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2023

Kuwait Energy Outlook

The Security-Transition Nexus of Kuwait's Energy System

Energy and Building Research Center
Kuwait Institute for Scientific Research

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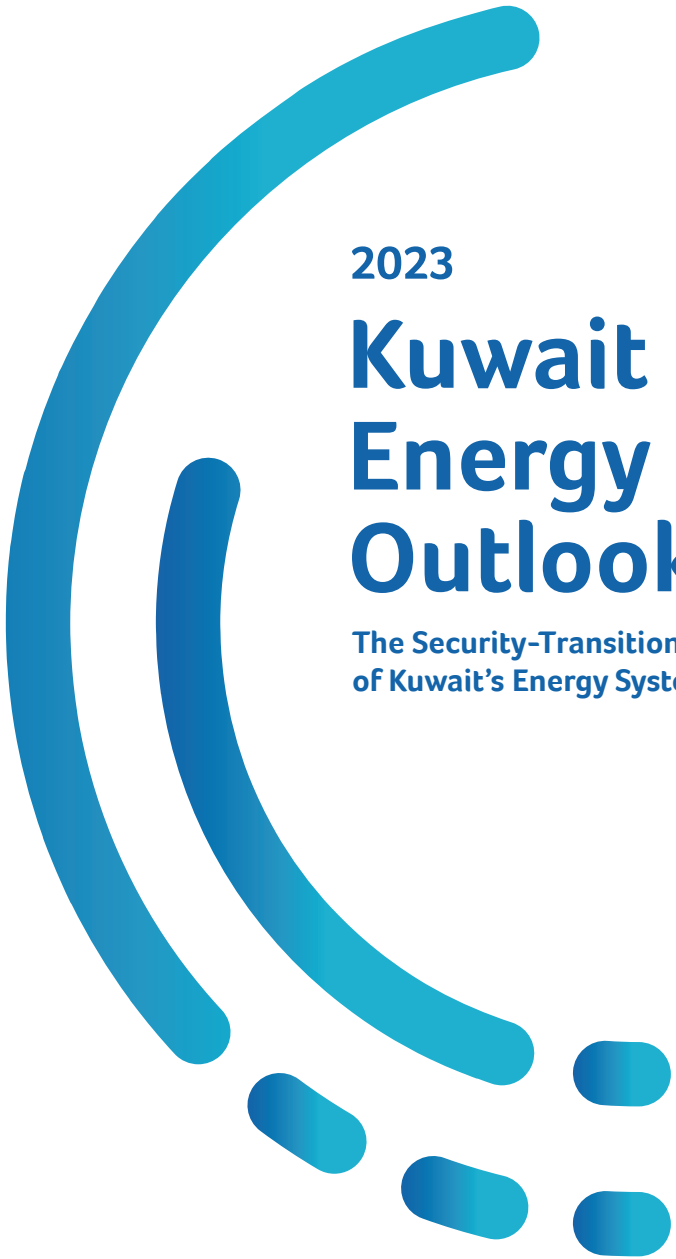

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Foreword

Kuwait's economy is profoundly dependent on oil exports, and the country is hence exposed to oil price instability which directly affects government revenues and its ability to sustain its goals, especially those associated with New Kuwait 2035. Kuwait may face more extreme weather events, more volatile markets, and more demanding consumers in the future. Due to its harsh hot weather conditions and natural freshwater poverty, Kuwait is compelled to depend on high energy-intensive systems that eventually impact the environment. To meet the challenges of a harsh climate and a volatile market for oil products, more authentic data and granular, detailed information are essential input for analysis. Information gleaned from a variety of sources allows us to design a more competitive and sustainable energy system to cater to our needs while preserving our natural resources. Kuwait Institute for Scientific Research (KISR) has already taken several significant steps towards establishing and prioritizing energy research and innovation.

KISR has played an essential role in contributing to building Kuwait's latest energy strategy by participating on the production of the White Paper on Sustainable National Energy Strategy in 2017, which was initiated and funded by the Kuwait Foundation for Advancement of Sciences (KFAS). These efforts were followed by the publication of the first edition of the Kuwait Energy Outlook in 2019 (KEO-2019), which was sponsored by the General Secretariat of the Supreme Council of Planning and Development (GSSCPD) through the United Nations Development Program (UNDP). The KEO-2019 examined the energy sector in Kuwait from upstream energy production to mid-stream conversion systems to downstream energy demand. Moreover, KEO-2019 provided an assessment for energy demand and supply until 2035 and the associated implications. The second edition of KEO-2020 updated to the KEO-2019 analysis with contemporary developments in Kuwait's energy sector, and policy recommendations were provided to enable meeting Kuwait's energy targets for 2035. KEO-2019 and KEO-2020 relied upon the International Energy Agency's energy balances due to a scarcity of local energy statistics. In this new edition, of the Kuwait Energy Outlook (KEO-2023), KISR has partnered with other authorities in Kuwait, which include Kuwait Petroleum Corporation and its subsidiaries, the Ministry of Electricity, Water, and Renewable Energy, the Central Statistical Bureau, and the Public Authority for Industry's Industrial Research Department, to develop these local energy statistics and the analysis provided in this edition are aligned with a more robust local data and reflect how energy is distributed within Kuwait.

KISR and KFAS, are pleased to present this third issue of the Kuwait Energy Outlook 2023 (KEO-2023), which will provide thorough updates on Kuwait's energy sector based on the Kuwait Energy Model and will serve as the essential foundation for addressing developments in Kuwait's energy sector in decades to come. With enhanced coordination between energy stakeholders in Kuwait, it is our hope that the future KEOs will be a valuable tool for decision makers in their analysis and development of robust and cost-effective energy policies and plans for a sustainable energy future.

Dr. Mane Alsudairawi
Acting Director General
Kuwait Institute for Scientific Research

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Foreword

The Kuwait Foundation for the Advancement of Sciences (KFAS), through its strategic programs, contributes and participates in finding solutions to address the key issues in the State of Kuwait. Issues that play an important role in sustainability such as energy, environment, water, health and other areas of significant social and economic impact are of paramount importance. In this regard, specifically in the field of energy, KFAS launched an initiative to publish a white paper on "Sustainable Energy Strategy of the State of Kuwait". Accordingly, KFAS commissioned the Kuwait Institute for Scientific Research (KISR) and Oxford Institute for Energy Studies (OIES) to develop the comprehensive White Paper, with the participation of all relevant stakeholders, to meet the challenges facing the energy sector and to achieve sustainable development in Kuwait. The White Paper prompted the formulation of the "Supreme Energy Committee" to oversee the implementation of the recommendations of the White Paper through its sub-committees and working groups.

As a continuation of these joint efforts, in 2020 KFAS funded the project "Extension of Kuwait Energy Outlook Leap Model to Address Economic Perspective", for which this report (Kuwait Energy Outlook - 2023) is one of its outputs. The project is an update of the (Kuwait Energy Outlook - 2019), which was funded by the General Secretariat of the Supreme Council for Planning and Development (GSSCPD) in 2019 in collaboration with KISR and the international strategic partner represented by the United Nations Development Program (UNDP). This report depicts the current situation of the energy sector in the State of Kuwait and future expectations until 2040, enabling decision-makers to design evidence-based policies to meet the energy-related goals for the Kuwait National Development Plan (KNDP).

Deeming the importance of digital transformation in improving the flexibility of this version of the report, KFAS has recently funded a project to develop the current model of energy in Kuwait. Python programming language is used to develop the model and provide an online tool allowing policy makers in Kuwait to track, analyse and display key performance indicators visually on a screen to monitor the status of the energy sector in Kuwait (Kuwait Energy Outlook Dashboard). In addition, the tool will allow analysing the results of the proposed policies in this sector, for a more secure, diversified, sustainable, and flexible energy strategy in line with local and international developments.

KFAS appreciates all the efforts made in preparing this report (Kuwait Energy Outlook-2023) and extends its thanks to everyone who contributed to its preparation.

Dr. Ameenah Rajab Farhan
Director General
Kuwait Foundation for the Advancement of Sciences

Acknowledgements

This report was prepared by the Energy Policy Team of the Energy Efficiency Technologies (EET) Program in the Energy and Building Research Center at Kuwait Institute for Scientific Research. The work was directed by **Yousef Mohammad Al-Abdullah**, Research Scientist in the EET Program, and supervised by **Fotouh Al-Ragom**, Program Manager of the EET Program. **Mohammad Khajah** from KISR Systems & Software Development Department (SSDD) has become an integral member of the KISR energy policy team and redeveloped the energy models in Python. **Krishnan Nair Sreekanth** is a key member of the team. **Shareefa Al-Adwani**, Assistant Professor and Department Chair of International Relations and Social and Behavioral Sciences at American University of Kuwait, performed a pivotal role and provided analysis on link between energy security and the energy transition and how it these two issues are affecting Kuwait.

For this report, chapter 1 was prepared by **Fotouh Al-Ragom** with contributions from Krishnan Nair Sreekanth, Mohammad Khajah, Yahya Al-Hadban, and Yousef M. Al-Abdullah. As for chapter 2, it was developed by **Yousef M. Al-Abdullah** with Mohammad Khajah and Krishnan Nair Sreekanth. Within chapter 2, Box 2.1 on Energy Savings through Automation, was written by **Fareed Al-Ghimlas** and **Fatma Alalawi.** In addition, Box 2.3 on Shagaya Renewable Energy Station Development was written by **Bashar Abdulrahman Al-Kandari** and **Ayman Al-Qattan**. Chapter 3 on the Security-Transition Nexus of Kuwait was overseen by **Osamah Alsayegh** and **Shareefa Al-Adwani**. Finally, several KISR Research Associates participated in the production of this report, including **Naser Hussain**, **Eissa Al-Nasrallah**, **Nourah Al-Safi**, **Mohammad Al-Jassam**, **Sarah Al-Osaimi**, and **Yousef Al-Qattan**.

This work in this report was sponsored by the ***Kuwait Foundation for the Advancement of Sciences*** under grant number AP19-35IC-01. Furthermore, this report was overseen by its editorial committee, headed by the General Secretariat for the Supreme Council of Planning & Development, and whose members include the Kuwait Foundation for the Advancement of Sciences, Kuwait Petroleum Corporation, Ministry of Electricity, Water, & Renewable Energy, Central Statistical Bureau of Kuwait, Kuwait Environment Protection Agency, Ministry of Oil, Public Authority for Housing & Welfare, Kuwait Authority for Partnership Projects, and Ministry of Interior.

Data is key for the type of analyses provided in this report. Without contribution from authorities, including Kuwait Petroleum Corporation along with its subsidiaries (Kuwait Oil Company, Kuwait Gulf Oil Company, Kuwait National Petroleum Company, Kuwait Integrated Petroleum Industries Company and Petrochemical Industries Company), the Central Statistical Bureau, the Ministry of Electricity, Water, & Renewable's Energy Statistics Department, and the Public Authority for Industry's Industrial Research Department. With these key contributions, it became possible to develop local energy statistics that were more representative of Kuwait's energy system. These local statistics were paired with International Energy Agency (IEA) energy balances to calibrate the models and their projections presented in the report. Furthermore, the team would like to thank Stockholm Environment Institute (SEI), US, and Charlie Heaps for his work on the original KEO models. His insights led to the development of the current models.

The individuals and organizations that contributed to this study are not responsible for any opinions or judgments contained herein.

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Executive Summary

As a member of the Organization of the Petroleum Exporting Countries (OPEC), it has significant oil reserves that support its economy. In fact, Kuwait's economy is primarily driven by its oil and gas industry. In 2019, Kuwait's oil revenues represented 40.5 percent of the GDP.

In 2021, Sustainable Crude Oil Production Capacity in Kuwait (including the partitioned zone) averaged 2,415 2,616 thousand barrels per day, with refinery throughput of 678 thousand barrels per day (Kuwait's refining capacity represented 0.8% of the world's total).

Kuwait exported 1,740 thousand barrels per day and 604 thousand barrels per day of oil-derived products in 2021. Compared to 2020, crude oil production fell by approximately 1 percent. Correspondingly, crude oil exports fell by 5 percent, but exports of oil-derived products increased by 15 percent.

As of 2022, Sustainable Crude Oil Production Capacity in Kuwait (including the partitioned zone) averaged 2,415 2,718 thousand barrels per day, with refinery throughput of 773 thousand barrels per day. Originally, all oil refineries in Kuwait were operated by KNPC, including Mina Abdullah and Mina Al-Ahmadi refineries. Formerly, KNPC operated Mina Shuaiba refinery, which was shut down in 2017. Prior to its closure, refining capacity in Kuwait was 936 thousand barrels per day, dipping to a low of 736 thousand barrels per day after the closure. However, after fully commissioning of Clean Fuel Project (CFP) in March 2022, KNPC's refining capacity reached 800 thousand barrels per day. It is to note that Al-Zour mini refinery 1 and 2 were commissioned in Dec'2022 and March'2023 respectively, where after fully commissioning of the third mini refinery, KIPIC's refining capacity, is expected to reach 615 thousand barrels per day (assuming to be operated 100% KEC).

The Ministry of Electricity, Water, & Renewable Energy (MEWRE) manages Kuwait's power generation sector, including regulation and operations. The power generation fleet is comprised mostly of conventional generation consisting of steam turbines, open-cycle gas turbines, and combined cycle gas turbines. Throughout the years MEWRE has been upgrading its power generation fleet to more efficient combined cycle generators mainly fueled by natural gas, lowering emissions.

Legislation related to mitigation and adaptation due to climate change for the period between 2015-2035 are well established as part of Kuwait's first nationally determined contributions (NDC) submitted to UNFCCC. As part of its first NDC strategy, the following seven features were designated for energy, including: (a) expanding the use of natural gas in the production of electricity, (b) increasing the share of renewable energy in the energy mix, (c) enhancing energy efficiency in various sectors, (d) using hydrogen as a fuel if possible, (e) relying on reverse osmosis (RO) in water desalination by increasing RO capacity, (f) reducing and recycling carbon in industry, and (g) reducing carbon emissions in the oil and gas sector through enhancing the refinery production process.

In the previous editions of the Kuwait Energy Outlook (KEO), KEO-2019 and KEO-2020, energy projections were based largely on data curated by the International Energy Agency (IEA). In the present edition, a comprehensive local dataset has been constructed based on direct communication with relevant entities, such as the K-companies and MEWRE. IEA data has still been used, but only in situations where they provide additional temporal coverage beyond locally sourced statistics. The KEO makes projections based on the collected datasets to characterize the *Business-as-Usual* (BAU) case, which reflects our judgement about a reasonable trajectory of development in Kuwait's energy economy to 2040.

In the Business-as-Usual (BAU) case, primary energy for local demand is simulated over the Outlook period from 2019 to 2040. The majority of primary energy devoted to meeting local demand is fulfilled by oil, averaging 55 percent share, followed by natural gas at 45 percent. In the BAU case, primary

energy to meet local demand will grow at a steady 1.3 percent over the Outlook period. Total primary energy in Kuwait is projected to grow from approximately 31 to 40 million tonnes of oil equivalent (Mtoe).

The buildings model of Kuwait incorporates demand from the residential and service sectors. Overall energy demand in buildings in Kuwait grows at a rate of 1.4 percent in a BAU case, with electricity fueling most of this demand. Over the Outlook period 2019 to 2040, buildings energy demand increases from approximately 5.1 to 6.9 million tonnes of oil equivalent (Mtoe). Air conditioning demand in Kuwait accounts for approximately 60 percent of total electricity demand in Kuwait. For total buildings demand for all fuels, air conditioning reaches a maximum of 67 percent over the Outlook period. Since air conditioning demand is growing at a rate of 1.5 percent annually from approximately 39 to 53 TWh over the Outlook period to 2040, Kuwait has an immense opportunity for reducing energy demand by applying energy efficiency policies.

The transportation sector in Kuwait is exclusively a road transportation network. From 2019 to 2040, total energy demand from all fuels grows at approximately 2.3 percent annually. As a result, demand for transport fuels grows from 5.1 to 8.3 million tonnes of oil equivalent over the Outlook period. By 2025, transportation becomes the sector with the most energy demand, and its share in total energy demand reaches 30 percent by 2040.

Natural gas fulfills most energy demand in the industrial sector, accounting for approximately 70 percent of industry demand today. By the end of the Outlook period in 2040, natural gas demand continues to increase; however, its overall share in the energy mix for industry lowers its share to approximately 65 percent. In addition to natural gas, the industrial sector utilizes diesel primarily in the construction sector, which accounts for 5 percent at most of demand over the Outlook period.

In the Business-As-Usual case (BAU), Kuwait's water production capacity will become more energy efficient due to the adoption of MED and RO desalination, while MSF plants will be decommissioned along with older power plants. Water production will increase from 761 to 1,133 million cubic meters. Energy demand, which includes heat production for thermal technologies and electricity for reverse osmosis, will increase from approximately 1.4 to 1.67 million tons of oil equivalent over the Outlook period.

The power generation fleet in Kuwait is operated and regulated by the state-owned utility, now known as the Ministry of Electricity, Water, and Renewable Energy (MEWRE). In 2019, the installed capacity was approximately 20 GW. The majority of this capacity is now more efficient combined cycle gas turbines, providing almost 9.1 GW. Finally, open cycle gas turbines, which mostly operate during peak load periods, have reached a capacity of approximately 2.1 GW.

Grid connected renewable energy in Kuwait comes from Shagaya Renewable Energy Park, which produces electricity via three renewable energy technologies, photovoltaics, wind, and concentrated solar power. Most of this capacity at Shagaya will be photovoltaics, reaching approximately 3 GW by 2035. CSP and wind in BAU case are assumed to be 0.25 GW.

In the past two years, KOC drilled 383 new wells for crude and associated gas extraction and announced four new hydrocarbon discoveries. Total daily production of both associated and non-associated gas for the 2019-20 2021/22 fiscal year was 1.928 1.752 billion standard cubic feet per day, while production of non-associated gas reached 490 510 million standard cubic feet per day, having a 10 percent increase compared to last year's figures. Kuwait currently has 32 operational gathering centers that process and separate gas and water from crude oil for downstream operations. In the period to 2040, Kuwait Oil Company aims to raise the production capacity to 60 and 25 thousand barrels of oil per day in the Ratqa and Umm Niqa fields, respectively.

