomes the main energy source, followed by oil products (32%). Renewables expand rapidly to 12%. Coal's share nearly vanishes (<0.2%), while oil shale remains stable at around 888 ktoe with a relative share of 7%. Hydrogen exports emerge after 2030 consistent with Jordan's green hydrogen initiatives. In 2035, total primary supply reaches roughly 15,220 ktoe, with natural gas leading at 45%, renewables reaching 31%, oil and oil products falling to 27%. Oil shale maintains a constant share of about 5%. Hydrogen exports increase towards 2035, in line with the ambitions of the Kingdom to become a major green hydrogen producer in the region. Overall, between 2025 and 2035, Jordan's total energy supply grows by 78%, while its composition becomes cleaner since fossil fuels' share declines from 90% to 77%, offset by strong increases in renewables.

6.4 Energy import and export

Due to the rapid growth in energy demand, natural gas from the Risha field is expected to be fully utilized domestically and therefore unavailable for export. Nevertheless, Jordan's energy outlook improves significantly over the coming decade. Higher domestic gas production, combined with the expansion of hydrogen and ammonia industries and a substantial increase in renewable energy generation, strengthens the country's energy security. As a result, Jordan's dependency on energy imports is projected to fall sharply, from 76.3% in 2025 to 19% by 2035, marking a major step toward greater self-sufficiency and resilience in the energy sector.

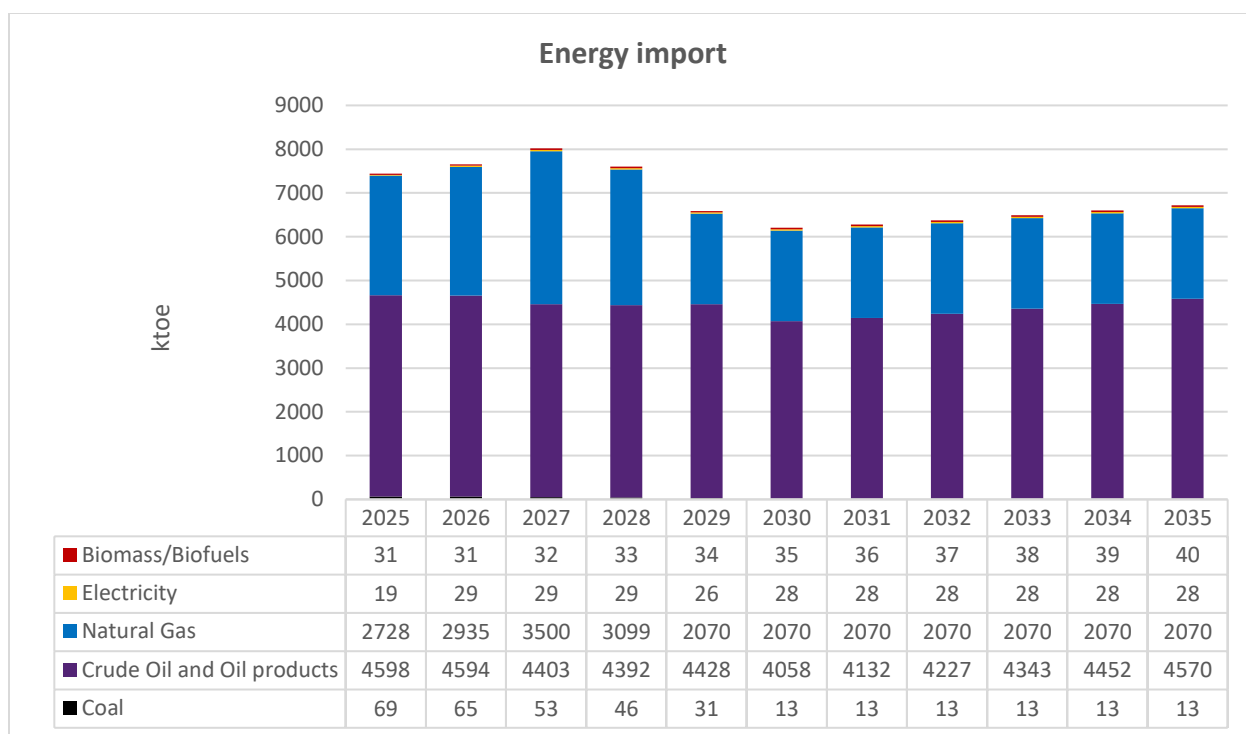


Figure 87: Energy import for the period 2025-2035

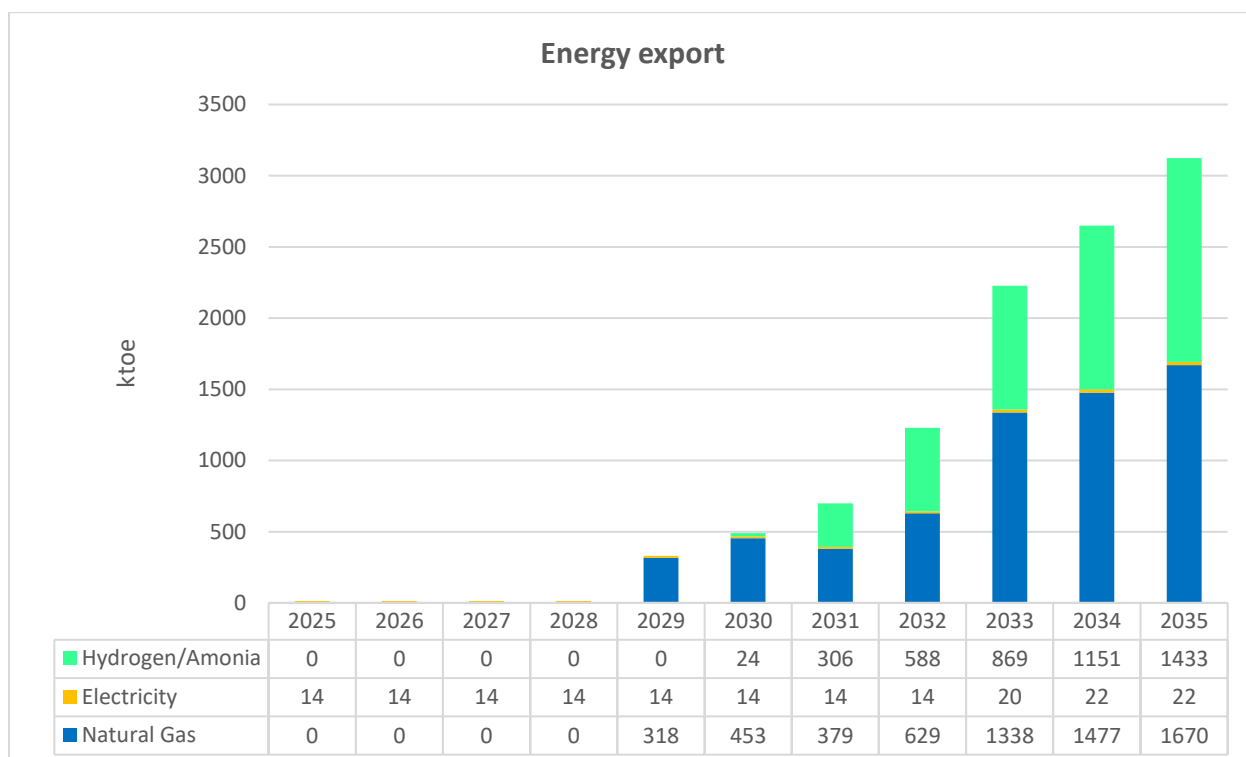


Figure 88: Energy export for the period 2025-2035

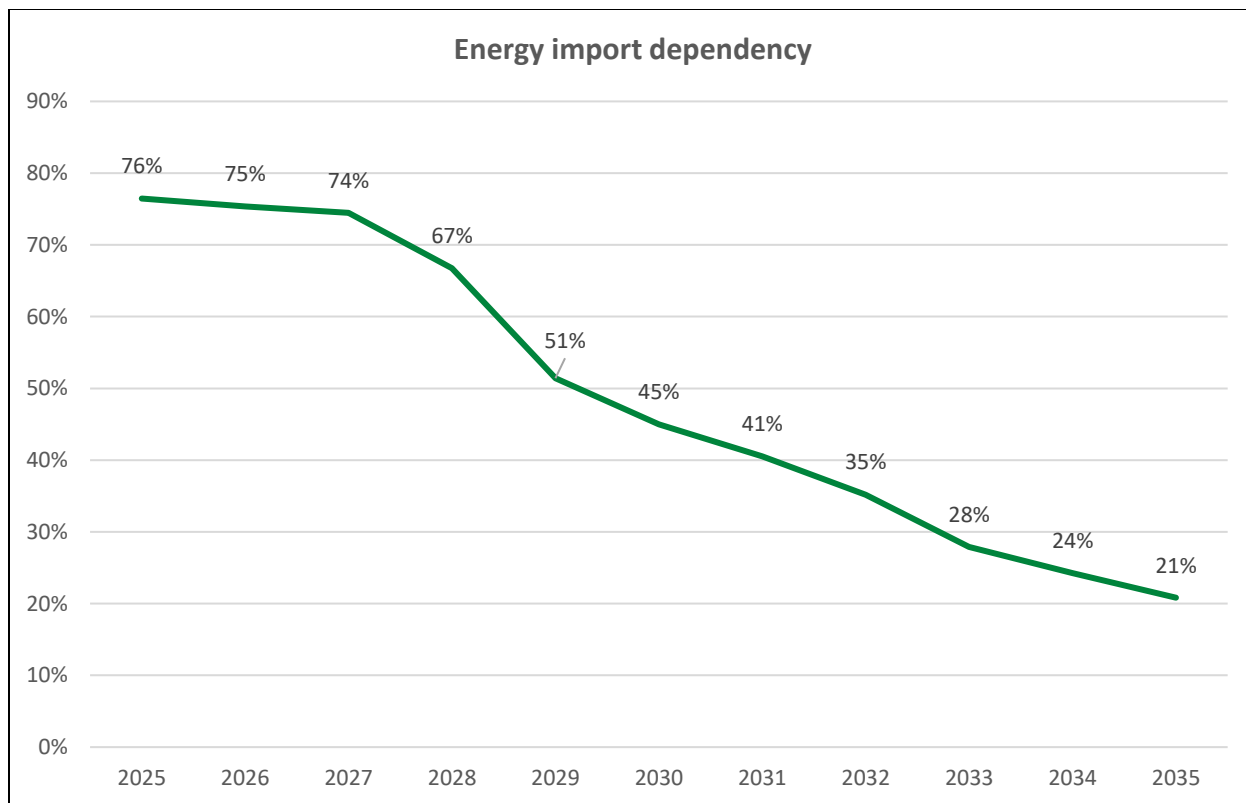


Figure 89: Energy import dependency

6.5 Electricity sector

Optimistic Pathway is developed with a target to reach 50% electricity production from renewables in 2033. Such Pathway requires much more flexible power system which can be achieved with large implementation of energy storage and strengthening interconnections.

Overnight investment costs are significantly higher in the Optimistic Pathway compared to the Reference Pathway, primarily due to the need for greater installed renewable capacity to generate the same amount of electricity, along with the additional deployment of battery storage systems to ensure security of supply and minimize curtailment of solar power plants.

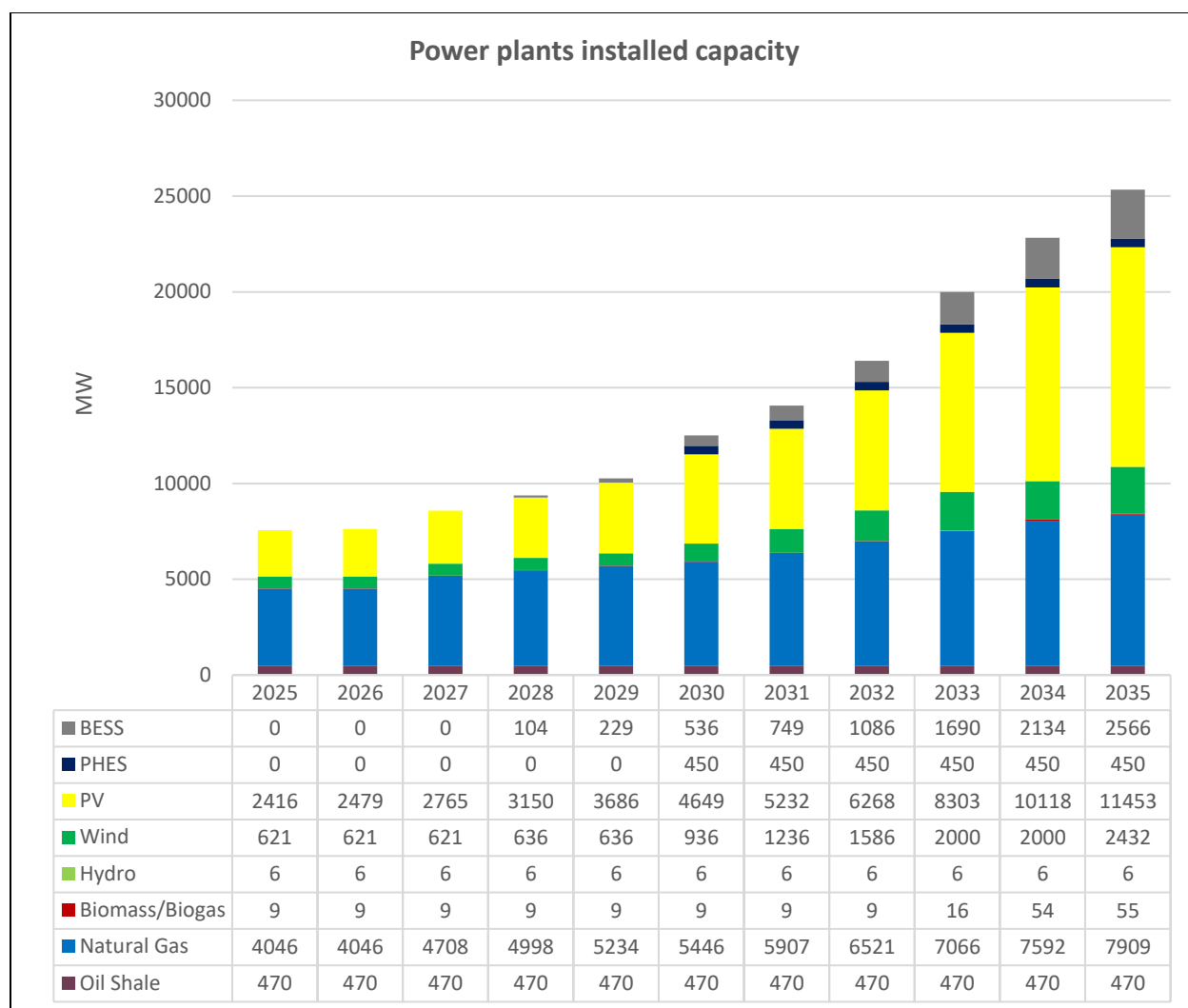


Figure 90: Installed capacity per type of power plants in the period 2025-2035

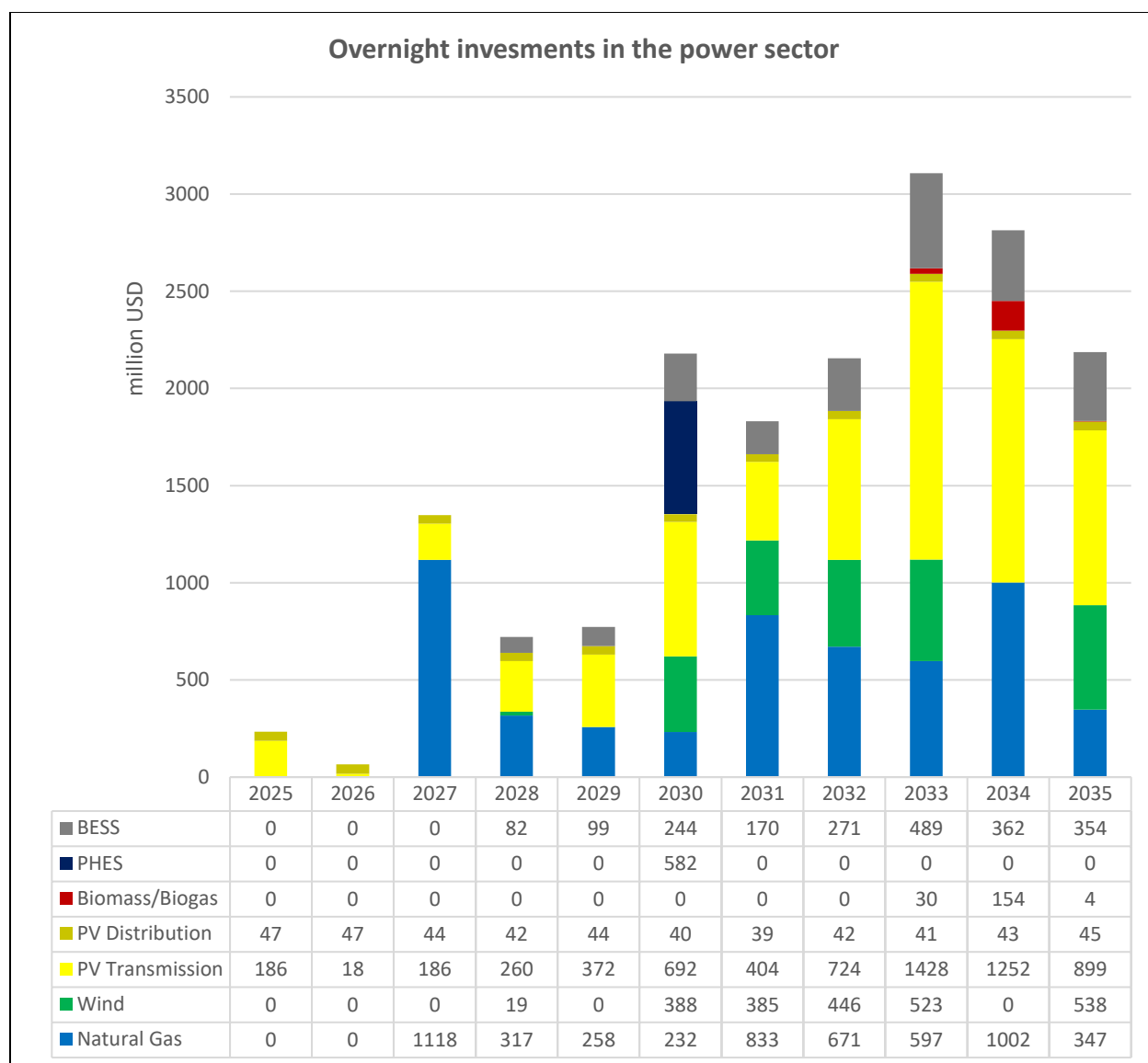


Figure 91: Overnight investment costs in the power system in the period 2025-2035

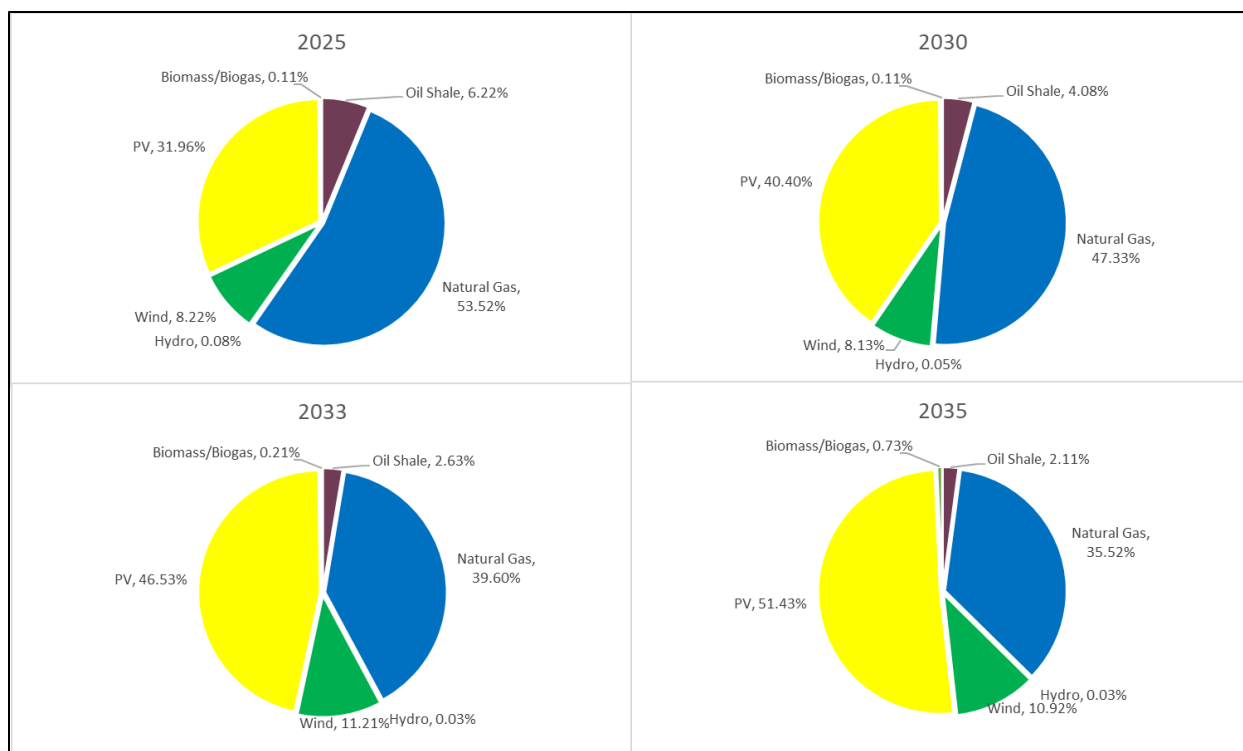


Figure 92: Share of the installed capacity per type of power plants in 2025, 2030, 2033 and 2035

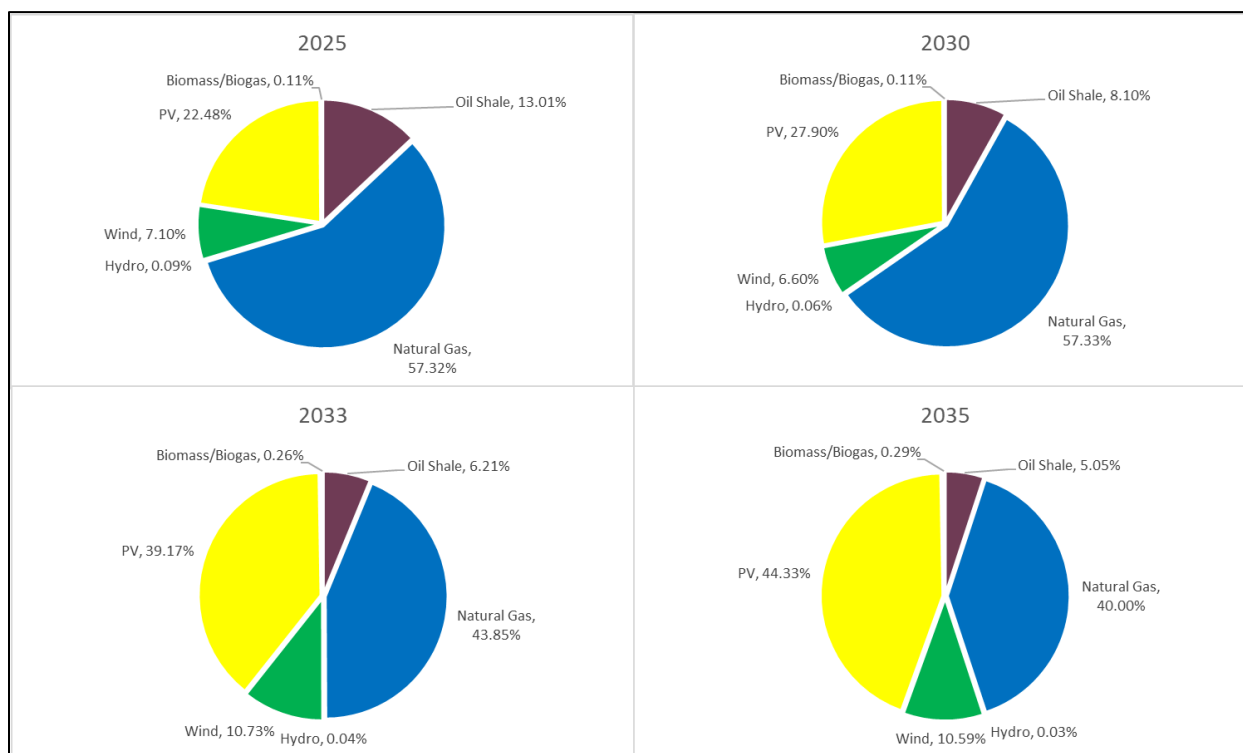


Figure 93: Share of the produced electricity per type of power plants in 2025, 2030, 2033 and 2035

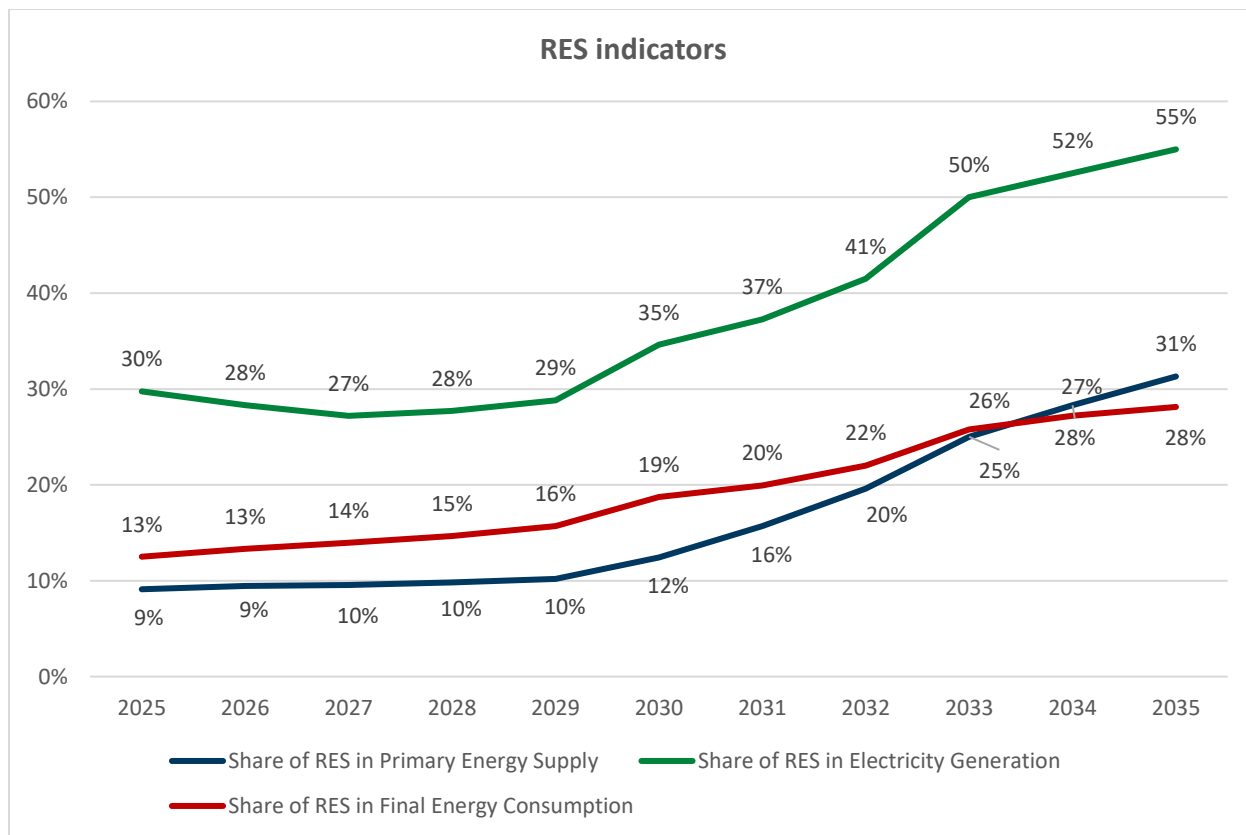


Figure 94: Indicators for RES penetration in the period 2025-2035

6.5.1 Disbursement Plan for the Optimistic Pathway

For this Pathway, it is evident that the investment requirements in the system are considerably higher, driven by the impact of the renewable energy penetration targets on the power system. The following figure presents the estimated annual disbursement plan for generation over the study period, broken down by technology type

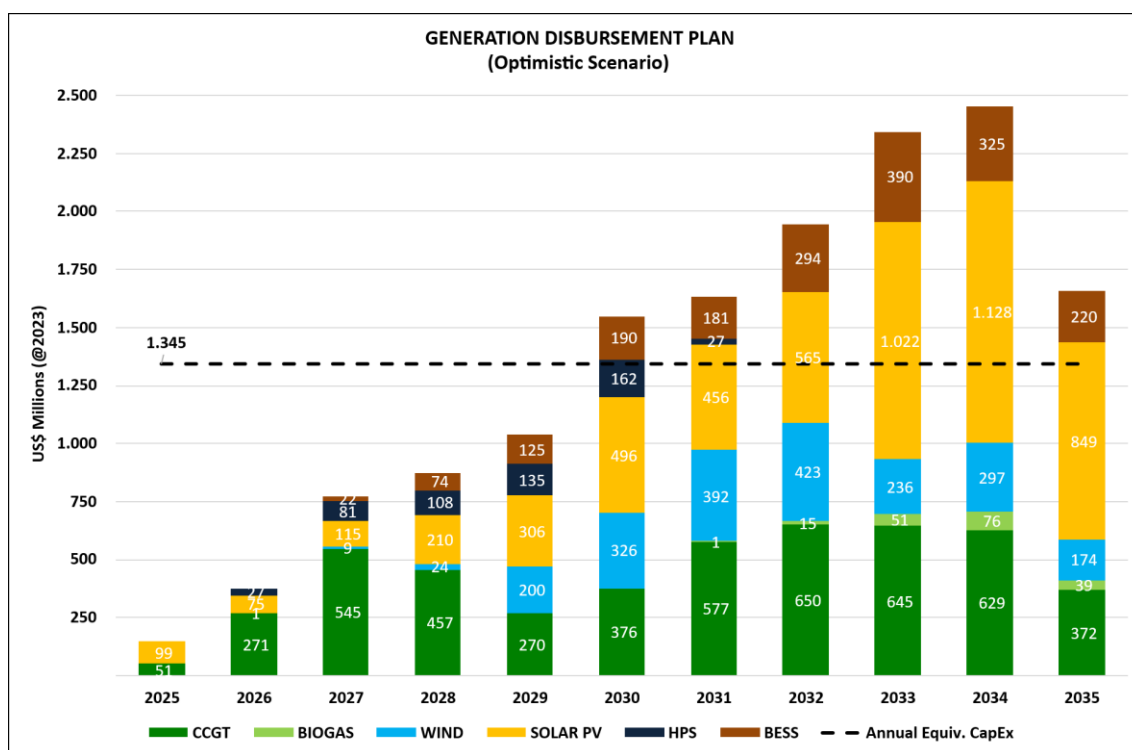


Figure 95: Generation Disbursement Plan (Optimistic Pathway)

As shown in the figure, the disbursement plan begins with USD 150 million in 2025 and increases annually to nearly USD 2,4 billion in 2034, before declining to USD 1,6 billion at the end of the study period. The capital requirements to finance generation expansion average USD 1,35 billion per year over the analysis period represent a significant demand for investment resources, the vast majority of which is expected to be covered by private investment opportunities.

For this same Pathway and study period, the next figure presents the total planned disbursement for both generation and transmission. The figure shows that transmission investments start at USD 32 million in 2025, peak at USD 276 million in 2033, and then progressively decline to USD 132 million in 2035, with an average annual transmission investment of approximately USD 153 million.

Considering the combined investments in both transmission and generation, total capital requirements average USD 1,49 billion per year. Annual investment needs start at USD 182 million in 2025, reach a maximum of approximately USD 2,67 billion in 2033, and decline to USD 1,78 billion by the end of the study period. On average, the annual investment requirements under this Pathway are almost 3 times higher than those of the Reference Pathway.

For the other two Pathways analyzed, Annex I presents the required disbursement schedules for the development of the corresponding power generation and transmission systems.

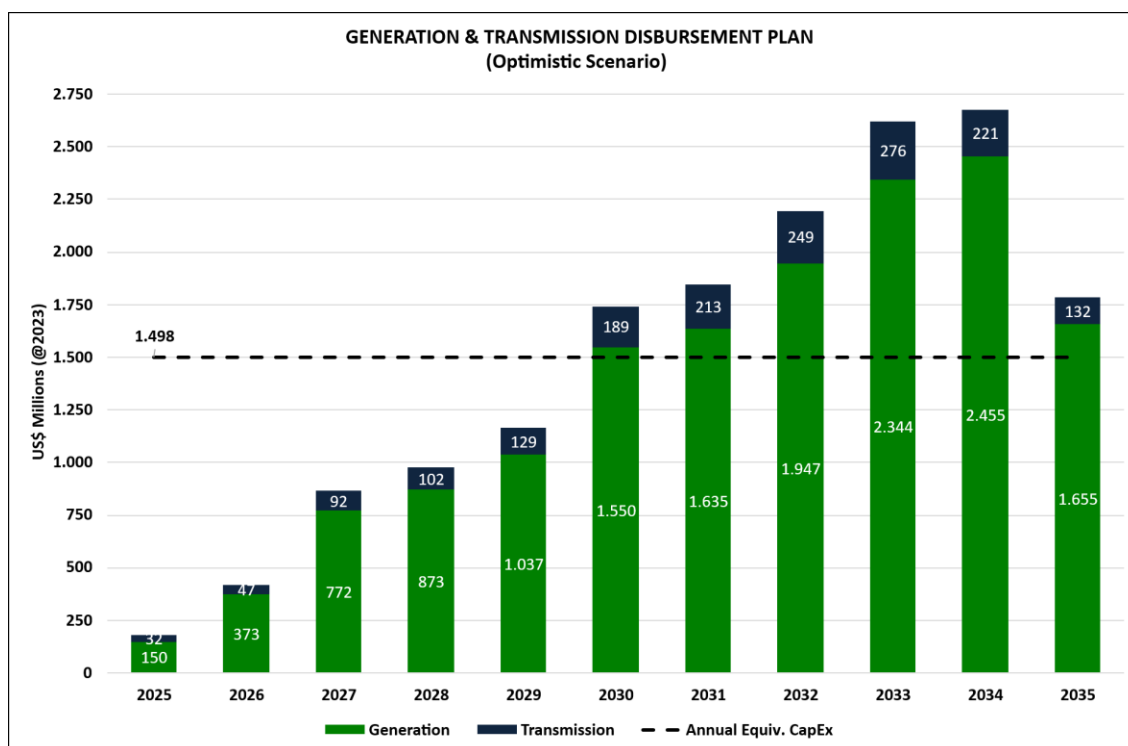


Figure 96: Generation & Transmission Disbursement Plan (Optimistic Pathway)

6.6 GHG emissions

Sector-specific and total emission outcomes emissions in the Optimistic Pathway are presented in the following graphs and tables.