Crude oil production in Kuwait is expected to increase from 2.7 million barrels per day in 2023 to 4.0 million barrels per day in 2040, growing at a rate of 1.9 percent per year. Kuwait continues to increase its use of natural gas. This strategy is supported by LNG imports that are expected to continue to be an important source of natural gas supply over the Outlook period. In 2021, Kuwait Integrated Petroleum

Industries Company built a new 3,000 billion British thermal units per day LNG import terminal with eight storage tanks at Al-Zour.

In the new BAU case, emissions start at approximately 83 and grow to 104 million tons of CO_2-equivalent over the Outlook period to 2040. While the total growth in emissions is approximately 1 percent over this period, at times it is negative. Another opportunity for reducing emissions is through energy efficiency measures in air conditioning.

As a hydrocarbon-based economy, Kuwait's energy system's security and, consequently, national security are impacted by the development of the global energy transition. Hence, in line with the global trends, KPC is focusing on investing in low-carbon solutions for maximizing the value its own resources (i.e. hydrocarbons). As of 2020, Kuwait holds 6 percent and 1 percent of the world's proven crude oil and natural gas reserves with 101.5 billion barrels and 1.7 trillion cubic meters, respectively. The average Sustainable Crude Oil Production for the past five years was about 2.75 million barrels per day. The average percentage of the crude and oil products exports out of the total oil production for 2016-2020 was about 85 percent.

The average local gas production growth rate was approximately 3 percent versus the 9 percent growth rate for imported gas. The average imported gas of the past ten years amounted to more than 18 percent of the total demanded quantity. Kuwait's import supply sources of liquefied natural gas (LNG) comes from several regions. In 2020, Kuwait's LNG import was 56 percent from the GCC region (Qatar and Oman), 28 percent from Africa, 9 percent from North America, and 7 percent from other regions.

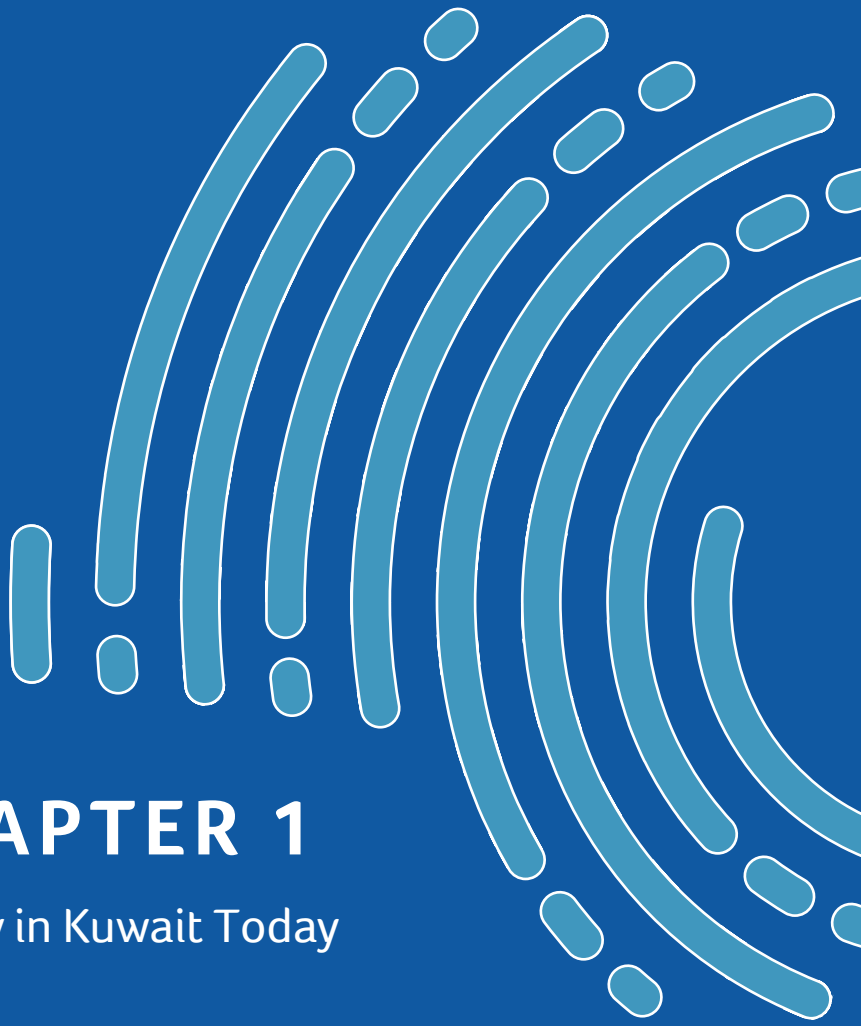
The five "P-concerns" of the national energy system, namely, Physical safety, sustainable Progress, Permanent consumption, breakeven Prices, and precise Planning; and the four "As" of the national energy system security, involving Availability, Affordability, Accessibility, and Acceptability are key to the national security at large. Given the rising dependence of the national electric power generation as well as the chemical and petrochemical sector on natural gas, the growth rate of gas imports, and its diverse import regions, global demand on gas has been increasing, impacting all importers of gas. Kuwait, as a consumer of gas imports, must contend with the classic elements of demand-side energy security, or rather, security of the supply of energy: availability, affordability, and accessibility, acceptability.

Kuwait is in a unique position, having concerns regarding supplying energy (oil) and importing of energy (gas). Under various assumptions, many scenarios expect the oil peak demand occurs as early as sometime during the 2020s and as late as the 2050s. In these scenarios, the oil demand would drop as low as 40 percent from the current demand level, i.e., from 100 to 60 million barrels/day. The export revenues from crude oil and oil-derived products represent about 80 percent of Kuwait's total revenues. Therefore, maintaining the well-being level provided by these export revenues require Kuwait to adapt to the global energy transition outcomes.

In 2020, Kuwait signed a fifteen-year agreement with Qatar to supply three million tons of LNG per year. Yet this deal alone cannot address the ever-increasing demand for natural gas in Kuwait: from 2020-2021, Kuwait experienced a 32 percent increase in consumption for natural gas.

The State of Kuwait has pledged to achieve Net-zero GHG emissions by 2060, while the Oil Sector to reach Net-zero GHG emissions by 2050, as announced in COP27 in Sharm Elsheikh, Egypt. The business-as-usual GHG emissions in 2035 are expected to be 65 percent more than in 2016. According to Kuwait NDC, the business-as usually of GHG emissions are expected to reach 142 million tons CO_2 equivalent.

Required policies to protect oil revenues, gas supply security, and mitigate GHG emissions may involve: sustain stable investment in the oil and gas sectors, adopt smart energy efficiency measures, accelerate the deployment of renewable energy, explore the feasibility of alternative clean energies, expand gas supply sources, integrate clean technologies with the nation's oil industry, invest in clean energy and technologies, and establish carbon credits.



CHAPTER 1

Energy in Kuwait Today

Chapter 1 Highlights

- As a member of the Organization of the Petroleum Exporting Countries (OPEC), Kuwait has significant oil reserves that support its economy. In fact, Kuwait's economy is primarily driven by its oil and gas industry. In 2019, Kuwait's oil revenues represented 40.5 percent of the GDP.
- As of 2021, Kuwait's refining capacity represented 0.8% of the world's total. Originally, all oil refineries in Kuwait were operated by KNPC, including Mina Abdullah and Mina Al-Ahmadi refineries.
- The Ministry of Electricity, Water, & Renewable Energy (MEWRE) manages Kuwait's power generation sector, including regulation and operations. The power generation fleet is comprised mostly of conventional generation consisting of steam turbines, open-cycle gas turbines, and combined cycle gas turbines. MEWRE has been upgrading its power generation fleet to more efficient combined cycle generators mainly fueled by natural gas, lowering emissions.
- Legislation related to mitigation and adaptation due to climate change for the period between 2015-2035 are well established as part of Kuwait's first nationally determined contributions (NDC) submitted to UNFCCC. As part of its first NDC strategy, the following seven features were designated for energy,

including: (a) expanding the use of natural gas in the production of electricity, (b) increasing the share of renewable energy in the energy mix, (c) enhancing energy efficiency in various sectors, (d) using hydrogen as a fuel if possible, (e) relying on reverse osmosis (RO) in water desalination by increasing RO capacity, (f) reducing and recycling carbon in industry, and (g) reducing carbon emissions in the oil and gas sector through enhancing the refinery production process.

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Energy in Kuwait Today

Overview

The geographical placement of Kuwait has played a pivotal role in establishing the country as a prominent oil-producing nation within the Middle East. Kuwait is located in the northeastern part of the Arabian Peninsula, which has exceptional geological conditions which gave rise to the abundant hydrocarbon reserves that were mainly driven by the tectonic, subsidence, and diagenetic processes that occurred in the region.[1] As a member of the Organization of the Petroleum Exporting Countries (OPEC), it has significant oil reserves that support its economy. In fact, Kuwait's economy is primarily driven by its oil and gas industry. In 2019, Kuwait's oil revenues represented 40.5 percent of the GDP PPP (2015 USD),[2] one of the highest among the GCC countries (see Figure 1.1). This demonstrates that Kuwait's economy is highly dependent on oil exports and reflects the country's economic performance is closely linked to the fluctuations in global oil prices and demand.

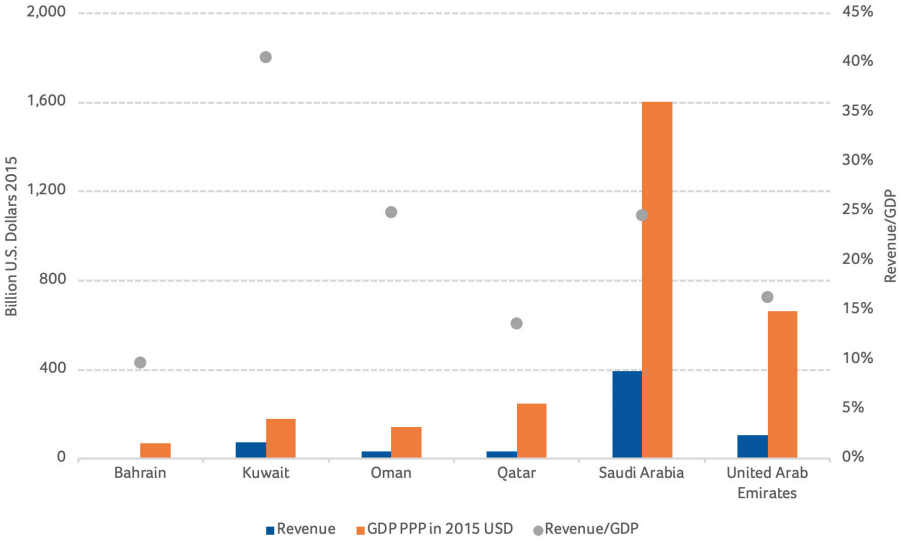


Figure 1.1 | Oil revenues and gross domestic product (PPP $2015)[2] of the GCC countries in 2019.

Since the 1940s, Kuwait has been one of the world's top ten oil producers. It has thirteen oil and gas fields, including Burgan, one of the world's largest oil fields. Figure 1.2 depicts Kuwait's oil and gas fields according to the Geographical Information Systems Section in KISR's Systems and Software Development Department (SSDD).

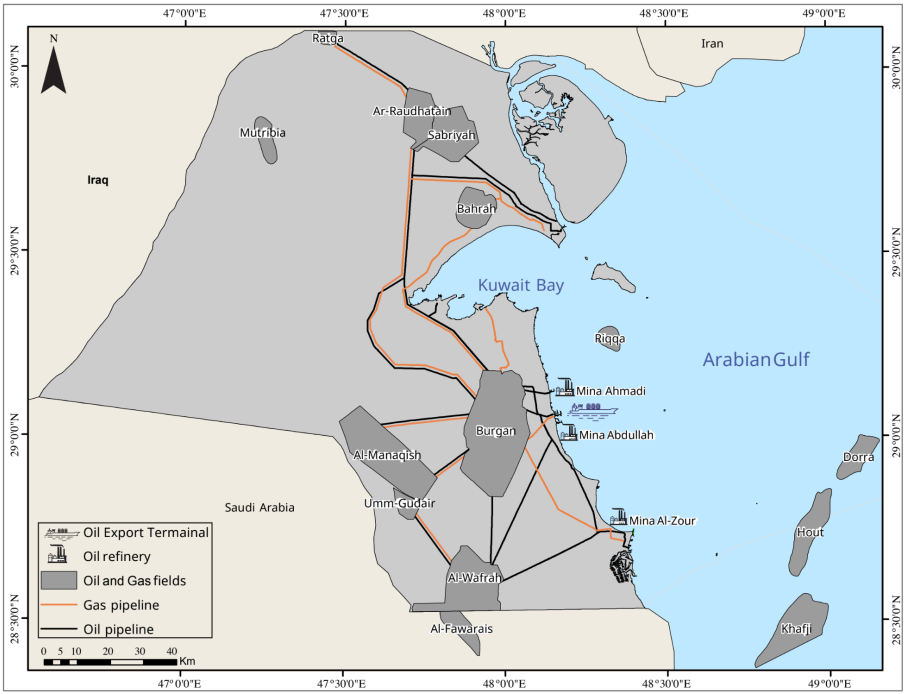


Figure 1.2 | Kuwait's oil and gas fields (Source: KISR GIS section).

The production and monitoring of crude oil, natural gas, and natural gas liquids (NGLs) are vital for Kuwait's energy sector and economic development. The country's ability to extract and manage these resources efficiently has made it a significant player in the global energy market. Kuwait Petroleum Corporation (KPC), a state-owned organization in charge of all facets of Kuwait's oil business and oversees the management of the nation's oil production.

Upstream operations are performed by Kuwait Oil Company (KOC) and Kuwait Gulf Oil Company (KGOC) as Subsidiaries of KPC. They are responsible for the exploration, drilling, production, and transport of oil and gas within Kuwait. KOC oversees operations in most of Kuwait including fields in the southeast, Burgan, Umm-Gudair, and Al-Manaqish, to northern fields such as Sabriyah. KGOC operates the same activities jointly with Saudi Arabian Chevron (SAC) in the Partitioned Zone (also known as the Divided Zone), an area where the maritime borders between Kuwait and Saudi Arabia are not clearly defined, leading to a shared jurisdiction over the exploration and production of hydrocarbon resources. These two entities collaborate under a joint operation agreement to explore, develop, and produce oil and gas from the shared reserves. After extraction, these primary products are sent to the gathering centers where three main lines of products are sent out.

KPC's subsidiaries manage Kuwait's oil operations via the process shown in Figure 1.3. KOC and KGOC process the working fluid extracted in the various fields throughout Kuwait and separate it into crude oil, natural gas liquids (NGLs), and natural gas, all of which are sent into gathering centers.

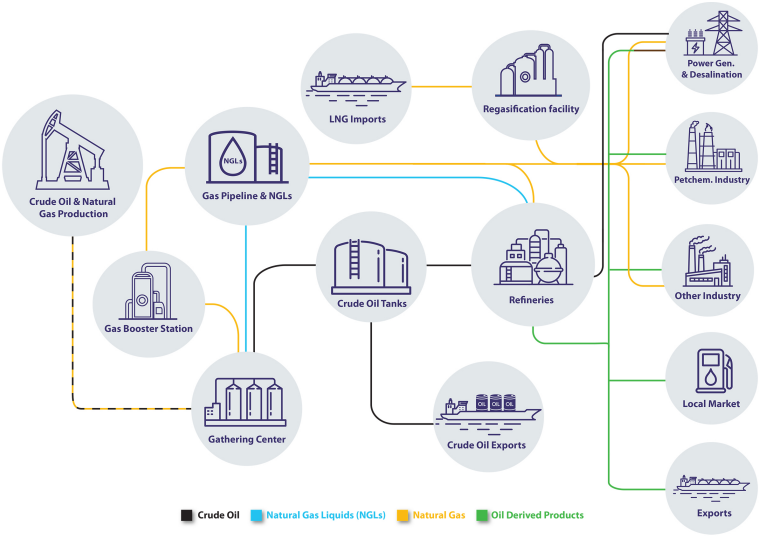


Figure 1.3 | Kuwait's Energy Supply Chain (Source: KISR Marketing Division).

In Figure 1.3, the first line (black) from gathering centers carries multiple types of crude oil, such as the following:

- Kuwait Export Crude (KEC): Kuwait Export Crude is the main type of oil produced in Kuwait. It is a high-quality light crude oil with low sulfur content. KEC is a benchmark for pricing crude oil in the Middle East.
- Kuwait Super Light Crude (KSLC): KSLC is a premium grade of crude oil. It is an extremely light crude oil with an API gravity higher than 40 degrees, making it very valuable in refining processes.
- Kuwait Medium-Heavy Crude (KMHC): This type of crude oil has a moderate to high density and viscosity, indicating a thicker and heavier composition compared to lighter crude oils.
- Kuwait Heavy Crude (KHC): This is a heavier grade of crude oil compared to KEC. It has a higher density and higher sulfur content. KHC requires more complex refining processes to extract valuable products.
- Kuwait Sour Crude (Eocene Crude): Kuwait Sour Crude refers to the crude oil produced in Kuwait with relatively high sulfur content. It is specifically sourced from the Eocene formation. It is known for its higher sulfur content, which gives it the "sour" designation. The exact specifications of Kuwait Sour Crude may vary depending on the specific oil field (typical sulfur content of around 4 percent).

From the crude oil storage tanks, the various types of crude oil are either exported internationally or routed to downstream operations, overseen by Kuwait National Petroleum Company (KNPC) and Kuwait Integrated Petroleum Industries Company (KIPIC). KNPC operates Mina Al-Ahmadi and Mina Abdullah refineries which turn crude oil into secondary oil-derived products. KIPIC runs the relatively new Al-Zour refinery, which refines oil and will potentially produce petrochemical products post completion of the Zour Integrated Petrochemicals Complex (PRIZe) project. KNPC and KIPIC refineries produce multiple products (brown lines in Figure 1.3), including liquified petroleum gas (LPG), gasoline, aviation type kerosene, naphtha, diesel (including low-sulfur diesel for the European market), fuel oil, petroleum

coke, and bitumen. Finally, fuel oil is also delivered to the power plants run by the Ministry of Electricity, Water & Renewable Energy (MEWRE) to be used as fuel for power generation and water desalination.

The grey lines in Figure 1.3 carry NGLs, which KOC calls condensates because they are the product of tank vapors in the gathering centers condensing back into liquid form. Originally extracted with crude oil, NGLs are sent to downstream operators (KNPC & KIPIC) to produce ethane, which is utilized as a feedstock for petrochemical products, and liquified petroleum gas (LPG), some of which is exported and the rest utilized locally for a variety of uses, including gas cooking stoves.

Finally, natural gas is pressurized at boosters and fed into the gas pipeline network operated by KOC (yellow lines). These pipelines connect to the downstream operations, including KNPC and KIPIC. Kuwait also imports liquified natural gas (LNG) to accommodate the additional needs of energy demand within the state of Kuwait, which enters Kuwait via an LNG terminal and is then re-gasified, joining the downstream operations consumer network. Once the LNG is in the consumer pipeline network, it primarily supplies the MEWRE-run power generation sector as well as the petrochemical and chemical industries, which use it in their production processes to create final products like ethylene, polyethylene, styrene, and other chemicals. The remainder goes on to other industries. However, this remaining amount of gas is considerably less than the levels offered to the power generation and petrochemical and chemical industries.

Upstream Oil Activities

Kuwait is a major oil supplier that exports oil to Asian countries, including China, India, South Korea, Japan, and Vietnam. In 2021, Kuwait exported 56,545 million USD worth of petroleum and imported 55,998 million USD worth of goods and services.[3] According to Worlds Exports, Kuwait was among the top 15 countries that exported the highest dollar value worth of crude oil during 2021.[4]

In 2021, Crude Oil Production Capacity in Kuwait averaged 2,415 thousand barrels per day with refining throughput of 773 thousand barrels per day.[5] Figure 1.4 shows production versus total exports. This reduction in exports can be attributed to a reduction in production in accordance with downward adjustments in production allocations for countries agreed in OPEC and non-OPEC Ministerial Meetings.[5]

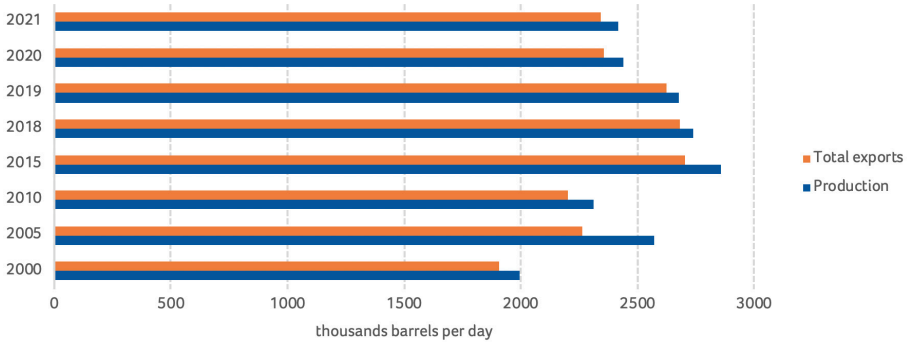


Figure 1.4 | Crude oil production vs. net exports in thousands of barrels per day.[5]

KOC and KGOC are striving to achieve their 2040 Strategy goals, which include actual production capacity from Non-Associated Gas. According to OPEC, Kuwait's proven natural gas reserves are 1,784 billion standard cubic meter.[5] Accordingly, KOC signed the Jurassic Production Facilities contracts at the end of 2021. These facilities are expected to achieve a Jurassic fields production capacity of one billion cubic feet of non-associated gas per day by 2024.

According to OPEC annual statistical bulletin, Kuwait's 2021 natural gas demand increased from 18,218 million standard cubic meter (scm) to 19,752 million scm, representing an annual increase of 8.4 percent.[5] Kuwait imported 5,335 and 7,024 million cubic meters in 2020 and 2021, respectively. Natural gas production fell from 12,883 to 12,728 million cubic meters from 2020 to 2021 (see Figure 1.5). Since 2009,[5] natural gas imports in Kuwait averaged 23 percent of production, but in recent years natural gas imports have grown to over 50 percent. This increase in imports is due to Kuwait strategically moving to natural gas to lower emissions.

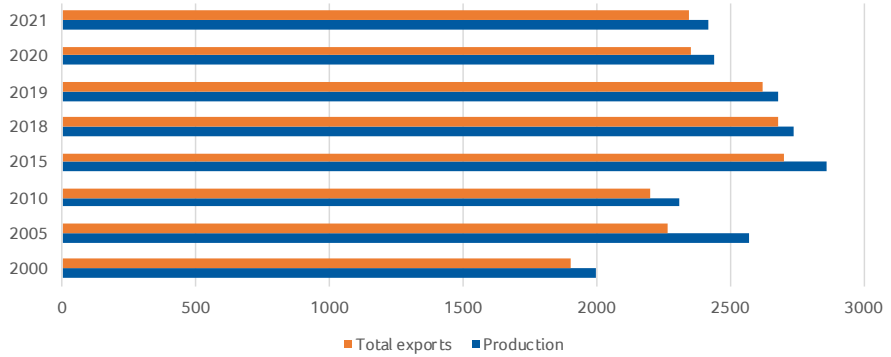


Figure 1.5 | Natural gas production and imports.[5]

Kuwait joined the Global Gas Flaring Reduction (GGFR) partnership in 2012, an initiative led by the World Bank to reduce emissions that result from the oil industry. The oil sector has been taking measures to reduce flaring, which involves the controlled burning of natural gas produced along with oil. Flaring is harmful to the environment and wastes valuable resources, so efforts to minimize it are important. Since 2012, Kuwait has managed to reduce gas flaring from 17 percent to less than 1 percent.[6] Recently, KOC managed to decrease gas flaring from 1 percent in May 2021 to 0.5 percent in March 2022.[7]

Kuwait is committed to maintaining its planned oil and gas production in the coming years while adhering to international environmental practices. To meet the national strategic goals by 2035, the oil sector in Kuwait is making significant investments in developing national oil and gas fields and improving production processes. One of the key initiatives in this regard is the implementation of oil well water injection with water treatment. This process involves the injection of treated water into oil wells, which helps to maintain reservoir pressure and improve oil recovery rates.[7,8] Moreover, offshore oil and gas exploration and drilling in Kuwaiti territorial waters are also among the efforts being made to bolster the country's energy sector. These efforts are crucial for achieving Kuwait's long-term economic goals and ensuring sustainable development for future generations. As a result of the offshore drilling, KOC estimates that about 200,000 barrels of oil per day will be produced from the project to contribute to KPC's Strategy 2040.[7,9,11]

Downstream Oil Activities

As of 2021, Kuwait's refining capacity represented 0.8% of the world's total. Originally, all oil refineries in Kuwait were operated by KNPC, including Mina Abdullah and Mina Al-Ahmadi refineries. Formerly, KNPC operated Mina Shuaiba refinery, which was shut down in 2017. Prior to its closure, refining capacity in Kuwait was 936 thousand barrels per day, dipping to a low of 736 thousand barrels per day after the closure. Mina Al-Ahmadi and Mina Abdullah have been upgraded and the capacity of these refineries has increased to approximately 800 thousand barrels per day as of 2022.[5] Mina Al-Ahmadi and Mina Abdullah produce a variety of oil-derived products from Kuwait Export Crude (KEC), and

Eocene, including motor gasoline, diesel, kerosene, LPG, naphtha, fuel oil, petroleum coke, and bitumen. Mina Al-Ahmadi refinery also houses a gas plant facility that separates natural gas and NGLs into leaner natural gas for utilization in the energy sector (including power stations), ethane for feedstock for petrochemicals, and a variety of liquified petroleum gases, some of which are used locally, especially for cooking, but also for exports. The capacity of this plant is approximately 2.485 billion standard cubic feet per day (SCFD).[12]

In 2016 KPC created a new subsidiary, Kuwait Integrated Petroleum Industries Company (KIPIC), to oversee the operations of the Al-Zour refinery complex, which converts a mix of Kuwaiti crudes into low sulfur fuel oil and lighter products, and enables KPC to realize certain national priorities by capturing additional revenues from downstream activities. The Al-Zour refinery is expected to have a capacity of 615 thousand bpd (assuming 100% KEC[13]) and has began commercial operations in November 2022.

The additional refining of Mina Al-Zour along with the upgrades to Mina Abdullah and Mina Al-Ahmadi can potentially enable Kuwait to diversify its energy portfolio and thus, increase export revenues of Kuwait. This goal can be achieved through enhancing the specifications of petroleum products to meet the quality standards of international markets. Furthermore, these upgrades can improve the quality of products for the local market by reducing the sulfur content in fuel oil burnt in local power stations.

Power Generation Sector

The Ministry of Electricity, Water, & Renewable Energy (MEWRE) manages Kuwait's power generation sector, including regulation and operations. The power generation fleet is comprised mostly of conventional generation consisting of steam turbines, open-cycle gas turbines, and combined cycle gas turbines. Throughout the years MEWRE has been upgrading its power generation fleet to more efficient combined cycle generators that are mainly fueled by natural gas (see Table 1.1).

Table 1.1 | Power generation & desalination capacities by station in 2022.[14]

Station	Generation Technology	Generation Capacity (MW)	No. of Desal. Units	Desal. Capacity (MIG per day)
Doha East	Steam turbine (7) OCGT (6)	1,122	7	42
Doha West	Steam turbine (8) OCGT (5)	2,541	16 distillers & RO	170.4
Az-Zour South	Steam turbine (8) OCGT (4) CCGT (15) CCST (4)	6,056	16 distillers & RO	140.4
Az-Zour North	CCGT (5) CCST (2)	1,532	10	107
Sabiya	Steam turbine (8) OCGT (4) CCGT (8) CCST (4)	6,745	8	100
Shuaiba South	Steam turbine (6)	720	6	30
Shuaiba North	CCGT (3) CCST (1)	875	3	45
Shuwaikh	OCGT (6)	252	3 distillers & RO	48.5
Shagaya	PV, wind, CSP	70	0	0
Total		19,913	69	683.3

Over the past decade, this commitment has led to lower emissions in the power generation sector even though electricity demand was growing at a high rate. However, due to the lockdowns and shutdown of operations in Kuwait's oil and gas sector, Kuwait had to rely on crude oil for power generation in 2020. While natural gas remained the highest fuel supplied for power generation at 9.3 Mtoe in 2020, crude oil accounted for 3.8 Mtoe of supply for power generation. Usually, fuel oil is the second most supplied fuel for power generation, but it fell to 3.3 Mtoe in 2020 from 5.6 Mtoe in 2019 (see Figure 1.6).[14] Kuwait has committed to renewable energy and the first renewable energy power station at Shagaya was interconnected fully in 2018. Over the period to 2035, Shagaya RE complex could reach up to 4.5 GW of installed capacity. However, to mitigate the variability and intermittency of renewables, Kuwait should make more sites for renewable energy generation available. Another potential site for a utility scale renewable energy power station is Liyah in the north of Kuwait. Furthermore, there are ongoing projects to assess the potential of offshore wind energy.

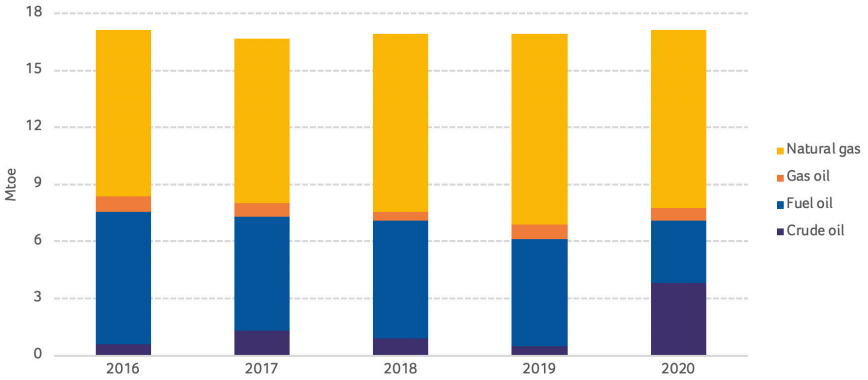


Figure 1.6 | Fuels used for power generation in Kuwait 2016 to 2020 (sourced from MEWRE statistics).

Comparison of National Energy Demand

Kuwait has one of the highest per capita energy intensities in the world, largely due to its heavy dependence on oil and gas as primary sources of energy. Energy intensity indicates the amount of energy required to produce one unit of economic output. Based on IEA statistics in 2019, as shown in Figure 1.7, Kuwait's energy intensity, which measures the amount of energy needed to generate one US dollar of economic output, reached about 205 ktoe per GDP (billion USD 2015).[15] Kuwait was ranked third in the GCC for energy intensity after Qatar and Bahrain, which consumed 219 and 297 ktoe per GDP (billion USD 2015), respectively in 2019. Overall, Kuwait's energy intensity is trending upward, similar to Qatar's, while Bahrain's and Oman's are trending downward.

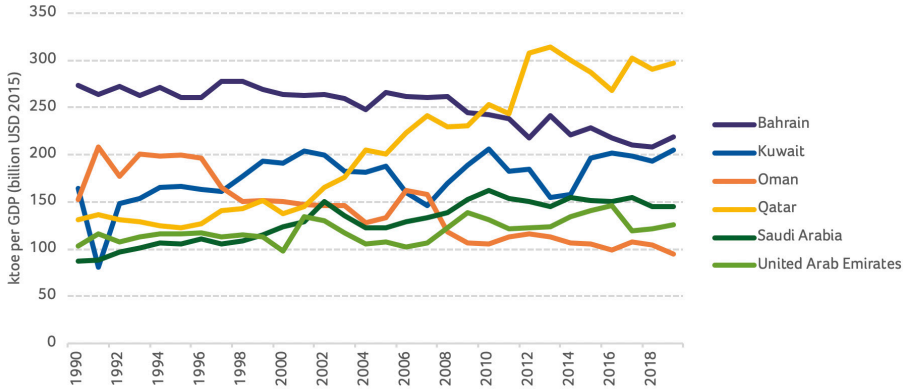


Figure 1.7 | Energy intensities of the various GCC states. [15]

Kuwait produces a massive amount of energy due to the abundance of its oil and gas reserves. Based on locally gathered statistics, Kuwait averaged approximately 20 Mtoe of total final energy demand during the period from 2016 to 2020. The energy sector is run by KPC and its subsidiaries. Most of the energy produced in Kuwait in the form of crude oil and oil-derived products from its refineries is exported (see Figure 1.8). Since 2016, exports have ranged from 77 to 80 percent of all energy production. Thus, on average, Kuwait supplies its needs with about 20 percent of the energy it produces.

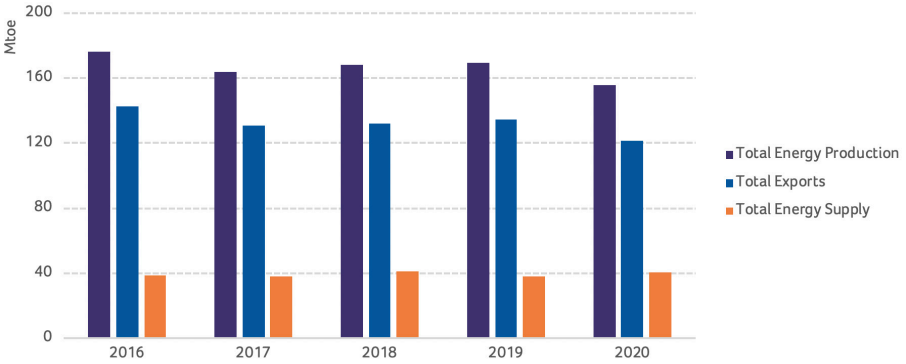


Figure 1.8 | Energy production, exports, and supply according to locally sourced statistics.

Based on local statistics, the three major sectors consuming energy in Kuwait are industry, transport, and buildings – see Figure 1.9. Kuwait's industry, especially it's growing chemical and petrochemical sectors, use natural gas as fuel and oil-derived products such as ethane and naphtha as feedstocks to produce petrochemical products that are then exported. Industry demand including feedstocks averaged approximately 4.3 Mtoe over the period 2016 to 2020 due to the growing share of feedstocks in the petrochemical sector. Notably, transportation is the leading sector for local energy consumption. Kuwait relies heavily on private vehicles due to a dearth of public transport. Demand by the transport sector averages approximately 5 Mtoe over the period according to locally available statistics. Inevitably transport demand will continue to grow unless Kuwait adopts mass transit systems, which could drastically cut demand (see Box 2.2 on Energy Efficient Transport via Metro Development). Finally, in the buildings sector, energy demand is dominated by the need for space cooling. During the period when local statistics became available, Kuwait averaged 4.6 Mtoe, with residential energy demand accounting

for approximately 72 percent of total building energy demand. Most of this demand is fulfilled by electricity, accounting for approximately 80 percent of building energy demand, which is mostly used to fulfill space cooling demand. A small amount of building energy demand is fulfilled by oil-derived products, such as liquefied petroleum gas (LPG) for cooking purposes.

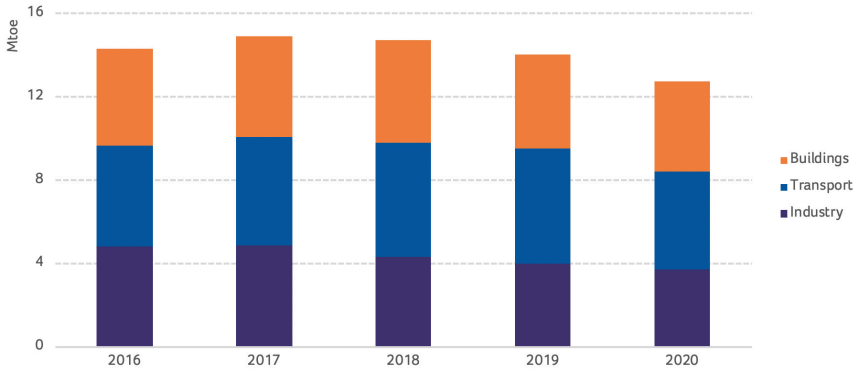


Figure 1.9 | Energy demand in the industry, transport, and buildings from locally source statistics.

Utilizing IEA statistics,[15] Kuwait can readily be compared to other countries. A comparison of Kuwait to the rest of the GCC shows that Kuwait usually ranks third in terms of electricity consumption per capita. Kuwait is now hovering at approximately 14 MWh per capita as of 2019 and 2020 according to the IEA statistics (see Figure 1.10). In 2020, Bahrain is the highest at approximately 18.7 MWh per capita and Oman is the lowest at approximately 6.5 MWh per capita.