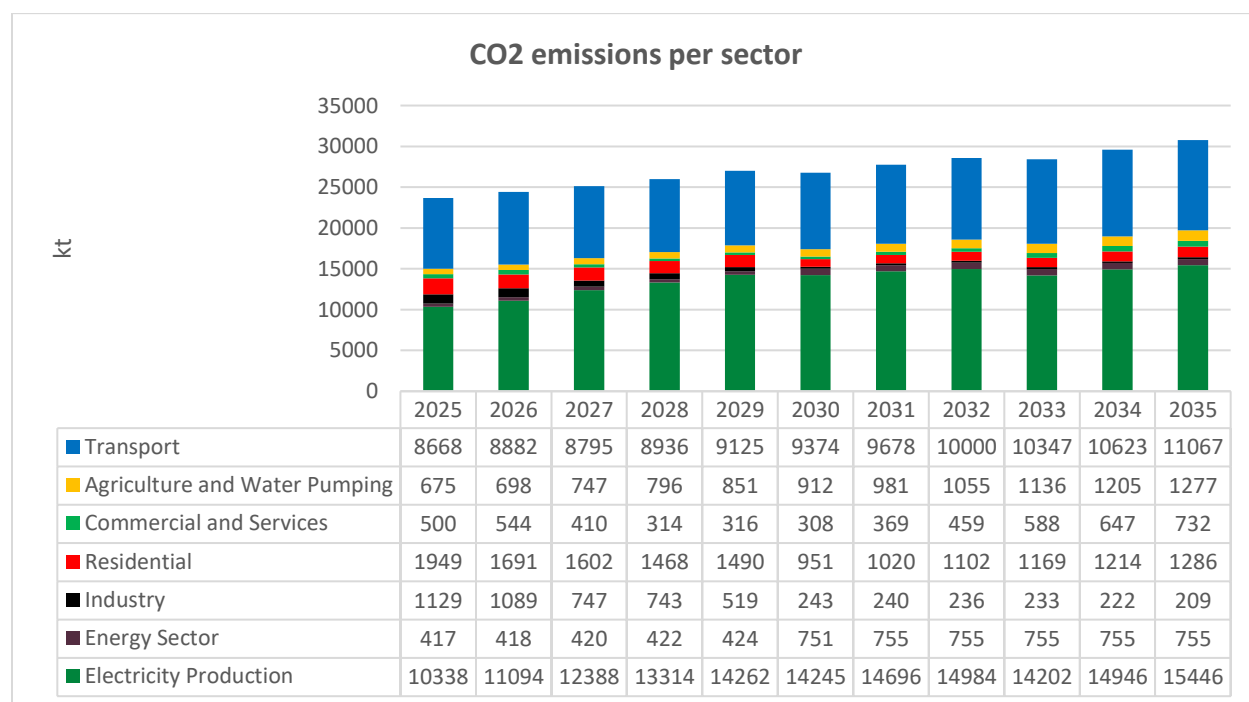


Figure 97: CO2 emissions by sector in the period 2025-2035

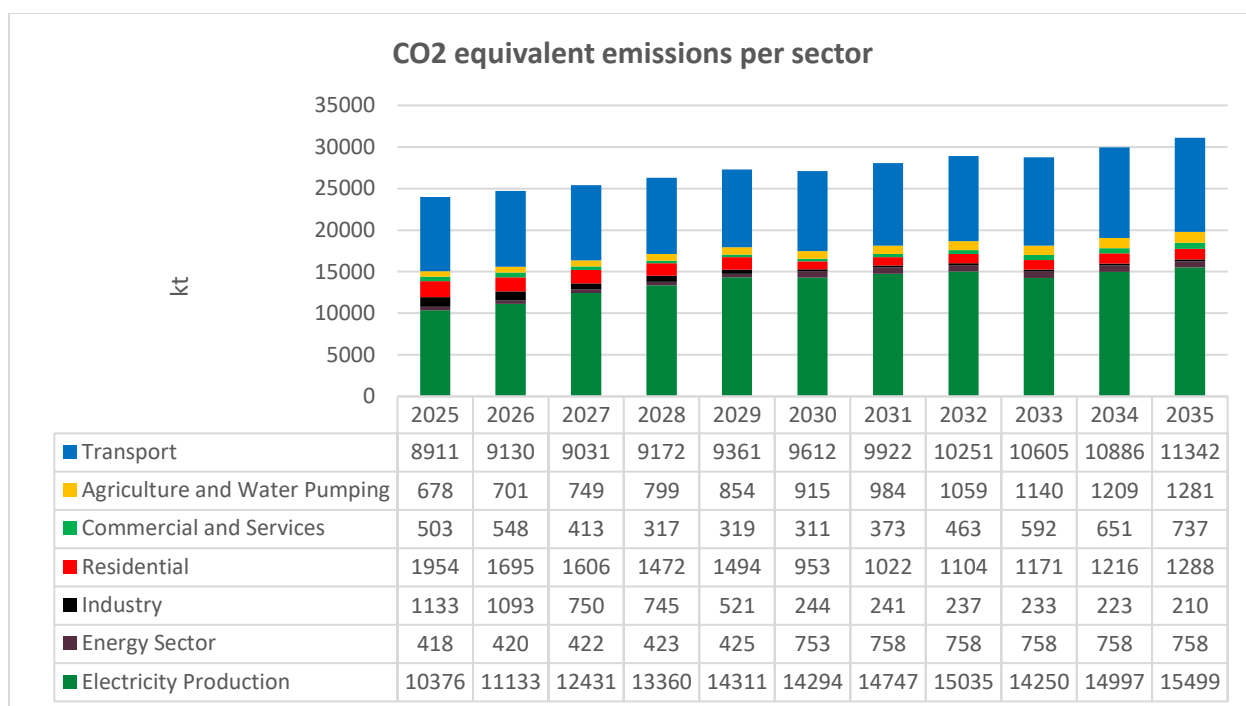


Figure 98: CO2 equivalent emissions by sector in the period 2025-2035

6.7 Impacts of the Optimistic Pathway on the Power System

Renewable energy sources, particularly photovoltaic and wind power, have presented new challenges for power systems. The large-scale integration of these sources is a central component of Jordan's national development vision, supporting the transition to a more sustainable and environmentally responsible energy system. A key objective of Jordanian energy strategy is to generate 50% of the country's electricity from renewable sources by the year 2033.

Due to the natural variability of solar and wind energy production, their integration into a power system with respect to both infrastructure management and control of energy flow in real-time is a real challenge. Furthermore, electricity demand will become less predictable and more variable due to the electrification of transport and heat.

Connection requirements for renewable energy sources encompass the technical, operational, and regulatory criteria established to enable the safe and efficient incorporation of these resources into the transmission grid. The primary objective of these requirements is to ensure the security of supply, as well as the stability and reliability of the electrical system, while accommodating an increasing share of renewable generation.

The relatively small size of Jordan's electricity system and its limited interconnections with neighboring countries mean that the shift towards an energy mix with a high share of renewable generation must be carefully planned and implemented, with due consideration given to potential dynamic constraints.

The dynamic behavior of a power system refers to how the electrical network responds over time to disturbances, changes in load, or system faults. It involves the study of transient, oscillatory, and steady-state responses to such events to ensure stability of the power system.

In the case of non-synchronous generation (such as photovoltaics and wind), the following characteristics must be taken into consideration:

- Variability of power generation;
- Impact on frequency management and balancing requirements;
- Impact on voltage and reactive power management;
- Reduction of system inertia;
- Variability of short-circuit currents;
- Geographic distribution of renewable generation across different locations;
- Changes in electrical flow patterns.

A comprehensive analysis is required to enable the safe integration of renewable energy sources into the power system, while maintaining a high level of security of supply.

6.7.1 Flexibility of the Jordanian power system

Flexibility is a critical attribute of modern power systems, referring to their ability to respond reliably and efficiently to variations and uncertainties in both supply and demand.

With the increasing share of variable renewable energy generation, the flexibility of both supply and demand becomes critically important. The power grid, as the backbone of the energy system, must evolve to meet this challenge. Key measures to enhance its flexibility include:

- Using FACTS (flexible AC transmission system) as "technological enablers" that increase the operational flexibility and adaptability of the transmission grid, allowing it to accommodate a higher percentage of renewable energy, thus reducing the immediate need for large investments in new infrastructure.
- Developing new infrastructure to strengthen interconnections and enable more extensive cross-border trading (both import and export).
- Implementing energy storage solutions to provide a wide range of services that support system security and reliability.
- Deploying demand response systems as advanced tools to improve grid responsiveness and stability.
- Introducing smart technologies across various areas, including forecasting, advanced metering, digital twins, and other digitalization initiatives.

Achieving the desired level of grid flexibility will require significant efforts and targeted improvements across multiple areas of the electricity sector.

6.7.1.1 Interconnection

The Jordanian system is connected to Egypt via a 400 kV line with a rated operational capacity of 250 MW, while the line itself has a thermal rating of approximately 550 MVA.

The interconnector with Syria is currently out of operation due to the ongoing conflict in that country, and no estimated timeline is available for its reactivation. Reactivating the interconnection with Syria could

play a pivotal role in strengthening Jordan's regional connectivity, expanding cross-border electricity trading opportunities, and facilitating access to European electricity markets via Syria and Turkey.

The interconnector with Iraq is currently operational with limited export capacity.

There is a connection between Jordan and Palestine, which is used to supply the Palestinian load, and this load is considered part of the total load of the Jordanian system.

The current Electricity Sector Master Plan envisages the potential construction of a new interconnector between Jordan and Saudi Arabia. It should be noted that the Saudi Arabian power system operates at a frequency of 60 Hz, which will require the use of a converter system and significantly increase the cost of the new interconnection.

Improved interconnection with neighboring grids is a key enabler of a more flexible and resilient power system. By allowing the exchange of surplus generation, facilitating access to a larger and more diverse resource base, and sharing reserves across borders, strengthened interconnections help balance fluctuations in supply and demand, reduce the need for costly backup capacity, and support the seamless integration of higher levels of variable renewable energy.

Regrettably, due to the unstable political situation in the region, it is currently not feasible for Jordan to rely on interconnectors as a means of enhancing the grid's flexibility.

6.7.1.2 Energy storage

System flexibility can be enhanced through a variety of measures, and energy storage is a strong candidate to play a central role in this regard. Energy storage can help balance the variable generation of solar and wind resources, respond rapidly to significant fluctuations in demand, and thereby reduce the need for additional backup capacity. In addition, it can support the grid during periods of peak demand, when electricity prices are typically at their highest.

With the relatively small size of the Jordanian power system and the limited availability of interconnections, energy storage emerges as the primary solution for enhancing system flexibility and facilitating the large-scale integration of renewable energy sources, particularly PV generation.

Energy storage systems play an essential role in compensating for the variability nature of solar and wind generation. They can respond rapidly to significant fluctuations in demand, thereby making the grid more resilient and responsive. Their fast-response characteristics also make them well-suited for providing ancillary services required to maintain the secure and reliable operation of the power system. In addition, energy storage can contribute to meeting demand during peak load periods. All these attributes position energy storage as a highly effective and cost-efficient solution for ensuring security of supply and maintaining the quality of service for grid participants.

The implementation of energy storage technologies is closely linked to potential revenue streams across various energy markets. In day-ahead and intra-day spot markets, revenues can be generated through price arbitrage, capitalizing on price spreads. In addition, energy storage systems can operate in a constant-power mode, providing rapid upward and downward regulation to support primary frequency control. These systems can also participate in balancing markets, offering services for both secondary and tertiary regulation. Moreover, when combined with variable renewable generation, energy storage can

enable effective hybrid operation, reduce imbalance costs and further expanding revenue opportunities across different market segments.



Figure 99: Usage of energy storages in different electricity markets

Energy can be stored using a variety of technologies. Pumped Hydro Energy Storage (PHES) is a well-known and highly suitable solution for storing and utilizing energy. While it is already widely implemented in many power systems, the growing demand for energy storage necessitates consideration of additional technical options. In this context, battery technology emerges as a logical choice, offering the ability to effectively manage the variability associated with wind and solar generation.

Lithium-ion batteries should be considered the first-choice technology for battery storage, offering high energy density, rapid response and relatively long cycle life. Their efficiency, compact design, and versatility make them ideal for both grid-scale and distributed applications.

6.7.1.3 Demand side management (DSM)

Demand-side management (DSM) is an essential tool for optimizing the operation of modern power systems. By encouraging end-users to adjust their electricity consumption patterns such as shifting load from peak to off-peak hours, DSM improves the balance between supply and demand and minimizes the need for the reserve capacity. In this way, DSM supports the integration of variable renewable generation and contributes to a more efficient, flexible, and resilient energy system.

Demand-side management (DSM) is closely linked to electricity markets, as it allows end-users to actively participate in market operations. By responding to price signals such as time-of-use tariffs or real-time pricing DSM encourages consumers to shift or reduce their load when prices are high or increase it when prices are low. In this way, DSM contributes to more efficient market outcomes, reduces the need for costly peak generation, and supports the integration of variable renewable energy. Moreover, DSM can participate directly in ancillary services and balancing markets, providing valuable flexibility and grid support while creating additional revenue streams for participating consumers and aggregators.

Although the electricity market in Jordan is not yet fully developed, making the implementation of demand-side management (DSM) for end-users challenging at this stage, there is potential to introduce DSM measures for selected industrial consumers.

Demand-side management potential within the water transmission system has been analyzed in the EGI study “Establishment of a Grid Development Strategy for the Jordanian Electricity System”, identifying a maximum downward flexibility of 22.2 MW and an upward flexibility of 155.3 MW.

6.7.1.4 Smart grid features

Smart grid technologies play a crucial role in increasing the flexibility and resilience of modern power systems. Features such as smart metering systems, automated demand response, and distributed energy resource (DER) management enable real-time adjustments of load and generation, allowing the system to respond effectively to fluctuations caused by variable renewable energy sources. By integrating advanced monitoring, communication, and control capabilities, smart grids enable more efficient and dynamic system operation. In addition, technologies such as dynamic line rating optimize the utilization of existing transmission infrastructure by assessing and adapting to actual thermal and environmental conditions, thereby increasing network capacity and operational efficiency. Meanwhile, digital twin platforms support high fidelity simulations and predictive analytics, facilitating improved forecasting, planning, and operational decision-making. Together, these innovations enhance the resilience, stability, and efficiency of the grid, making it better suited to accommodate higher shares of renewable generation.

6.7.1.5 Artificial intelligence (AI)

Artificial intelligence plays a central role in supporting and enhancing these smart grid features. By analyzing vast amounts of data from smart meters, sensors, and digital twin platforms, AI algorithms enable more accurate forecasting, optimized dispatch, and predictive maintenance. This allows the system to anticipate fluctuations, detect anomalies, and adjust in real time, ensuring that advanced metering infrastructure, automated demand response, distributed energy resource management, and dynamic line rating operate at their highest efficiency. In this way, AI acts as the core enabler that ties together smart grid technologies, facilitating more resilient, adaptive, and intelligent power system operation.

6.7.2 Electricity markets

Electricity markets play a central role in ensuring the efficient and secure operation of the power sector. By facilitating the competitive trading of electrical energy, these markets enable optimal resource allocation, price discovery, and investment signals for generation, storage, and grid infrastructure. They provide a platform for both traditional and renewable generators, as well as flexible resources such as storage and demand-side management, to participate in a cost-reflective manner. Through spot markets, forward contracts, and ancillary service markets, electricity markets help balance supply and demand in real time, promote transparency, and foster long-term reliability and sustainability of the power system.

Currently, Jordan operates under a single-buyer model, where NEPCO serves as the sole purchaser of all electricity generated within the system. NEPCO procures electrical energy from both public and private generation facilities, typically under long-term Power Purchase Agreements (PPAs), and resells it to distribution companies or directly to end-users. In this role, NEPCO is responsible for generation planning, ensuring the reliability of supply, and managing the dispatch of available units.

The single-buyer model is common in markets transitioning from fully regulated environments, providing a centralized mechanism for risk management, investment planning, and the integration of new generation technologies, such as renewables, while limiting exposure to market volatility for both producers and consumers.

The transition from a single-buyer model to more developed electricity markets typically involves the gradual introduction of competitive market mechanisms and institutional reforms. Under this approach, the central purchasing role of the single buyer is progressively replaced by a framework that allows multiple participants, including independent generators, retailers, and large consumers, to trade electricity through competitive platforms such as spot markets, forward contract markets, and ancillary service markets. This evolution aims to foster efficiency, transparency, and innovation in the sector by providing price signals that encourage cost-effective generation and investment. It also facilitates the integration of renewable energy resources and advanced technologies, such as energy storage and demand-side management, while maintaining reliability and security of supply. Making this transition work well takes solid regulations, strong market institutions, and a grid that's ready to handle a more dynamic and diverse mix of energy sources.

It is planned to introduce bilateral trading in the Jordanian power system as an initial step towards transitioning from the single-buyer model. In general, the core structure of the existing market will be preserved. Most generators will continue to supply electricity to NEPCO under long-term PPAs, and consumers will still be served by the distribution companies or NEPCO, depending on their connection.

The main change will be the introduction of direct bilateral agreements between new generators and new consumers, complementing them rather than replacing the current market structure. The following applies to the arrangements shown in the next Figure:

- The new segment will be limited to new generation and new loads, regardless of legal entity (unlike the current self-generation scheme).
- An annual cap will be introduced to manage the expansion of this segment, especially for intermittent renewables, and new renewable projects will be required to include co-located storage.
- New generators will be subject to an aggregate capacity limit per project to promote competition.
- Like existing wheeling arrangements, bilateral parties will pay regulated network and balancing tariffs.
- To reduce tariff distortion and manage liquidity risks, load participants will be charged "market participation fees," with revenues used to support regulated consumer categories and lower cross-subsidies for existing large consumers.

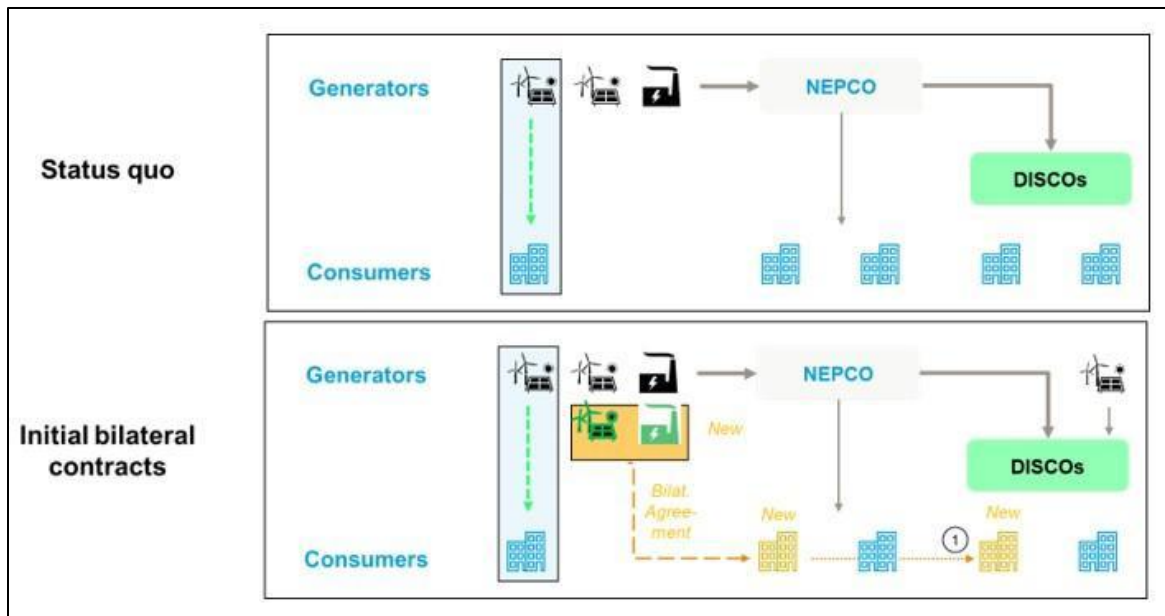


Figure 100: Outline of possible initial bilateral contracts

In the development of the bilateral market in Jordan, the following considerations should be addressed:

- Limit bilateral agreements to new generation, while making them available to both existing and new eligible consumers to ensure fairness and prevent discrimination.
- Clearly define eligible consumer categories (e.g., industrial customers) and establish an initial participation threshold based on installed capacity.
- Introduce an annual cap aligned with the available new generation capacity and gradually reduce the eligibility threshold over time as more generation becomes available.
- Establish clear regulations and rules to define the responsibilities of all parties and minimize balancing issues.

7 Analysis and recommendations

7.1 Assessment with respect to the strategic pillars

The strategic pillars that drive the development of the energy system of Jordan are Reliability, Affordability, Security, Sustainability, Accessibility, Maximizing the Use of Domestic Resources, and Optimizing Renewable Energy.

Reliability

The reliability of Jordan's power system, understood as its ability to ensure security of supply and stable operation, faces growing challenges due to the rising share of variable renewable energy and limited regional interconnections. The system currently operates with constrained flexibility, particularly under high renewable penetration pathways. With Jordan targeting a 50% share of renewables by 2033, ensuring system reliability requires a combination of grid enhancements, storage deployment, and dynamic stability improvements. Due to low inertia during daytime PV peaks, the system is vulnerable to disturbances, such as generator failures or interconnector outages, potentially leading to unacceptable frequency deviations. To mitigate these risks, measures including the deployment of synchronous condensers, expansion of pumped hydro and battery storage, and minimum inertia thresholds must be introduced. Previous studies and the current analysis show that technologies like the Mujib PHES and synchronous condensers are effective in limiting the rate of change of frequency (RoCoF) and stabilizing voltage under fault conditions. Nevertheless, because storage availability is not always guaranteed, maintaining reliability will require further investments in real-time system management and reserves. Grid integration studies also emphasized the need for dynamic simulations across various high-risk operating conditions, leading to corrective actions such as tuning AVR settings and reinforcing grid infrastructure.

Affordability

Affordability of energy in Jordan remains a key policy consideration, especially given the country's historical reliance on imported fossil fuels and its impact on consumer prices.

The transition pathways outlined in the Reference and Optimistic pathways aim to address this challenge by shifting toward greater use of domestic energy resources and renewable generation.

In both pathways, the increase in natural gas production from the Risha field and the integration of large-scale renewable energy reduce exposure to volatile international energy markets, thereby contributing to greater price stability.

The Optimistic Pathway, driven by strong economic growth and rapidly rising energy demand, combines an accelerated rollout of renewable energy with higher upfront investment requirements, particularly for generation and battery storage. However, these costs are offset over time by lower operational expenses due to reduced fuel imports. Thus, despite the greater capital needs, the Optimistic Pathway enhances long-term affordability through structural cost reductions and reduced import dependence. Furthermore, the expansion of local green hydrogen and ammonia production, primarily for export in both pathways, creates additional revenues that can help balance overall system costs.

While short-term affordability may be challenged by necessary infrastructure investments, both pathways and particularly the Optimistic one, lead to more stable and sustainable energy costs over the long term.

Security

Across all pathways, Jordan's energy supply security is progressively strengthened through diversification of natural gas sources and greater reliance on domestic resources. In the Reference Pathway, import dependency decreases from 76% in 2025 to 10% by 2035, supported by expanded natural gas production and steady renewable deployment, aiming for 40% renewable electricity production by 2035. In the Optimistic Pathway, the reduction in import dependency is less pronounced, reaching 21% by 2035, due to substantially higher energy demand driven by stronger GDP growth, despite targeting 50% renewable electricity production by 2033.

The country continues to import natural gas via long-term contracts with Egypt and Chevron. These contracts, lasting until 2033 and 2035 respectively, contribute to the stability of supply under both pathways. LNG at Aqaba remains as a back-up option for the whole-time horizon of the analysis. Complementing these imports, the exploitation of the Risha gas field is strategically expanded, with production increasing to 418 MMSCFD by 2029, and 812 MMSCFD by 2035, thereby reducing import dependence and enhancing resilience. Additionally, the significant scaling-up of renewable energy, particularly solar PV and wind, boosts the share of indigenous resources in electricity generation. In the optimistic pathway, local resource utilization becomes dominant. Finally, the deployment of RES for the production and export of green hydrogen substantially increases the share of local energy sources.

Sustainability

Sustainability is a central pillar of Jordan's energy transition in both the Reference and Optimistic pathways, with a clear trajectory toward lower greenhouse gas emissions, expanded renewable energy use, and stronger energy efficiency measures. In both cases, natural gas continues to serve as a transitional fuel, particularly in the industrial and power sectors, supporting a more gradual shift away from imported oil products.

The Reference Pathway accelerates decarbonization by expanding natural gas production and steadily scaling up renewables, aiming to reach a 40% share of electricity production from renewable sources by 2035. This pathway provides a balanced trajectory that strengthens energy security, reduces import dependency, and steadily lowers emissions while maintaining economic stability.

The Optimistic Pathway drives a faster transition by targeting 50% renewable electricity by 2033, enabled by large-scale deployment of solar PV and wind. It also integrates the development of green hydrogen infrastructure, significantly enhancing Jordan's potential as a regional exporter of clean energy carriers.

As a result, CO₂ emissions are substantially reduced in both pathways in the electricity and transport sectors, which remain the largest contributors. The shift from imported fossil fuels to domestic renewables also minimizes environmental impacts linked to hydrocarbon extraction, transport, and combustion. Meanwhile, energy efficiency measures across transport, residential, industrial, and service sectors further curb demand growth and reinforce the sustainability of supply.

Taken together, the Reference Pathway supports a structured and steady decarbonization process, while the Optimistic Pathway positions Jordan on a faster and more ambitious trajectory toward long-term environmental and economic sustainability.

Accessibility

Accessibility in Jordan's energy system improves progressively under both the Reference and Optimistic pathways, with particular emphasis on expanding equitable access to modern energy services across all sectors. In both pathways, the electrification of end-use sectors, including residential, commercial, and transport, is supported by increased domestic energy production and infrastructure investments, ensuring a more stable and widespread energy supply.

Increased domestic natural gas production from the Risha field enables broader distribution of cleaner fuels to industrial and urban consumers. The strategy also acknowledges the importance of price reforms, shifting toward cost-reflective tariffs while safeguarding vulnerable consumers through targeted subsidies, especially in the residential sector. This balanced approach supports both the financial viability of the energy sector and the affordability of energy for lower-income households.

Maximizing the Use of Domestic Resources

Maximizing the use of domestic energy resources is a core objective in Jordan's energy planning, reflected in both the Reference and Optimistic pathways through the intensified exploitation of local natural gas, oil shale and renewable energy.

The expansion of production from the Risha gas field significantly reduces dependence on imported natural gas, providing a stable and cost-effective supply for power generation, industrial and residential/commercial use. Simultaneously, the large-scale development of solar and wind resources in both pathways, capitalizes on Jordan's high solar irradiance and favorable wind conditions, positioning renewables as the backbone of future electricity generation. Oil shale continues to play a strategic role in ensuring energy security, with the Attarat power plant (470 MW) already in operation and producing electricity using direct combustion of domestic shale deposits.

Looking beyond 2035, nuclear energy can be considered as a long-term diversification option. Jordan possesses substantial uranium resources, with confirmed reserves of about 42,000 tons of uranium oxide (U_3O_8) and has undertaken exploration and mining pilot projects through the Jordan Uranium Mining Company (JUMCO). The Jordan Atomic Energy Commission (JAEC) has outlined a strategy to potentially develop small modular reactors (SMRs) in the post-2035 horizon to complement renewables and meet growing electricity demand.

Optimizing Renewable Energy

The Reference Pathway, driven by moderate economic growth and lower overall energy demand, foresees a steady expansion of renewable generation, reaching a 40% share of electricity production by 2035. Between 2025 and 2035, renewable capacity grows by more than 2.4 GW of solar PV, of which 400 MW is distributed, and an additional 430 MW of wind. This expansion is supported by the commissioning of the Mujib Pumped Hydro Energy Storage (PHES) plant and the integration of 100 MW of battery storage systems with four-hour duration by 2028 and additional 200MW until 2035. Together, these measures strengthen energy security and ensure reliable renewable integration.

The Optimistic Pathway accelerates this transition, targeting a 50% share of renewable electricity by 2033. In this case, the renewable share in the power system rises from 29% in 2025 to approximately 55% by 2035. Stronger economic growth in this pathway drives higher overall energy demand, which in turn requires a faster and larger deployment of renewable energy. Installed capacity for solar PV and wind

expands significantly, with renewables representing 63% of total installed capacity by 2035. This growth is supported by the deployment of over 8.9 GW of new utility-scale PV and 1.8 GW of wind projects, complemented by an additional 400 MW of distributed PV. To minimize curtailment and maximize utilization of variable renewable energy (VRE), the pathway also incorporates the Mujib PHES and 2.5 GW of battery storage with four-hour duration. These measures enable efficient dispatch of renewables, displace fossil fuel generation, and reinforce the long-term sustainability of the energy system

In addition to the large-scale RES deployment for electricity generation, Jordan's strategy to optimize the use of renewable energy includes tapping into thermal renewable technologies such as solar water heaters and geothermal heat pumps. Solar water heaters are already widely adopted in the residential sector and are increasingly used in commercial and service buildings, contributing to reduced electricity and fuel consumption for water heating. Their expansion aligns with national targets to improve energy efficiency and reduce peak demand. Both pathways anticipate a growing role for geothermal heat pump systems in commercial buildings for space heating and cooling. These systems offer high energy performance and year-round efficiency by utilizing the stable underground temperatures. Combined with the projected increase in electricity generation from renewables, these technologies support a broader shift toward electrified, renewable-based energy services. Their integration complements the overall decarbonization strategy by reducing fossil fuel use in end-use sectors and contributing to a more diversified and sustainable energy portfolio.

Taken together, the Reference Pathway provides a structured and reliable expansion of renewables, while the Optimistic Pathway demonstrates the potential for a more ambitious transformation, accelerating Jordan's progress toward a cleaner, more secure and more resilient energy future.

7.2 Socio-Economical Pathways Comparison

This section presents a comparative analysis of the main social and economic indicators across both pathways.

From a social perspective, the employment related to renewable energy installations in the power sector differs significantly between the two pathways. In the Reference pathway total direct employment due to renewables for electricity generation, amounts to 6,310 job-years in construction and 336 permanent O&M jobs, corresponding to the installation and maintenance of rooftop PV, utility-scale PV, and wind farms. Rooftop PV creates the largest number of jobs per MW because of its distributed nature, yet utility-scale PV dominates total construction employment due to its higher capacity share²⁵. Wind employment is smaller in absolute terms but contributes a larger share of long-term O&M positions (Figure 101). When renewables dedicated to green hydrogen are added, total job creation increases markedly to 20,753 job-years during construction and 1,217 O&M jobs. This more than triples the workforce demand compared with power-sector renewables alone, illustrating the strong labor intensity of the planned hydrogen build-out under the baseline pathway. In the Optimistic Pathway, total direct employment generated by renewable energy installations rises sharply compared with the Baseline case, reflecting both higher overall investment volumes and the accelerated deployment of renewable and storage technologies across power generation. The Pathway creates 19,188 job-years in construction and installation, together

²⁵ The employment factors for RES technologies were taken from "Updated employment factors and occupational shares for the energy transition", J. Rutovitz, R. Langdon, C. Briggs, F. Mey, E. Dominish, K. Nagrath, Renewable and Sustainable Energy Reviews, Vol. 212, April 2025, available at <https://www.sciencedirect.com/science/article/pii/S1364032125000127>

with 1,315 long-term O&M positions, in the electricity generation sector. Utility-scale PV accounts for more than half of the construction employment (11,272 job-years), followed by wind (4,799 job-years) and rooftop PV (1,756 job-years). Battery energy storage systems (BESS) add 1,362 job-years and 77 permanent O&M jobs, indicating the growing importance of storage in managing higher shares of renewables. When the renewable capacities dedicated to green hydrogen are included, total direct employment expands to 34,623 job-years during construction and 2,275 O&M jobs. Overall, the Optimistic-EMV GDP pathway yields a 67% increase in construction-phase employment relative to the Baseline and nearly doubles the number of permanent operational jobs.