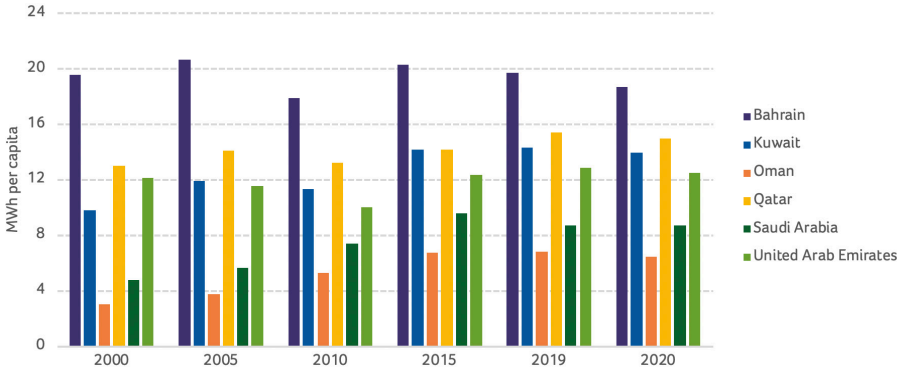


Figure 1.10 | Total electricity consumption in MWh per capita comparing Kuwait to the rest of the GCC.[15]

A comparison of these nations' per capita utilization of electricity for the residential sector changes the outcomes. When comparing residential electricity consumption, Kuwait and Qatar become the highest consumers in the GCC. Kuwait's electricity per capita consumption was approximately 6.4 and 6.2 MWh per capita in 2019 and 2020, respectively (see Figure 1.11). Qatar was the highest at approximately 6.8 and 7 MWh per capita in 2019 and 2020, respectively. Observe, how the metric has changed for Bahrain. In 2020, residential electricity consumption was approximately 5 MWh per capita which is much lower compared to the overall electricity consumption per capita at approximately 18.7 MWh per capita.

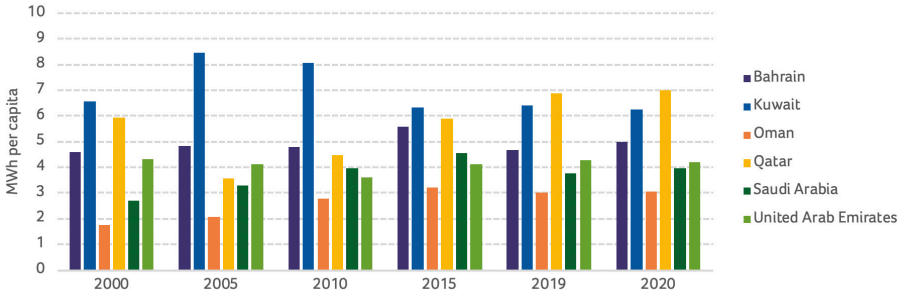


Figure 1.11 | Residential electricity in MWh per capita comparing Kuwait to the rest of the GCC.[15]

However, the comparison for the residential sector among countries should not exclusively be limited to electricity but also should include all energy forms consumed. For example, Kuwait's residential sector utilizes LPG for cooking purposes. Therefore, when accounting for all energy forms that are consumed in the residential sector in 2019 and 2020, Kuwait and Qatar consumption track higher (see Figure 1.12). Kuwait consumed approximately 7 MWh per capita energy consumption. Kuwait and most of the GCC countries experience extreme heat during certain months of the year that increases the need for space cooling. If Kuwait wishes to lower overall residential demand, it needs to adopt energy efficient technologies such as district cooling to lower energy demand in the residential sector. Kuwait could also adopt more renewable energy by allocating more sites for utility scale renewable energy power stations, thus, lowering emissions due to electricity. All countries need to have their needs for spatial comfort met and be supplied by affordable and clean energy – Sustainable Development Goal Number 7 of the United Nations.[16]

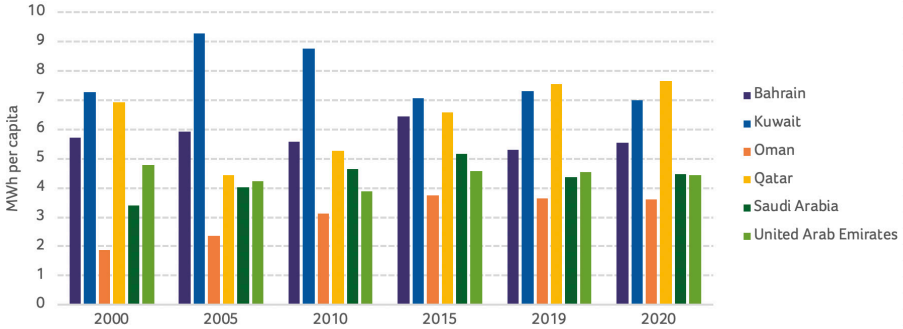


Figure 1.12 | Residential energy consumption in MWh per capita comparing Kuwait to the rest of the GCC.[15]

Kuwait's National Low-Carbon Development Strategy for Nationally Determined Contribution (NDCs)

Kuwait's commitment to lowering carbon emissions and adapting to the energy transition will depend upon the circular economy of carbon. Legislation related to mitigation and adaptation due to climate change for the period between 2015-2035 are well established as part of Kuwait's first nationally determined contributions (NDC) submitted to UNFCCC. As part of its first NDC strategy, the following seven features were designated for energy, including: (a) expanding the use of natural gas in the production of electricity, (b) increasing the share of renewable energy in the energy mix, (c) enhancing energy efficiency in various sectors, (d) reducing emissions by using carbon capture and storage in the oil and gas, (e) reducing emissions by using industrial applications.

At 2025 Kuwait will be updating its NDCs with new national long-term low-carbon development strategies for different sectors by 2050 and reaching carbon neutrality in 2050 in the oil sector and for all sectors in 2060, including energy, transportation, agriculture, waste management, and industry. In addition, the country is planning to achieve the following six major energy targets by 2060, which are, (i) increasing renewable capacity to 15 percent by 2030 and reaching more than 30 percent by 2060, (ii) improving energy efficiency in all government buildings by 30 percent by 2025 and 50 percent by 2050, (iii) reducing carbon emissions by 50 percent due to oil refining by 2040 and reaching neutral carbon emissions by 2050 in the oil sector, (iv) expanding carbon capture, storage, and utilization projects and blue hydrogen production in the country, (v) relying on reverse osmosis (RO) in water desalination by increasing RO capacity, and (vi) reducing carbon emissions in the oil and gas sector through enhancing the refinery production process.[17] Kuwait is also targeting the development of a public transport network and infrastructure development as part of mitigation along with plans for capacity building for maintenance of electric vehicles. However, if Kuwait would like to see significant emission savings in the transport section, it would adopt a network of metro, trams, and bike paths for the country – see Box 2.2 on Energy Efficiency Transport via Metro Development in the subsequent chapter.

Projecting Future Developments

In the previous editions of the Kuwait Energy Outlook (KEO), KEO-2019 and KEO-2020, energy projections were based largely on data curated by the International Energy Agency (IEA). In the present edition, a comprehensive local dataset has been constructed based on direct communication with relevant entities, such as the K-companies and MEWRE. IEA data is still being used, but only in situations where they provide additional temporal coverage beyond locally sourced statistics. The KEO makes projections based on the collected datasets to characterize the *Business-as-Usual* (BAU) case, which reflects our judgement about a reasonable trajectory of development in Kuwait's energy economy to 2040. In this section, an overview of how model projections were derived is briefly presented, and the reader is invited to read Chapter 2 for their results. Analytical methods start by estimating the energy demand (e.g., buildings, transportation, water desalination, etc.) over the period from 2020 to 2040. Those estimates are then used to calculate the required electricity and fuel production, which finally is used to estimate the emissions based on IPCC emission factors.[1,18]

KEO-2023 is a significant improvement over KEO-2019 and KEO-2020. In the previous editions, the paucity and opacity of data prevented characterizing energy demand in certain sectors. One such improvement in KEO-2023 is the modeling of air-conditioning demand. In KEO-2019 and 2020, only residential air-conditioning demand could be modeled. Energy demand could not be represented in the service/government sector, leaving a serious gap in the analysis. Now, with data from PACI[19] on buildings, the KEO-2023 has a building air-conditioning demand model. Air-conditioning demand projections are based on the projected number of buildings in Kuwait by type (e.g., houses, police stations, schools, hospitals, etc.). Energy demand of other uses is based on CSB survey data,[20] as in the previous edition of the KEO.

Turning to transport, the model uses historical vehicle counts (data from CSB) and fuel sales data (from KNPC and, for more temporal resolution, from IEA) to project transport energy demand. Industrial energy demand projections are based on local energy statistics derived from K-companies and CSB, which were developed in the years since KEO-2020. Finally, water demand projections are based on historical MEWRE consumption figures and per-capita water consumption.

Table 1.2 provides the GDP and population assumptions for the *Outlook* period ending in 2040. The economy of Kuwait experienced rapid growth in the decade 2000-2010. This growth decelerated over the decade 2010-2020. Since the COVID-19 pandemic has ended, Kuwait's economy is expected to recover and grow at an average rate of 3 percent up to 2030 and after, which will decrease to a rate of 2.6 percent through 2040. GDP and GDP growth rates were based on the World Bank's World Development Indicators.[21] While historical population statistics were sourced from the Public Authority

for Civil Information,[22] the projections for populations were based upon the growth rates derived in United Nations World Population Prospects.[23] In the period to 2030, population in Kuwait increases at an average rate of 0.5 percent. After 2030, population increases at approximately 1.1 percent.

Table 1.2 | Population and average GDP growth rate* assumptions in the Business-As-Usual case.

	2000	2010	2022	2030	2040	2000-2010	2010-2020	2020-2030	2030-2040
GDP (billion $US 2015)	61.3	95.9	104.3	140.4	181.5	4.8%	1.0%	3.0%	2.4%
Population (thousand)	2,217	3,582	4,671	4,810	5,221	4.9%	2.7%	0.5%	1.1%

***Average annual growth rates.**
Source: GDP growth assumptions from World Bank World Development Indicators. Population assumptions from United Nations World Population Prospects 2022.

Since the demand for electricity and water is a major portion of overall energy demand, the KEO uses a dedicated water and electricity production model that explicitly characterizes power plants, their specifications, and stated future expansion plans. The model better reflects MEWRE operations. The result of this optimization is the projected power plant fuel requirements. Table 1.3 to Table 1.6 presents the MEWRE power generation and water desalination capacity plans. Based on those requirements and the estimated demand, the oil and gas model uses efficiencies and historical production and export data from K-companies to calculate required crude oil and natural gas. Finally, IPCC emission factors are used to estimate emissions at every point in the model sector where fuel is burned.

Table 1.3 | Power generation capacity plan for MEWRE (2023-2029).

Year	Electric power in MW				Renewable Energy (MW)
	Available maximum capacity	Safe capacity	Added capacity	Phase out Capacity	
2023	18,277	17,717		Not updated	
2024	18,997	18,067	600		
2025	19,597	18,667	250		30
2026	19,847	18,917	2,100		2,100
2027	21,947	21,017	5,100		1,900
2028	27,047	26,117	1,200		
2029	28,247	27,317			

Table 1.4 | MEWRE Plan for construction of new power plants till 2040.

Capacity (MW)	Plan
1800	Construction of Khiran second phase
3600	Construction of Nuwaiseeb second phase
660	Removal of Shuaiba South
910	Removal of Doha East
2700	Renewal of Doha East
1350	Renewal of Shuaiba South

Table 1.5 | MEWRE Plan for construction of new water desalination plants till 2040.

Capacity (Million Imperial Gallons per day)	Plan
60	Construction of Doha West RO (second phase)
120	Construction of Az-Zour North (second and third phase)
33	Construction of Khiran
30	Construction of Shuaiba South
50	Renewal of Shuaiba South
42	Removal of Doha East Phase 1
70	Renewal of Doha East Phase 1
75	Construction of Nuwaiseeb plant

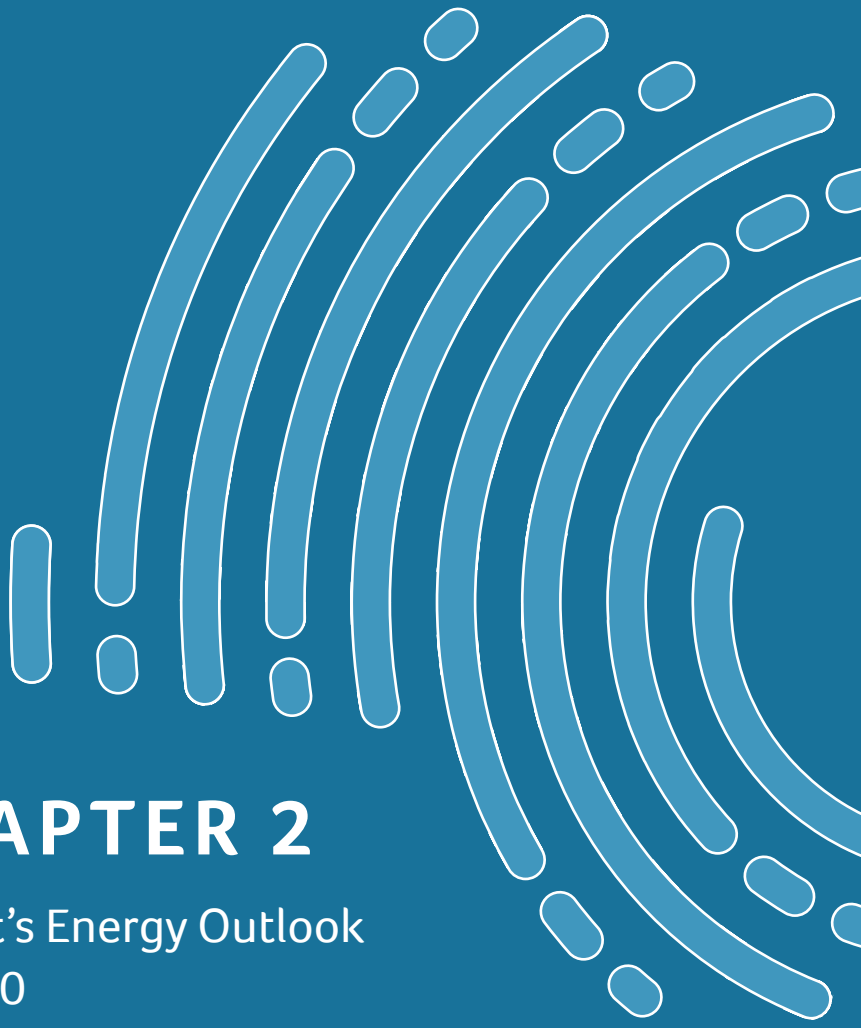
Table 1.6 | Electric power stations and water desalination projects for MEWRE from 2023-2029.

Project	Station type	Capacity (MW)	Year of commencement
Subiya Station project phase 4	Open cycle GT	600	Q2-2025
	Combined cycle ST	300	Q3-2026
Nuwaiseeb station project Phase 1	Open cycle GT	2400	Q4-2027
	Combined cycle ST	1200	Q3-2028
Subiya station reinforcement project	Combined cycle ST	250	Q2-2026
Az-Zour North station project (Phase 2 & 3)	Open cycle GT	1800	Q2-2027
	Combined cycle ST	900	Q1-2028
Khiran station project Phase 1	Open cycle GT	1200	Q3-2027
	Combined cycle ST	600	Q2-2028
Shagaya station project Phase 2	PV solar panels	1100	Q4-2026
Shagaya station project Phase 3	CSP Solar thermal energy	200	Q1-2028
Shagaya station project Phase 4	PV solar panels	1500	Q1-2027
Shagaya station project Phase 5	PV solar panels	1700	Q4-2027
Photovoltaic panels project on water tanks	PV solar panels	30	Q3-2025

The present KEO has made strides in the level of detail of its modeling thanks to the cooperation of relevant local entities; however, there are still deficiencies in data curation that should be addressed in the future. First, there is no reliable historical breakdown of electricity consumption in Kuwait by sector. Such a breakdown can help improve the calibration of the demand models and ultimately increase the accuracy of the projected electrical load. Second, the oil and gas model does not characterize individual refineries and their specifications, as the required data is not available. By increasing the level of detail here, one could construct more complex models that allow for better representation of electricity and water production and refinery fuel production. Third, the transport model makes assumptions about the distance driven by vehicles. It would be more desirable to use actual data. Finally, the lack of collaboration between energy players leads to long delays in receiving feedback and data from energy entities.

The previous issues show that there is a pressing need to improve data collection efforts in Kuwait. These problems could be solved by improving the institutional capacity for data collection and cross-institutional collaboration. The analysis in this edition of the Kuwait Energy Outlook was only possible due to data provided by the Kuwait Petroleum Corporation and its subsidiaries Kuwait Oil Company and Kuwait National Petroleum Corporation, Central Statistical Bureau, Ministry of Electricity, Water, & Renewable Energy, Public Authority for Civil Information, and Public Authority for Industry. While efforts still need to be made to improve the consistency and reliability of data in Kuwait, it must be recognized that the analysis presented in this KEO-2023 edition is only possible because of contributions of the previously mentioned entities. Greater refinement in data collection would result in a more nuanced analysis.

Finally, chapter 3 explains Kuwait's perspective on the energy security-transition nexus. As a net exporter of energy products, Kuwait has a unique view of the energy transition. Security of energy demand is necessary for Kuwait because it is highly dependent on its energy sector. Chapter 3 recommends national policies supporting the development of a sustainable energy system, alleviating potential challenges, and making use of opportunities. The proposed policies are based on the assessments of the national energy system's status quo and possible future developments concerning economic and geopolitical concerns and impacts.



CHAPTER 2

Kuwait's Energy Outlook to 2040

Chapter 2 Highlights

- This edition of KEO improves the projection models with new locally sourced statistics from various energy players.
- Primary energy to fulfill all local demand is projected to increase by 29 percent over the Outlook period.
- By the end of the Outlook period, primary energy supply to fulfill local demand continues to be dominated by oil and natural gas, with renewable energy constituting a negligible amount.
- Buildings, transport, industrial, non-energy use, and desalination sectors are the major categories of the final energy demand in Kuwait. Over the outlook period, their shares of the final energy demand remain relatively constant.
- Buildings and transport sectors are the most energy demanding at 28 percent each in 2019, followed by industry and non-energy use sectors (36 percent combined in 2019), and desalination (8 percent in 2019).
- Desalination energy demand stays relatively constant: Unlike other sectors, desalination's share of total demand drops from 8 to 5.5 percent over the Outlook period, despite increasing water demand, due to the retirement of older Multi-Stage-Flash (MSF) plants and the planned introduction of efficient Reverse Osmosis (RO) plants.
- Tremendous opportunities for reducing building energy demand: Building energy demand grows by 35 percent over the outlook period with air conditioning constituting the bulk of it at 67 percent. The government has

a big opportunity to reduce building energy consumption by auditing AC demand in government buildings, utilizing smart building applications, and setting policies for building automated systems. The government can also reduce emissions from residential buildings by increasing the efficiency of cooking appliances, which mainly use Liquid Petroleum Gas (LPG).

- Transport fuel demand grows by 63 percent by 2040, and EVs will not solve the issue. Solving this problem requires considering alternative modes of transport to road transportation, such as the Metro. Electric vehicles are not sufficient to halt fuel demand growth as they shift the demand from the vehicles to electric power plants.

- By 2040, natural gas will account for most of the energy demand in the industry (64 percent), followed by electricity (32 percent), and Diesel. MEWRE could expedite the adoption of renewable energy in this sector by selling renewable energy certificates.

- Crude oil production in Kuwait is expected to increase from 2.7 million barrels per day in 2019 to 4.0 million barrels per day in 2040, growing at a rate of 1.9 percent per year. Kuwait continues to increase its use of natural gas. This strategy is supported by LNG imports that are expected to continue to be an important source of natural gas supply over the Outlook period.

- Emissions are dominated by the power generation sector followed by transport and oil and gas sectors. The government could thus reduce emissions by accelerating the retirement of older steam and water desalination technologies, adopting more renewable energy plants, and exploring the use of blue hydrogen to run the oil & gas sector instead of natural gas and diesel.

Kuwait Energy Outlook to 2040

Overview of Energy Demand Trends

In the initial publication of the Kuwait Energy Outlook-2019 (KEO-2019), it was stated that reliable data and robust projections will serve as the essential foundation for Kuwait's policy choices as it prepares for a more sustainable energy future. KEO-2019 was published while local energy statistics were incomplete and thus relied on IEA energy balances.[1] Since then, the various energy players have been working with the Kuwait Institute for Scientific Research (KISR) to enhance this analysis. In this current edition, KEO-2023 is built with local statistics when available and IEA energy balances when not available. In this chapter, results from the energy system model developed for Kuwait is presented in a Business-As-Usual (BAU) case developed with local statistics reflecting the trends in Kuwait's energy system until 2040.

Kuwait is experiencing ever-increasing domestic energy demand. As this demand grows, more crude oil and oil-derived products that could be exported must be diverted to meet local demand. In the BAU case, primary energy for local demand is simulated over the *Outlook* period from 2019 to 2040 (see Figure 2.1). Most of the primary energy devoted to meeting local demand is fulfilled by oil, averaging 55 percent share, followed by natural gas at 45 percent. While Kuwait has begun exploiting renewable energy, its share in the overall energy mix to meet local demand is currently negligible but will largely grow in order to achieve the national target of reaching Net-zero GHG Scope 1 and Scope 2 emissions by 2060. This is lower than the previously stated 3 percent in KEO-2019 due to the delay and cancellation of some renewable energy projects. In the BAU case, primary energy to meet local demand will grow at a steady 1.3 percent over the *Outlook* period. Total primary energy in Kuwait is projected to grow from approximately 31 to 40 million tonnes of oil equivalent (Mtoe).

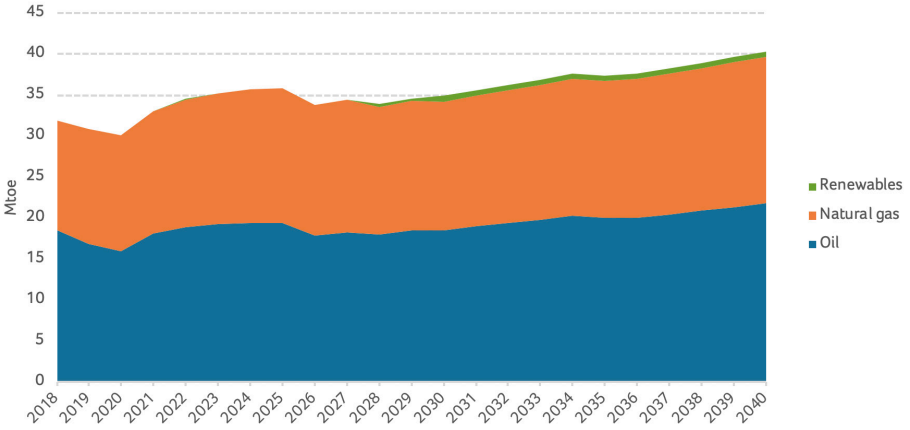


Figure 2.1 | Primary energy required to fulfill local demand over the Outlook period to 2040.

Prepared with new local statistics, the KEO-2023 improves upon the energy demand models developed and has rerun the BAU case with these local statistics. One such improvement in KEO-2023 is that the original residential and services models have been combined into a building model, where it becomes possible to quantify demand by building type – as described in the section on *Buildings* below. The new energy demand models for the BAU case have been modified to project demand in buildings, transport,

industry, non-energy, and desalination (see Figure 2.2). Final energy demand in Kuwait is growing at approximately 2 percent per annum. While buildings and transport demand consumed the most energy in 2019 at approximately 28 percent each, the transport energy demand grows at a higher annual rate (2.3 versus 1.4 percent for buildings). Thus, transport energy demand is projected to be highest by the end of the *Outlook* period, reaching a level of approximately 30 percent of all final energy demand in Kuwait. Industry and non-energy use sectors are dominated by final demand from the chemical and petrochemical industry. These sectors combined account for approximately 36 percent of demand in 2019 and the share increases to almost 40 percent over the *Outlook* period to 2040. Note that the final demand from the non-energy use sector is mainly feedstocks of oil-derived products, such as ethane, that are not used as a fuel for energy purposes. Finally, desalination's total share of final energy demand falls over the *Outlook* period from approximately 8 to 5.5 percent.

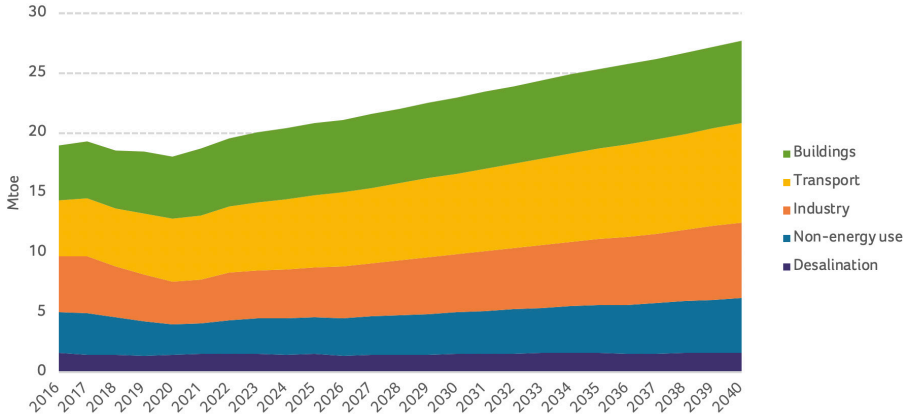


Figure 2.2 | Total final energy demand by sector over the Outlook period to 2040.

In the BAU case, in order to fulfill the demand of all the sectors mentioned above, Kuwait will have to provide energy in a variety of forms, including electricity, natural gas, oil products, and heat for desalination (see Figure 2.3). Electricity demand, which is mostly consumed in the buildings sector, grows at a compound annual rate of 1.6 percent annually. Natural gas in the final energy demand is consumed by industry and grows at the fastest rate, approximately 2.3 percent annually. Compared to natural gas, oil-derived products, consumed by the buildings, transport, and industry sectors, will witness slightly lower but steady growth at 2.2 percent. Most of this growth is due to transport sector demand, followed by industry, and is mostly driven by demand for diesel, which grows the fastest for oil-derived products, at a rate of approximately 2.6 percent annually. Finally, heat for desalination grows at less than 1 percent annually due to adoption of more efficient multi-effect water desalination technology over the *Outlook* period.

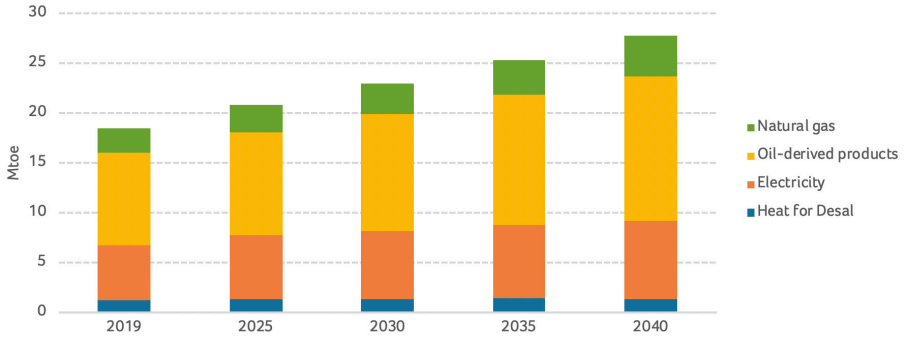


Figure 2.3 | Total final energy demand by fuel over the Outlook period to 2040.

Buildings

The buildings model of Kuwait incorporates demand from the residential and service sectors. This is an update over the original models and the new Business-As-Usual (BAU) case models air conditioning demand not just in the residential sector, but also in government buildings as well as the rest of the service sector. These new models were only possible due to the authorities heeding the call from the last KEO-2019 and releasing data. Specifically, this model was possible due to the data set provided by the Public Authority for Civil Information (PACI), which lists buildings in Kuwait by type and the area in square meters. This data was paired with final energy demand data from the K-companies and the MEWRE to model building energy demand. Overall energy demand in buildings in Kuwait grows at a rate of 1.4 percent in a BAU case, with electricity fueling most of this demand. Over the *Outlook* period 2019 to 2040, buildings energy demand increases from approximately 5.1 to 6.9 million tonnes of oil equivalent (Mtoe) – see Figure 2.4.

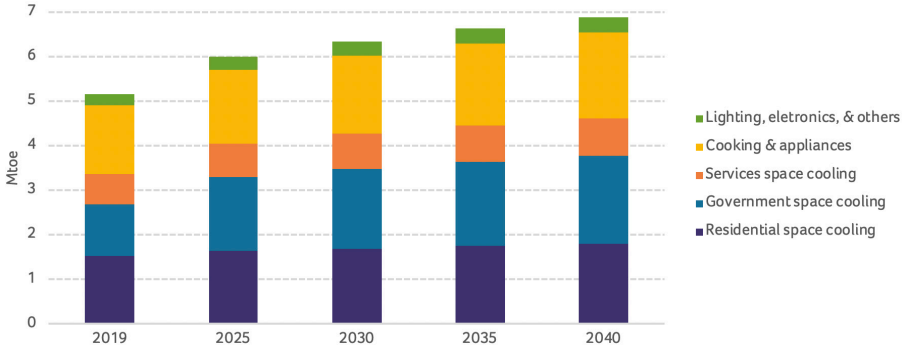


Figure 2.4 | Total final energy demand in buildings by end-uses including LPG for cooking purposes.

Air conditioning accounts for approximately 60 percent of total electricity demand in Kuwait. For total buildings demand for all fuels, air conditioning reaches a maximum of 67 percent over the *Outlook* period. Since air conditioning demand is growing at a rate of 1.5 percent annually from approximately 39 to 53 TWh over the *Outlook* period to 2040, Kuwait has an immense opportunity for reducing energy demand by applying energy efficiency policies. The government can start by tackling air conditioning demand in government office buildings, which is projected to double over the *Outlook* period to 2040, reaching over 22 TWh. Kuwait can start by demanding energy audits by certified energy auditors in

government buildings, who can evaluate performance of air conditioning systems and recommend practices to building operators to lower overall demand. Kuwait's updated building code stipulates limits on the power requirements (Watts per square meter) for different end-user systems (ex. lighting and A/C) and types of buildings. Thus Kuwait can evaluate introducing energy targets to control energy consumption (kWh/m^2.year) in various types of buildings.

Kuwait can also encourage the adoption of smart building applications and set policies for building automated systems (*see Box on Energy Savings through Automation*). Since government office buildings demand such a high amount of space cooling, decision makers can apply energy efficiency measures in government offices first, which would then be a model for the residential and service sector.

Other notable energy demands in buildings are cooking, appliances, lighting, and electronics. Over the *Outlook* period, demand from these end-uses grows at 1.1 percent annually. While most of these end-uses utilize electricity, LPG is the major fuel for cooking, at over 95 percent fuel share with the remainder fulfilled by electricity. Kuwait could reduce emissions by encouraging the use of energy-efficient cooking appliances in the residential and services sectors.

Box 2.1 | Energy Savings through Automation

With high energy demand for space cooling in the country, the Kuwait Institute for Scientific Research continuously seeks solutions to reduce demand through energy efficient practices. Working with a Korean consortium that included the Korean Conformity Laboratory and OnTest Incorporated, KISR conducted a project entitled Development of Model-Based Active Control of Home Energy Management System. This was an experiment-based project where KISR utilized a demonstration home to apply an active energy efficiency management system to reduce energy consumption due to space cooling.

Thermostats control the operation of all air-conditioning (A/C) systems. A typical thermostat operates the A/C system by controlling the room air temperature based the occupant's set temperature. For this project, thermal comfort was used to control the operation of the A/C system. The assessment of thermal comfort was determined following ASHRAE Standard 55-2017[2]: Thermal Environmental Conditions for Human Occupancy[2], which utilizes the predicted mean vote (PMV) model developed by P.O. Fanger[3]. This model provides an index, mainly based on 5 contributing parameters, to predict the mean thermal sensation of a group of persons in an air-conditioned environment. The five parameters are air temperature, radiant temperature, relative humidity, air velocity, activity, and clothing of occupants.

The PMV scale extends from -3 to +3, with the former indicating the environment is too cold, and the latter indicating the environment is too hot. Thermal neutrality, or thermal comfort, is considered to have been achieved when the index is at 0. ASHRAE-55 suggests maintaining PMV index between ±0.5 to ensure reasonable thermal comfort in an environment.

For this project, a model home resembling a typical local villa was constructed and equipped with sensors and devices necessary to control the air conditioning units using thermal comfort conditions. By aiming to maintain a ±0.5 PMV index range as a target, it was found that the model home was able to reduce A/C consumption by 26 percent compared to typical thermostat-based utilization. If adopted and based on the current housing stock in the country, Kuwait could potentially save approximately 4.5 TWh or approximately 6 percent of gross electricity production on space cooling demand. Going forward, if such a practice is verified to be viable, it could be standard for new cities such as Saad Al-Abdullah Smart City.

Transport

The transportation sector in Kuwait is exclusively a road transportation network. In 2019, the Central Statistical Bureau of Kuwait[4] reported a road network extending 8.1 thousand km dominated by about 1.79 million private vehicles. Additional modes of road transport include trucks, buses, taxis, and others, which bring the total to approximately 2.24 million vehicles. These vehicles are fueled by gasoline and diesel. From 2019 to 2040, total energy demand from all fuels grows at approximately 2.3 percent annually. As a result, demand for transport fuels grows from 5.1 to 8.3 million tonnes of oil equivalent over the *Outlook* period (see Figure 2.5). By 2025, transportation becomes the sector with the most energy demand, and its share in total energy demand reaches 30 percent by 2040. This growth will continue unabated until there are alternatives for residents in Kuwait. Because Kuwait's transport sector is dominated by road transport and in particular private vehicles, it can take advantage of adopting energy efficient modes of transport, such as a Metro (*see Box 2.2 on Metro*).

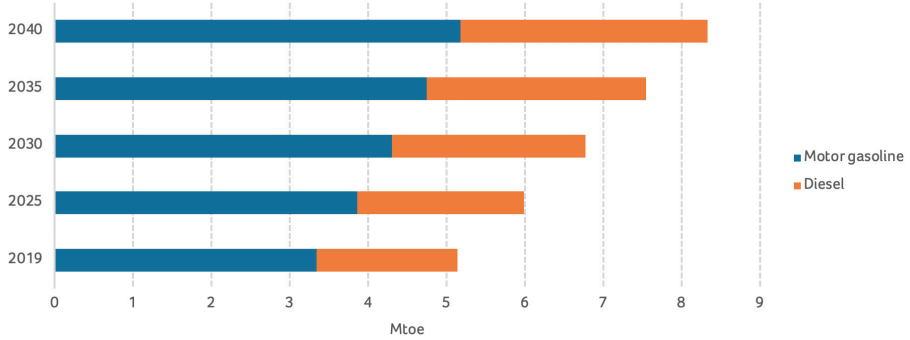


Figure 2.5 | Motor gasoline and diesel demand in the BAU case over the Outlook period to 2040.

Box 2.2 | Energy Efficient Transport via Metro Development

Most of the Gulf Cooperation Council (GCC) countries, i.e., United Arab Emirates, Qatar, and Saudi Arabia have operational metro systems. The Dubai Metro, which began operations in 2009, is the oldest in the region. As of 2021, the Rail & Transport Authority of Dubai[5] operates a Metro network that spans 89.3 km with 53 stations and a fleet of 125 trains. Dubai's metro is augmented by a 10.6 km tram network featuring 11 stations and 11 trains. In 2021, the Dubai Metro and Tram served 151.3 and 5.34 million passengers, respectively.

Qatar's metro and tram network started operating in 2019 in its capital city of Doha. The Doha Metro network is 76 km with 40 stations and 75 trains6. Lusail Tram, Qatar's tram network, extends for 5.5 km and features 7 stations. The combination of the metro and tram was essential for hosting the World Cup. Since tourists do not always wish to ride in taxis, convenient, clean, and safe public transport is essential for countries that wish to host tourists. With Qatar having just hosted a well-organized and successful World Cup, imagine the chaos and complaints tourists might have had if Qatar had not developed the metro and tram networks.

Saudi Arabia, which hosts pilgrims from all over the world for Hajj, built its first Metro in Mecca[7] in 2011. Saudi Arabia also has trains in multiple cities, including Medina, Jeddah, and Riyadh. Currently, Oman is planning a metro in its capital, Muscat, to run to the airport.