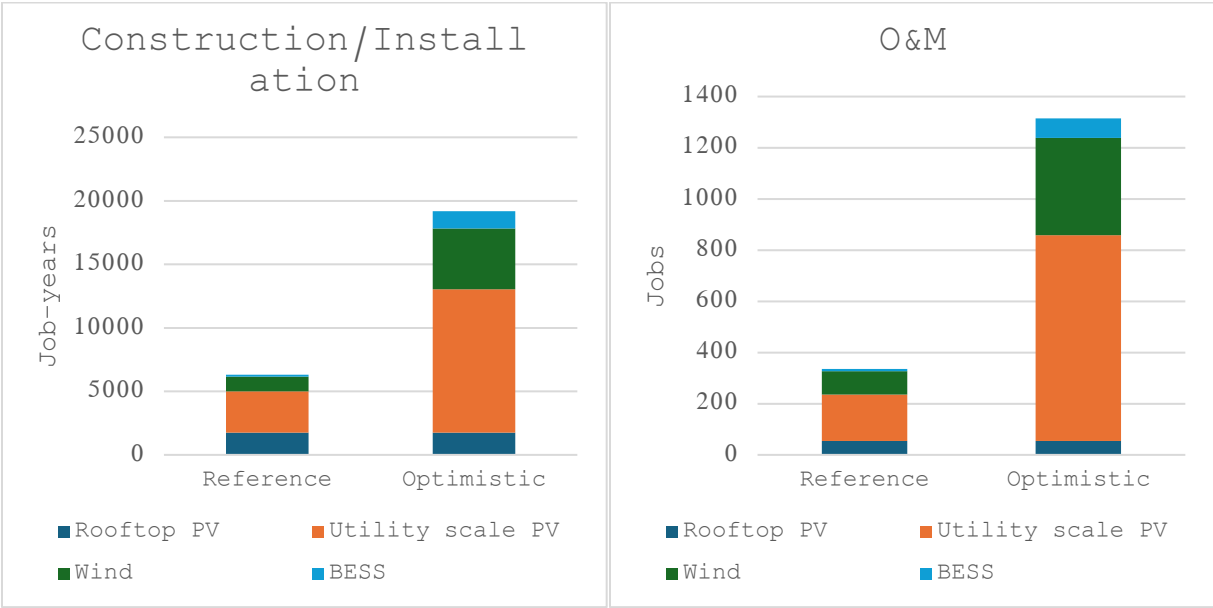


Figure 101: Direct employment effect of RES in the power sector

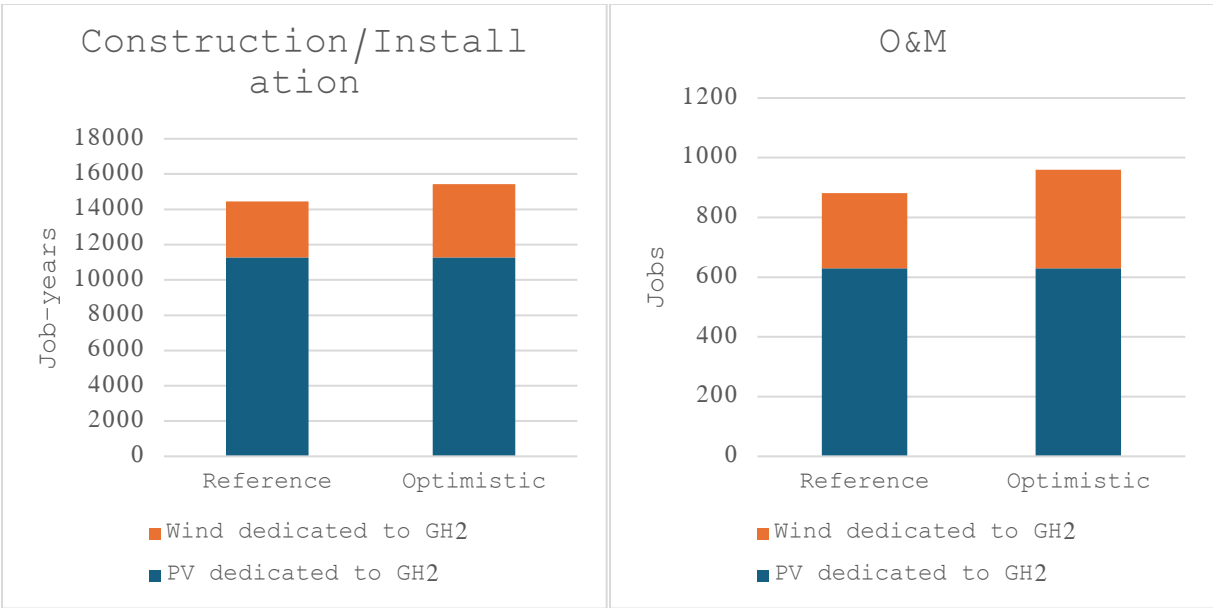


Figure 102: Direct employment effect of RES dedicated to electrolyzers

From an economic perspective, Figure 103 illustrates the evolution of costs associated with the power sector. The analysis encompasses investment, fixed and variable operation and maintenance (O&M), and fuel costs related to the planned expansions throughout the study period. The results are presented in terms of the relative variation of the electricity service cost over time, taking 100% as the reference value corresponding to the first year of the analysis. In that base year, all pathways share the same cost level in US\$/MWh; therefore, only the reference scenario is shown in the figure.

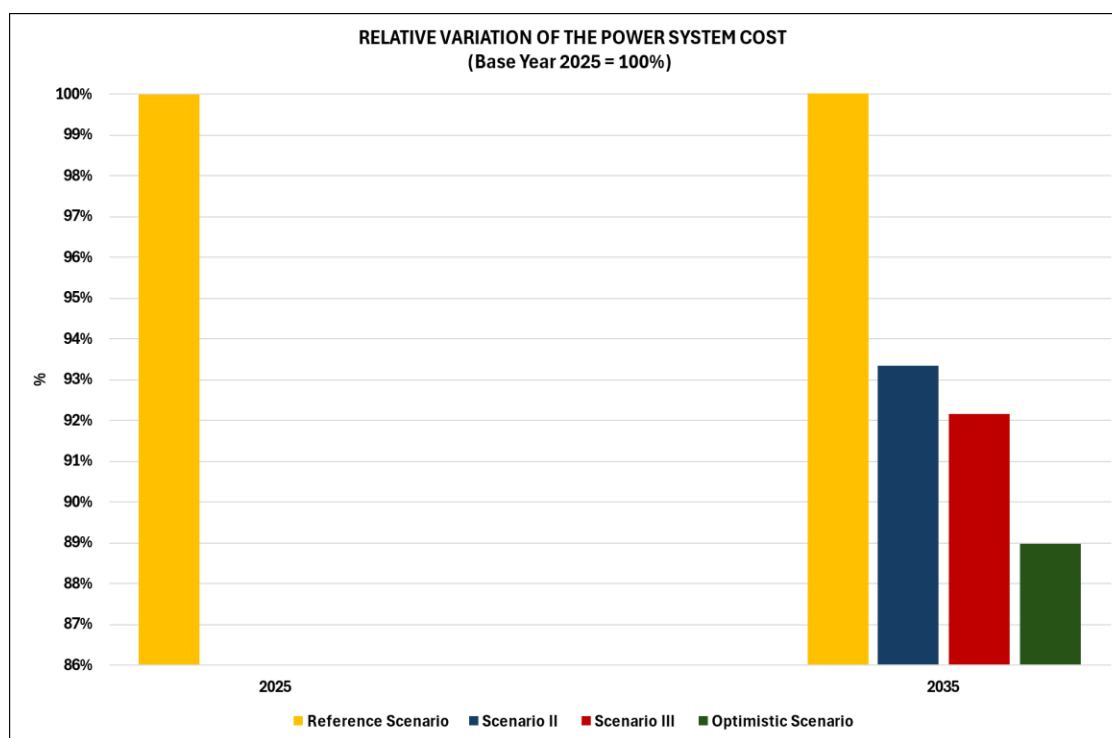


Figure 103: JESS's Cost for the Power Sector

As shown in the figure, only the reference scenario maintains a cost structure in the power sector that keeps the equivalent cost of electricity close to the value observed in the first year. This indicates that, although there is no reduction in the service cost, there is also no significant increase over the study period.

For the remaining scenarios, a decrease in the equivalent cost of electricity is observed, ranging from about 6.5% in Scenario II, nearly 8% in Scenario III, and reaching up to 11% in the optimistic scenario.

In conclusion, under any of the scenarios, the proposed strategy allows the equivalent cost of electricity to be maintained at levels like current conditions, with potential reductions of up to 11%, depending on which pathway is ultimately implemented in the Kingdom.

7.3 Assessment of specific topics

In order to provide a comprehensive view of Jordan's energy transition, the present study examines sector-specific dynamics that influence both supply and demand. Each subsector, oil, natural gas, electricity, renewable energy beyond electricity, transport, and water, presents distinct challenges and opportunities, which together determine the pace and feasibility of achieving national energy and climate objectives. The following assessment summarises the current status, emerging trends, and strategic

considerations for each area, forming the basis for targeted recommendations and the identification of ‘no regret’ options.

7.3.1 Oil sector

The oil sector continues to play a significant role in the short term, in Jordan’s energy system, though the country is highly dependent on imported crude oil and refined products. The planned refinery expansion is expected to come online around 2030, increasing the refining capacity to 73,000 bbl/day with a capital investment of USD 2 billion. This project is designed to enhance domestic supply security and reduce import dependency on oil products, although the crude oil will still have to be imported. Therefore, Jordan will continue to face exposure to global oil price volatility, and the gradual decarbonization of the economy suggests that demand for oil products will plateau towards 2035, particularly as electrification expands in transport and efficiency measures reduce consumption.

7.3.2 Natural gas sector

Natural gas is the backbone of Jordan’s electricity generation, with NEPCO acting as the single buyer for imports, local production, and LNG delivered via Aqaba. Long-term supply contracts up to 2035 underpin the sector’s stability, while new initiatives are promoting expanded use of gas in industries to replace more expensive liquid fuels. Projects for city gas distribution networks in Amman and Zarqa, supported by private investment, would reduce costs and emissions, although uptake in the residential sector is constrained by infrastructure requirements and household conversion costs. Looking ahead, gas will play a critical role, but diversification, preparation for hydrogen blending and increase contribution of renewables in the power sector are increasingly important to avoid lock-in.

7.3.3 Electricity sector

The electricity sector is undergoing a structural transformation, with renewable energy already playing a significant role and further integration targeting 50% penetration by 2033 in the Optimistic Pathway and 40% by 2035 in the Reference Pathway. System integration challenges, including curtailment and limited flexibility, should be addressed through storage solutions, and regulatory reforms. Distribution losses, historically high compared to OECD benchmarks, are targeted to be reduced to 8% by 2035, strengthening efficiency and financial sustainability. At the same time, market liberalization and the introduction of demand-side management tools will align the sector with global best practice.

7.3.4 Other RES (non-electricity)

Renewables beyond electricity, particularly solar water heaters, offer important opportunities. Solar thermal is already present in more than one-third of households, representing a significant contribution to reduced electricity and LPG demand for water heating. Biogas from municipal waste and wastewater treatment is limited but holds potential for scaling, especially in urban centres. These resources contribute directly to emissions reduction, and energy security, even though they remain outside the central power sector.

7.3.5 Transport sector

Transport is the largest final energy consumer and a major contributor to emissions. While oil products remain dominant, rapid growth in e-mobility and CNG fleet conversions is projected. Both pathways project steady uptake of electric vehicles, supported by charging infrastructure and fiscal incentives. Public transport electrification, including bus fleets in Amman and secondary cities, will further reduce oil dependency and improve urban air quality. Nonetheless, achieving these outcomes requires sustained policy support, investment in infrastructure, and behavioural change.

7.3.6 Water sector

The water sector is a major energy consumer, particularly for pumping, desalination, and treatment. The integration of renewable energy into water pumping and desalination projects, alongside efficiency upgrades in distribution networks, will be critical for reducing costs and emissions. The sector is thus both a challenge, due to its rising energy intensity, and an opportunity, given the synergies between water security and sustainable energy development.

7.4 Recommendations

Several actions stand out as ‘no regret’ measures that can be pursued immediately, as they generate clear economic, environmental, and social benefits under all plausible pathways. These include

- The continued deployment of renewable electricity to replace fossil fuels remains a central element of Jordan’s energy transition strategy. Solar and wind already contribute nearly one-third of power generation, with targets of 40% penetration by 2035 in the Reference Pathway and 50% penetration by 2033 in the Optimistic Pathway. This further expansion of renewable electricity will directly reduce import dependency, improve the balance of payments, and protect the economy from global price volatility, while also strengthening Jordan’s position as a regional hub for clean energy. To ensure that these benefits are realized without compromising system performance, it is recommended that a comprehensive, detailed power-system expansion study be carried out. For the Optimistic Pathway, this study is essential and should cover multiple scenarios of renewable penetration, including and exceeding the 50% target by 2033, to identify the specific investments and operational measures required to maintain system flexibility, security, and reliability. For the Reference Pathway, a similar assessment is necessary, particularly after 2030, to determine the actions required to safeguard system performance as renewable penetration increases.
- The systematic reduction of electricity distribution losses to converge with international best practice (8% by 2035 compared to current double-digit levels) offers a cost-effective opportunity to improve system efficiency. Lower losses translate into reduced generation requirements, lower fuel imports, and improved financial sustainability for the sector. Investments in smart metering, grid modernization, and tighter performance standards for distribution equipment are critical enablers of this outcome.
- The expansion of solar water heating systems presents a mature and immediately scalable solution for reducing residential and commercial demand for electricity and LPG. With more than one-third of Jordanian households already equipped, scaling up adoption through targeted incentives and awareness campaigns could deliver significant savings in peak load, reduce household expenditure, and accelerate the achievement of national energy efficiency targets.

- The promotion of natural gas in industry to displace fuel oil and diesel represents a pragmatic bridging option. The switch to natural gas enhances industrial competitiveness by lowering energy costs, while simultaneously delivering measurable reductions in local pollutants and greenhouse gas emissions. Ongoing efforts to expand city gas networks in Amman and Zarqa, combined with fiscal incentives for fuel switching, will determine the speed and scale of these benefits.
- Strengthening e-mobility policies constitutes a robust pathway given the co-benefits of reduced emissions, improved urban air quality, and enhanced energy security. Measures such as fiscal incentives for electric vehicle purchases, investment in charging infrastructure, and the electrification of public transport fleets will accelerate uptake. In the long term, these initiatives contribute to diversifying final energy consumption away from imported oil products and align transport development with global low-carbon mobility trends.
- Green hydrogen production using dedicated renewable energy presents an opportunity to enhance Jordan's potential as a regional hub for green hydrogen.

Collectively, these no-regret measures improve security of supply, reduce costs, and align Jordan's trajectory with its climate commitments, regardless of future uncertainties in global energy markets.

8 Appendixes

8.1 Appendix I: Alternative Pathways

8.1.1 Introduction

To assess the key challenges in the development of Jordan's energy system, two additional pathways—Pathway II and Pathway III—are analyzed as part of the planning process. These pathways explore different combinations of assumptions related to economic growth and sustainability policies related to energy efficiency and renewable energy expansion (Figure 104).

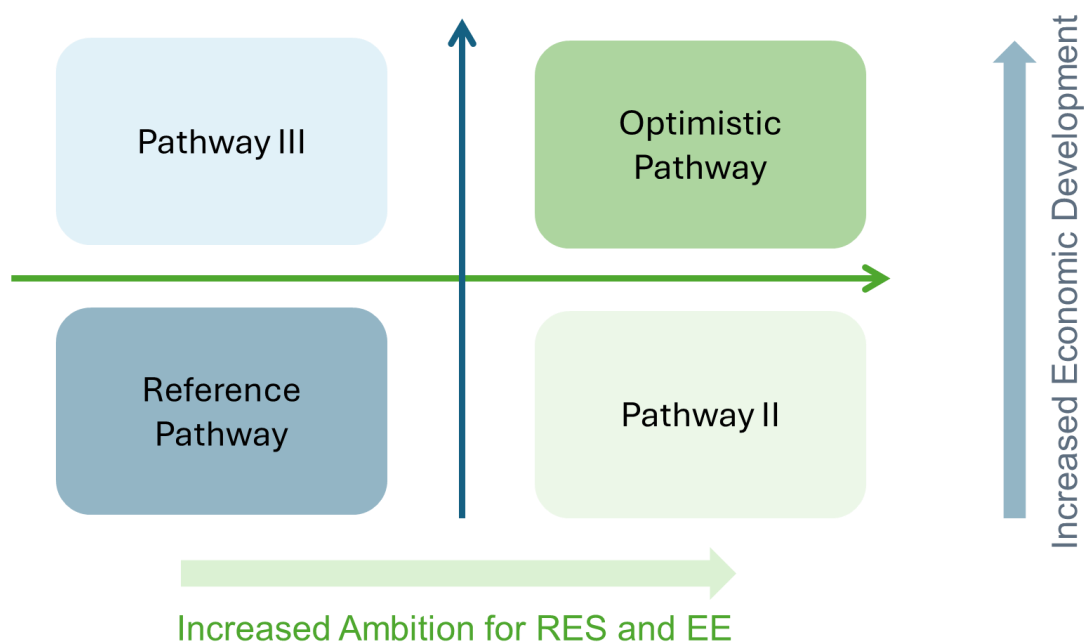


Figure 104: Overview of analysed pathways

Table 16: Key attributes of analysed pathways

Nº	Pathway	GDP	RES Electricity	Energy Efficiency
I	Reference	Reference GDP (3% until 2028, 2.6% after that)	33% by 2030 40% by 2035	Current trend
II	Pathway II	Reference GDP (3% until 2028, 2.6% after that)	50% by 2033	Increased EE
III	Pathway III	EMV GDP (5.6% average)	33% by 2030 40% by 2035	Current trend
IV	Optimistic	EMV GDP (5.6% average)	50% by 2033	Increased EE

Both pathways share common assumptions on population growth and household formation but differ in their GDP growth projections. These socioeconomic drivers are critical for shaping future energy demand: population growth determines residential consumption and infrastructure requirements, while GDP growth influences industrial activity, transport demand, and overall energy intensity. The interaction of these factors underpins how Jordan's energy system must adapt to ensure reliability, affordability, and sustainability in the years ahead.

Pathway II assumes EMV GDP growth, at 5.6% per year on average. It reflects a continuation of current trends, with gradual improvements in energy efficiency and renewable energy integration and it targets 40% renewable electricity generation by 2035.

Pathway III assumes reference GDP growth, at a level of 3% until 2028 and 2.6% afterwards, consistent with the assumptions used in the Electricity Masterplan (2024), targeting 50% renewable electricity generation by 2033 and it incorporates enhanced energy efficiency measures.

All other assumptions remain consistent with those used in the Reference and Optimistic Pathways.

8.1.2 Results for the Pathway II

This chapter presents the results of Pathway III, an ambitious pathway targeting 50% of electricity production from renewable sources, driven by reference GDP growth.

8.1.2.1 Final Energy Consumption

The following graphs and tables present the estimated final energy consumption by sector and fuel type for the period 2025-2035, illustrating how various fuels are utilized across different sectors in Pathway II.

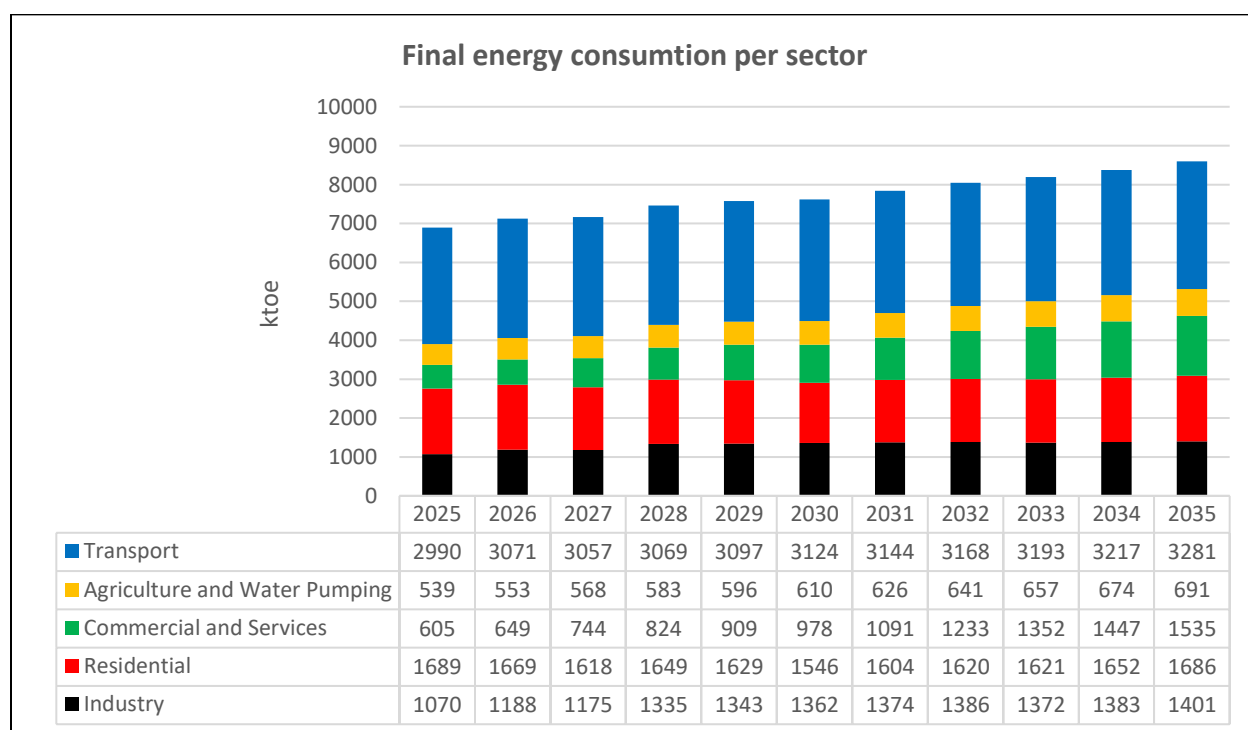


Figure 105: Final energy consumption per sector for the period 2025-2035

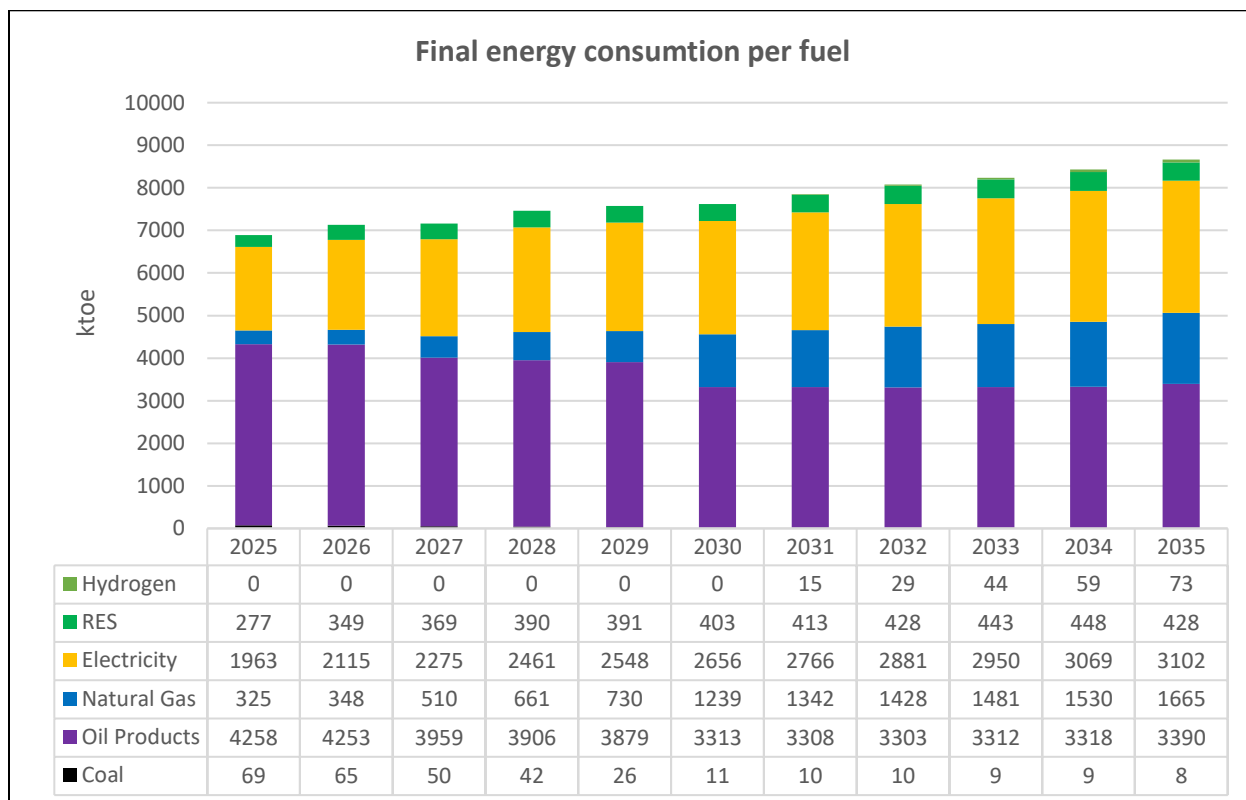


Figure 106: Final energy consumption per fuel for the period 2025-2035

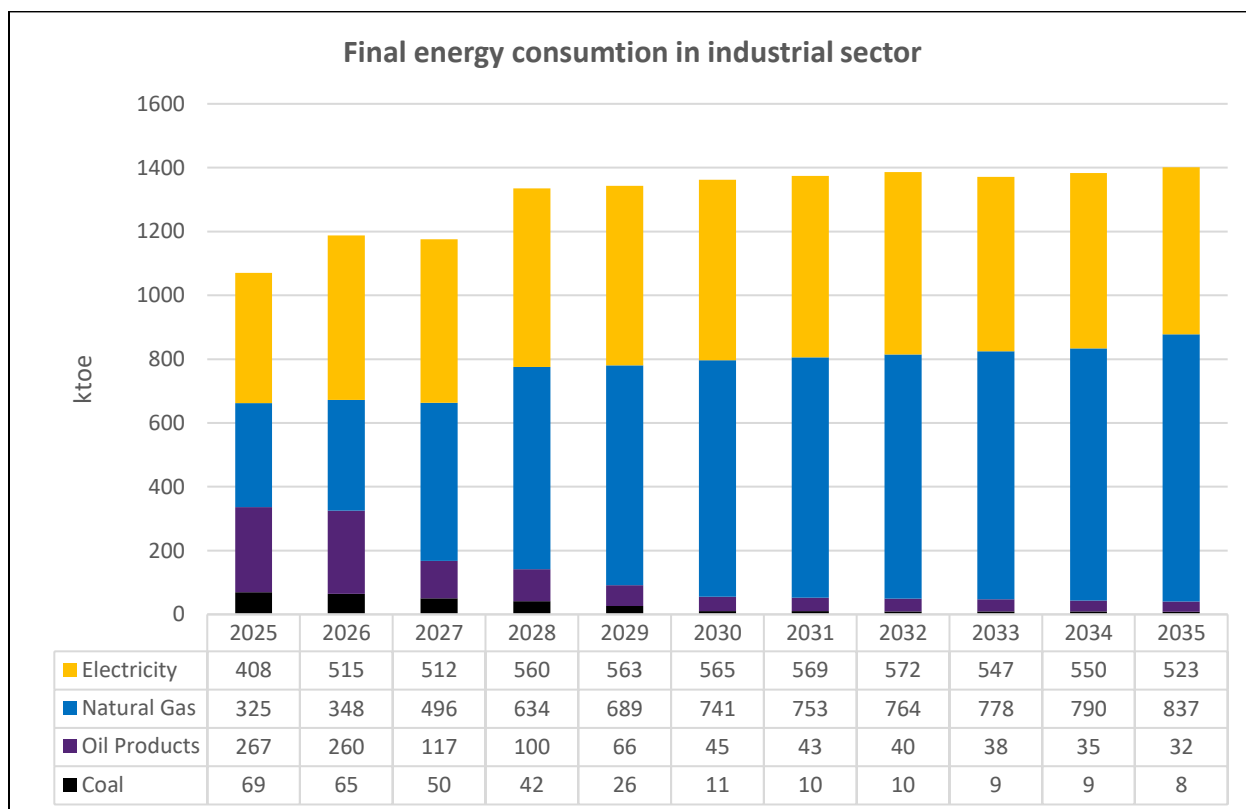


Figure 107: Final energy consumption in the industrial sector for the period 2025-2035

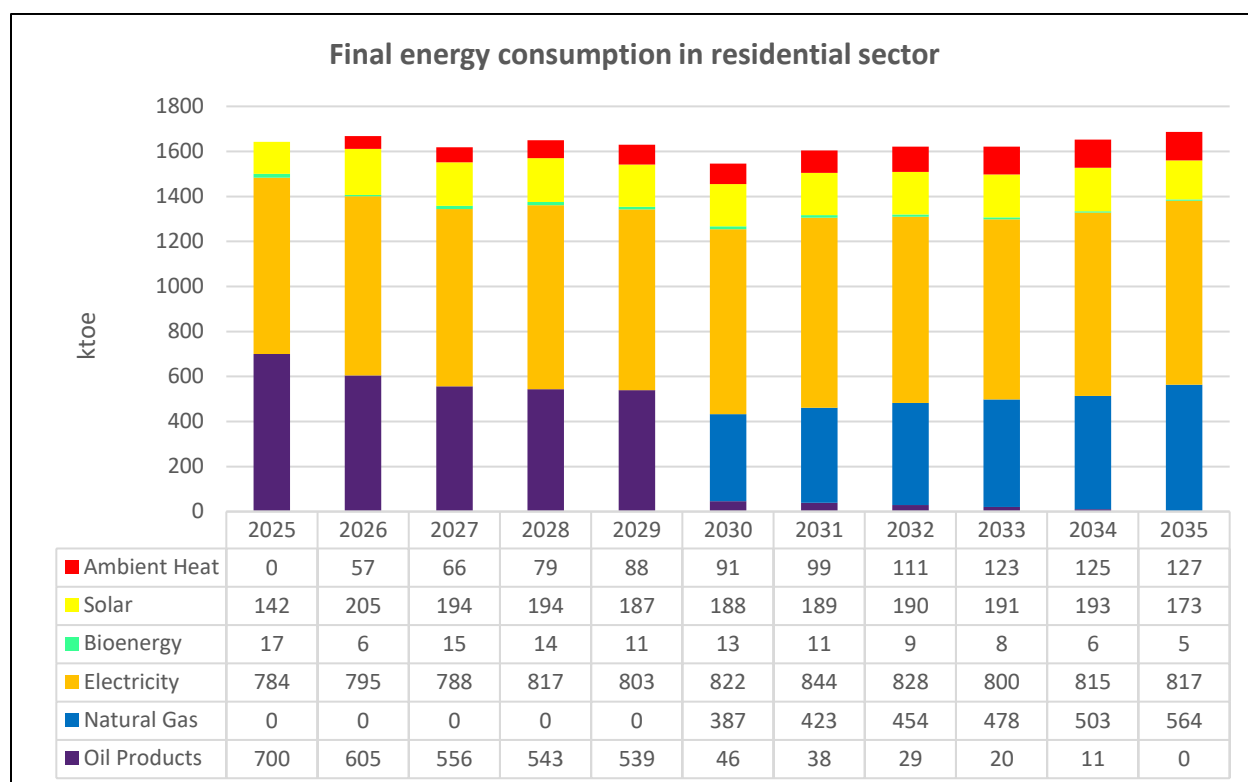


Figure 108: Final energy consumption in the residential sector for the period 2025-2035

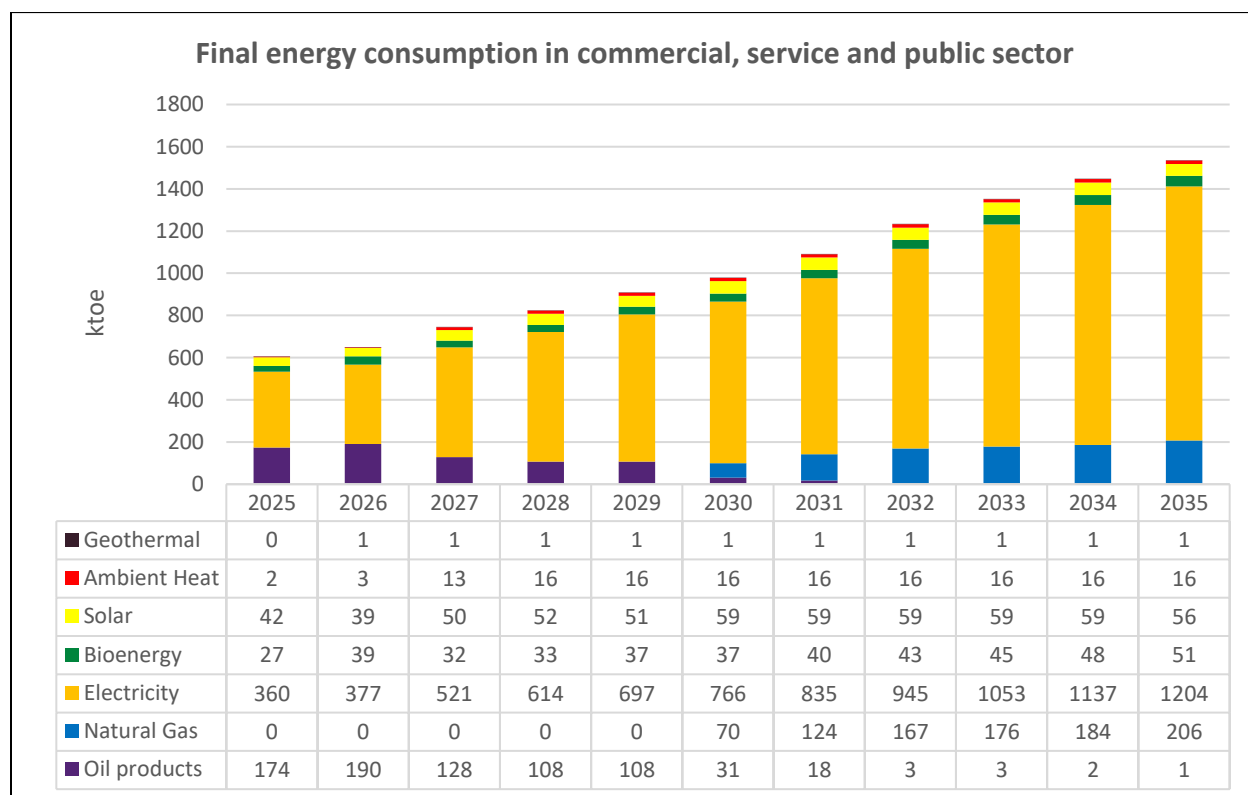


Figure 109: Final energy consumption in the commercial, service and public sector for the period 2025-2035