Several years ago, Kuwait too had plans to adopt a metro and the construction was to be completed in five phases. The first phase would have been 50 km and would have traversed the densest areas of the country. This first phase would have split by taking passengers to two major hubs - one terminating at Kuwait University's Shadiyah Campus and the other at Kuwait International Airport. The planned completion date for the first phase was 2025. The remaining four phases would have extended the metro's network to 160 km with 68 stations. The final phase was to have been completed in 2040. Forty-four million passengers were projected to be served in the first phase alone, ultimately reaching 61 million when all five phases would have been completed. The metro would have substantially reduced traffic congestion because residents and tourists would have had options other than road transport.

The adoption of the proposed metro was postponed for a variety of reasons. However, the pros and cons for introducing the policy of mass transit in Kuwait should be revisited because of its many benefits and the success of other GCC countries in adopting this mode of transportation. Based on the original Metro design,8 a metro of 160 km could consume approximately 1.1 Mtoe or 13 TWh of electricity. This would account for approximately less than 10 percent of additional electricity demand in 2040. According to demographic projections, with the adoption of this metro, Kuwait could reduce energy consumption for transportation by 3.5 Mtoe (due to reduction in consumption of motor gasoline and diesel for transport). This would mean 2.4 Mtoe of energy savings in 2040, a 32 percent improvement. Furthermore, Kuwait would gain an alternative mode of transport that could alleviate the increasingly onerous traffic congestion on the nation's road network. To date, there is only one mode of travel – road transportation. Due to a lack of alternatives, emissions from transportation are the highest after the power generation sector. Adopting electric vehicles would merely shift emissions to the power generation sector, which would not reduce emissions unless renewables were substantially adopted. Furthermore, if electric vehicles were massively adopted by 2040, electricity demand could increase by 60 TWh. In 2021, Kuwait's gross electricity production was 75 TWh. However, the adoption of a metro could significantly reduce emissions in the transportation sector. Energy demand would be transferred from motor fuels (gasoline and diesel) to electricity, but the transport sector would lower emissions and the power generation sector could make efficiencies by supplementing with renewable energy, adoption of more efficient combined-cycle power stations, and retirement of less efficient older power stations.

Industry & Non-Energy Use

Natural gas fulfills most energy demand in the industrial sector, accounting for approximately 61 percent of industry demand today. By the end of the *Outlook* period in 2040, natural gas share of the demand continues to to approximately 64 percent. In addition to natural gas, the industrial sector utilizes diesel primarily in the construction sector, which accounts for 5 percent of the industrial demand by the *Outlook* period.

Most of demand for energy in industry is due to the chemical and petrochemical sectors. These sectors consume most of the natural gas supplied to industry. They also utilize oil-derived products, such as ethane and naphtha, as feedstocks to produce high value-added products for non-energy use. These high value-added products include polyethylene, styrene, ethylene glycol, paraxylene, olefins, aromatics, and fertilizers, which contribute 20-30 percent[4] of value-added in the manufacturing sector of Kuwait.

Turning to electricity, MEWRE reports that the electricity demand from industry was approximately 12 TWh in 2019, which constituted 34 percent of industrial demand. Projections predict this share of the demand will decrease over the *Outlook* period to 32 percent, even though the actual electricity demand is expected to grow at about 2.3 percent annually (see Figure 2.6).

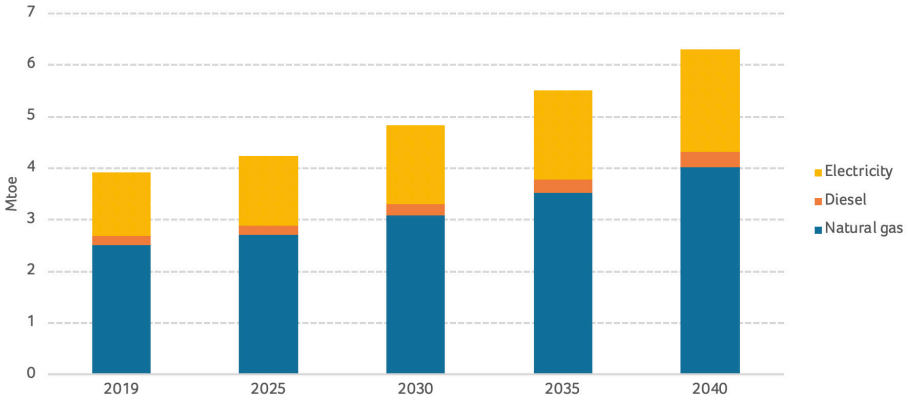


Figure 2.6 | Industrial energy demand in Kuwait by fuel type.

Kuwait and the MEWRE could expedite the adoption of renewable energy by selling renewable energy certificates (REC) to industrial companies. RECs are a market-based mechanism that could hasten the adoption of more renewable energy power stations. RECs would allow industrial companies in Kuwait to certify that their total electricity demand has been purchased from renewable energy. That is, over the course of the year, enough renewable energy would have been generated to meet their demand, and the REC provides the industrial company the right to the renewable energy. Industrial companies could then present these certificates to their customers. The amount of energy required from renewables would require more sites for renewable energy stations to meet this demand.

Desalination

Water is scarce in Kuwait. It depends on desalination technologies to produce potable water. Desalination plants operated by the MEWRE include three distinct technologies. The first is Multi-Stage Flash (MSF) which is the oldest technology deployed for potable water production in Kuwait and is the most energy intensive. It is a thermal based desalination technology that is part of a co-generation cycle and is typically paired with older steam turbine generators. The second technology is Multi-Effect Distillation

(MED), a more efficient thermal based co-generation desalination technology that was commissioned in 2015 in Kuwait's first independent water and power plant at Shamal Az-Zour (also known Az-Zour North). Finally, reverse osmosis (RO) is the most efficient desalination technology and has doubled in capacity since its original introduction in 2011.

In the Business-As-Usual case (BAU), Kuwait's water production capacity will become more energy efficient due to the adoption of MED and RO desalination, while MSF plants will be decommissioned along with older power plants (see Figure 2.7). Water production will increase from 761 to 1,133 million cubic meters. Energy demand, which includes heat production for thermal technologies and electricity for reverse osmosis, will increase from approximately 1.4 to 1.67 million tons of oil equivalent over the *Outlook* period (see Figure 2.8).

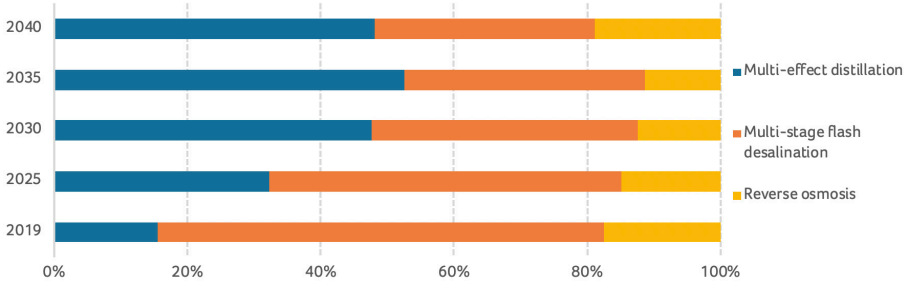


Figure 2.7 | Percent of water production by desalination technology.

Despite the increase in desalination capacity and water production, desalination energy demand only slightly increases by about 1 percent annually because of the adoption of more efficient desalination technologies (MED and RO) and the retirements of older facilities that produce water via MSF. This demonstrates that adoption of energy efficient systems by the MEWRE can meet Kuwait's needs while providing the same level of service. The MEWRE could even lower its energy demand by increasing the adoption and utilization of seawater RO plants.

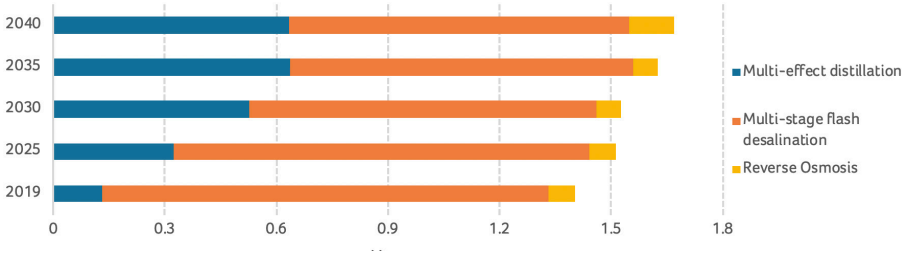


Figure 2.8 | Total energy demand (heat and electricity) by desalination technology.

Power Generation

The power generation fleet in Kuwait is operated and regulated by the state-owned utility, now known as the Ministry of Electricity, Water, and Renewable Energy (MEWRE). In 2019, the installed capacity was approximately 20 GW. The majority of this capacity is now more efficient combined cycle gas turbines, providing almost 9.1 GW. Additionally, Kuwait is served by older conventional steam turbine generators with capacity reaching another 9 GW. These older steam turbines will be retired and decommissioned over the coming decades, including Shuaiba South power plant and Doha East power plant. Note that

these retired power stations will likely become brownfield sites for new capacity development. Finally, open cycle gas turbines, which mostly operate during peak load periods, have reached a capacity of approximately 2.1 GW.

Kuwait has adopted grid scale renewable energy. Grid connected renewable energy in Kuwait comes from Shagaya Renewable Energy Park (SREP) (*see Box on Shagaya Renewable Energy Station Development*), which produces electricity via three renewable energy technologies, photovoltaics, wind, and concentrated solar power. Photovoltaics and wind energy at Shagaya are each rated at approximately 10 MW, while the concentrated solar power plant is rated at 50 MW and operates similar to conventional power plants due to the 10-hour molten salt storage.

To keep pace with rising electricity demand, Kuwait has begun opening its power generation sector to independent power producers (IPPs) and independent water and power producers (IWPPs) to increase the private sector's involvement. The first example of this is the Az-Zour North power station, which is listed on Kuwait's stock exchange.

Planned capacity additions are modeled in the BAU and include Khiran and Nuwaiseeb power plants. Planned conventional power plant additions are assumed to be combined cycle power plants due to Kuwait's commitments to reducing emissions.[9] Other capacity additions will come in the form of renewable energy generation. The majority of this will come from SREP, which has a planned capacity of 3.5 GW by 2030. Most of this capacity at Shagaya will be photovoltaics, reaching approximately 3 GW. CSP and wind in BAU case are assumed to be 0.25 GW – see Figure 2.9 below. This is modeled as such due to the delays in the execution of Shagaya. Kuwait's nationally determined contributions (NDCs) has changed so that renewables should be 15 percent of capacity by 2030. Due to the delays, this is likely not to occur. One major reason for the delays has been the lack of laws or legislations specifying the entity that should oversee renewable energy. This has now been resolved and renewable energy plants are overseen by the MEWRE.

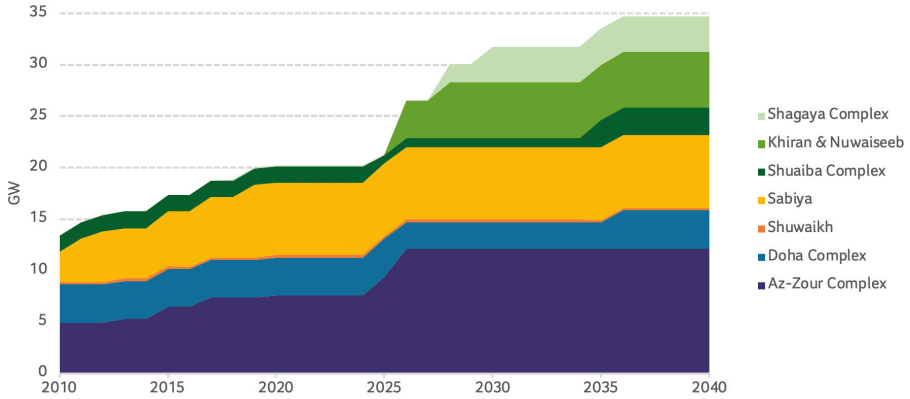


Figure 2.9 | Power generation development in Kuwait in the BAU case over the Outlook period to 2040.

Box 2.3 | Shagaya Renewable Energy Station Development

In 2018, Kuwait appointed a Higher Energy Committee to oversee the adoption of renewable energy technologies. This committee revised Kuwait's renewable energy target previously set in 2012 from 15 percent total electric energy to 15 percent of electric capacity by 2030. This change will allow Shagaya, a centralized multi-technology renewable power plant, to fulfill Kuwait's renewable energy target upon its completion. In addition, decentralized renewable energy installations as well as other grid scale power plants will all contribute to the fulfillment of Kuwait's 2030 energy goals. The total capital expenditure of Phase-I, including all needed infrastructure, was 176.6 million Kuwaiti Dinars.[10]

Shagaya Phase-I, led by the efforts of the Kuwait Institute for Scientific Research, has demonstrated the feasibility of renewable energy in Kuwait. The current technologies based at Shagaya include a 50 MW concentrated solar power plant using parabolic troughs with 10 hours of molten salt storage, a 10 MW photovoltaic plant, and 10 MW of wind turbines. The three renewable power plants, with a total installed capacity of 70 MW, produce approximately 200 GWh of clean renewable electric energy to the national grid annually. Shagaya Phase-I is an important achievement by Kuwait. It serves as the cornerstone for the next phase and has paved the way for future business and employment opportunities, and investment in the field of renewable energy.

Shagaya's concentrated solar power plant operates almost continuously as a conventional power plant due to its thermal energy storage capability. The CSP stations began operating in February 2019. In 2020, during the lockdowns due to COVID-2019, the plant produced 160.1 GWh of electricity, a capacity factor of 36 percent. Complementing the CSP plant, the photovoltaic plant at Shagaya has had some of the smoothest operations of all. In 2019, it produced approximately 20 GWh of net electricity. While the capacity factor is 23 percent, its energy yield is more predictable than wind. Previous studies,[11-16] included wind energy in Shagaya have not usually selected this technology due to underlying constraints regarding land allocation. Nevertheless, wind energy in Kuwait also has great potential because of its higher capacity factor. In 2019, Shagaya's wind turbines produced around 35 GWh (approximately 75 percent more energy than photovoltaic) with a capacity factor of approximately 39 percent. This capacity factor rivals some offshore sites. Yet wind energy has not typically been considered a viable renewable energy source because of its erratic nature and the larger amount of land required, which is in short supply in Kuwait. Nevertheless, it is a sustainable option that diversifies the energy supply mix for Kuwait.

Shagaya Phases 2 and 3 are now being handled by the Kuwait Authority for Partnership Projects (KAPP). The two phases will be developed together. KAPP has formed a committee that includes MEWRE and KISR to work with the project consultant Ernst & Young for the preparation of a new feasibility study that will optimize the choice of renewable technologies for the final layout of the Shagaya Renewable Energy Park and all tender documents. Previous studies,[11-16] on the renewable energy mix of Shagaya recommend photovoltaics occupy the largest share and thus total energy yield at a competitive energy cost when land is at a premium and is restricted. Wind energy, on the other hand, has a higher capacity factor and tends to produce more energy than PV, at a slightly higher cost. Thus, if land is not a constraint, wind turbine technology remains a viable choice for electricity production. If the final capacity of Shagaya reaches 3.5 GW with the majority of the capacity coming from solar and wind power plants, it could save Kuwait around 8.8 million barrels of oil equivalent in the year 2040. Shagaya would save even more at higher capacities and the final layout could reach 4.5 GW of capacity. Depending on the technology mix and capacity factor, Shagaya could generate somewhere in the range of 7 to 10 TWh when fully commissioned.

Overview of Energy Supply Trends

With a current production-to-reserves ratio of about 1 percent, Kuwait will no doubt remain one of the world's leading oil producers until 2040. Amidst the COVID-2019 pandemic, KOC overcame many challenges and enhanced technical service agreements (ETSAs) with international firms. KOC is also developing its offshore fields. In the past two years, KOC drilled 383 new wells for crude and associated gas extraction and announced four new hydrocarbon discoveries. Natural gas production (both associated and non-associated gas) also increased since the start of the pandemic. Total daily production of both associated and non-associated gas for the 2021-22 fiscal year was 1.752 billion standard cubic feet per day. Still, natural gas production is expected to increase more, especially with the improvements made in operations and maintenance procedures, as well as the expected commissioning of Dorra field, which will increase Kuwait's non-associated gas production by 500 million standard cubic feet per day. One such improvement is KOC's operational goal to reduce gas flaring to less than 1 percent. As part of offshore exploratory drilling activities, KOC is planning to drill six Jurassic and Cretaceous exploratory wells. This offshore project will be implemented within the framework of KOC's 2040 strategy.

KOC manages the production and export from more than twelve developed oil fields. The oilfields are divided into north, west, south, and east fields, each of which is locally administered. Kuwait currently has 32 operational gathering centers that process and separate gas and water from crude oil for downstream operations. KOC has outlined plans for major developments at the Ratqa, Umm Niqa, Ratawi, and East Umm Guddair fields over the *Outlook* period. Enhanced-oil recovery projects and expanded production capacity are major components of these plans to increase oil and natural gas production.[17] In the period to 2040, KOC aims to raise the production capacity to 60 and 25 thousand barrels of oil per day in the Ratqa and Umm Niqa fields, respectively. Moreover, the company intends to develop its capabilities in the use of enhanced oil recovery (EOR) technologies. Table 2.1 outlines other proposed projects in the oil and natural gas sectors.

The total daily production of associated and non-associated gas for the 2021-2022 fiscal year was 1.752 billion standard cubic feet per day, while production of non-associated gas reached 510 million standard cubic feet per day. KOC has ambitious plans to develop further the Jurassic reserves with contracts for additional early production facilities. Currently, there are six production facilities being developed, two of which came on stream at the end of 2022. The capacity of the new facilities would increase the production of non-associated gas to 2.5 billion cubic feet per day.[18] Table 2.2 presents the natural gas supplies required for the power generation and industry sectors over the *Outlook* period.

Table 2.1 | Planned oil and gas infrastructure and development projects. (Source: KPC[18])

Upstream	
Oil	Build four gathering centers in the north, south, and east. The south will focus production of sour crude oil from Burgan's Minagish Field.
	Develop heavy-oil enhanced oil recovery programs in the north.
	Develop Wafra pressure maintenance programs (Phases I and II).
Gas	Develop five Jurassic production facilities in the coming years to increase the production of non-associated gas from 500 million to 1 billion cubic feet per day.
	Complete Wafra Joint Operation to capture and process associated flared gas.
Downstream	
Oil	Increase refinery capacity through the commissioning of capacity creep* projects at Mina Abdullah refinery and Al Zour.
	Build new, and revamp existing, sulfur-handling facilities at Mina Al-Ahmadi refinery. Also, upgrade and expand Mina Al-Ahmadi for clean fuel project.
	Build new crude distillation unit and bitumen production units.
	Commission a new acid gas recovery unit and revamp the existing units at Mina Al-Ahmadi refinery.
Gas	Commission the 5th LNG gas-processing train.
	Commission the new 3,000 billion British thermal units per day LNG import terminal in Az-Zour, to come online.
	Develop an ethane cracker by 2025.
	Initiate a joint venture for derivatives and specialty products.