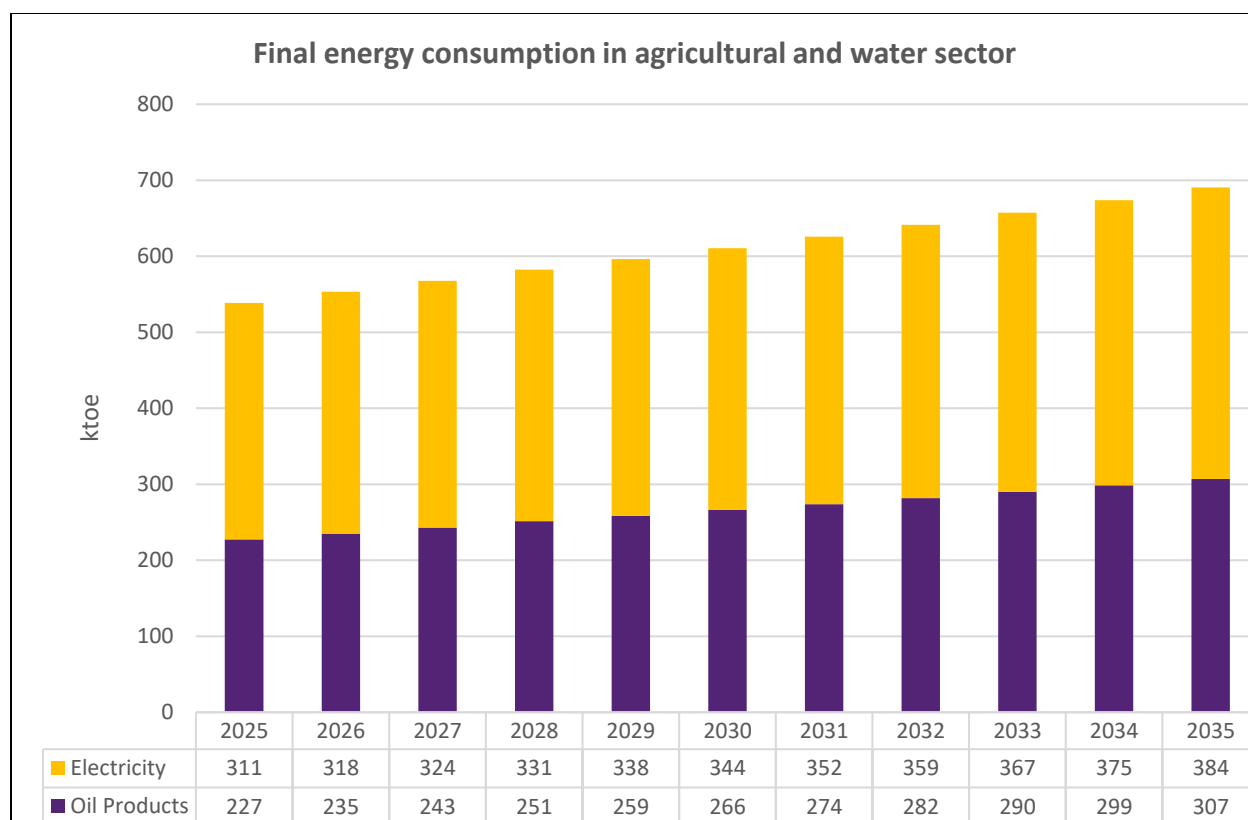


Figure 110: Final energy consumption in the agricultural and water sector for the period 2025-2035

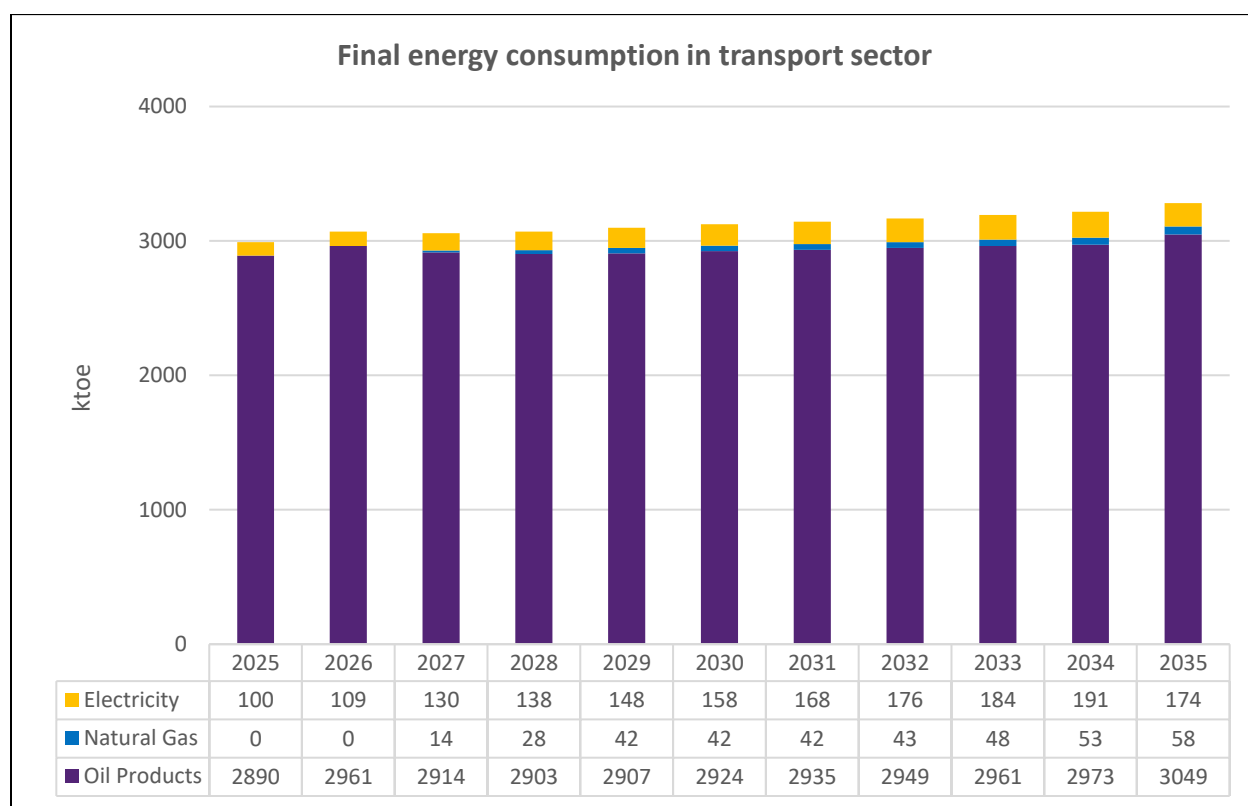


Figure 111: Final energy consumption in transport sector for the period 2025-2035

8.1.2.2 Primary Energy

The expansion of renewable energy for electricity generation and for hydrogen and ammonia production, together with increased domestic output from the Risha gas field, is set to significantly transform Jordan's overall energy landscape.

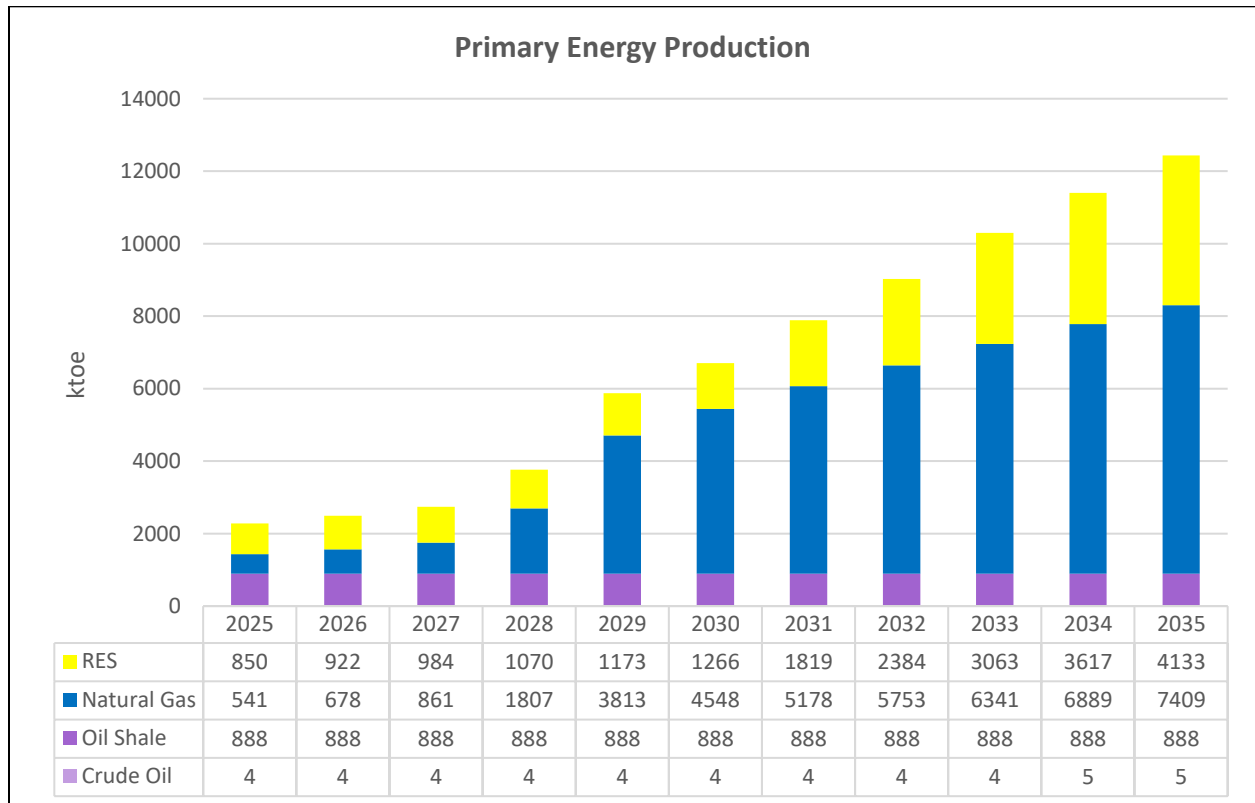


Figure 112: Primary energy production for the period 2025-2035

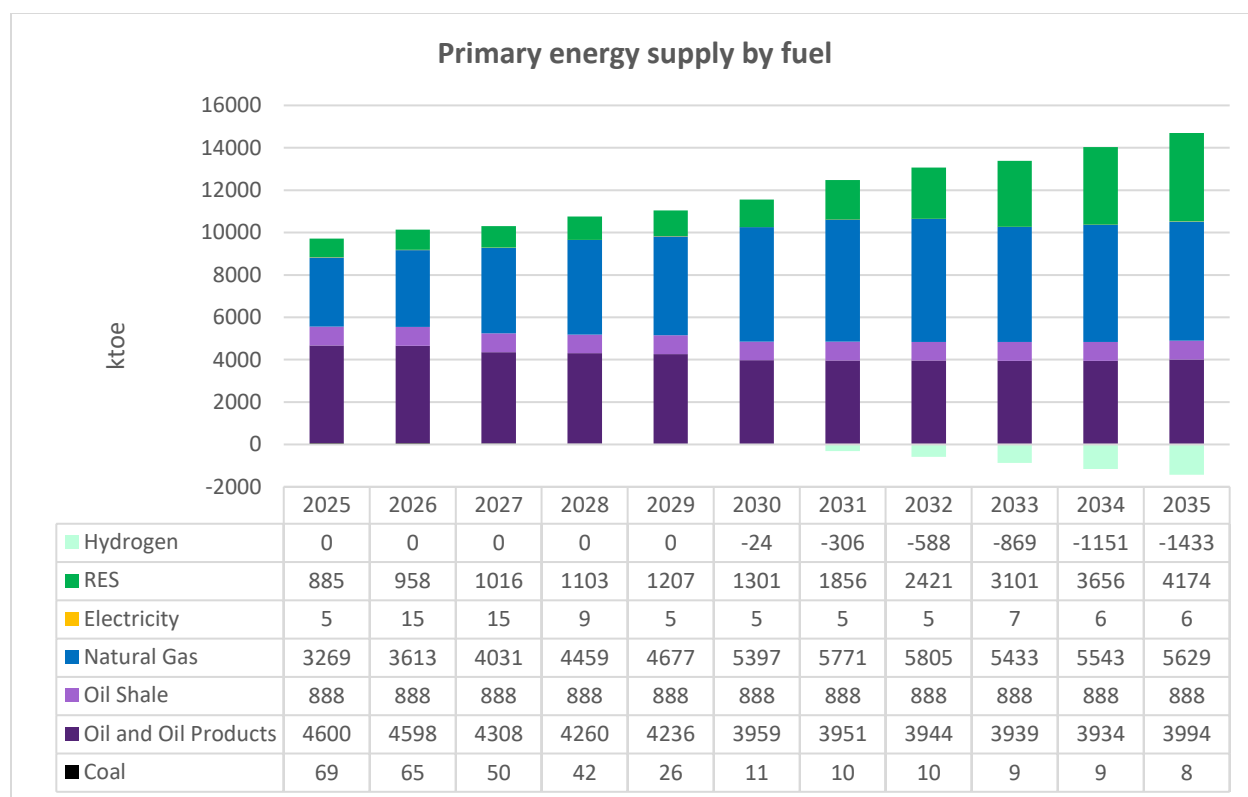


Figure 113: Primary energy supply by fuel for the period 2025-2035

8.1.2.3 Energy import and export

Energy imports are expected to reduce, while energy exports are anticipated to increase, due to higher domestic natural gas production, the projected export of hydrogen and ammonia, and the increased penetration of renewable energy.

Driven by increased production from the Risha gas field, the expansion of hydrogen and ammonia production, and a substantial rise in renewable energy generation, energy import dependency is projected to decline significantly, from 76.3% in 2025 to as low as 5.3% by 2035.

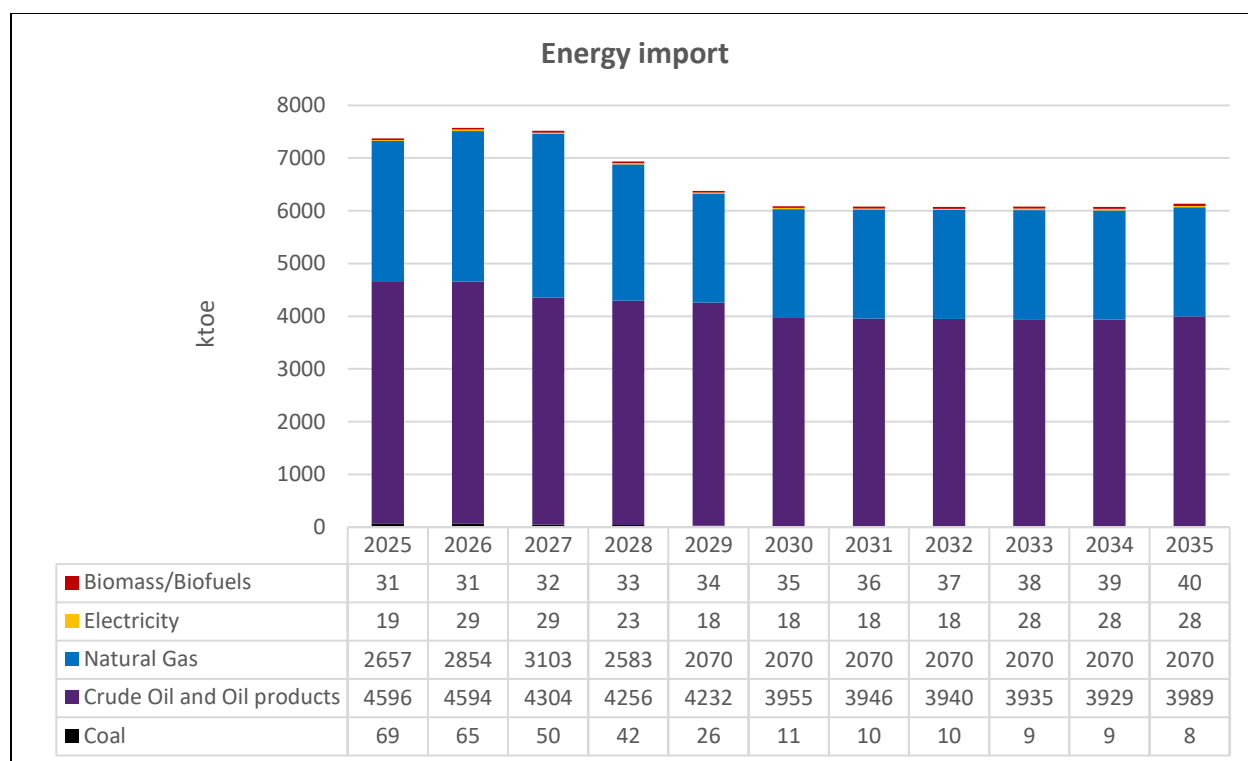


Figure 114: Energy import for the period 2025-2035

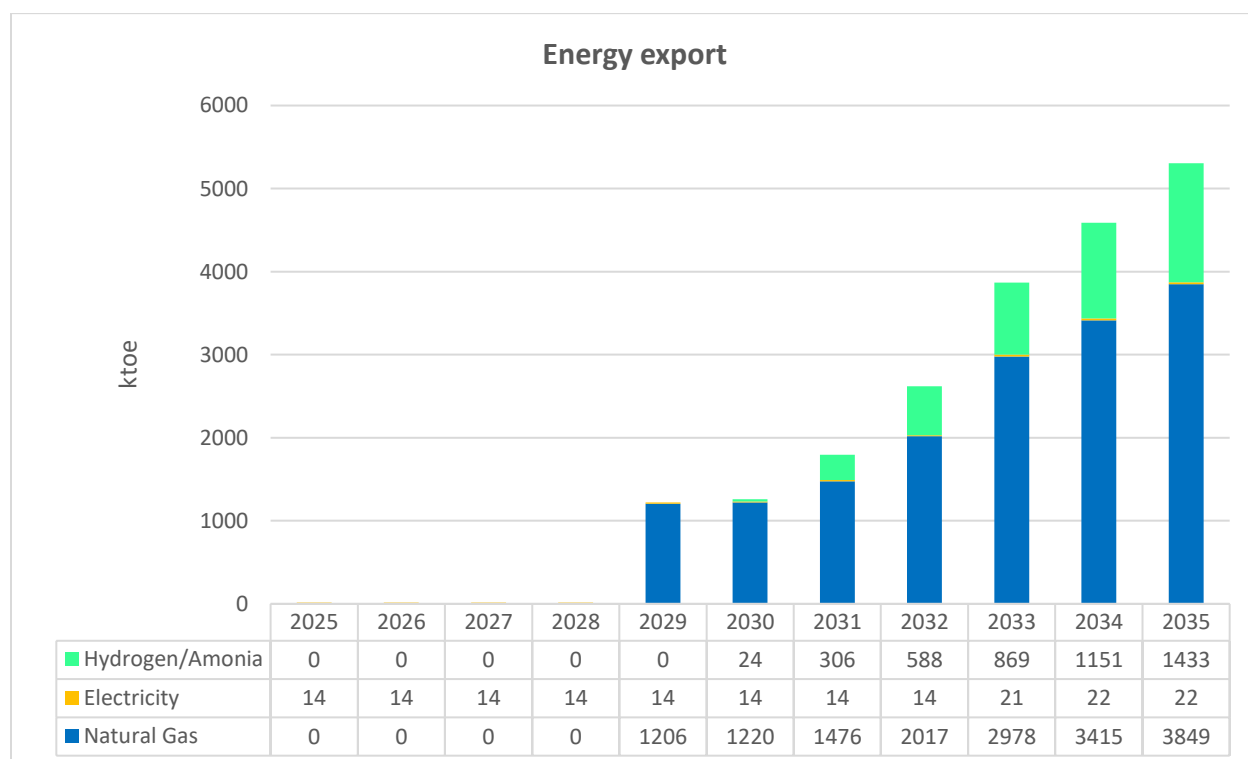


Figure 115: Energy export for the period 2025-2035

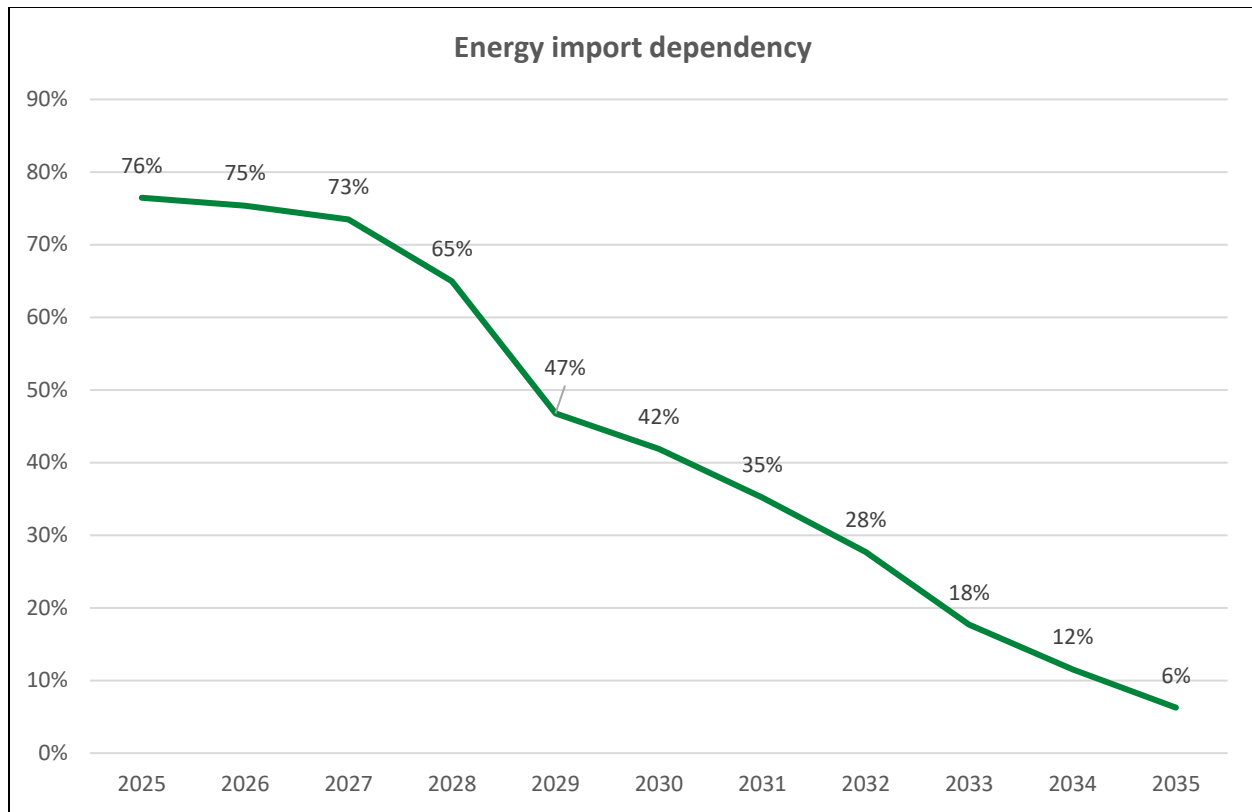


Figure 116: Energy import dependency

8.1.2.4 Electricity sector

Optimistic Pathway is developed with a target to reach 50% electricity production from renewables in 2033. Such scenario requires much more flexible power system which can be achieved with large implementation of energy storage.

Overnight investment costs are high in the Optimistic Pathway due to the need for greater installed renewable capacity to generate the same amount of electricity, along with the additional deployment of battery storage systems to ensure security of supply and minimize curtailment of solar power plants.

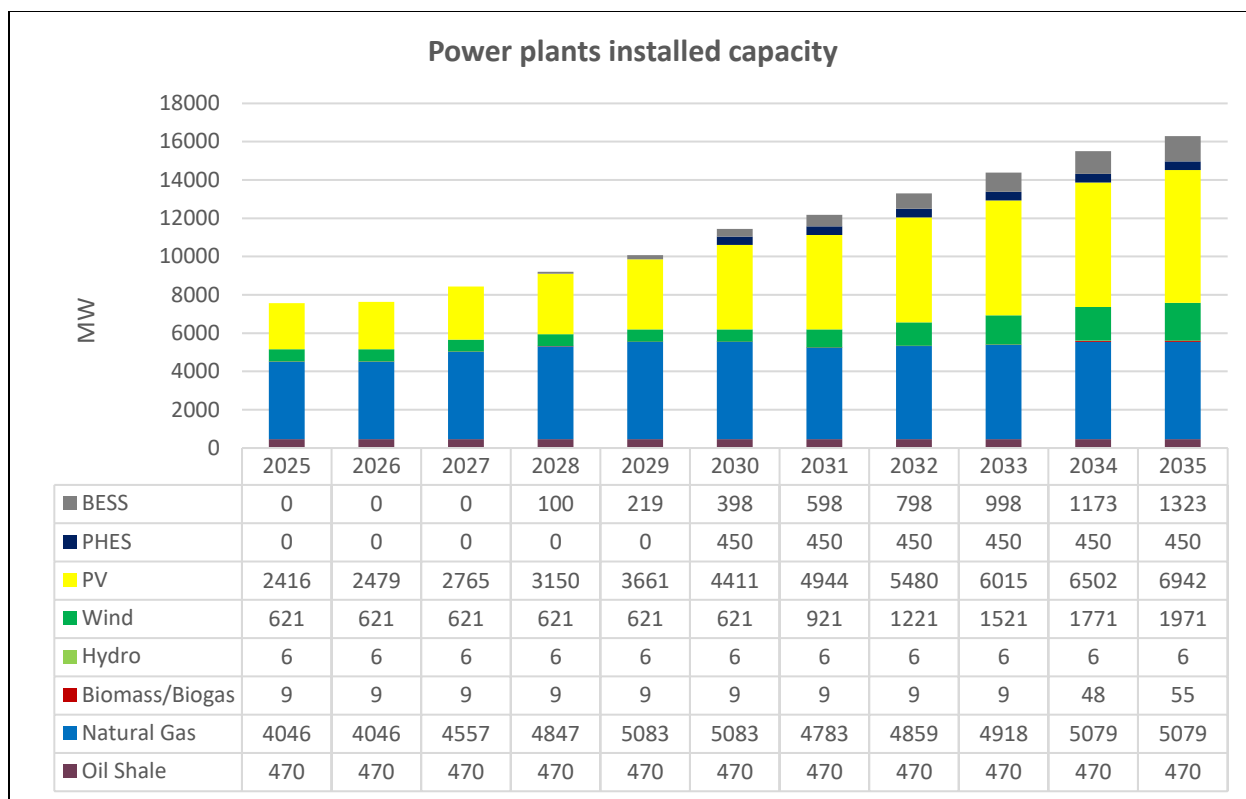


Figure 117: Installed capacity per type of power plants in the period 2025-2035

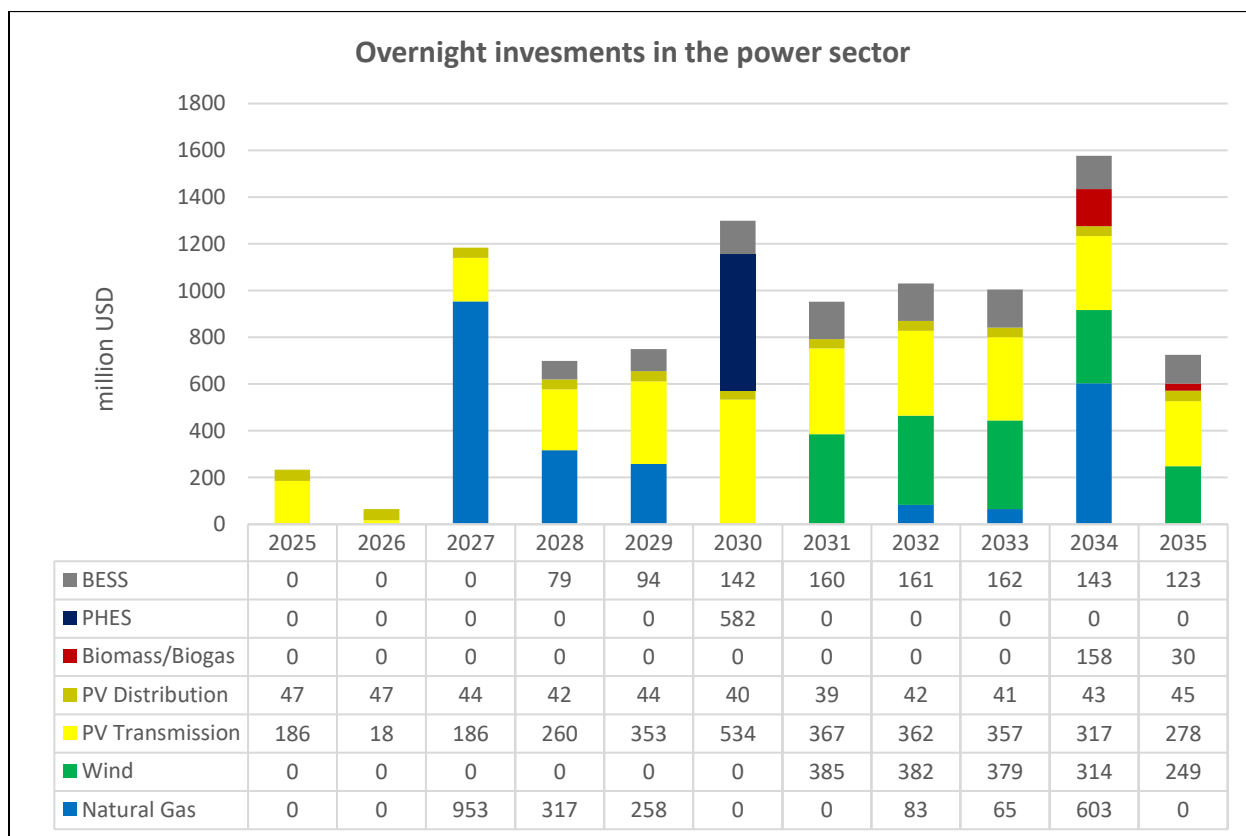


Figure 118: Overnight investment costs in the power system in the period 2025-2035

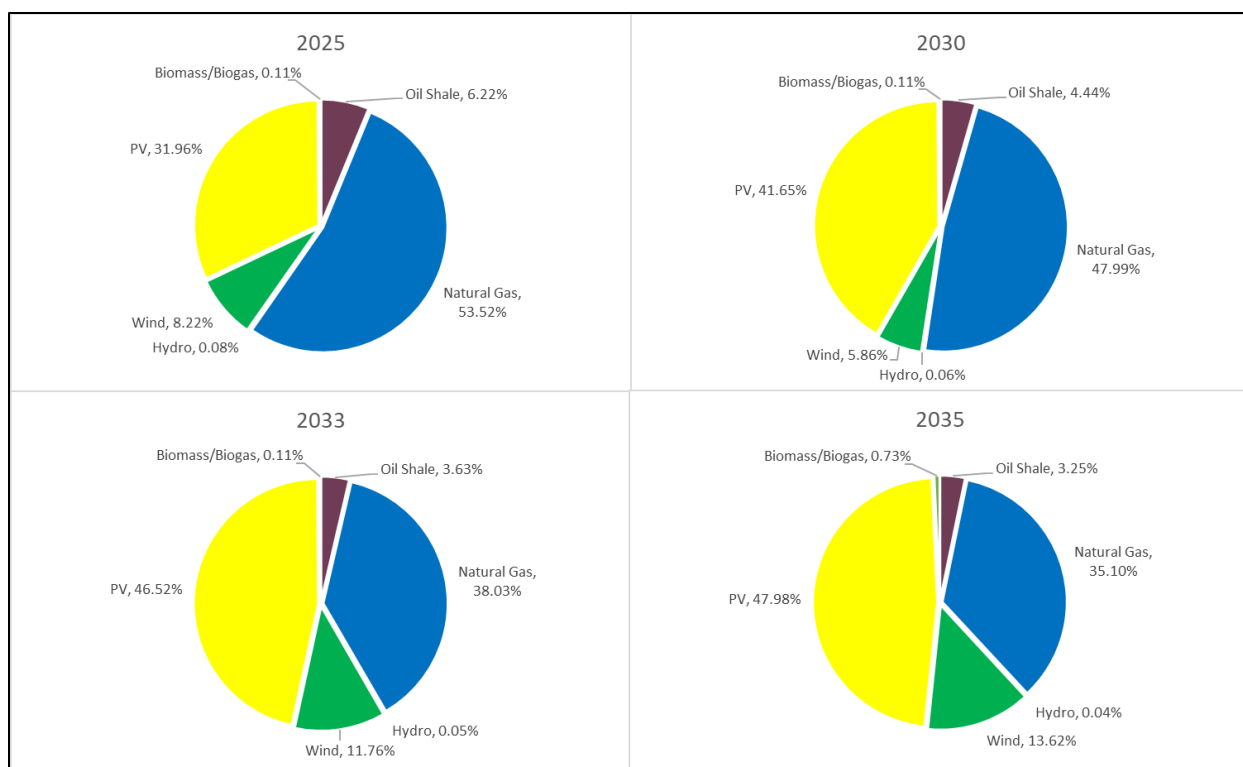


Figure 119: Share of the installed capacity per type of power plants in 2025, 2030, 2033 and 2035

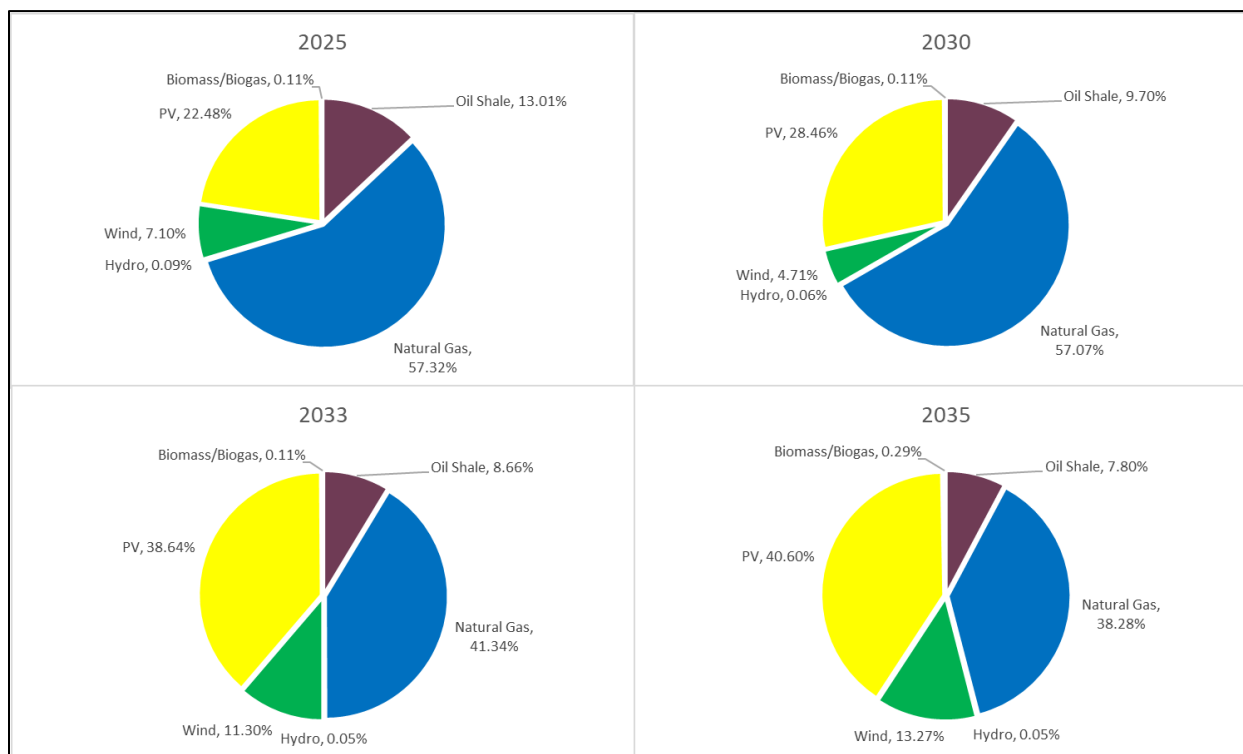


Figure 120: Share of the produced electricity per type of power plants in 2025, 2030, 2033 and 2035