*** Capacity creep occurs as firms acquire additional production experience and able to achieve more production volume with their existing facilities.**

Table 2.2 | Natural gas supply to the power generation and industry over the Outlook period. (Source: KPC[18])

Natural gas supply per sector	Units	2019	2025	2030	2035	2040
Power generation sector	ktoe per day	31.75	37.75	34.75	36.42	38.24
Industry	ktoe per day	21.83	24.90	25.18	27.49	30.09
Oil & gas sector	ktoe per day	14.96	17.49	16.72	17.83	19.06
Other industries	ktoe per day	6.87	7.41	8.45	9.66	11.03

In the BAU case, crude oil production in Kuwait is expected to increase from 2.7 million barrels per day in 2023 to 4.0 million barrels per day in 2040, growing at a rate of 1.9 percent per year – Table 2.3. This estimate is based on the country's plans to increase production capacity to 4 million barrels per day by 2040, reflecting the global oil industry's assessment of future production levels in Kuwait. The main factors influencing this assessment are a likely deceleration in global demand for oil, particularly in Asian countries, as governments strive to meet their climate change goals and commitments under the Paris Agreement. Furthermore, Kuwait faces increasing competition from unconventional oil supplies and non-OPEC suppliers, who have significant production potential, especially over the medium-term, could impact global oil supplies.

Kuwait continues to increase its use of natural gas. This strategy is supported by LNG imports that are expected to continue to be an important source of natural gas supply over the *Outlook* period. KIPIC built a new 3,000 billion British thermal units per day LNG import terminal with eight storage tanks at Al-Zour. In addition, KNPC has signed a 15-year import contract with Shell to supply Kuwait an undisclosed volume of LNG from 2020.[19] Natural gas production and capacity increases are ambitious. Kuwait is aiming to utilize more natural gas locally and become more self-reliant. In a BAU case, natural gas supply is simulated, with KOC and KGOC meeting all local gas demand, thus becoming net neutral gas production.

Table 2.3 | Crude oil and net natural gas production in the Business-as-Usual Case. (Source: KPC[18]).

Primary Fuel production	Units	FY 2021/2022	2030	2040
Crude oil	Million barrels per day	2.9	3.2	4
Free gas	Million cubic feet per day	510	1500	2000

Emissions

In this edition of the Kuwait Energy Outlook-2023, the models were built utilizing local statistics as much as possible. In the BAU case, emissions start at approximately 83 and grow to 104 million tons of CO_2-equivalent over the *Outlook* period to 2040 (see Figure 2.10). While the total growth in emissions is approximately 1 percent annually over this period, at times it is negative. Emissions in Kuwait are driven by the fuels burned at the electric generation sector that includes older inefficient power plants, such as Shuaiba South and Doha East, which utilize older steam generation and water desalination technologies installed in the 1970s. Kuwait could hasten the reduction in emissions by retiring these stations. However, Doha East is a critical power station for the MEWRE that provides black start service for Kuwait. Specifically, Doha East is the power station that restarts Kuwait's power system in the event of a blackout, such as the one that occurred in 2005 due to a fault that occurred in one of Kuwait's substations.

Kuwait could also reduce emissions by accelerating the adoption of renewable energy. While Shagaya Phase 2 and 3 were modeled in the BAU case, other renewable energy projects such as Abadaliyah integrated solar and combined cycle, distributed PV, and other sites for renewables such as Liyah, could be explored. Due to a variety of reasons, such as cancellations, these were not modeled in the BAU case.

Another opportunity for reducing emissions is by increasing the efficiency of air conditioning. AC demand makes up the majority of electricity demand and can be further reduced by encouraging government offices to adopt innovative energy efficiency methods which could serve as an example of what can be achieved without sacrificing quality of life and inspire the same practices to be adapted to the private commercial and residential sectors. One such example that Kuwait could adopt is district cooling in newly planned cities. KFAS has published the *White paper on District Cooling: Towards Establishing District Cooling Regulations for Kuwait*[20]. The creation of this White Paper was initiated in response to a solicitation from the Energy Efficiency Team, led by the Ministry of Electricity and Water and Renewable Energy (MEWRE). This team operates within the framework of the Supreme Energy Committee. The MEWRE, along with the Renewable Energy division, operating under the auspices of the Supreme Energy Committee, collaborated on this endeavor. The Kuwait Foundation for the Advancement of Sciences (KFAS) enlisted an international consultant to author a White Paper aimed at developing District Cooling (DC) Regulations for Kuwait. KFAS organized two workshops: The initial workshop spanned two days in October 2020, with key stakeholders participating to deliberate on present conditions, hurdles, and forthcoming strategies. The aim was to pinpoint gaps and challenges related to District Cooling (DC) regulations and formulate a roadmap for their implementation in Kuwait. A subsequent workshop took place in November 2021, involving stakeholders in a review of the White Paper. By April 2022, the ultimate edition of the White Paper had been dispatched to key stakeholders, including the Ministry

of Electricity, Water and Renewable Energy, the Public Authority for Housing Welfare, the Municipal Council, and the Supreme Council for Planning and Development.

Additionally, Kuwait can reduce demand in the transportation sector. To date, Kuwait has only one mode of transport – road transportation. Due to a lack of alternatives, emissions from transportation are the highest after the power generation sector. If Kuwait adopted electric vehicles, it would shift emissions to the power generation sector, which would solve nothing unless renewables were substantially adopted. However, the adoption of a Metro could substantially reduce emissions in the transportation sector. Originally, a Metro was designed but not adopted perhaps because not all stakeholders took part in the design. However, when fully developed, the Metro would have only consumed approximately 13 TWh. This would have accounted for less than 10 percent of additional electricity demand. While this energy demand is transferred from motor fuels (gasoline and diesel) to electricity, the transport sector would lower emissions if supplemented by renewable energy, adoption of more efficient power stations, and retirement of less efficient older power stations.

Finally, in the BAU case, Kuwait becomes energy independent with natural gas due to policies developed by the oil sector companies. As a result, emissions from the oil and gas sector are modeled to be higher than previously reported in KEO-2019. This is due to (a) better local energy statistics and (b) the increased extraction of local natural gas, causing more emissions since the various oil sector companies must have fuel (natural gas and diesel) to perform their operations. To reduce emissions in the oil and gas sector, the use of hydrogen (e.g., blue hydrogen) should be explored. Other technologies that are not yet mature will need to become available if Kuwait is to become net-zero in its oil and gas sector.

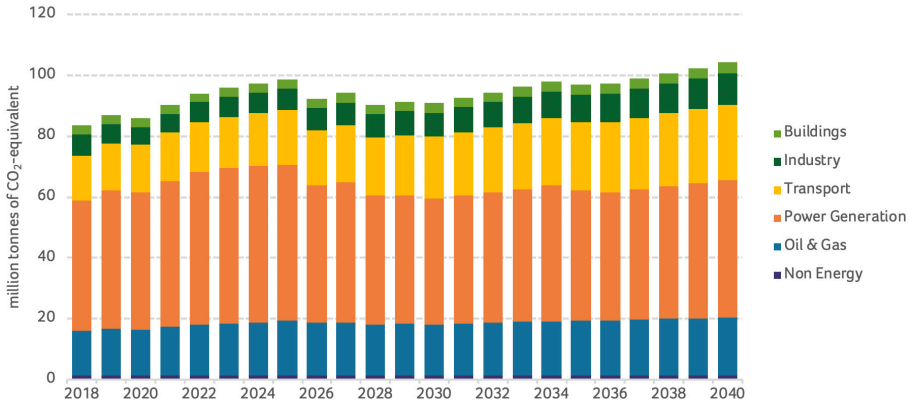


Figure 2.10 | Emissions over the Outlook period to 2040 in million tonnes of CO_2-equivalent.

CHAPTER 3

The Security-Transition Nexus of Kuwait's Energy System

Chapter 3 Highlights

- As a hydrocarbon-based economy, Kuwait's energy and national security are seriously impacted by the global energy transition away from fossil fuels. As of 2020, Kuwait holds 6 percent and 1 percent of the world's proven crude oil and natural gas reserves, respectively. The average percentage of the crude and oil products exports out of the total oil production for 2016-2020 was about 85 percent.
- Natural gas imports are growing at a faster rate than local production (9 versus 3 percent annually). Over the past ten years, 18 percent of the total demanded natural gas was imported. In 2020, imports of Liquified Natural Gas (LNG) were predominantly from the GCC region (56 percent), Africa (28 percent), and North America (9 percent). In 2020, Kuwait signed a fifteen-year agreement with Qatar to supply three million tons of LNG per year. Yet this deal alone cannot address the ever-increasing demand for natural gas in Kuwait. For example, from 2020-2021, Kuwait experienced a 32 percent increase in consumption for natural gas.
- Given Kuwait's rising dependence on natural gas for electric power generation, and chemical and petrochemical production, and the increasing global demand for natural gas, Kuwait must contend with the classic elements of demand-side energy security: availability, affordability, and accessibility, acceptability.

- In addition to energy demand concerns (gas), Kuwait also has energy supply concerns (oil). Under various assumptions, oil demand would drop by as much as 40 percent from the current demand level as early as 2020s and as late as 2040s. Since export revenues from crude oil and oil-derived products represent about 80 percent of Kuwait's total revenues, maintaining the well-being level provided by these export revenues requires Kuwait to adapt to the global energy transition outcomes.
- Kuwait is not on target to fulfill its pledge to reduce GHG emissions by 7.4 percent by 2035. The business-as-usual GHG emissions in 2035 are expected to be 65 percent more than in 2016.
- Required policies to protect oil revenues, gas supply security, and mitigate GHG emissions may involve: sustaining stable investment in the oil and gas sectors, adopting smart energy efficiency measures, accelerating the deployment of renewable energy, exploring the feasibility of alternative clean energies, expanding gas supply sources, integrating clean technologies with the nation's oil industry, investing in clean energy and technologies, and establishing carbon credits.

The Security-Transition Nexus of Kuwait's Energy System

The drivers of the energy transition and the concept of energy security have evolved over time. From the 19th to late 20th century, energy transition was driven mainly by cost-benefit economic factors. By then, the concern about energy security was primarily based on the flow of energy supply.[1] However, in the present 21st century, the energy transition has progressed to be guided by international and domestic political agendas and environmental requirements, in addition to cost-benefits factors. The concept of energy security has expanded to include the stability and sustainability[2] of both energy supply and demand.[3] Increased global interdependence and cooperation has compelled the discussion of interrelated energy security and energy transition, as they both impact national and global economic and political stabilities.

As a hydrocarbon-based economy, Kuwait's energy system's security and, consequently, national security, are impacted by the development of the global energy transition. Such impacts raise challenges and provide opportunities in both domestic and international dimensions for which Kuwait should prepare. The State of Kuwait pledged net-zero carbon emissions by 2060, while committing to deliver net-zero carbon emissions in its oil and gas sector a decade earlier, by 2050. Kuwait through energy transition is committed to have the Kuwaiti barrel of oil as the most competitive barrel in the world, in terms of both cost and emissions.

This chapter follows up on the outcomes of Chapter 2. It reviews and analyzes national energy security concerns and global energy transition impacts on national security. Furthermore, it identifies and recommends national policies supporting the development of a sustainable energy system, alleviating potential challenges, and making use of opportunities. The proposed policies are the implications of the assessment outcomes of the national energy system's status quo and possible future developments concerning economic and geopolitical concerns and impacts.

National Energy Security

In 2020, Kuwait held 6 percent and 1 percent of the world's proven crude oil and natural gas reserves with 101.5 billion barrels and 1.7 trillion cubic meters, respectively.[3] The average Sustainable Crude Oil Production Capacity for the past five years was about 2.75 million barrels per day.[4] The average percentage of the crude and oil products exports out of the total oil production for 2016-2020 was about 85 percent.[5] Oil products are highly tenable due to the abundance of local oil resources.

Despite the relatively high local natural gas reserve, current gas production capacity does not meet the local demand, mainly for electric power generation, water desalination, as well as chemical and petrochemical industries (see Chapter 2).

Figure 3.1 shows the local gas production and import profiles for the past eight years. The average local production growth rate was approximately 3 percent versus the 9 percent growth rate for imported gas. The average imported gas of the past ten years amounted to more than 18 percent of the total demanded quantity. The slow pace of gas development in Kuwait is due to multiple factors, including unattractive fiscal terms, government delays in approving contracts, and the relatively high cost of producing ultra-sour non-associated gas from tight formations.[6] Kuwait's import supply sources of liquified natural gas (LNG) comes from several regions. In 2020, Kuwait's LNG import was 57 percent from the GCC region (Qatar and Oman), 27 percent from Africa, 9 percent from North America, and 7 percent from other regions (see Figure 3.2). Over the last decade, Kuwait's natural gas imports have increased tenfold.[5]

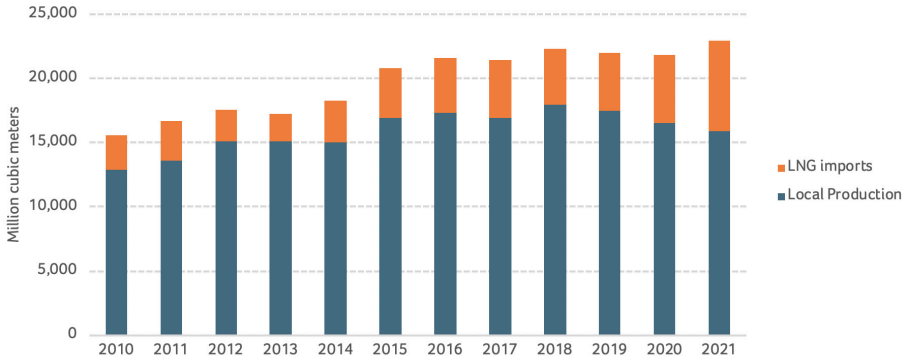


Figure 3.1 | Kuwait natural gas supply.[5]

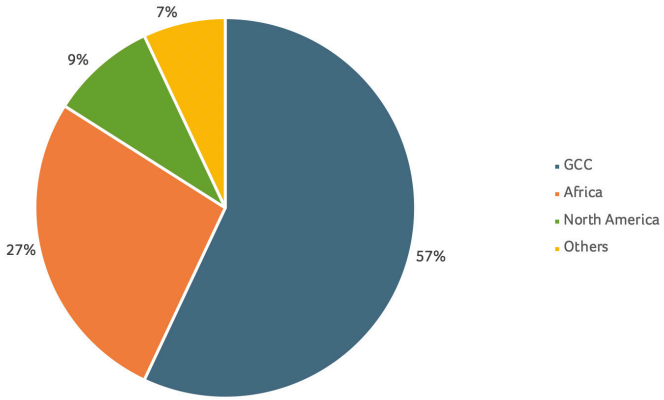


Figure 3.2 | Kuwait's import sources of LNG in 2020.[3]

Thus, as both a supplier of oil and a consumer of gas, Kuwait's energy system security should be assessed with respect to both perspectives.

Kuwait's Oil: Supply-Side Security

Energy security has often been conceptualized on the demand side, highlighting uninterrupted availability and affordability for energy consumers.[7] More recently, this has been expanded to the four "As" of energy security: availability, affordability, and accessibility, acceptability.[2] Yet these, too, have been attributed to demand-side energy security in the literature.[8] Thus, there is less of a comprehensive conceptualization of *supply-side energy security* in the literature. This section of the report attempts to offer a more comprehensive approach to supply-side energy security and apply it to recent, current, and future global and market conditions faced by natural resource energy suppliers such as Kuwait.

Supply-side energy security may be understood as incorporating the following "Five P's":

1. Physical Safety: The safety of extraction institutions and transportation lines,
2. Sustainable Progress: The upkeep and/or development of current and/or new extraction institutions and transportation infrastructure without hindering future production,
3. Permanent Consumption: A stable and/or increasing rate of consumption and consumers,
4. Breakeven Prices: At minimum, fiscal breakeven prices for natural resources, and
5. Precise Planning: Accurately forecasted prices for natural resources.

While demand-side and supply-side security are different sides of the same coin, the goals are quite different, as would be between a buyer and a seller in any transaction.

Physical Safety: Energy Extraction and Transportation Security

Historically and currently, natural resource extraction sites and transportation infrastructure have been targeted using weapons and violence for political reasons. Attacks to refineries disrupt the sale of the natural resources and disrupt the market, causing prices to increase (not necessarily a negative impact for other suppliers) until the attacked supplier state repairs the facility. The repair may cost millions of dollars and months of time, diverting the attacked state's resources to addressing an exogenous force outside the market. The physical safety of extraction facilities and processes are of prime importance to natural resource suppliers.

Safety of natural resource transportation is also of prime national interest for resource-dependent suppliers. In general, the majority of the world's oil is transported by sea,[9] and for the oil exporters in the Arabian Gulf, over 90 percent is transported by sea.[10] Oil tankers from Saudi Arabia, Kuwait, and the United Arab Emirates, among others, have been historically targeted and attacked in the area. Safety of the sea lanes and safety of the tankers is of global importance, as these exports find their way to international consumers.

Both physical infrastructure and a mode of transportation, pipelines are also vulnerable to violence and targeting. For all physical facilities and for transportation equipment, however, the most recent concern is the potential for cyberattacks, as both oil and gas firms in the region have been targeted and will continue to be targeted.

Not all physical safety concerns are planned by combatants – accidents occur, and natural disasters happen. The recent Suez obstruction, whereby the transport ship Ever Given blocked the Suez Canal for six days, cost the world billions of dollars a day and disrupted the global supply chain. About twelve percent of global trade is conducted through the Suez, including oil.[11] Suppliers could not send their natural resources to clients, and re-routing goods would be costly in both time and resources.

Sustainable Progress: Development of Extraction Institutions

Development of extraction institutions encompasses maintenance of current institutions, upgrading current institutions infrastructurally and technologically, and building new institutions such as refineries, ports, pipelines, and tankers, with a focus on sustainability. These developments are to meet current and forecasted market demand for energy. In general, growth rates for demand of fossil fuels are decreasing,[12] including oil, indicating that maintenance, upgrading, and building new institutions are practical plans for energy suppliers. Kuwait, for example, has the newly launched Al-Zour refinery to meet international demand.