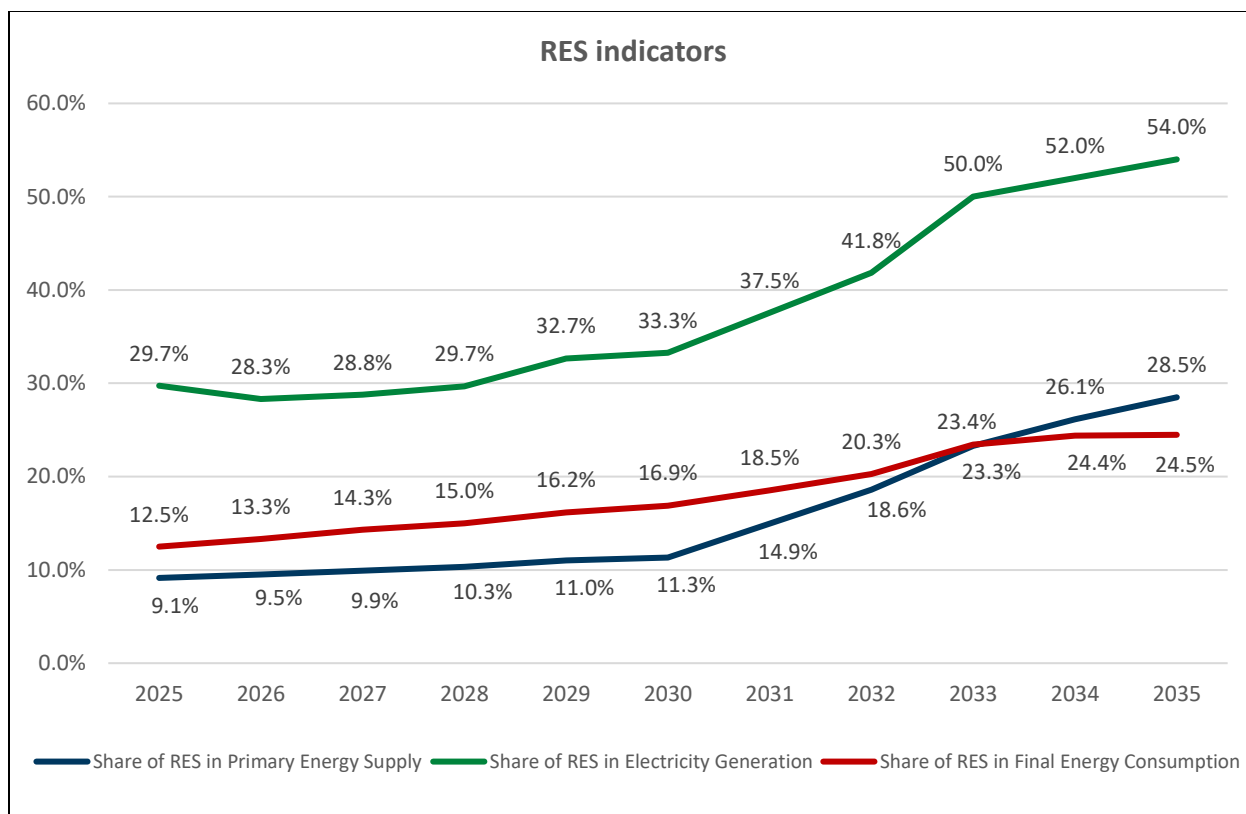


Figure 121: Indicators for RES penetration in the period 2025-2035

8.1.2.5 Disbursement Plan

The next figures present, respectively, the estimated annual investment for the generation system, broken down by technology type, and the estimated investment in both generation and transmission for the Reference Pathway. For this Pathway, the average annual investment requirement amounts to USD 808 million, of which USD 729 million per year would be allocated to generation expansion, and the remaining USD 79 million per year would be directed toward the expansion and upgrading of the transmission system.

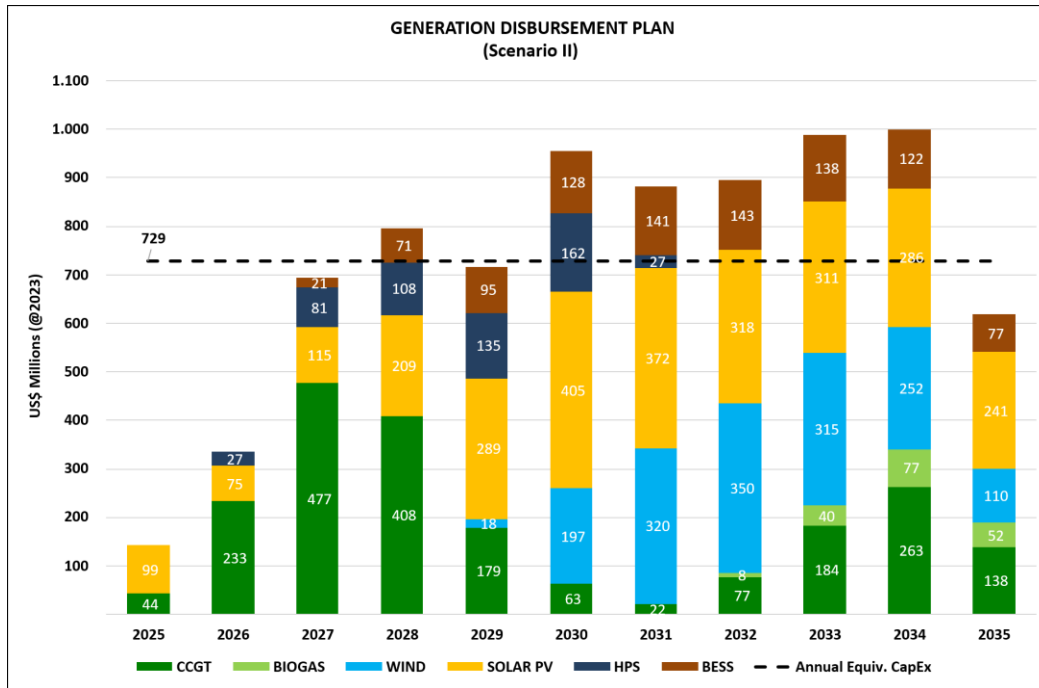


Figure 122: Generation Disbursement Plan (Pathway II)

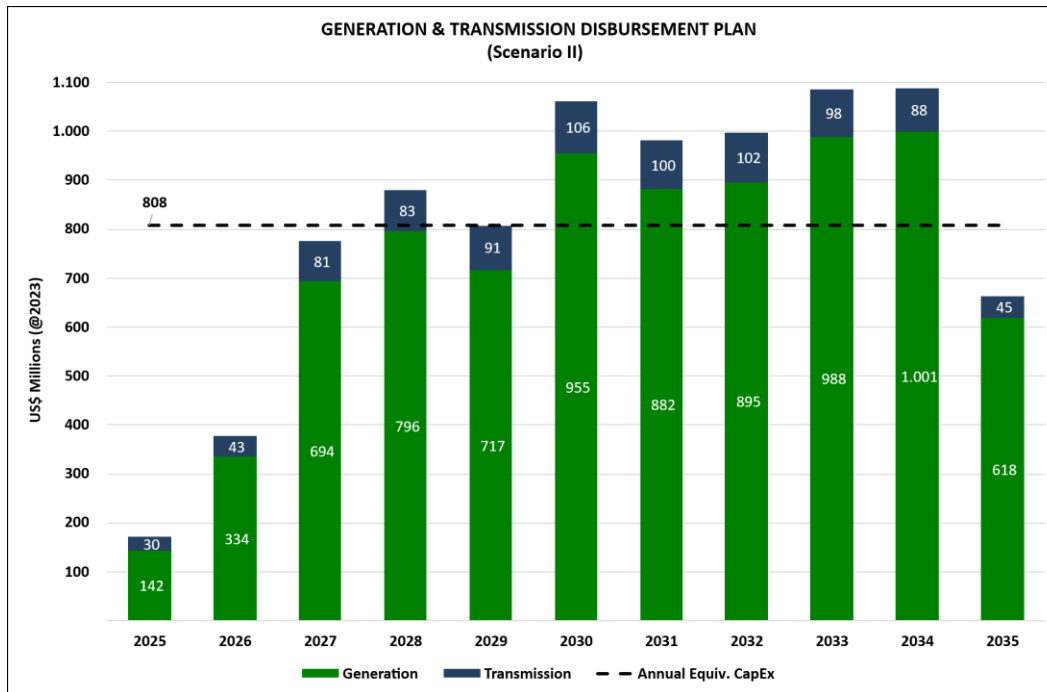


Figure 123: Generation and Transmission Disbursement Plan (Pathway II)

8.1.2.6 GHG emissions

Detailed sectoral and aggregate GHG emission results are shown in the subsequent graphs and tables. The electricity and transport sectors remain the primary contributors to GHG emissions.

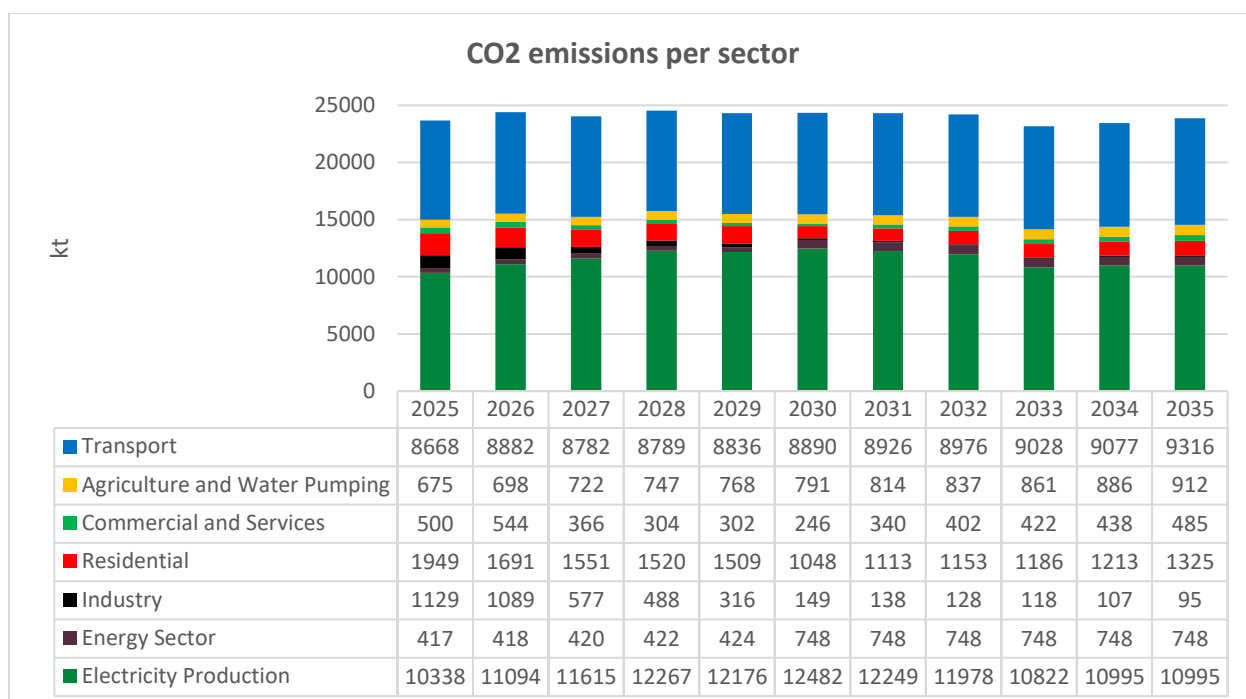


Figure 124: CO2 emissions by sector in the period 2025-2035

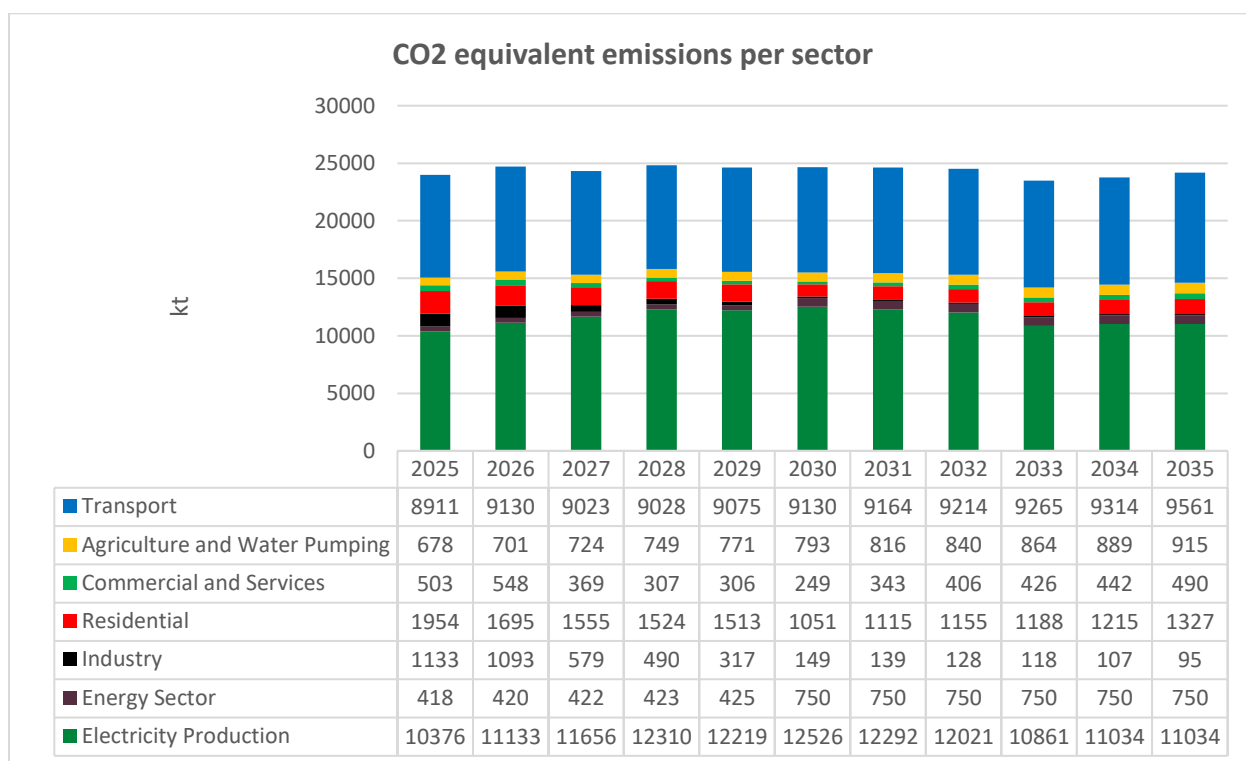


Figure 125: CO2 equivalent emissions by sector in the period 2025-2035

8.1.3 Results for the Pathway III

This chapter presents the results of Pathway III, which reflects a scenario of ambitious economic growth and targets 40% renewable electricity generation by 2035.

8.1.3.1 Final Energy Consumption

The following graphs and tables present the estimated final energy consumption by sector and fuel type for the period 2025-2035, further illustrating the distribution of fuel use across various sectors under the Pathway III.

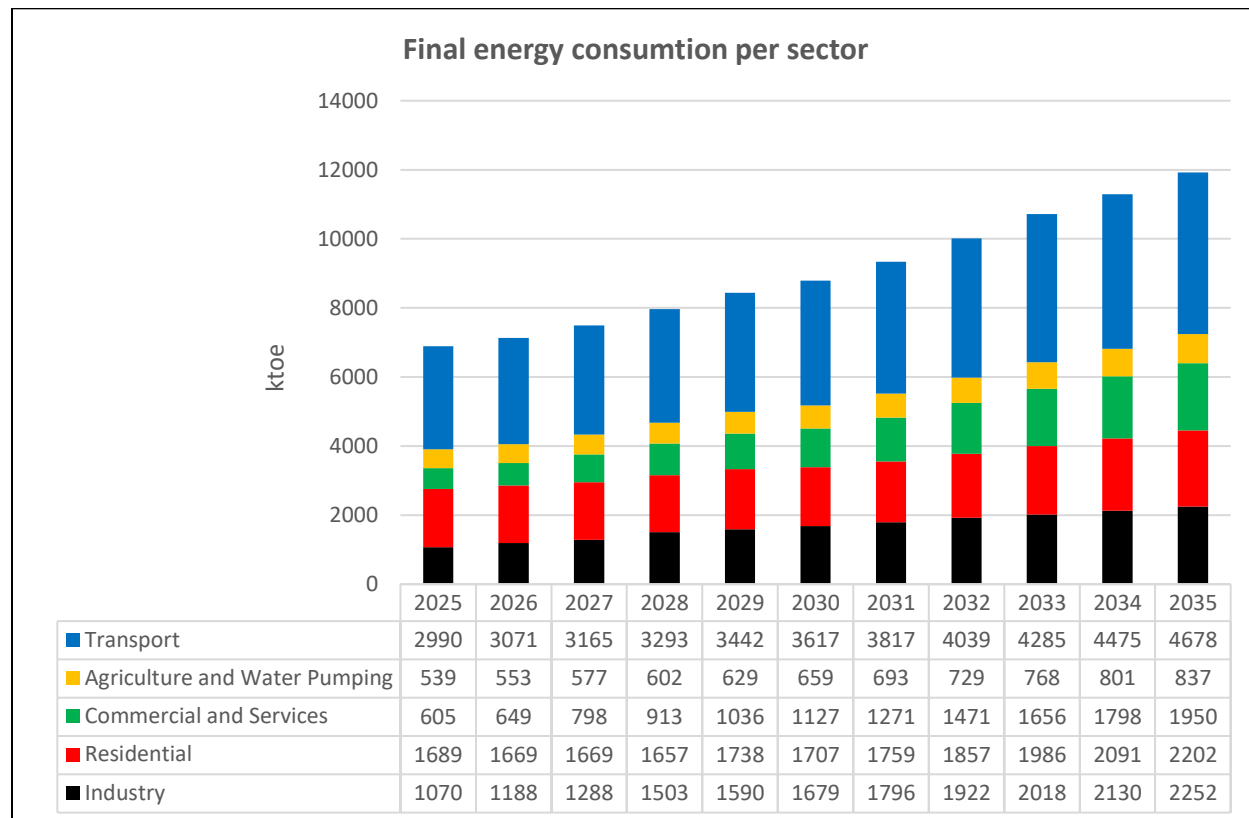


Figure 126: Final energy consumption per sector for the period 2025-2035

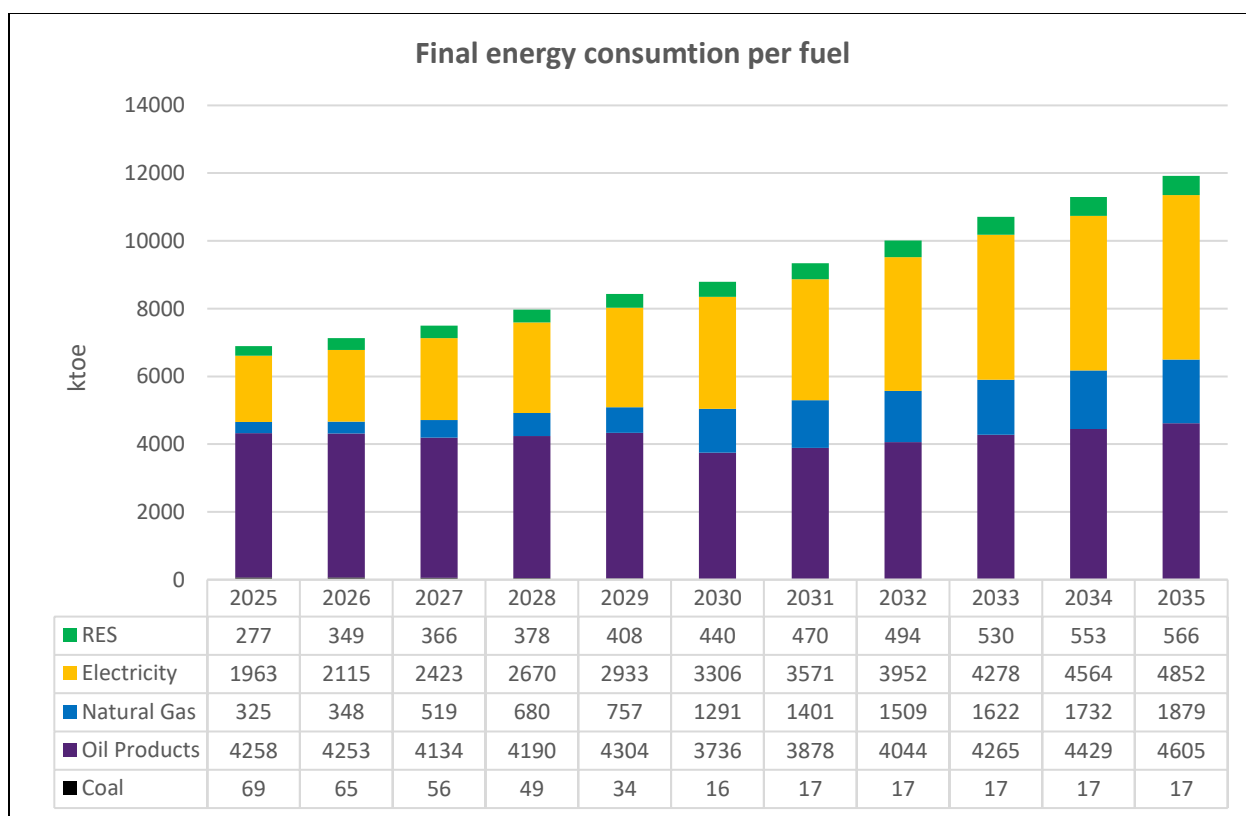


Figure 127: Final energy consumption per fuel for the period 2025-2035

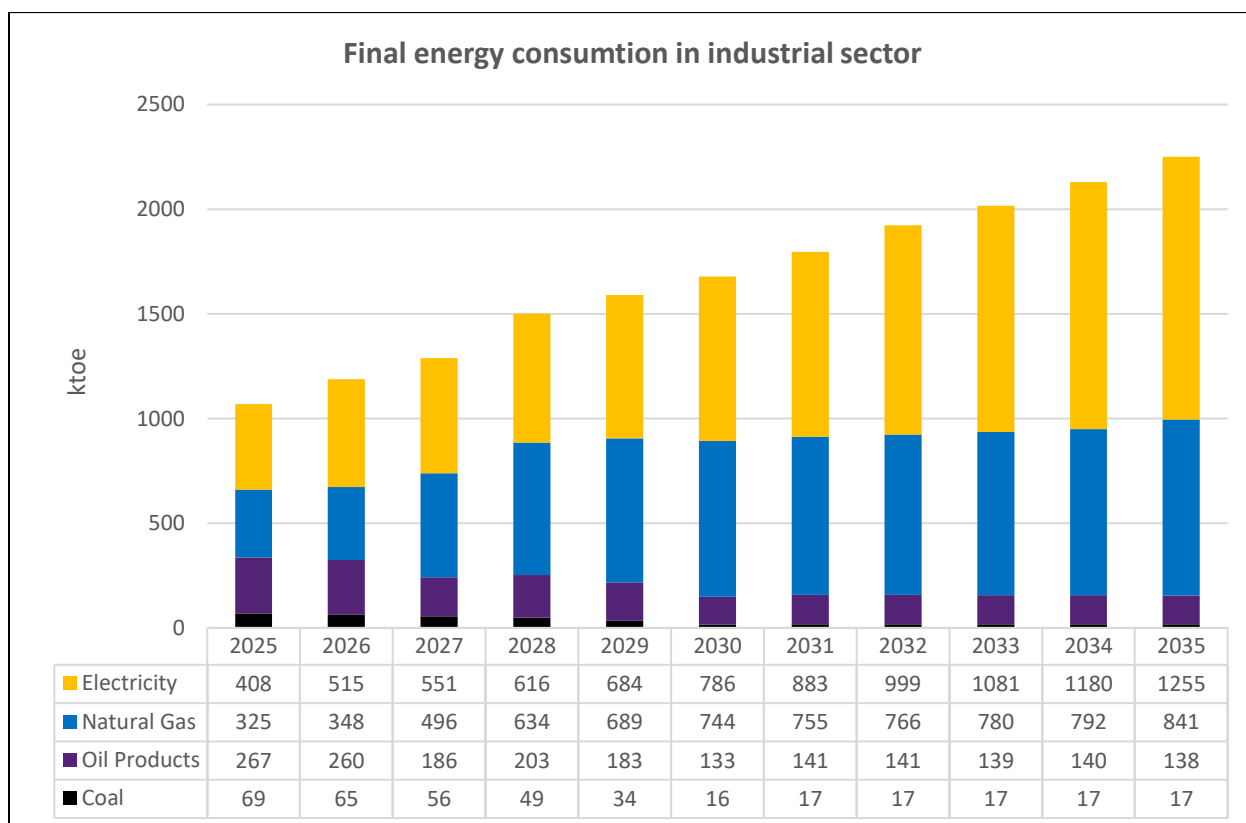


Figure 128: Final energy consumption in the industrial sector for the period 2025-2035

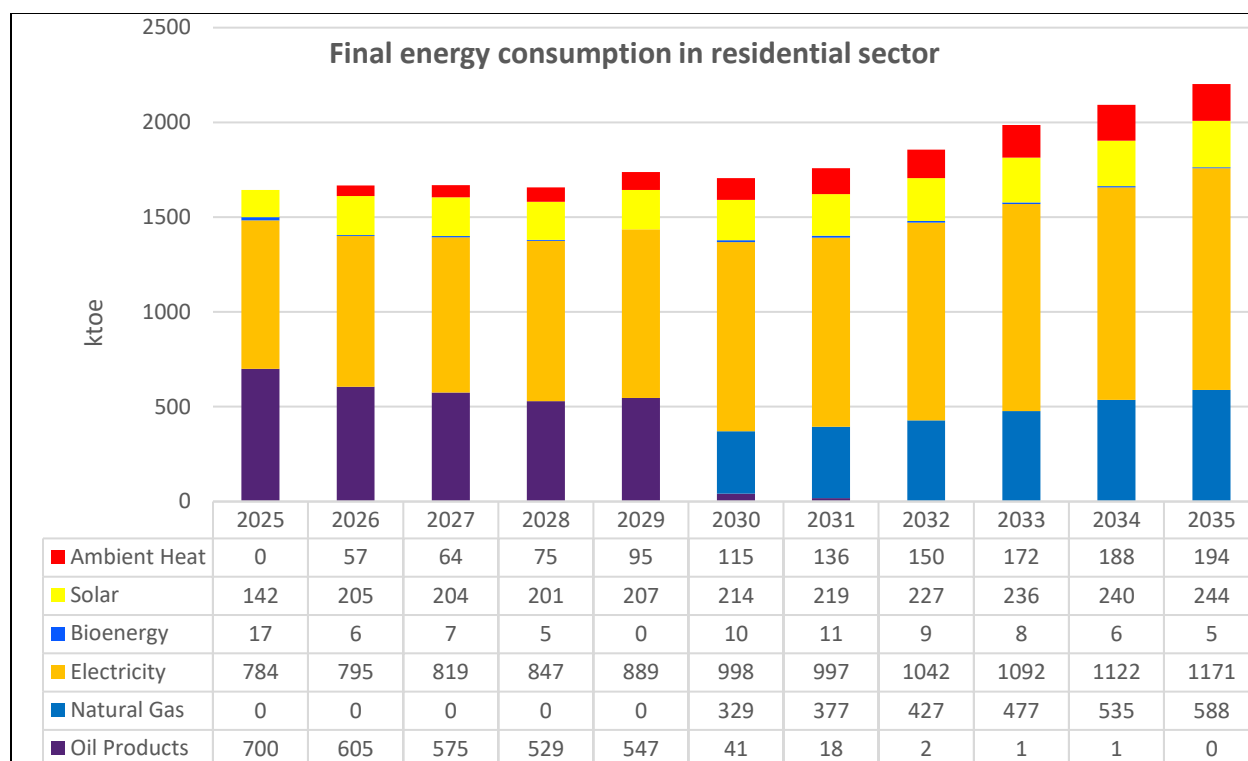


Figure 129: Final energy consumption in the residential sector for the period 2025-2035

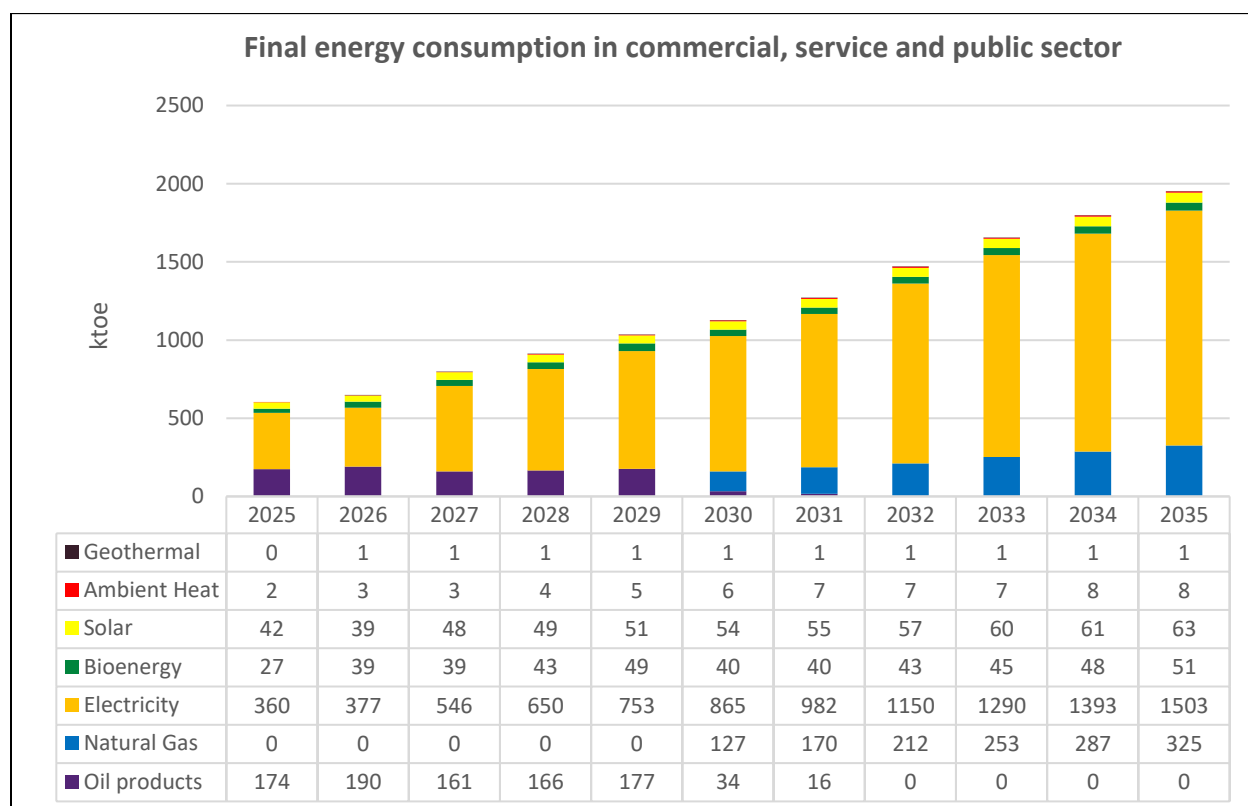


Figure 130: Final energy consumption in the commercial, service and public sector for the period 2025-2035

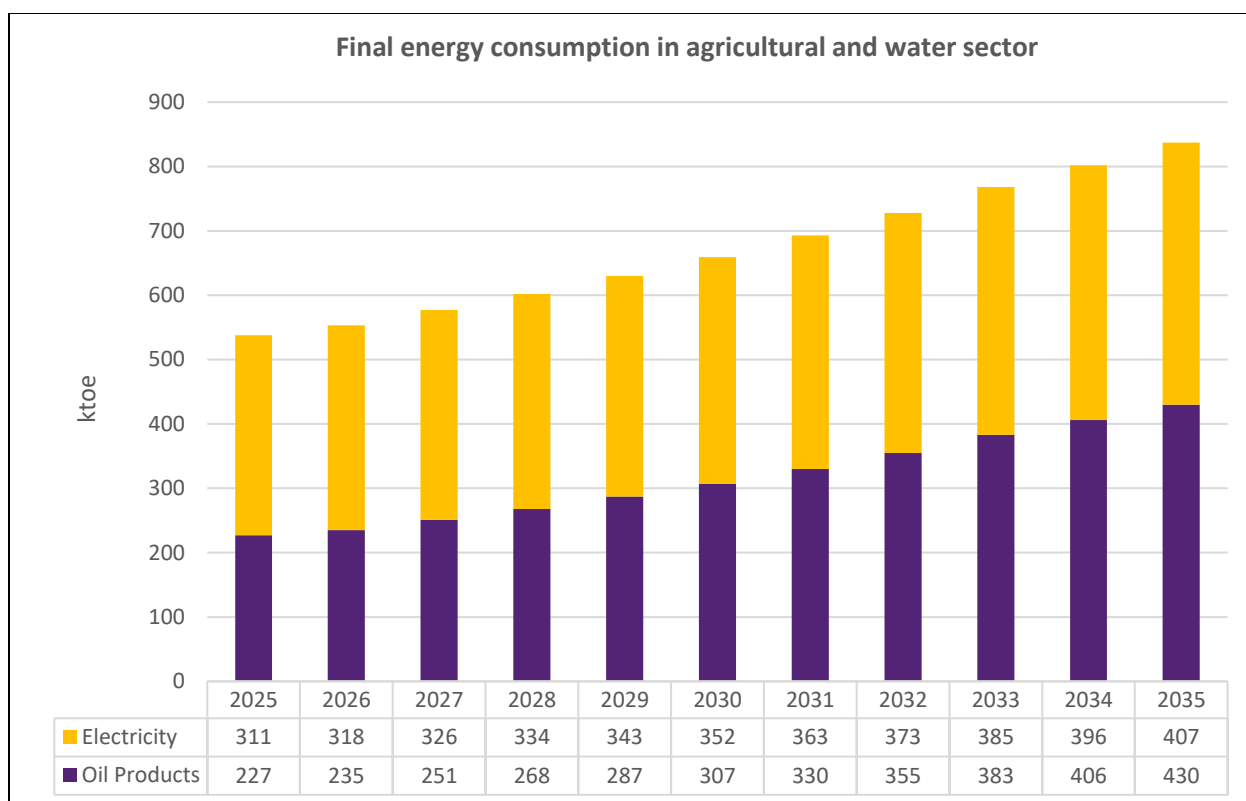


Figure 131: Final energy consumption in the agricultural and water sector for the period 2025-2035

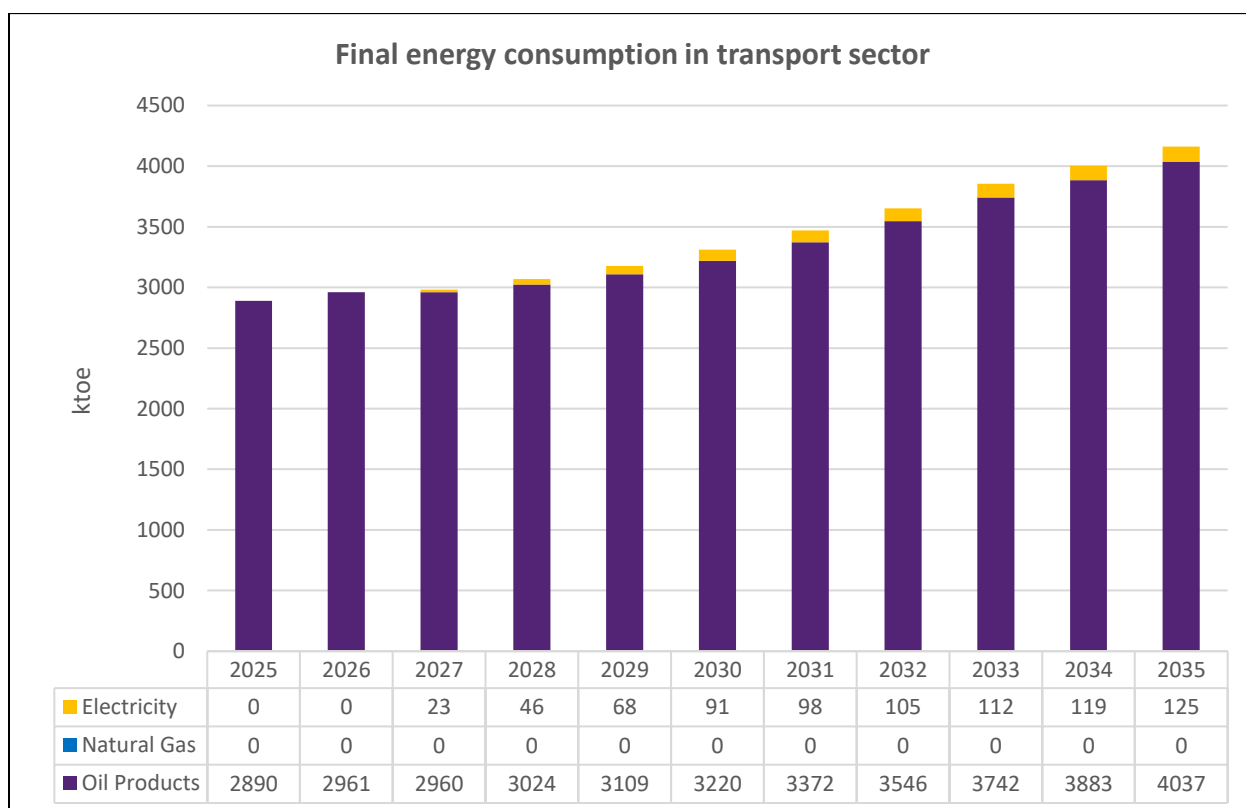


Figure 132: Final energy consumption in transport sector for the period 2025-2035

8.1.3.2 Primary Energy

Due to the anticipated increase in natural gas production from the Risha gas field, a significant rise in primary energy production is expected over the next decade. Additionally, the large-scale integration of renewable energy into the power system as well as its use in green hydrogen and ammonia production will further contribute to the overall growth in primary energy output.

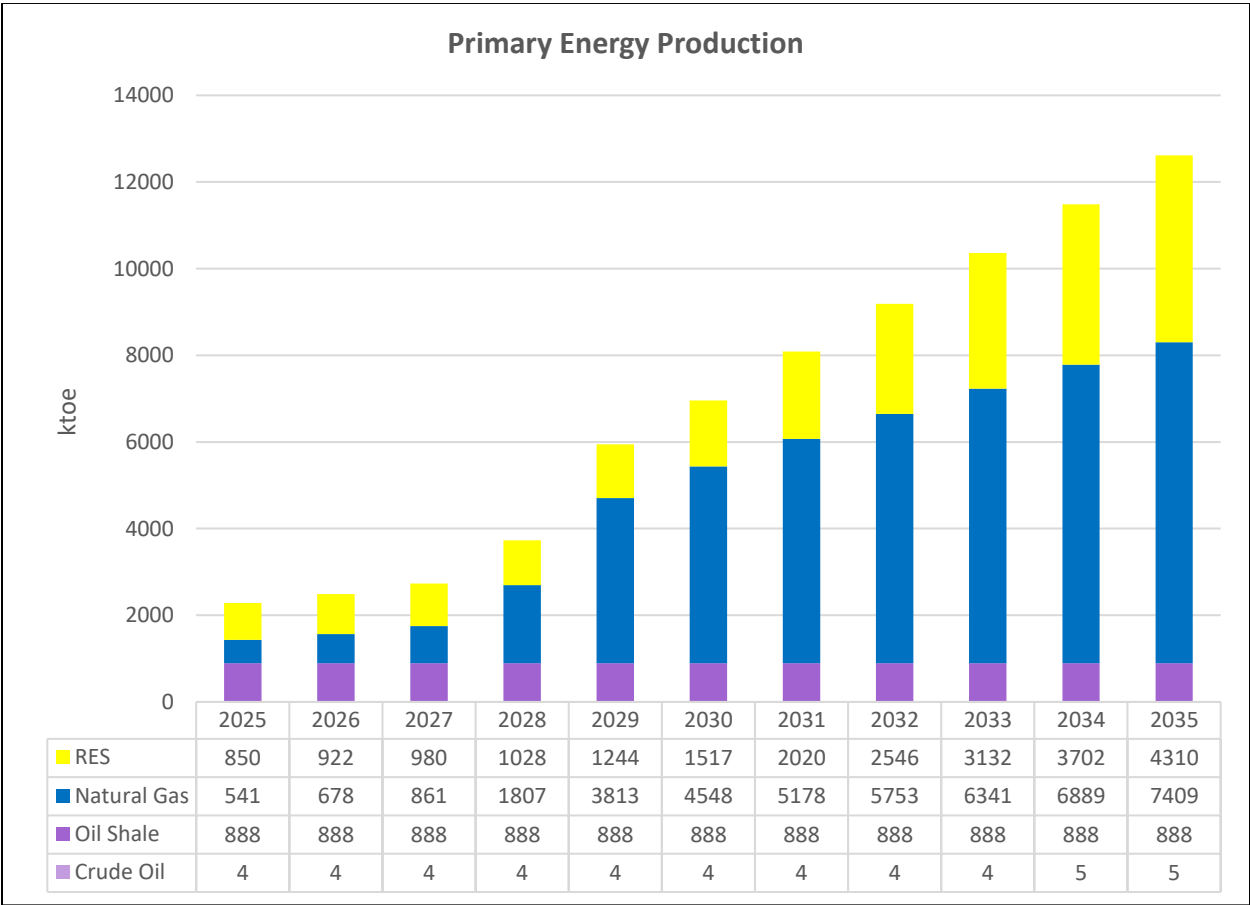


Figure 133: Primary energy production for the period 2025-2035

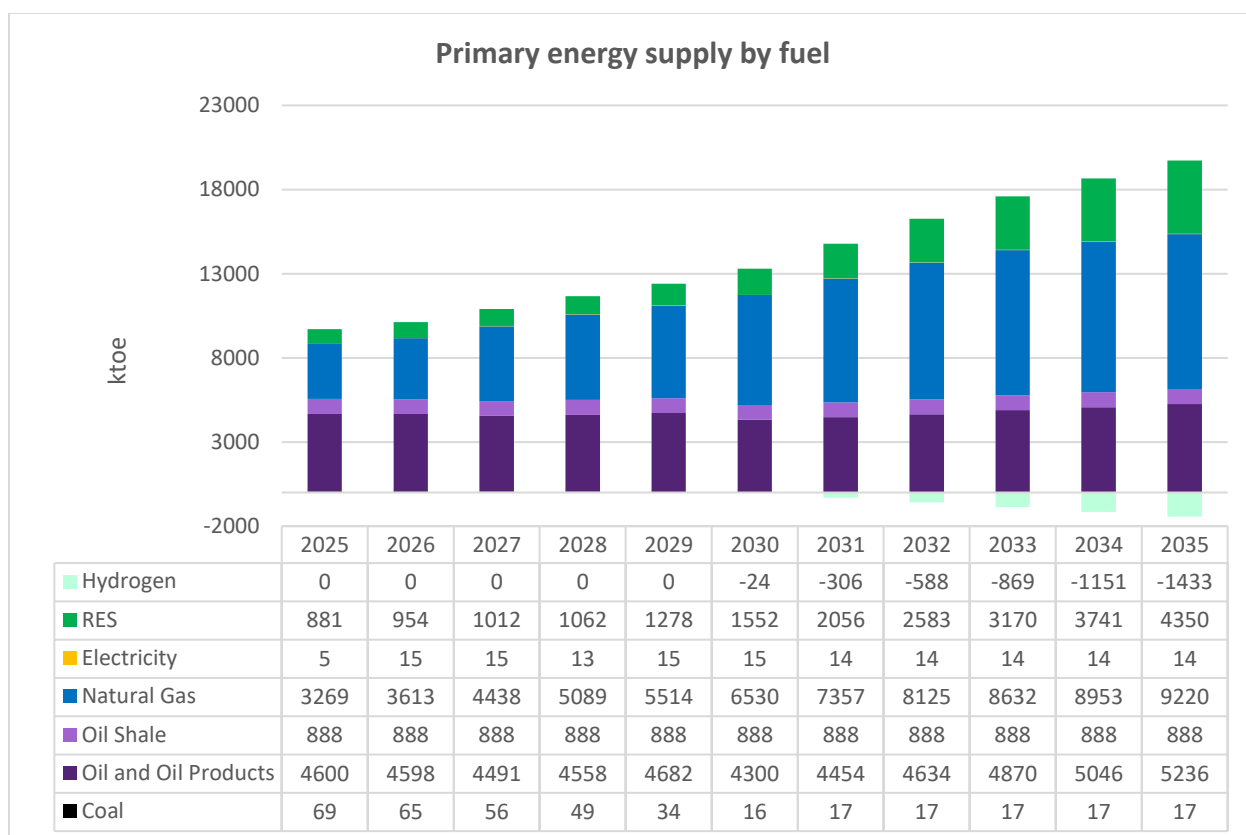


Figure 134: Primary energy supply by fuel for the period 2025-2035

8.1.3.3 Energy import and export

Increased domestic gas production, coupled with the expansion of hydrogen and ammonia industries and a significant rise in renewable energy generation, enhances the country's energy security. Consequently, energy import dependency is projected to decline sharply from 76.3% in 2025 to 28.6% by 2035, representing a major step toward greater self-sufficiency and resilience in the energy sector.

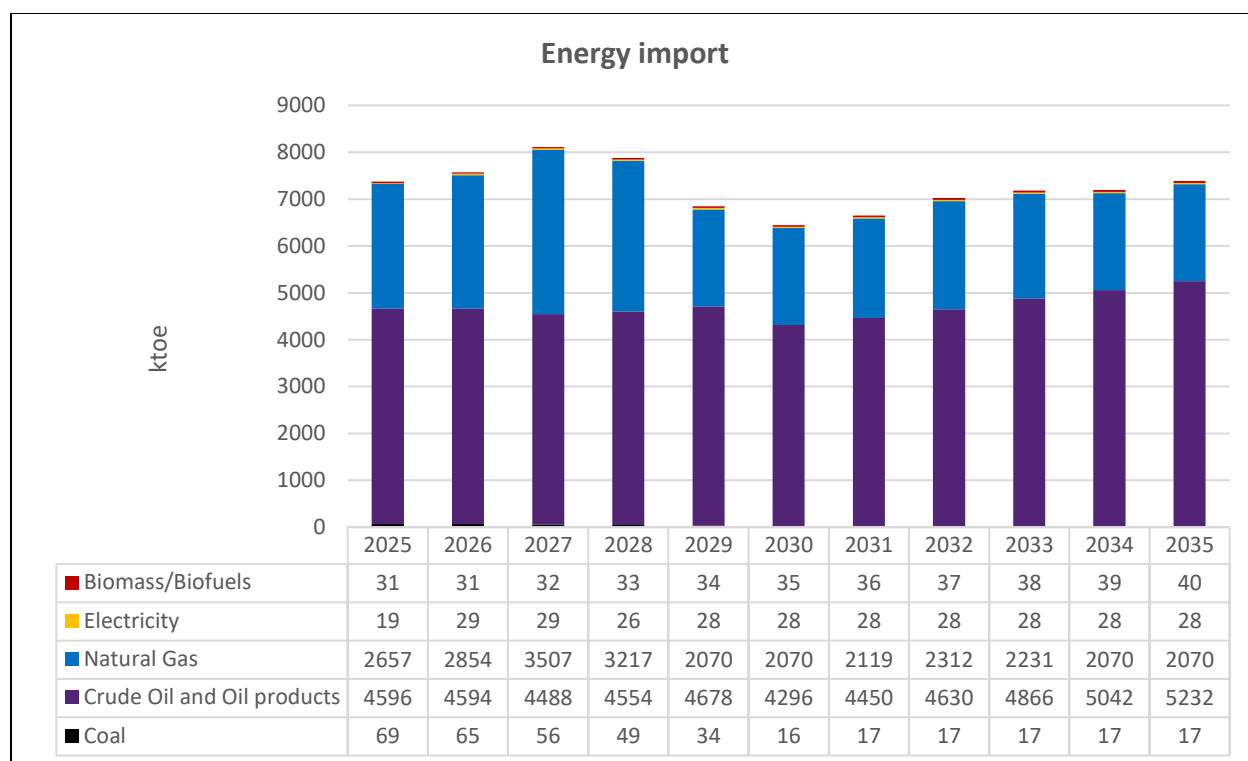


Figure 135: Energy import for the period 2025-2035

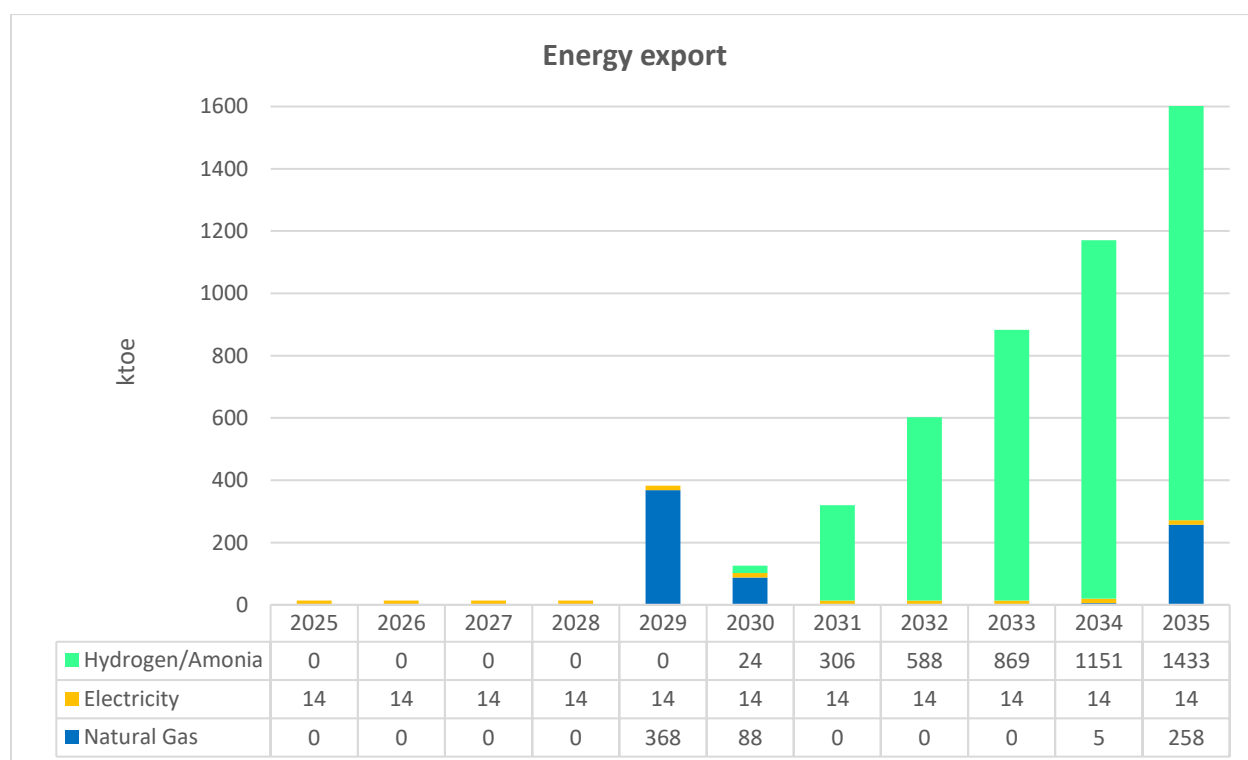


Figure 136: Energy export for the period 2025-2035

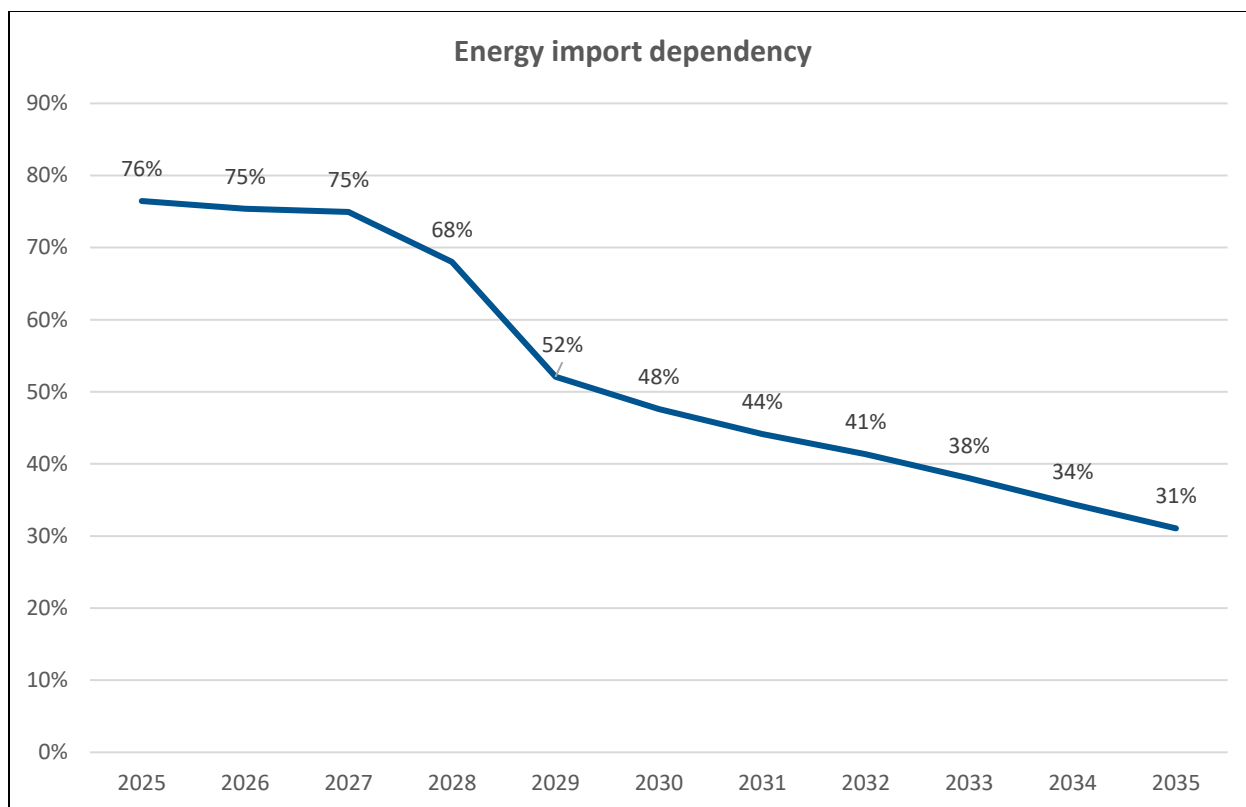


Figure 137: Energy import dependency

8.1.3.4 Electricity sector

The electricity sector is well diversified, relying on a mix of energy sources for power generation. In Pathway II, electricity production is expected to be primarily based on natural gas, supplemented by an increasing share of renewable energy, particularly from solar power plants. Renewable generation is projected to reach approximately 40% of total electricity production by 2035.

Overnight investment costs reflect a primary focus on natural gas power plants, alongside substantial investments in solar power and the PHES Mujib project, which is crucial for enhancing system flexibility and supporting greater renewable integration. Additional renewable deployment after 2030 is facilitated by the deployment of battery energy storage systems.

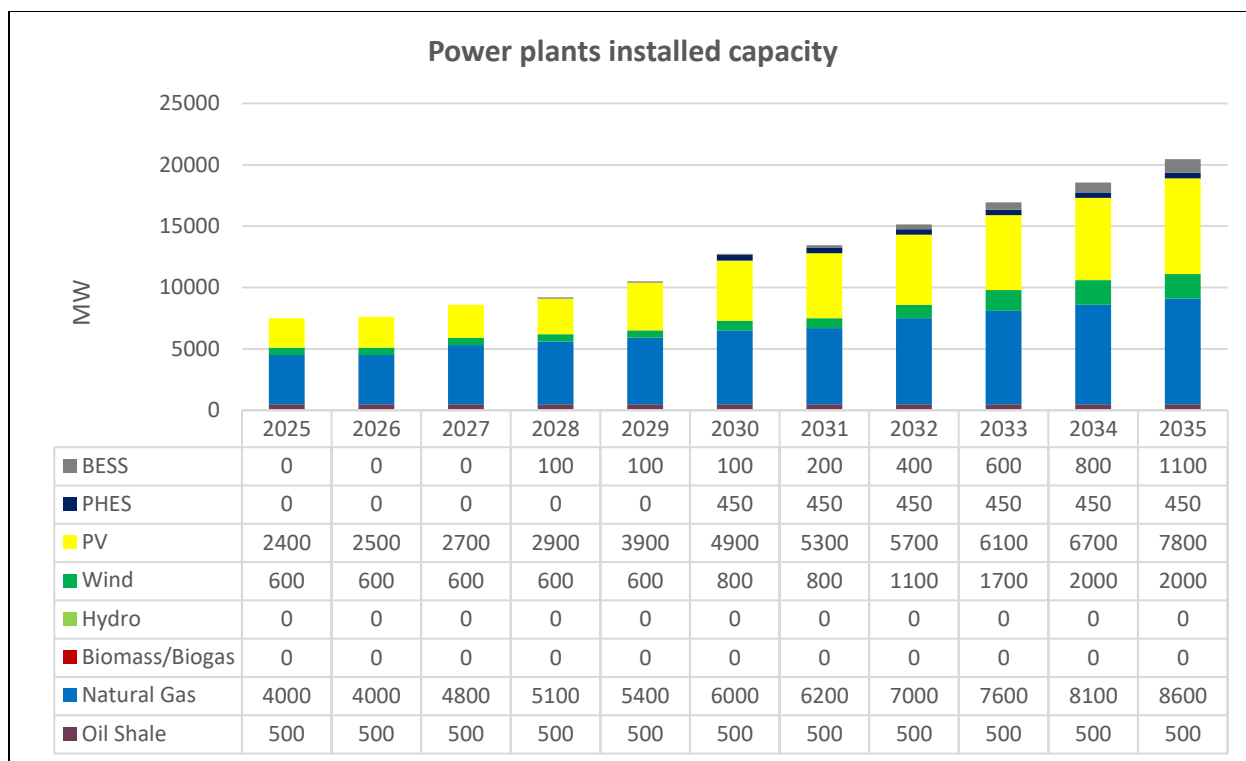


Figure 138: Installed capacity per type of power plants in the period 2025-2035

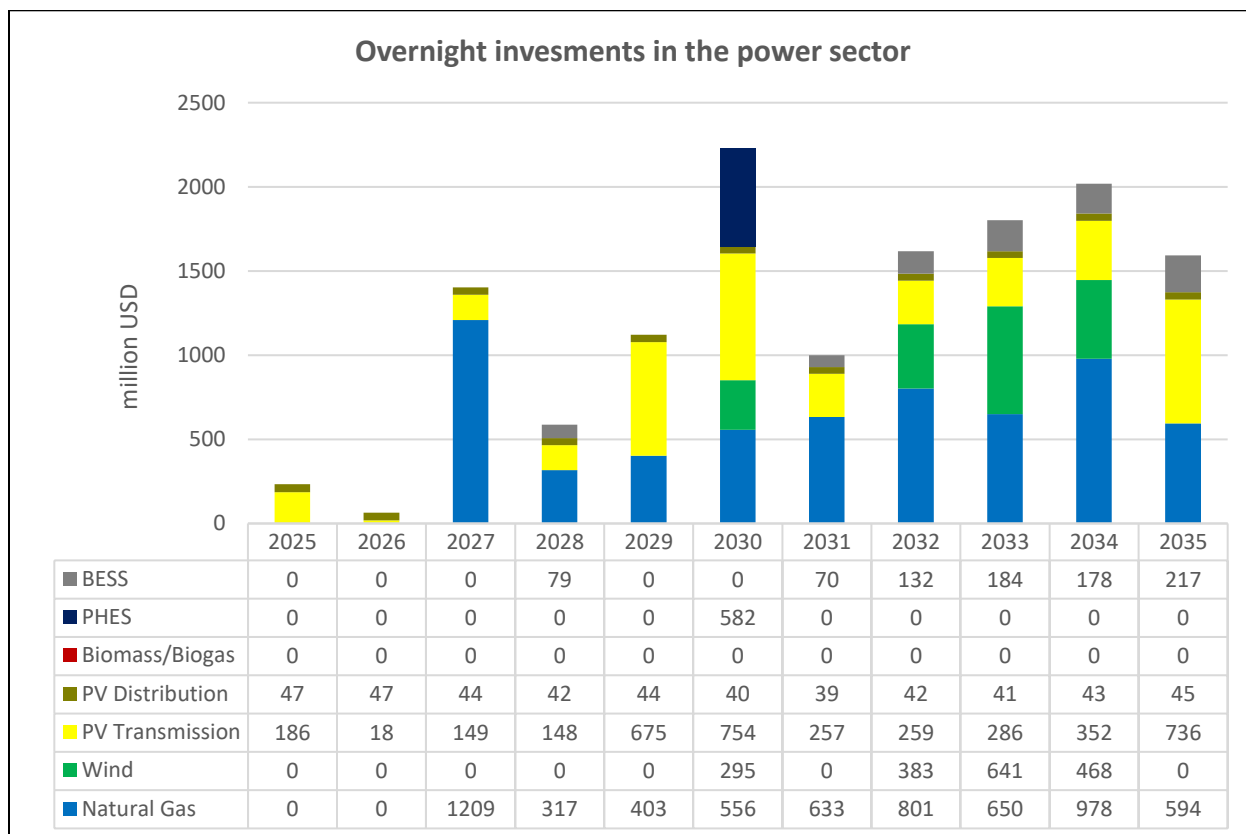


Figure 139: Overnight investment costs in the power system in the period 2025-2035

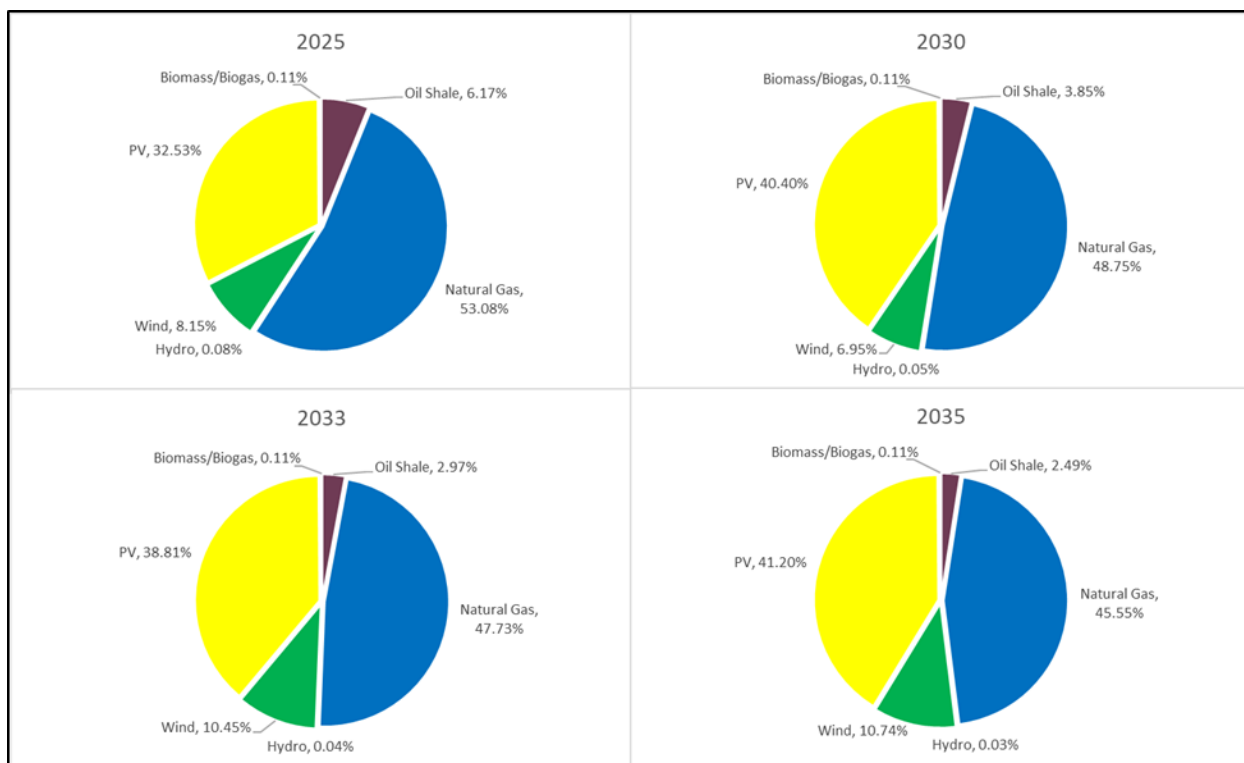


Figure 140: Share of the installed capacity per type of power plants in 2025, 2030, 2033 and 2035

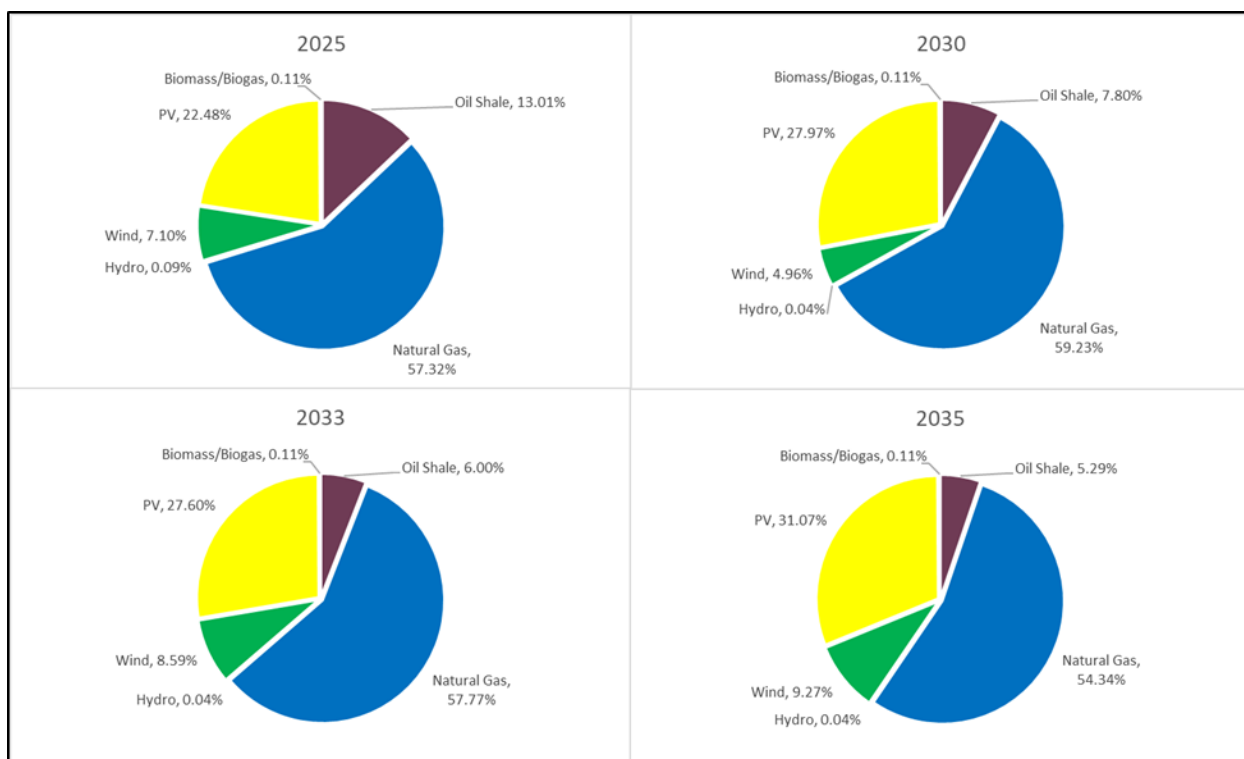


Figure 141: Share of the produced electricity per type of power plants in 2025, 2030, 2033 and 2035

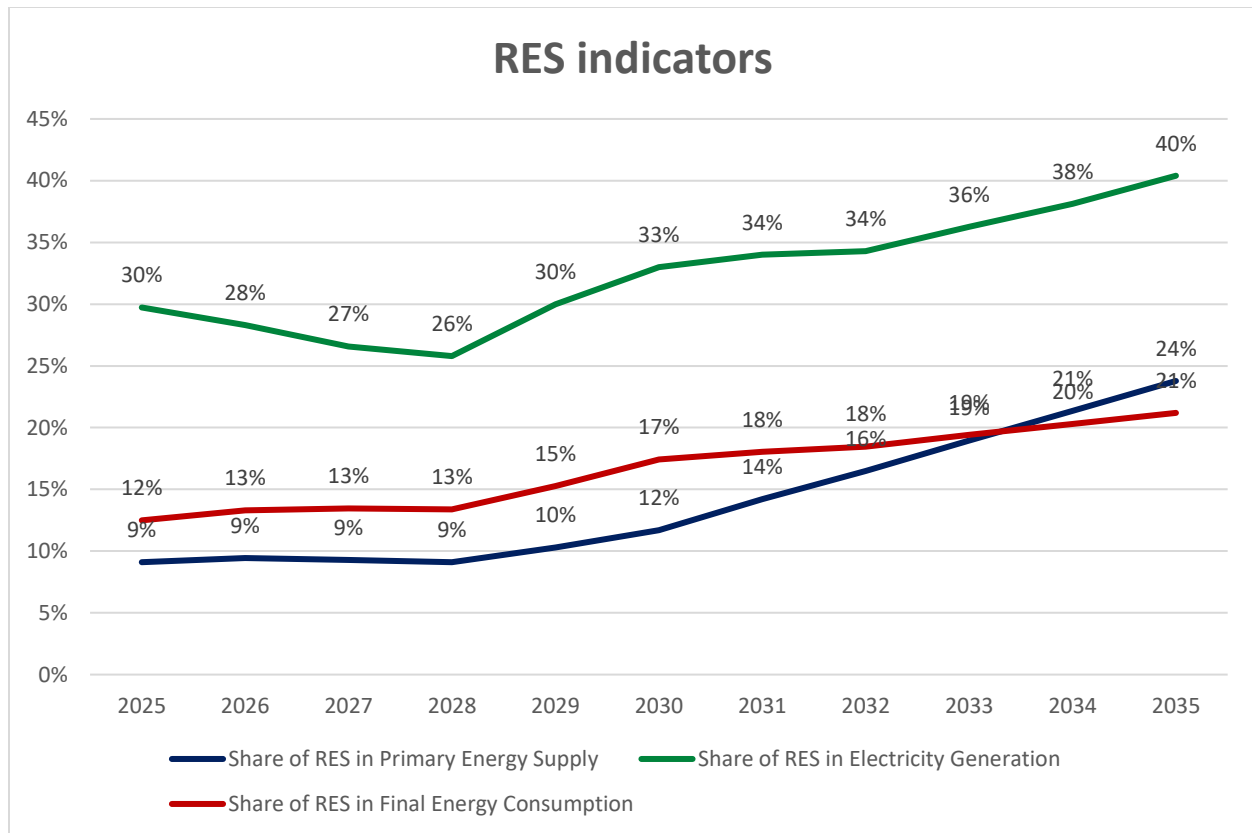


Figure 142: Indicators for RES penetration in the period 2025-2035

8.1.3.5 Disbursement Plan

The next figures show, respectively, the estimated annual investment for the generation system, broken down by technology type, and the estimated investment in both generation and transmission for the Optimistic Pathway. For this scenario, the average annual investment requirement amounts to USD 1162 million, of which USD 1049 million per year would be allocated to generation expansion, and the remaining USD 113 million per year would be directed toward the expansion and upgrading of the transmission system.

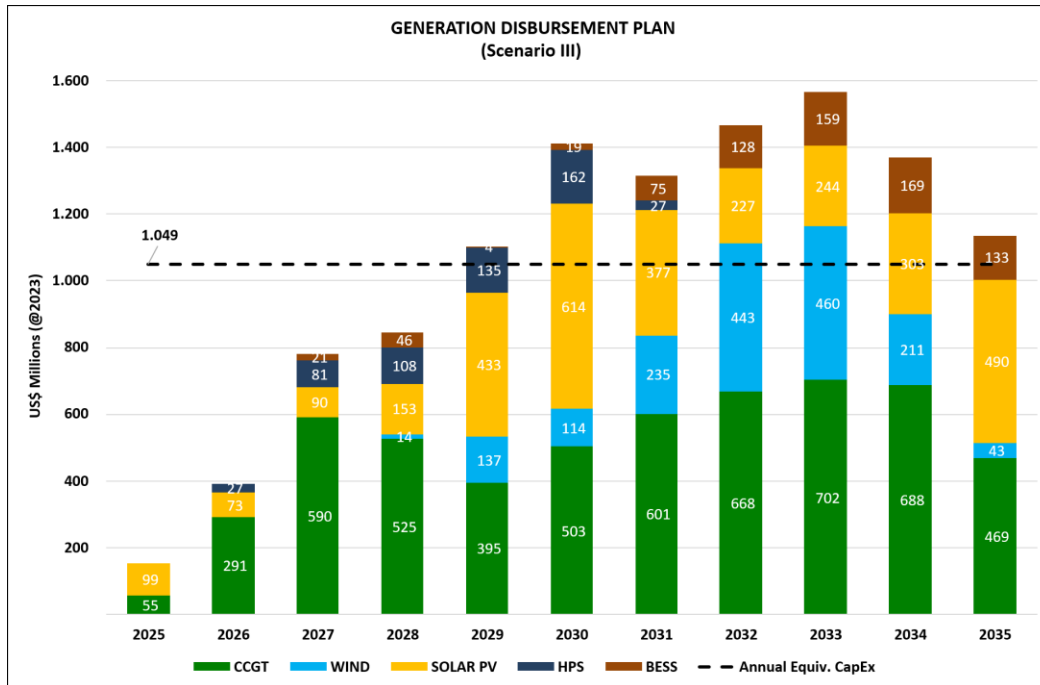


Figure 143: Generation Disbursement Plan (Pathway III)

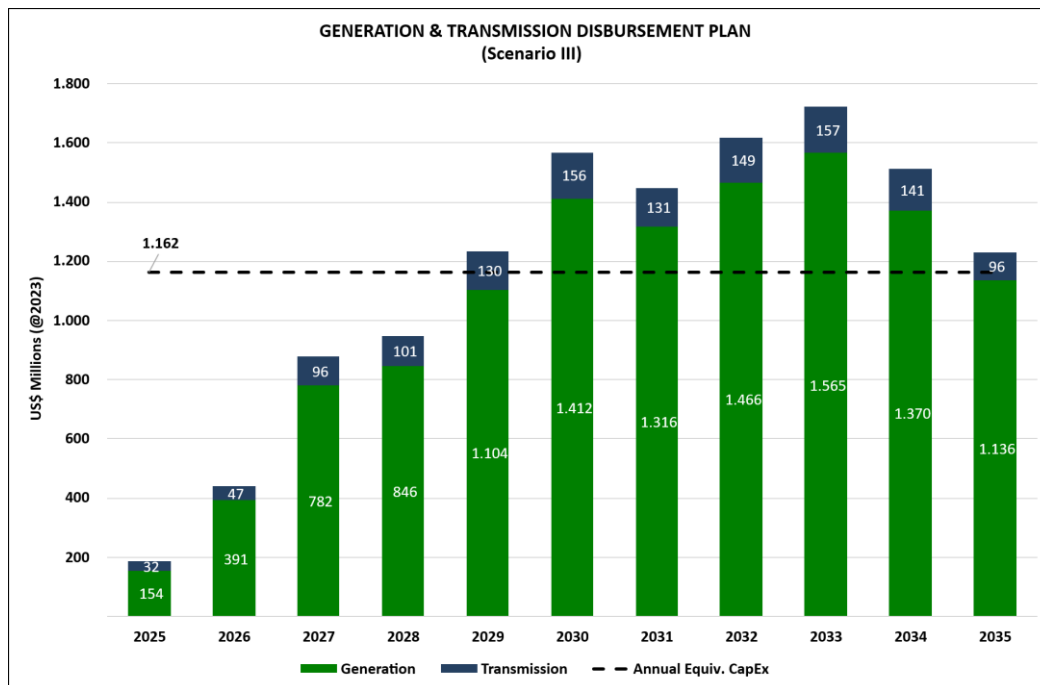


Figure 144: Generation and Transmission Disbursement Plan (Pathway III)

8.1.3.6 GHG emissions

The higher penetration of renewables, along with increased adoption of electric vehicles, leads to a substantial reduction in GHG emissions in the Pathway III. Sector-specific and total emission outcomes are presented in the following graphs and tables.

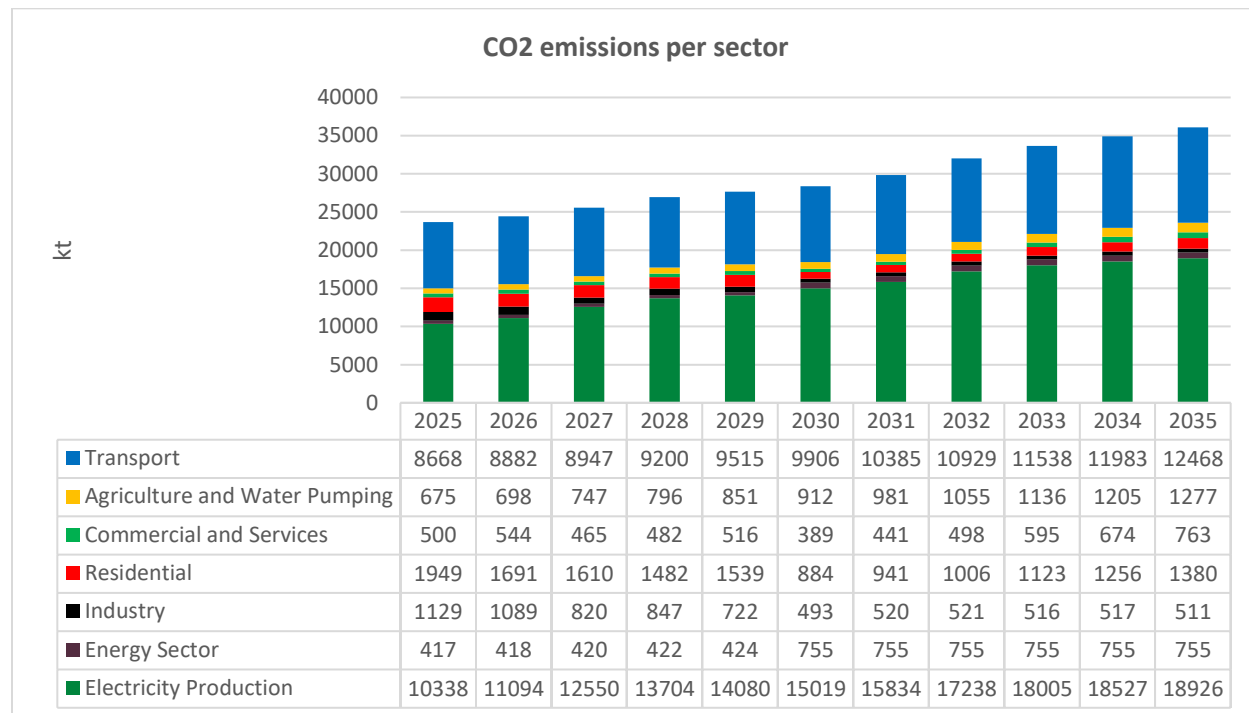


Figure 145: CO2 emissions by sector in the period 2025-2035

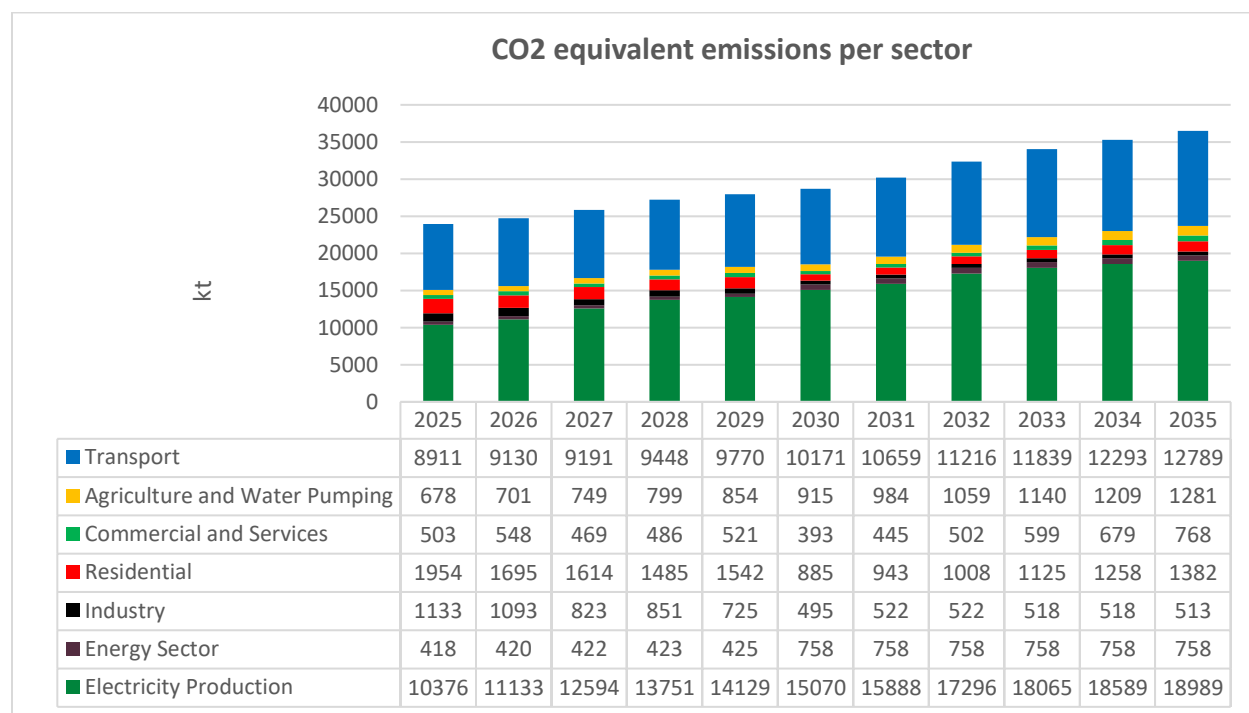


Figure 146: CO2 equivalent emissions by sector in the period 2025-2035

8.1.4 Power System Analysis

Renewable energy sources, particularly photovoltaic and wind power, have presented new challenges for power systems. The large-scale integration of these sources is a central component of Jordan's national development vision, supporting the transition to a more sustainable and environmentally responsible energy system. A key objective of Jordanian energy strategy is to generate 50% of the country's electricity from renewable sources by the year 2033.

Due to the natural variability of solar and wind energy production, their integration into a power system with respect to both, infrastructure management and control of energy flow in real-time is a real challenge. Furthermore, electricity demand will become less predictable and more variable due to the electrification of transport and heat.

Connection requirements for renewable energy sources encompass the technical, operational, and regulatory criteria established to enable the safe and efficient incorporation of these resources into the transmission grid. The primary objective of these requirements is to ensure the security of supply, as well as the stability and reliability of the electrical system, while accommodating an increasing share of renewable generation.

The relatively small size of Jordan's electricity system and its limited interconnections with neighboring countries mean that the shift towards an energy mix with a high share of renewable generation must be carefully planned and implemented, with due consideration given to potential dynamic constraints.

The dynamic behavior of a power system refers to how the electrical network responds over time to disturbances, changes in load, or system faults. It involves the study of transient, oscillatory, and steady-state responses to such events to ensure stability of the power system.

In the case of non-synchronous generation (such as photovoltaics and wind), the following characteristics must be taken into consideration:

- Variability of power generation;
- Impact on frequency management and balancing requirements;
- Impact on voltage and reactive power management;
- Reduction of system inertia;
- Variability of short-circuit currents;
- Geographic distribution of renewable generation across different locations;
- Changes in electrical flow patterns.

A comprehensive analysis is required to enable the safe integration of renewable energy sources into the power system, while maintaining a high level of security of supply.

The steady state and dynamic stability analyses of the power system were conducted as part of the comprehensive project "Grid Integration Study for Renewable Energy Sources in the Jordanian Electricity System", carried out by Elia Grid International (EGI).

The results of this study serve as the foundation for the parameterization of the TIMES model, with a particular focus on the 50% renewable energy scenario.

The hourly dispatch and unit commitment of generating units were performed by the DAI technical team, and these results formed the basis for the minimum inertia analysis conducted for the year 2033, when a 50% share of renewable generation was anticipated.

8.1.4.1 Stochastic Dual Dynamic Programming (SDDP) Analysis for Power Sector in 2033

As Jordan continues to increase the share of renewable energy in its power mix while ensuring security of supply and cost-effectiveness, Stochastic Dual Dynamic Programming (SDDP) tools offer a valuable approach for long-term and medium-term electricity system planning under uncertainty.

Jordan's power system faces several challenges:

- High reliance on imported fuels;
- Growing penetration of variable renewable energy (solar and wind);
- Water–energy nexus concerns linked to desalination;
- Pumped hydro and battery storages;
- Limited interconnection capacity with neighboring countries.

Given these conditions, SDDP tools are well-suited to model and optimize Jordan's power system under uncertainty.

In Jordan, where the electricity sector is evolving to accommodate a higher share of solar and wind energy, annual hourly dispatch modeling using SDDP plays a crucial role in capturing the operational dynamics of the power system.

By integrating stochastic inputs (e.g., solar irradiation, wind speeds), SDDP determines the most economical way to dispatch thermal units and energy storages on an hourly basis. SDDP helps quantify expected curtailment levels and required reserves to maintain system reliability while maximizing renewable energy usage.

An SDDP-based analysis was conducted by the DAI technical team for the year 2033, incorporating the following assumptions:

- 50% renewable energy share;
- Operation of the Mujib pumped hydro energy storage (PHES);
- Deployment of battery storage sized at 0.25 MW per 1 MW of new VRE after 2027;
- Increased demand due to data centers and crypto mining;
- Oil shale power plants treated as must-run units due to technical constraints.

The SDDP analysis demonstrates that reaching 50% renewable electricity production requires a significant amount of energy storage capacity, as it is the only viable option to enhance system flexibility without depending on regional interconnections.

In addition to PHES Mujib, the SDDP analysis indicates that an additional 1,500 MW of energy storage with a 4-hour duration is required to reduce unserved energy to zero. Even with this level of storage, annual curtailment of renewable energy is still expected to reach approximately 283 GWh in 2033.

The results of this modelling provided detailed hourly dispatch data, which served as the foundation for assessing minimum system inertia and supporting broader planning decisions.

8.1.4.2 Outcomes of the study “Grid Integration Study for Renewable Energy Sources in the Jordanian Electricity System”

The project “Grid Integration Study for Renewable Energy Sources in the Jordanian Electricity System” aims to define a long-term grid development strategy for the Jordanian power system to enable the integration of an increased share of renewable energy generation capacity by 2030. This initiative builds upon the earlier project “Establishment of a Grid Development Strategy for the Jordanian Electricity System,” focusing on refining its scenarios and aligning the investment model implemented in PLEXOS with the grid model implemented in Power Factory. The work is further supplemented by comprehensive steady-state and dynamic analyses.

Operational Cases and Scenarios for the Jordanian Electricity System

The analyses were conducted across 9 different operational cases:

- Maximum Gross Load;
- Maximum Net Load (Gross Load - RES Infeed);
- Minimum Gross Load;
- Minimum Net Load;
- Maximum RES Infeed in absolute terms (i.e., in MW);
- Maximum RES Infeed in relative terms (i.e., as a percentage of gross load);
- Minimum Inertia;
- High RES and High Load;
- High RES and Low Load.

These analyses were performed for three scenarios:

- Baseline scenario: 31% RES (+a new CCGT)
- Scenario I: 50% RES + new CCGT
- Scenario II: 50% RES + pumped hydro

The 50% RES scenarios incorporate the following developments:

- Additional growth in distributed PV of 279 MW in comparison to the 31% RES scenario
- Five new utility PV plants with a total capacity of 975 MW
- Three new wind farms with a total capacity of 460 MW
- A hydropower plant (King Talal) with an 18 MW capacity
- A biogas power plant (Ghabawi) with a 7 MW capacity.

Moreover, the investment model implemented in PLEXOS identified the addition of a 60 MW / 2h battery energy storage system (BESS) as yielding a positive cost-benefit outcome for the 50% RES + pumped hydro scenario.

Steady-state analysis – main outcomes

The investments identified through the steady-state analysis are necessary to enable the optimal power dispatch defined by the PLEXOS model, while ensuring compliance with the N-1 security criterion in relation to the thermal limits of transmission lines, cables, and transformers, as well as the statutory voltage limits specified in the Jordanian Grid Code.

The “copper plate” model represents an idealized case with no transmission constraints (i.e., infinite transfer capacity), but still incorporates system and economic constraints, such as reserve requirements and take-or-pay fuel contracts. The “grid model” reflects the case where all investments identified as cost-beneficial by the Plexus model have been implemented.

The 31% RES scenario represents a “business-as-usual” case, in which Renewable Energy Sources (RES) account for approximately 34.5% of Jordan’s annual electricity demand in 2030.

In the 50% RES + CCGT scenario, RES penetration reaches 44.7%; however, this value decreases to 38.3% of annual demand when grid constraints are taken into account. RES curtailment occurs mainly due to system and economic limitations, representing 18.8% of available RES generation in the copper plate model and 20.4% in the grid-constrained model.

In comparison, the inclusion of the Mujib Pumped-Hydro Storage (PHS) unit instead of a new CCGT plant improves RES integration. In this case, RES generation covers 49.7% of annual demand in the copper plate model and 47.9% when grid constraints are considered. RES curtailment is approximately 10%, with the majority caused by system and economic constraints.

There are instances when RES generation is very high, presenting operational challenges for the system. In the 31% RES scenario, variable RES generation meets at least 80% of the load for 7.7% of the time. In the 50% RES scenario, variable RES generation surpasses the load for more than 20% of the time, and available RES generation meets or exceeds 80% of the load for over 30% of the time.

The following figures illustrate the percentage of annual load met by Renewable Energy Sources in each scenario, as well as the annual RES curtailment across the different scenarios.

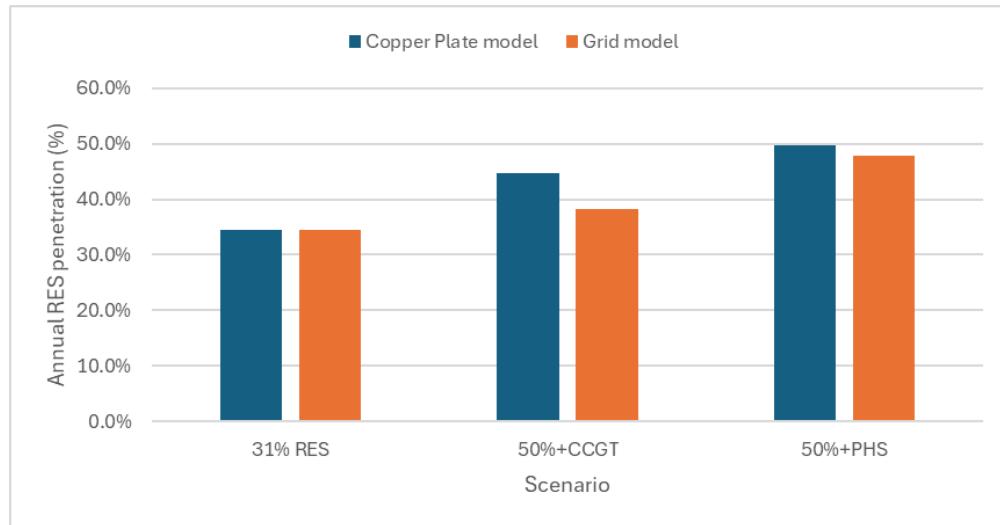


Figure 147: Annual RES penetration in different scenarios²⁶

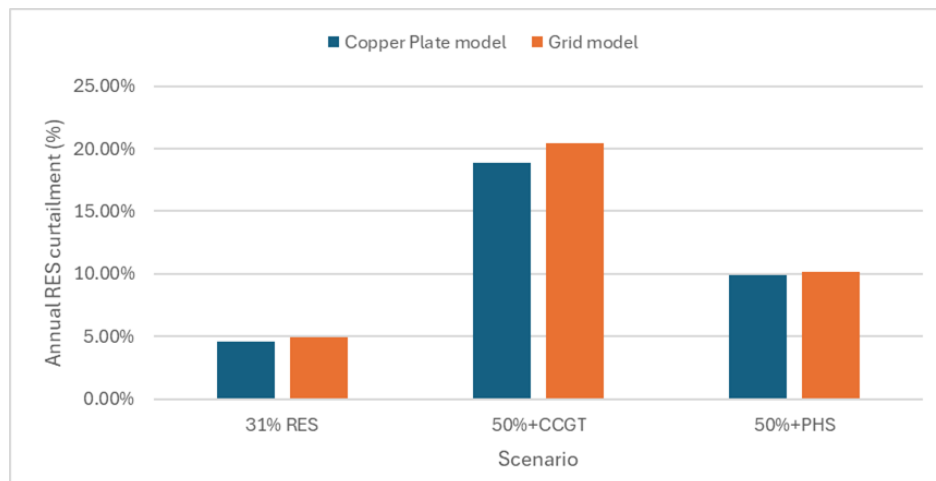


Figure 148: Annual RES curtailment in different scenarios²⁷

The primary outcome of the steady-state analysis is the identification of necessary grid investments, driven mainly by the anticipated increase in electrical demand by 2030. Most of these investments are common across the examined scenarios, providing a robust and resilient pathway for the development of the transmission grid.

The required grid reinforcements have been incorporated into the Electricity Sector Master Plan for the period 2023–2035.

An important finding is that the Jordanian power system is expected to experience significant load variations within a 12-hour period, particularly from December to February. These variations will present a challenge for the system's steady-state voltage control, necessitating more frequent adjustments to reactive power compensation equipment.

²⁶ Source: Grid Integration Study for Renewable Energy Sources in the Jordanian Electricity System

²⁷ Source: Grid Integration Study for Renewable Energy Sources in the Jordanian Electricity System

The harmonic analysis indicated that a significant number of transmission nodes may experience unacceptable levels of harmonic distortion by 2030. However, further investigation is required before drawing definitive conclusions. This should include more detailed data on the harmonic injection profiles of individual RES plants and major loads (e.g., large industrial facilities), as well as a more accurate representation of the frequency-dependent impedance characteristics of transmission lines and transformers.

Dynamic analysis – main outcomes

The dynamic report aims to assess the challenges associated with the dynamic operation of the system across different levels of renewable energy integration, as defined by the three scenarios considered. Through a comprehensive analysis of critical operating modes, the study seeks to identify and propose optimal network measures that address these dynamic issues, while preserving the targeted levels of RES generation. The objectives of the study are defined as follows:

- Evaluate the dynamic stability of the system in accordance with NEPCO’s transmission planning criteria, including:
 - Frequency stability
 - Rotor-angle stability
 - Dynamic voltage stability
- Propose cost-effective mitigation measures for the identified dynamic constraints and demonstrate their effectiveness.

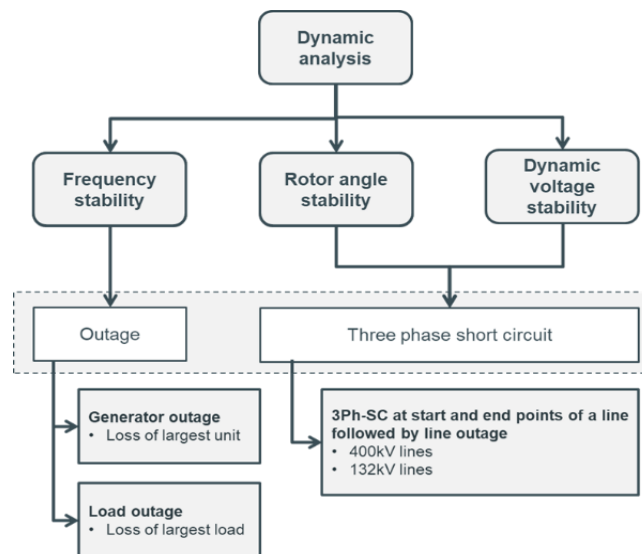


Figure 149: Summary of Dynamic Analysis (source: Grid Integration Study for Renewable Energy Sources in the Jordanian Electricity System)

Accordingly, a comprehensive assessment of the Jordanian transmission system’s dynamic stability, including transient, frequency, and voltage behavior, was conducted for three distinct RES integration scenarios across a selected set of critical operating conditions. These operating modes were chosen to capture those instances where the system is expected to experience its highest dynamic stresses following specific disturbances and contingencies. Prior to conducting the analyses, the network model was

initialized for dynamic simulations, allowing for the identification and correction of any deficiencies within the model.

For the 31% RES scenario, the system load is projected to reach a peak of 5425 MW, with a minimum load of 1587 MW and an annual average of 3099 MW. When the distributed PV infeed is accounted for, the minimum load in this scenario decreases further to 988 MW.

For the 50% RES scenarios, the system load is projected to have a peak of 5434 MW, a minimum load of 1699 MW, and an annual average of 3158 MW. When considering the distributed PV infeed, the minimum load similarly decreases to 988 MW. Notably, although the 50% RES scenarios feature a larger distributed PV capacity, this is counterbalanced by a higher overall demand, resulting in the same minimum load at the transmission level as in the 31% RES scenario.

To assess frequency stability, the outages of the largest generating units in each operating mode were simulated, along with the loss of the highest load levels for specific cases: Maximum Gross Load and Minimum Gross Load for the 31% RES scenario, Maximum Net Load and Minimum Net Load for the 50% RES CCGT scenario, and Maximum Net Load, Maximum RES Infeed (as a percentage), Minimum Net Load, and Minimum Inertia for the 50% RES PHS scenario.

To evaluate transient and voltage stability, three-phase faults were simulated at both ends of all 400 kV and 132 kV lines, followed by the disconnection of the faulted line after 60 ms. The system's transient stability was assessed based on three criteria: first, by verifying that generators remained synchronized with the grid under fault conditions (rotor angle stability), second, by analyzing the damping of electromechanical oscillations to confirm that the system possessed adequate damping torque, and third, by assessing the recovery of voltage at the terminals of connected renewable energy sources following a fault, to evaluate the dynamic voltage stability of the system.

A comprehensive examination of the aforementioned faults across a range of operating conditions was conducted to assess the small-signal stability of the system. Small-signal stability is a critical aspect of power system dynamics, as it evaluates the ability of the system and its components to dampen oscillations following disturbances. By analyzing the system's response to three-phase faults on the 132 kV and 400 kV lines, followed by their disconnection, instances of small-signal instability were identified, facilitating the formulation of appropriate mitigation measures.

System stability issues were identified across all three scenarios, arising from multiple factors:

- Inappropriate settings of certain Automatic Voltage Regulator (AVR) parameters on specific generators within the system.
- Insufficient system inertia (kinetic energy) due to the limited number of connected synchronous generators, resulting in reduced support for voltage stability.
- Inadequate reserve margins during isolated system operation, particularly in the absence of the Egypt interconnection.

AVR-related issues were identified across all scenarios and addressed by proposing targeted adjustments to specific AVR control parameters, based on a thorough technical assessment. In addition, the rotor angle stability analysis for the 50% RES scenarios revealed further deficiencies in the AVR settings, which were subsequently corrected and implemented in the final models.

The initial assessment indicated that, under the 50% RES scenarios, the network's dynamic response was insufficient for fault events associated with the loss of the Egypt interconnector, particularly in low-inertia

operating conditions. This limitation was observed in the Minimum Net Load, High RES/Low Load, and Maximum RES Infeed (MW) operational regimes.

When a three-phase short circuit occurs near the Egypt interconnector, the electrical output of synchronous units decreases sharply while their mechanical input remains constant. As a result, the surplus mechanical energy is stored as rotational kinetic energy, causing the synchronous units to accelerate. The low-inertia nature of the system intensifies this phenomenon. In the post-fault period, following disconnection of the interconnector, the network's dynamic stability becomes critically reliant on the limited inertia of the connected synchronous units, making recovery more challenging and the system more sensitive to instability.

To mitigate these issues and enhance the network's dynamic behavior under low-inertia conditions, the installation of synchronous condensers is proposed, providing additional rotational inertia, improved damping of electromechanical oscillations, and enhanced dynamic voltage support.

For the 50% RES CCGT scenario, a total of 200 MVA of synchronous condensers were identified as necessary to address transient stability issues following faults and the loss of the interconnector to Egypt.

In the 50% RES PHS scenario, a total of 250 MVA of synchronous condensers was identified as necessary to improve system damping and ensure stable operation. It is important to note that the observed optimal sizing (2×125 MVar) is feasible only after appropriate tuning of the AVR settings of the pumped hydro storage units.

The analysis confirms that the system remains resilient to Low Voltage Ride-Through (LVRT) and High Voltage Ride-Through (HVRT) violations across all examined fault scenarios and operational regimes, underscoring the effectiveness of the investments and modifications implemented during the steady-state analysis.

8.1.4.3 Minimum inertia assessment

Achieving the target of 50% renewable electricity generation in Jordan by 2033 will require a strengthened transmission grid to enable smooth and reliable integration. At the same time, the large-scale deployment of renewables will result in periods with very high shares of renewable generation, leaving only a limited contribution from conventional generators.

Large conventional generators units provide inertia which is critical for the existing frequency control process. Inverter based resources like solar/wind/storage do not inherently provide inertia.

Lowering the minimum inertia requirement will reduce the number of conventional thermal units required to remain online, thereby facilitating the integration of a higher share of renewable generation. In this way, the energy that would have been produced by these units can be replaced by available renewable generation that would otherwise be curtailed

In an alternating current (AC) power system, the rotational speeds of grid-connected machines are linked to the system frequency at their terminals. The total mechanical inertia stored in these machines provides a natural resistance to changes in their rotational speed, and, by extension, to fluctuations in the system frequency. As a result, this inherent inertia is a critical parameter that underpins the stable and synchronized operation of modern power systems.

Minimum inertia analysis was separately performed by DAI technical team in order to identify must run generators in the Jordanian power system from the inertia point of view.

Annual average inertia values

The inertia values for each synchronous machine have been obtained from the DIgSilent model provided by NEPCO and are presented in the table below.

Table 17: Inertia values of synchronous generators

Generator	Pn (MW)	H (s) at Sn	Generator	Pn (MW)	H (s) at Sn	Generator	Pn (MW)	H (s) at Sn
AMME GT-1	130	4,00	King Talal Dam Hydro	18	5,71	SAMRA GT-1	100	3,70
AMME GT-2	130	1,59	Mujib Unit Ternary 1	225	5,60	SAMRA GT-2	100	3,70
AMME STM	130	4,00	Mujib Unit Ternary 2	225	5,60	SAMRA GT-3	100	3,70
AQWA GT-11	110	6,80	New CC Gas GT-1	200	2,11	SAMRA GT-4	100	3,70
AQWA GT-12	110	6,80	New CC Gas GT-1	200	2,11	SAMRA GT-5	140	6,00
AQWA GT-13	110	6,80	New CC Gas GT-2	200	2,11	SAMRA GT-6	140	6,00
AQWA STM-10	180	6,17	New CC Gas GT-2	200	2,11	SAMRA GT-7	155	6,50
ATPS STM-3	130	6,00	New CC Gas STM-1	200	4,00	SAMRA STM-1	100	4,83
ATPS STM-4	130	6,00	New CC Gas STM-1	200	4,00	SAMRA STM-2	100	4,00
ATPS STM-5	130	6,00	QATRANA GT-1	130	2,11	SAMRA STM-3	140	6,50
ATTARAT STM-1	235	4,83	QATRANA GT-2	130	2,11	SAMRA STM-4	70	4,00
ATTARAT STM-2	235	4,83	QATRANA STM-1	130	4,00			
Al Ghabawi Biogas	7	5,71	REHAB GT-12	84	4,83			
IPP3 DG-GROUP-1	15	0,48	REHAB GT-13	84	4,83			
IPP3 DG-GROUP-2	15	0,48	REHAB STM-1	80	5,50			
IPP3 DG-GROUP-3	15	0,48	RESHA_N GT-4	30	5,71			
IPP3 DG-GROUP-4	10	0,48	RESHA_N GT-5	30	6,32			
IPP4 DG-GROUP-1	15	0,48						
IPP4 DG-GROUP-2	15	0,48						

Based on the market dispatch and unit commitment of generating units developed for the year 2033, and utilizing the inertia data of each generator, a system inertia assessment was conducted for a critical operational regime.

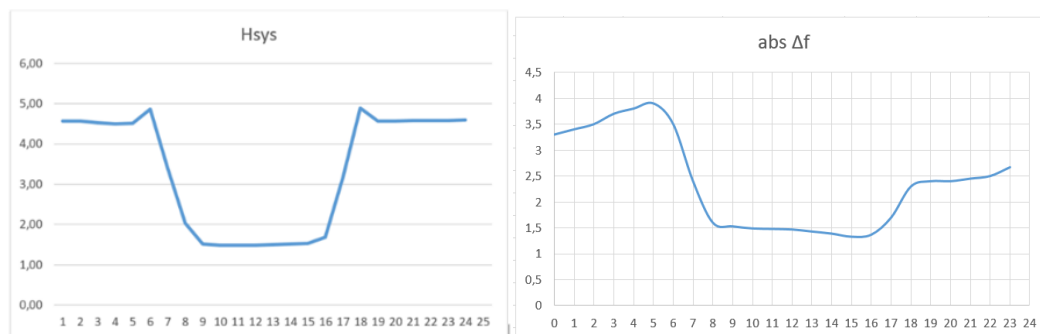


Figure 150: Annually average hourly values of inertia and kinetic energy in the year 2033

The most critical conditions with regard to system inertia occur during the daytime, when PV generation is at its highest and the overall system inertia is at its lowest level.

RoCoF calculations

The oil shale thermal generators (2 x 235 MW) in the Attarat power plants are considered as must-run units due to their production process characteristics, which do not allow for rapid shutdown and restart.

The IPP4 gas generator (243 MW) is also assumed to be in operation to provide voltage and stability support, due the long length of its connecting line.

The following criteria have been used to identify the critical regime:

- The operation of two oil shale thermal units at the Attarat Power Plant (2 × 235 MW) and the 243 MW gas unit at the IPP4 Power Plant;
- Maximum infeed of renewable energy sources (RES).
- Maximum load of system (Inelastic demand plus electric vehicles)

There are more critical hours identified for the year 2033, and one of them is on May 23 at 4:00 p.m. with the following data:

Table 18 – System data used for RoCoF calculations

Date	23/05/2033
Hour	16h
Load	4125 MW
Conventional generators	Attarat: 2x235 MW IPP4: 243MW
RES production	3548 MW
BESS	-136 MW
Import/export from Egypt	0 MW

Cases with the Mujib Pumped Hydro Storage (PHS) facility connected to and disconnected from the grid have been analyzed. In addition, the critical regime has been examined with two synchronous condensers connected to the grid.

Two contingency events have been considered for the RoCoF calculations:

- The loss of one generating unit at the Attarat Power Plant.
- The disconnection of the interconnector to Egypt.

The RoCoF (Rate of Change of Frequency) limit for the Jordanian system is set at 0.7 Hz/s, as defined by NEPCO.

Case 1 – PHS Mujib is not on the grid

The results of the calculations for the loss of one generating unit at the Attarat Power Plant and for the outage of the interconnector to Egypt are presented in the table below.

Table 19: Results of calculations when PHS Mujib is not on the grid

	Event 1 - Outage of one generator in Attarat	Event 2 - Outage of interconnector to Egypt
Hsys	1,811 s	1,811 s
RoCoF	0,643 Hz/s	0,656 Hz/s
Ekin	1926,56 MWs	1926,56 MWs

Ekin/Load	0,467	0,467
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Although the outage of the interconnector to Egypt has a more severe impact on the system, the resulting RoCoF values in both cases are very close to the permissible limit (0.7 Hz/s). As such, these conditions cannot be considered secure for system operation.

Case 2 – PHS Mujib is on the grid

The results of the calculations for the loss of one generating unit at the Attarat Power Plant and for the outage of the interconnector to Egypt are presented in the table below.

Table 20: Results of calculations when PHS Mujib is not on the grid

	Event 1 - Outage of one generator in Attarat	Event 2 - Outage of interconnector to Egypt
Hsys	2,608 s	2,608 s
RoCoF	0,449 Hz/s	0,477 Hz/s
Ekin	2376,566 MWs	2376,566 MWs
Ekin/Load	0,576	0,576

With the PHS Mujib connected to the grid, RoCoF values remain below 0.5 Hz/s, clearly demonstrating its positive contribution to system stability.

However, as PHS Mujib may not always be available (e.g., when the reservoir is full), it will be necessary to implement additional measures to ensure the required dynamic stability of the system.

Case 3 – With synchronous condensers and PHS Mujib not on the grid

The results of the calculations for the loss of one generating unit at the Attarat Power Plant and for the outage of the interconnector to Egypt are presented in the table below.

Table 21: Results of calculations with included synchronous condensers and PHS Mujib not on the grid

	Event 1 - Outage of one generator in Attarat	Event 2 - Outage of interconnector to Egypt
Hsys	2,299 s	2,299 s
RoCoF	0,499 Hz/s	0,501 Hz/s
Ekin	2176,56 MWs	2176,56 MWs
Ekin/Load	0,528	0,528

Synchronous condensers play a crucial role in providing the necessary stability from an inertia perspective. RoCoF values remain significantly beyond the defined limits, even when the PHS Mujib unit is disconnected from the grid.

Dynamic study performed by EGI also recommends the use of synchronous condensers to mitigate issues related to small-signal stability and the damping of oscillations within the power system, further supporting the case for their installation.

The installation of synchronous condensers is essential to ensure overall stability and secure operation of the grid, especially in scenarios with a high share of renewable energy generation.

8.2 Appendix II: Recommendations regarding energy statistics

During the analysis of data for the development of JESS several points have been identified in the statistical data that are needed for energy systems analysis. The following sections offer some proposal for mitigating the issues and improving significantly the data that is needed for the energy strategy analysis.

8.2.1 Energy Statistics Methodology Revision

Jordan should discontinue the use of the *substitution principle* for renewables in its national energy balance because it diverges from the internationally accepted accounting methodologies established by the International Energy Agency (IEA) and Eurostat, which both apply the *physical energy content method*. Under the substitution method, renewable electricity from wind, solar, and hydro is reported as the equivalent of the fossil fuel energy input that would have been required to generate the same electricity output in a thermal power plant. This practice overstates the contribution of renewables in primary energy supply, obscures actual energy use patterns, and limits the comparability of Jordan's statistics with those of OECD and EU member countries. The joined OECD, IEA, Eurostat *Energy Statistics Manual*²⁸ and UN's *Energy Statistics Compilers Manual*²⁹ both recommend using the physical energy content approach, whereby renewable electricity is recorded at its actual output, measured in MWh converted directly to ktoe or PJ, rather than an assumed avoided fossil input. Transitioning to this method would align Jordan's reporting with international standards, improve transparency, and enable more accurate monitoring of the contribution of renewable energy in the energy mix of the Kingdom.

A roadmap for updating Jordan's energy balance should begin with establishing a dedicated technical working group under MEMR, including EMRC, NEPCO, and the Department of Statistics, tasked with revising the statistical methodology in coordination with IEA and Eurostat experts. The following steps are proposed:

- In the short term (2025–2026), the group should prepare dual reporting tables, one using substitution and one using the physical content method, to quantify the impact of the change and train national statisticians.
- In the medium term (2026–2027), once the physical energy content methodology is officially adopted, MEMR should undertake a systematic recalibration of historical energy balance data to ensure methodological consistency across time and comparability with IEA and Eurostat datasets. This process should begin with identifying all series in which the *substitution principle* was previously applied, mainly in the calculation of primary energy supply from renewable electricity and derived indicators such as total primary energy supply, import dependency, and renewable energy shares. For each affected year, the values of renewable electricity expressed in primary energy terms should be replaced by their actual output, converted using standard physical conversion factors¹. To maintain statistical continuity, MEMR should produce bridging tables

²⁸ https://www.oecd.org/content/dam/oecd/en/publications/reports/2004/11/energy-statistics-manual_g1gh4bd8/9789264033986-en.pdf

²⁹ https://unstats.un.org/unsd/energystats/methodology/documents/escm_2017850e.pdf

showing the quantitative difference between the substitution and physical content series for each year. These tables will allow analysts to understand the structural break and ensure that the revised balances can be used seamlessly in energy policy evaluation. Finally, MEMR should document the full methodological revision in an updated *Jordan Energy Statistics Manual*, providing metadata, conversion factors, and adjustment coefficients, so that all future energy and climate reporting rests on a coherent and internationally harmonised statistical foundation.

- In the long term (by 2030), the revised balances should be fully integrated into national GHG inventories, the NEEAP monitoring framework, and the monitoring of the National Energy Strategy, ensuring full alignment with IEA/Eurostat reporting formats and enabling international benchmarking of Jordan's renewable energy transition.

8.2.2 Data Issues Identified during the development of JESS and Suggested Mitigation measures

The key points identified in the process of developing JESS and proposed mitigation measures are presented in the following sections.

1) Detailed energy consumption by industrial sub-sector

Issue: The JESS process found that consumption data for the industrial sector are aggregated at a high level "industry total" but lack breakdowns into finer subsectors (e.g. cement, chemicals, food processing, steel etc.). Without these breakdowns, it is difficult to analyse energy efficiency potentials, benchmark performance, model demand, or target sector-specific policies. This is a common data gap in many countries' energy statistics. Although electricity consumption data per subsector can be easily compiled, the consumption of oil products and natural gas is a harder issue to be resolved.

Mitigation:

- Collect existing administrative or company-level data and compile a benchmark sample covering energy-intensive subsectors.
- Construct a sectoral energy-use survey or a specialized industrial energy consumption module, targeting the top 80 % of energy use in industry.
- Use proxies or engineering models to disaggregate aggregate industry data where direct measurement is not feasible. for instance, allocate consumption proportionally based on value-added or production volumes, adjusted by known energy intensities from literature or comparable countries. IEA technical support is available for the development of this methodology.
- Encourage large industrial facilities to report annual energy consumption by fuel type and process use (heating, steam, motor drive, process heat) as part of environmental or energy regulation frameworks.
- Introduce confidentiality-protected data protocols so that individual company data can feed into the aggregate without disclosing sensitivities.

2) Dedicated survey of energy consumption by end-use in the residential and services sectors

Issue: For the residential and services (tertiary) sectors, existing data are limited to fuel consumption totals per sector, but they do *not* provide a breakdown by end-use. The latest energy use survey in these sectors was performed more than ten years ago and therefore an update is imperative to capture changes in consumption patterns.

Mitigation:

- Design and implement a residential & services energy use survey that collects data on appliance stock, fuels used, and usage patterns.
- In the service sector, include a stratified sample of office buildings, hotels, hospitals, schools, retail, and public administration buildings, obtaining metered sub-consumption by end use where possible.
- Coordinate with utilities to secure anonymized metered data, with disaggregation where available, e.g. via smart metering, as a complement to the survey.
- Periodically repeat the survey (e.g. every 5 years) to track changes in appliance penetration, efficiency improvements, behavioural shifts, and technology adoption.

3) Additional Data Challenges, constraints and mitigation proposals

Beyond the core issues above, JESS identified the following additional gaps:

Issue	Description / Relevance to Jordan	Mitigation / Action
Lack of integration between energy and economic / socio-demographic data	Energy use is not sufficiently linked to building typology, household income, spatial distribution, or industrial production data in Jordan. This limits cross-policy analysis (e.g. energy-poverty, energy efficiency uptake).	Integrate energy surveys with household socio-economic surveys from the Department of Statistics. Use GIS mapping of building stock, land use, and demographic data. Cross-link industrial energy use with industrial census, manufacturing statistics, and trade data.
Confidentiality concerns and data sharing reluctance	Private firms or utilities may resist sharing consumption data due to competition or confidentiality concerns.	Develop anonymization and aggregation protocols and confidentiality clauses. Guarantee that individual-level data won't be publicly disclosed. Use aggregated or sector-level reporting.
Resource constraints (staffing, funding, technical capacity)	Preparing surveys, calibrating historical data, and maintaining detailed datasets impose significant institutional demands.	Seek donor or development partner support. Train local staff. Phase implementation incrementally. Use open-source tools and frameworks. Leverage partnerships with universities and research institutes to assist data collection, modelling, and analysis.

8.2.3 Recommendation for the National Energy Information System

Building on the findings from the JESS process and the ongoing work of MEMR to strengthen data governance, the update of the National Energy Information System (NEIS) represents an opportunity to institutionalize a modern, integrated, and internationally compatible framework for energy data collection, validation, and dissemination. Below are targeted recommendations that could be incorporated in the current NEIS upgrade to address the key data issues identified and to future-proof Jordan's energy statistics architecture.

1. Introduce Sectoral and End-Use Granularity

The NEIS database structure should allow multi-dimensional disaggregation of final energy consumption:

- Industry: introduce subsector codes consistent with ISIC Rev. 4. Link each subsector to data from industrial surveys and emission reporting.
- Residential and services: design data tables to capture end-uses (space heating, cooling, lighting, water heating, appliances, cooking). Include attributes for building typology, climate zone, and fuel mix.
- Transport: distinguish between passenger and freight modes, and between energy carriers.

2. Establish Automated Data Exchange and Integration between institutions

Develop Application Programming Interfaces (APIs) or secure data-exchange protocols between MEMR, EMRC, NEPCO, the three electricity distribution companies, JPRC, JREEEF, the Department of Statistics (DoS), and the Ministry of Environment. This would enable automatic import of generation data, fuel imports, refinery throughput, reducing manual entry and error risk. Harmonized data templates should follow IEA/Eurostat energy balance structures.

A Data Coordination Committee chaired by MEMR and comprising these entities should meet quarterly to validate updates, reconcile differences, and agree on metadata.

3. Integrate Survey and Metering Data

The NEIS should host and manage new energy consumption surveys (industrial, residential, and services) as separate but linked modules. Survey instruments, metadata, and sampling weights should be embedded in the system to allow consistent periodic updates. In parallel, link NEIS with **smart-metering systems** operated by NEPCO and the distribution companies. Where advanced metering infrastructure exists, anonymized load profiles (15-min/hourly data) could feed directly into the NEIS analytical layer to support demand-side management, storage planning, and renewable integration analysis.

4. Integrate with Energy Efficiency and Renewable Energy Monitoring

To support implementation of the Third NEEAP (2024-2026) and JESS, NEIS should include dedicated dashboards tracking:

- Energy savings by measure, sector, and year.
- Installed renewable capacities by technology and location.
- Indicators such as energy intensity (ktoe/000 JOD GDP) and avoided CO₂ emissions.
- Automated links between NEIS and JREEEF project databases would allow continuous monitoring of energy-efficiency investments and outcomes.

5. Develop Data Validation, and Quality Assurance Modules

Integrate built-in **quality-control checks**, for example, automatic balance verification, range checks, and flagging of outliers. MEMR's statistics team should periodically issue Quality Reports (similar to Eurostat's quality criteria) summarizing accuracy, timeliness, and coherence.

6. Establish User-Friendly Dashboards and Open-Data Interfaces

A public-facing Energy Data Portal can increase transparency and policy visibility. The interface should allow visualization of energy flows, indicators, and time series in interactive dashboards, while protecting sensitive or confidential data. Open datasets can be exported in machine-readable formats. This will align Jordan's NEIS with international best practice (e.g., IRENA's Stat platform, IEA's data explorer).

8.3 Appendix III: Brief Description of the TIMES model generator

TIMES (The Integrated MARKAL EFOM System) is an energy system model, which has been developed over the past 30 years under the auspices of International Energy Agency (IEA) Energy Technology Systems Analysis Programme (ETSAP) implementing agreement.

TIMES is bottom-up technology rich optimization model. The use of this framework in more than 60 countries and 200 institutions attests to the success of the methodology and approach, and the relevant insights gained from the application of the system. In addition, the input and output can be implicitly linked to Excel workbooks. This is a huge advantage in terms of setting up new scenarios and extracting results in “report ready” format.

The main policy targets that are usually examined in the analysis of the energy system of the country dictates certain characteristics for the model that should be used:

- Analysis of energy efficiency measures: In order to analyse the potential for EE, identify the sectors, analyse the alternatives and monitor the implementation, a bottom up, technology rich model is needed that can capture the technology details.
- Increased use of renewables for electricity generation in order to reach the policy targets: requires a technology rich model to take into account the variability of energy production from renewables on a daily and seasonal basis and an optimization approach in order to find the least cost alternatives.
- Effect of changes in prices (changes in tariff structure and removal of subsidies): requires a technology rich model in order to examine fuel switching through the economic appraisal of alternative technologies and fuels, in the absence of data for cross-product price elasticity's that an econometric model would require.
- An integrated approach to provide input for energy and environmental policy requires an engineering-economic-environment model to examine to study the energy system as a whole.

These were the main reasons that lead to TIMES as the most appropriate tool to provide answers to policy questions that can help formulate the energy strategy of the country. Using an optimization model in a normative mode, means using the model in order to see what a “rational planner” should do in response to a number of given systemic and policy constraints. This approach produces solutions by mixing and matching the available resources under all kinds of systemic and policy restrictions. The model can generate insights about important interplays in the overall system that can be hard to see intuitively, let alone quantify. These insights can be useful to guide the system under any kind of market. The scope of the scenario modelling approach using models is not to “predict the future”. It is to examine what is the rational way in which the system should respond to different policy and resource constraints and therefore give information to the policy maker on the decision process of guiding the development of the system. Furthermore, given the restrictions on indigenous energy resources, an optimization model is considered appropriate in order to examine the optimal combination of limited indigenous resources on the supply side (oil, gas, renewable energy), imported energy sources (oil, coal, gas) and energy efficiency options on the demand side.

TIMES (an acronym for The Integrated MARKAL-EFOM System) is an economic model generator for local, national or multi-regional energy systems, which provides a technology-rich basis for estimating energy dynamics over a long-term, multi-period time horizon. It is usually applied to the analysis of the entire

energy sector, but may also be applied to study in detail single sectors (e.g. the electricity and district heat sector).

Reference case estimates of end-use energy service demands (e.g., car road travel; residential lighting; steam heat requirements in the paper industry; etc.) are provided by the user. In addition, the user provides estimates of the existing stock of energy related equipment in all sectors, and the characteristics of available future technologies, as well as present and future sources of primary energy supply and their potentials.

Using these as inputs, the TIMES model aims to supply energy services at minimum global cost (more accurately at minimum loss of surplus) by simultaneously making equipment investment and operation, primary energy supply, and energy trade decisions, by region. For example, if there is an increase in residential lighting energy service relative to the reference scenario (perhaps due to a decline in the cost of residential lighting, or due to a different assumption on GDP growth), either existing generation equipment must be used more intensively or new – possibly more efficient – equipment must be installed. The choice is done by the model based on the analysis of the characteristics of alternative generation technologies, on the economics of the energy supply, and on environmental criteria (expressed as costs of GHG emissions). TIMES is thus a vertically integrated model of the entire extended energy system.

The scope of the model extends beyond purely energy-oriented issues, to the representation of environmental emissions, and perhaps materials, related to the energy system. In addition, the model is suited to the analysis of energy environmental policies, which may be represented with accuracy thanks to the explicitness of the representation of technologies and fuels in all sectors.

The TIMES model is particularly suited to the exploration of possible energy futures based on contrasted scenarios. Given the long horizons simulated with TIMES, the scenario approach is really the only choice (whereas for the shorter term, econometric methods provide useful projections). Scenarios, unlike forecasts, do not pre-suppose knowledge of the main drivers of the energy system. Instead, a scenario consists of a set of coherent assumptions about the future trajectories of these drivers, leading to a coherent organization of the system under study. A scenario builder must therefore carefully test the assumptions made for internal coherence, via a credible storyline.

The TIMES energy economy is made up of producers and consumers of commodities such as energy commodities, materials, energy services, and emissions. TIMES, like most equilibrium models, assume competitive markets for all commodities. The result is a supply-demand equilibrium that maximizes the net total surplus (i.e. the sum of producers' and consumers' surpluses). TIMES may, however, depart from perfectly competitive market assumptions by the introduction of user-defined explicit constraints, such as limits to technological penetration, exogenous oil price, constraints on emissions, etc.

The TIMES energy economy consists of three types of entities:

- Technologies (also called processes) are representations of physical devices that transform commodities into other commodities. Processes may be primary sources of commodities (e.g. mining processes, import processes), or transformation activities such as conversion plants that produce electricity, energy-processing plants such as refineries, end-use demand devices such as cars and heating systems, etc.,
- Commodities consisting of energy commodities, energy services, materials, monetary flows, and emissions. A commodity is generally produced by some process(es) and/or consumed by other

process(es), and

- Commodity flows, which are the links between processes and commodities. A flow is of the same nature as a commodity but is attached to a particular process and represents one input or one output of that process.

It is helpful to picture the relationships among these various entities using a network diagram, referred to as a Reference Energy System (RES). In TIMES, the RES processes are represented as boxes and commodities as vertical lines. Commodity flows are represented as links between process boxes and commodity lines. Using graph theory terminology, a RES is an oriented graph, where both the processes and the commodities are the nodes of the graph. They are interconnected by the flows, which are the arcs of the graph. Each arc (flow) is oriented and links exactly one process node with one commodity node. Such a graph is called bi-partite, since its set of nodes may be partitioned into two subsets and there are no arcs directly linking two nodes in the same subset.

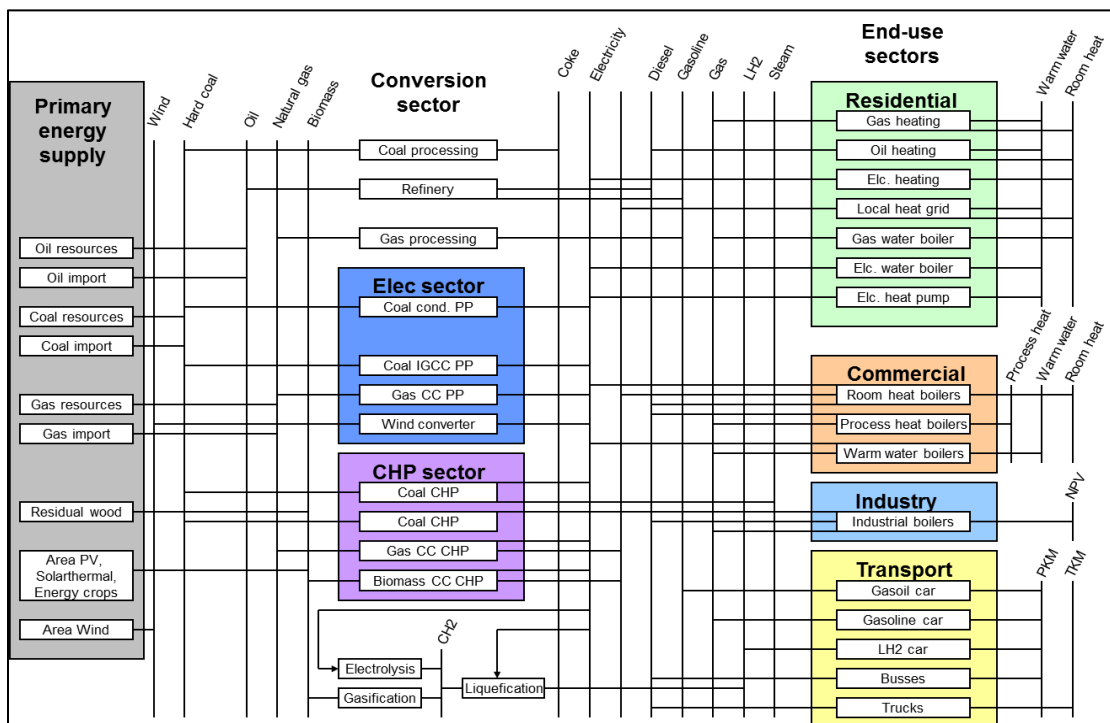


Figure 151: Example of the Reference Energy System

Each technology is described in TIMES by several technical and economic parameters. Thus, each technology is explicitly identified (given a unique name) and distinguished from all others in the model. A TIMES model may include several thousand technologies in all sectors of the energy system (energy mining, conversion, processing, transmission, and end-uses) in each region. Thus, TIMES is not only technology explicit, but also rich as well. Furthermore, the number of technologies and their relative topology may be changed at will, purely via data input specification, without the user ever having to modify the model's equations. The model is thus to a large extent data driven.

TIMES computes a partial equilibrium on energy markets. This means that the model computes both the flows of energy forms and materials as well as their prices, in such a way that, at the prices computed by the model, the suppliers of energy produce exactly the amounts that the consumers are willing to buy in each region that is included in the model. This equilibrium feature is present at every stage of the energy

system: primary energy forms, secondary energy forms, and energy services. A supply-demand equilibrium model has as economic rationale the maximization of the total surplus, defined as the sum of suppliers and consumers surpluses. The mathematical method used to maximize the surplus must be adapted to the particular mathematical properties of the model. In TIMES, these properties are as follows:

- Outputs of a technology are linear functions of its inputs;
- Total economic surplus is maximized over the entire horizon, and
- Energy markets are competitive, with perfect foresight.

As a result of these assumptions the following additional properties hold:

- The market price of each commodity is equal to its marginal value in the overall energy system, but marginal prices can be different per region and
- Each economic agent (each consumer and each producer) maximizes its own profit or utility.

This Surplus Maximization objective is transformed into an equivalent Cost Minimization objective by taking the negative of the surplus, and calling this the total system cost. The TIMES objective is therefore to minimize the total cost of the system. All cost elements are appropriately discounted to a selected year. While the TIMES constraints and variables are linked to a period, the components of the system cost are expressed for each year of the horizon (and even for some years outside the horizon). This choice is meant to provide a smoother, more realistic rendition of the stream of payments in the energy system. Each year, the total cost includes the following elements:

- Capital Costs incurred for investing into and/or dismantling processes;
- Fixed and variable annual Operation and Maintenance (O&M) Costs, and other annual costs occurring during the dismantling of technologies;
- Costs incurred for exogenous imports and for domestic resource production;
- Revenues from exogenous exports;
- Delivery costs for required commodities consumed by processes;

TIMES then computes a total net present value of the stream of annual costs, discounted to a user selected reference year. These discounted costs are then aggregated into a single total cost, which constitutes the objective function to be minimized by the model in its equilibrium computation:

$$NPV = \sum_{y \in \text{years}} (1 + d_y)^{REFYR-y} \cdot ANNCOST(y)$$

where:

NPV: is the net present value of the total cost (the TIMES objective function);

ANNCOST(y): is the total annual cost in year *y*; which includes the annualized capital costs of investment in new technologies, fixed and variable operation and maintenance cost, costs of imports of energy products and costs for domestic resource production, revenues from exports of energy commodities, taxes and subsidies associated with energy commodity flows or investments, salvage value of processes at the end of the model time horizon and environmental damage costs.

dy : is the general discount rate for year y ;

REFYR: is the reference year for discounting;

YEARS: is the set of years for which there are costs, including all years in the horizon, plus past years (before the initial period) if costs have been defined for past investments, plus a number of years after end of the model horizon, where some investment and dismantling costs are still being incurred, as well as the salvage value.

While minimizing total discounted cost the TIMES model must satisfy a large number of constraints (the so-called equations of the model) which express the physical and logical relationships that must be satisfied in order to properly depict the associated energy system. TIMES constraints are of several kinds. If any constraint is not satisfied, the model is said to be infeasible, a condition caused by a data error or an overspecification of some requirement.

In addition to the standard TIMES constraints, the user interested in developing reference case projections of energy market behavior, typically introduces additional constraints to express these special conditions. For example, there may be a user defined constraint limiting investment in new nuclear capacity, or dictating that a certain percentage of new electricity generation capacity must be powered by renewable energy sources. User constraints may be employed across time periods.

In some cases, the linearity property of the TIMES model may become a drawback for the accurate modelling of certain investment decisions. A characteristic example of this is the case of investments in new power plants in which new capacity comes in certain block sizes only. Therefore, the size of an electricity generation plant proposed by the model would have to conform to an implementable minimum size (it would make no sense to decide to construct a 50 MW nuclear plant). Processes subject to investments of only specific size increments are described as “lumpy” investments. Imposing such a constraint on an investment is impossible to formulate using standard LP constraints and variables. It requires the introduction of integer variables in the formulation. The optimization problem resulting from the introduction of integer variables into a Linear Program is called a Mixed Integer Program (MIP). Although the formulation of lumpy investments looks simply, it has a profound effect on the resulting optimisation program. Indeed, MIP problems are far more difficult to solve than LPs and far more time consuming. Using MIP rather than LP has an important impact on the interpretation of the TIMES shadow prices. Once the optimal MIP solution has been found, it is customary for MIP solvers to fix all integer variables at their optimal (integer) values, and to perform one additional iteration of the LP algorithm, so as to obtain the dual solution (i.e. the shadow prices of all constraints). However, the interpretation of these prices is different from that of a LP. Consider for instance the shadow price of the natural gas balance constraint: in a pure LP, this value represents the price of natural gas. In MIP, this value represents the price of gas conditional on having fixed the lumpy investments at their optimal integer values. What does this mean? We shall attempt an explanation via one example: suppose that one lumpy investment was the investment in a gas pipeline; then, the gas shadow price will not include the investment cost of the pipeline, since that investment was fixed when the dual solution was computed.

8.4 Appendix IV: Description of the Stochastic Dual Dynamic Programming (SDDP) Tools

SDDP is a powerful optimization methodology used to support long-term and medium-term planning of hydrothermal and renewable-dominated power systems under uncertainty. These tools are especially

valuable for systems with significant variability in inflows (hydro), renewable generation (wind/solar), and demand.

Key Features are the following:

- Stochastic Modelling: SDDP handles uncertainty by using probabilistic scenarios (e.g., hydrological years, wind/solar variability), allowing planners to evaluate system behaviour over thousands of possible future states.
- Multi-Stage Decision Making: It breaks down complex, time-linked decisions (e.g., water reservoir dispatch, generation scheduling) into sequential stages while considering future uncertainty.
- Dual Decomposition: It solves the problem iteratively by using dual variables to optimize both immediate and future costs or benefits.

Main areas of SDDP applications of are:

- Hydropower Planning: Optimizing reservoir operations while accounting for stochastic inflows and seasonal patterns.
- Renewable Integration: Evaluating how much variable renewable energy (VRE) can be reliably integrated into the system.
- Expansion Planning: Informing investments in generation, storage, and transmission infrastructure over multi-year horizons.
- Market Simulations: Modelling wholesale electricity market behaviour under uncertain fuel prices, demand growth, and generation mix.

Benefits of using SDDP tools are:

- Helps quantify trade-offs between flexibility, reliability, and cost.
 - Enables robust decision-making under climate and market uncertainty.
 - Enhances coordination between short-term dispatch and long-term planning.
-