These pragmatic plans of growth and development rest on a general trend of increasing demand for fossil fuels, however, the global energy transition toward mitigating carbon emissions might curb oil and gas demand. Almost all countries are party to the Paris Agreement, which calls for net-zero emissions by the middle of this century. As the use of fossil fuels accounts for a majority of carbon emissions, many countries have already implemented policies to diversify their energy mix including clean energy, e.g.,

renewables, hydrogen, and nuclear. While the transition to clean energy itself uses natural resources, nonetheless, energy suppliers will have to carefully incorporate the predictions of their clients' growing use of environmentally friendly technologies in their development plans, as well as their own plans of sustainable development in their production systems. The Al-Zour refinery, to continue the example, aligns with international environmental standards, increasing sustainability.

Permanent Consumption: Stable / Increased Consumption and Consumers

Stable and/or increasing demand enhances supplier security in the energy market. As the world's economy and population grow, energy demand rises. Currently, fossil fuels constitute about 80 percent of world's energy mix and are expected to maintain such levels in the coming three decades.[13-14]

Suppliers are less secure, however, when the energy demand rate is volatile. The recent COVID-19 pandemic grounded much of the world's transportation, the largest sector of natural resource consumption. The oil market crashed, with oil prices close to zero at some points in time during 2020.[15] Energy suppliers were reluctant to decrease production, as it was unclear how long the crisis would last and how the crisis would impact energy consumption in the short- to medium- term.[15] While COVID-19 is still present in the world today, countries and markets have re-opened. The transportation sector demand specifically and energy demand overall has recovered to more standard rates.

As countries were implementing business-as-usual policies again, a new energy crisis was introduced as Russia invaded Ukraine in February of 2022. Both the oil and gas markets were impacted. For oil, the US has boycotted Russian oil and European countries has pledged to boycott Russian oil at the end of 2022. OPEC+ members have worked to stabilize oil market and maintain desired oil prices. Not all members of OPEC+, however, can increase production due to the limited production capacity that resulted from the low investments in the sector and political issues, e.g. – Iranian and Venezuelan oil sanctions and Libyan oil production disruption. Oil suppliers in the Arabian Gulf may temporarily increase their market share; however, in the long-term, idle (e.g., Iran, Libya, Venezuela) and new (e.g., East Africa) producers may eventually come online and compete for their shares in the oil market.

Breakeven Prices: Fiscal Breakeven Prices for Natural Resources

Some oil supplier economies are highly dependent on the rents from natural resources, and Kuwait is no exception, with a majority of its government revenues being rents from natural resources. The government then use those revenues to pursue spending programs and service provision. In order for Kuwait to continue to provide services for their people, a minimum price (assuming stable demand) for those natural resources is required. Below in Table 3.1 are IMF estimates for the fiscal breakeven oil prices in US dollars for GCC countries.

Table 3.1 | Breakeven Oil Prices[16] units in U.S. dollars per barrel.

Fiscal Breakeven Oil Price[2]	Average				Projections	
MENAP oil exporters	2000–2017	2018	2019	2020	2021	2022
Bahrain	72.2	94.3	80.6	100.4	88.2	85.8
Kuwait[1]	...	53.6	55.0	68.1	69.3	64.5
Oman	...	96.7	85.1	95.8	72.3	61.8
Qatar	44.5	49.2	50.0	46.2	43.1	40.4
Saudi Arabia	...	88.6	81.9	77.9	76.2	65.7
United Arab Emirates	48.7	64.2	61.7	68.2	64.6	60.4

Sources: National authorities; and IMF staff estimates and projections.
[1]Kuwait's fiscal breakeven oil price is before the compulsory 10 percent revenue transfer to the Future Generations Fund including investment income.
[2]The oil price at which the fiscal balance is zero.

When oil prices fall below breakeven prices, natural resource revenue-dependent governments operate at a deficit. Reduction of spending in itself is not negative: many governments could benefit from well-planned reductions in spending. Unexpected deficits and unplanned reductions in the budget, however, can lead to hasty decisions and reductions in critical government services such as health and security, and thus result in domestic instability.

Precise Planning: Accurately Forecasted Prices for Natural Resources

Forecasting prices for natural resources is a difficult task, with many, many variables, often overlapping and imbedded in multiple economic, socio-cultural, environmental, and political networks and structures. There is no single agreed-upon algorithm or model for these future predictions. However, government access to dependable forecasting information is critical for future planning and stability.

Relatively recent geostrategic political uncertainties may have introduced new factors into these forecasts. Some uncertainties are general, such as pandemics and their impact on supply chains, or cybersecurity in natural resource infrastructure. Many more uncertainties are specific, such as the duration and spread of the 2022 European conflict and the global move to renewable energy. All of them, however, require thought as to their impacts on natural resource energy markets.

Supply-side energy security requires accurate forecasting of the energy market – difficult, if not impossible to do for long-term planning. However, recent experiences with various global events may involve new variables in planning, including pandemics, conflicts, and international renewable energy goals. New considerations such as monkeypox, the duration and potential spread of the 2022 European conflict beyond Ukraine and possibly involving other states and international organizations, and the tracking of and engagement with the renewable energy market all will impact forecasting.

Kuwait's Gas: Demand-Side Security

In the previous section, the concern regarding oil from the Kuwaiti perspective is one that is supply-side: i.e., the security concern for the supplier. However, Kuwait is a net importer of gas, and thus has demand-side or consumer-side security issues. Stated differently, this may be stated as a consumer's security concern regarding the *supply* of gas. Given the rising dependence of national electric power generation as well as petrochemical sector on natural gas, the growth rate of gas imports and its diversification of import regions, global demand on gas has been increasing, impacting all importers of gas. Kuwait, as a consumer of gas imports, must contend with the classic elements of demand-side energy security, or rather, security of the supply of energy: availability, affordability, accessibility, acceptability.

Availability

About 43 percent (Figure 3.2) of Kuwait's imported gas sources are outside the GCC region, i.e., Africa and North America. Geopolitical and domestic conflicts and instability in and around these regions would jeopardize the gas supply to Kuwait. The high gas price surge due to regional conflicts, e.g., the Russia-Ukraine war, would burden the national fiscal accounts.

The current Russia-Ukraine war has potential short- and long-term (post-war) effects on the gas import stability to Kuwait. With Russia reducing and threatening to cut the gas supply to Europe completely, European countries are seeking new long-term gas supply sources. African nations are among sources of gas supply sought by Europe. Despite the rich high gas reserves in Africa, gas production capacity is relatively low due to the poor infrastructure in the hydrocarbon industry in the region. Therefore Kuwait, under the pressure of the Russian gas cuts to Europe, faces competition from European nations seeking alternatives to Russian gas, potentially affecting Kuwait's imported quota.

Moreover, if Kuwait continues to source natural gas from North America, primarily the USA, imports could ultimately be disturbed due to the USA's political priorities in supporting the European nations through the current crisis. However, this could be less of an issue due to timing. European nations

demand more natural gas during the cold winter months due to heating requirements, while Kuwait, needs more natural gas during the hot summer months for electric power generation to meet cooling demand. Though Kuwait's gas imports from Africa and North America constitute about 10 percent of its local demand, events mentioned above should raise a flag to decision makers to mitigate potential disturbances to Kuwait's natural gas supply.

Affordability

Most natural gas contracts are long-term, and therefore short-term changes in gas prices tend to not impact gas consumers. However, new contracts currently being established, such as Qatar's recent 15-year LNG contract with Germany, are being made concurrently with Russia's decrease of gas supply to Europe, impacting the negotiation price. Unless Qatar increases production to meet demand, Kuwait may have to compete with new buyers as more and more new contracts are drafted. Moreover, Russia may wish to reinvigorate the Gas Exporting Countries Forum, informally known as "Gas OPEC," whose members possess almost three-fourths of the world's gas reserves. While gas is not a single market, and there are different prices for different geographic locations around the world, it is possible that greater coordination at the Gas Exporting Countries Forum (GECF) may result in increased prices for all new contracts around the world.

Accessibility

Similarly, the gas supply from the GCC region (constituting 15 percent of the local demand) could face disruptions due to the stand-off between Iran, on the one side, and the GCC countries with the West, on the other side, on several issues. A pressing issue is Iran's nuclear deal. Lately, Iran's response in August 2022 to the European Union (EU) proposal was not satisfactory to both the USA and EU. Another issue may be the still unresolved division of gas resources between Iran and Qatar's maritime border in Qatar's North Field and Iran's South Pars. Ongoing disputes with Iran could increase the risks to Kuwait's maritime routes and thus the accessibility of gas, as was experienced in the 1980s.

Acceptability

Countering the supply risks of natural gas involves increasing the production capacity of local natural gas and adopting alternative energy forms, including renewables and green hydrogen. However, on the issue of expanding the production capacity of local gas production, it should be mentioned that the Kuwait Oil Company (KOC) has put a strategic goal to increase its output of non-associated gas to 1,500 million cubic feet annually by 2040. Most of this increase would originate from domestic Jurassic reserves. Recently, Kuwait Gulf Oil Company (KGOC) signed a Memorandum of Understanding with Saudi Aramco Gulf Operations Company to develop the joint offshore Dorra gas field in the partitioned neutral zone. The Dorra field project development program's goal is to produce 1.0 billion cubic feet of gas per day (of which Kuwait's share is 500 million cubic feet per day) and 84,000 barrels of liquefied gas per day, which is to be divided equally between Kuwait and Saudi Arabia.[17] Dorra development might face delays due to Iran's objections to this agreement and its claims of sharing territorial offshore borders with the Dorra gas field. Yet again, Kuwait will continue to import gas in the long-term foreseen future. Expansion of domestic capacity in general, however, whether at Dorra or elsewhere, must be carried out in alignment with current and future sustainability and environmental practices to ensure acceptability.

Kuwait's energy security concerns are multi-dimensional, given that Kuwait is both an exporter and an importer of energy. Added to these domestic concerns is an international concern - the outcomes and requirements of the global energy transition.

Facing the Global Energy Transition

The prime manifestation of the global energy transition is the continual transformation of the world's energy demand mix. Throughout the 1990s, the multiple wars in the Gulf, the collapse of the Union of Soviet Socialist Republics, trends toward privatization and liberalization of energy industries and markets, integration of more national oil companies with importing countries, and institutionalization of climate change caused the emergence of energy demand-side security.

Continuing into the new millennium, the 2000s to date has shown a high level of global electrification (except in Sub-Saharan Africa) and highly active environmental protection actions. Furthermore, proactive environmental-related incentives led to the rapid technological development of renewable energy and clean technologies which are moving toward being cost-competitive with conventional oil and gas technologies. Kuwait is in a unique position, having concerns regarding supplying energy (oil) and the supply of energy (gas). There is a legitimate concern about the potential of reaching peak oil demand and maintaining access to affordable natural gas.

Under various assumptions, many scenarios expect the oil peak demand occurs as early as sometime during the 2020s and as late as the 2050s.[18] In these scenarios, the oil demand would drop as low as 40 percent from the current demand level, i.e., from 100 to 60 million barrels/day.[18] Regardless of whether the peak demand will take place, Kuwait must hedge against oil demand disruption and losing its market share. The export revenues from crude oil and oil-derived products represent about 80 percent of Kuwait's total revenues.[19] Therefore, maintaining the level of well-being provided by these export revenues requires Kuwait to adapt to the global energy transition outcomes.

The global demand for natural gas is on the rise, including in Kuwait (see Figure 3.3).[5] As an importer of natural gas, Kuwait must consider the security of supply of natural gas. In 2020, Kuwait signed a fifteen-year agreement with Qatar to supply three million tons of LNG per year. Yet this deal alone cannot address the ever-increasing demand for natural gas in Kuwait: from 2020-2021, Kuwait experienced a 32 percent increase in consumption for natural gas.[5] Other suppliers of LNG to Kuwait include countries in Asia (Indonesia, South Korea), Africa (Egypt, Angola), and Europe (Norway, Spain), among others, highlighting the importance of import diversity. Import diversity of key energy sources has been of particular note in the 2022 European conflict, as many countries had been highly dependent on Russian gas imports and Russia used this dependency in their own favor. If any particular importer of LNG is unable to fulfill their contracts, import diversity will mitigate short-term costs to Kuwait. Diversity of *type* is also critical to maintaining access to natural gas. While Kuwait's new Al-Zour refinery has an LNG import terminal, there should also be considerations of restarting negotiations of establishing pipelines to nearby regional natural gas suppliers. This includes negotiations regarding the Kuwait-Qatar pipeline and the Kuwait-Iran pipeline, whose successes would offer Kuwait diversity of natural gas type, as well as may also offer lower carbon emissions.

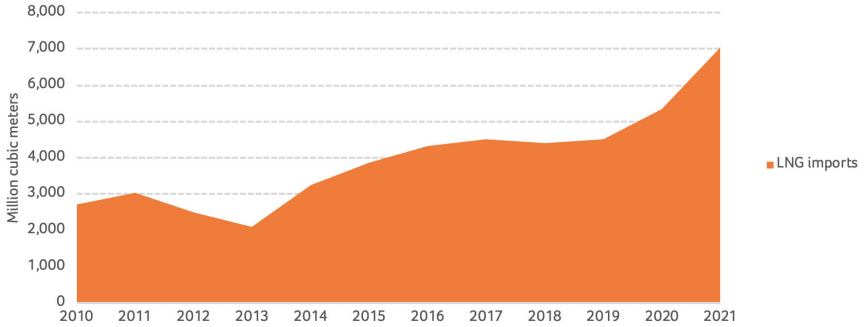


Figure 3.3 | Total annual imports of liquified natural gas.[5]

Kuwait is urged to hedge against peak oil demand to increase and protect its market share. The strategy includes three pillars (Figure 3.4). The first pillar is to reduce consumption of oil derived products in the local market through energy efficiency, exploitation of renewable energy, and green hydrogen. By adopting any of these strategies, crude oil and oil-derived products would then be more available for export. Renewables and hydrogen are not limited to fueling electric power generation and industrial sectors. These clean energy sources can also fuel the transportation sector, e.g., hydrogen vehicles.

The second pillar aims to mitigate greenhouse gas (GHG) emissions and reuse and recycle major sectors' wastes. The pillar's outcomes reduce the carbon footprints of Kuwait's oil industry. In other words, they make oil products more appealing, sustain export levels, and ensure better market shares. Moreover, the outcomes of the second pillar are expected to create new sectors in the economy. Consequently, added values come from businesses utilizing wastes to support several local industries, e.g., CO_2-enhanced oil and water recoveries, concrete manufacturing via CO_2 chemical reaction,[20] farming by increasing the production and growth of crops by enhancing the photosynthesis process.[21]

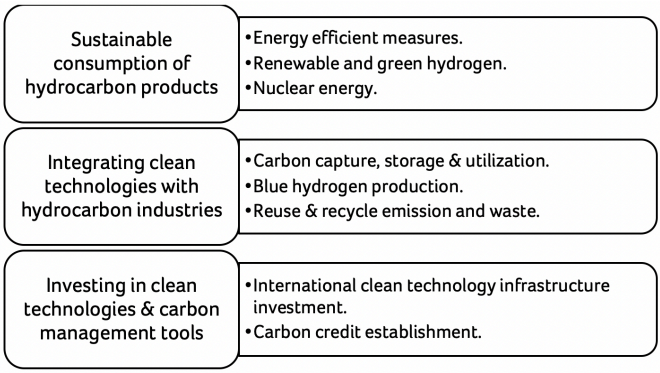


Figure 3.4 | Proposed hedging strategy against peak oil demand challenge.

Kuwait is also required to take a proactive approach in investing in international clean energy projects and technology development to alleviate the impact of the global energy transition. Such an approach allows the state to be a beneficiary of the transition toward the global decarbonization process. Hydrocarbon net-exporting nations have taken such action with successful outcomes. Saudi Acwa Power, Emirati Masdar, and Qatari Nebras Power are examples of national companies that invest, develop, and operate international projects abroad with a total asset profile of 71.5 GW.[22] Moreover, owning clean energy technology rights is a significant additional strategy to face the challenges of global transition geopolitics. A lesson may be learned from the Kingdom of Saudi Arabia, which is negotiating a technology co-ownership deal with South Korea for the Korean-designed small modular reactor (known as SMART). This potential joint venture will improve the original reactor design, license its use for deployment in Saudi Arabia, and develop business models and infrastructure to promote and export the technology to other countries. In this way, the Saudis will cut their local hydrocarbon consumption, reduce GHG emissions, and create new sectors (direct and indirect) in their economy.

The emission reductions in local and internationally owned industries can lead to earning carbon credits (CCs). A carbon credit is equal to one ton of CO_2 equivalent cut. Kuwait is recommended to prepare a system to trade CCs in international markets. CCs trading is another option hedging against the global energy transition.

Initial political signs of the global energy transition have already emerged through intergovernmental organizations. Kuwait has pledged to reduce GHG emissions by 7.4 percent by 2035.[23] The business-as-usual GHG emissions in 2035 are expected to be 65 percent more than in 2016. According to Kuwait NDC, the business-as-usual GHG emissions are expected to reach 142 million tons CO_2 equivalent. [23] The emission cut would be the result of Kuwait's energy system transition toward a more efficient and cleaner system. The institutional, infrastructural, and governance enablers in Kuwait are still developing toward maturity to achieve the just transition.[24]

Policy Recommendations

Energy security and energy transition engage in a circular influencing cycle on each other. They are interrelated dynamic affairs involving domestic and international influential factors. Hence, addressing the challenges of the national security-transition nexus of energy calls for measures leading to a resilient and sustainable national energy system.

On the domestic level, there are two major concerns: the growing local energy demand and GHG emissions. The ever-increasing local demand for oil-derived products lessens the amount available for export and, subsequently leads to declining income revenues. Rising local gas demand entails higher dependence on gas imports, undermining national energy security.

Required policies to protect oil revenues, gas supply security, and mitigate GHG emissions may involve:

- Sustaining Stable Investment in the Oil and Gas Sectors. Campaigns against oil and gas investments (mainly from developed economies) have intensified since the late 2000s. Such pressure has slowed the global hydrocarbon sector's investments across its chain and curbed its production. As a result, the world's energy security and markets are paying a high price for delays in the oil and gas development. The ramifications of the Russia-Ukraine war have also proved that the world's energy security and economy are vulnerable to oil and gas availability. Kuwait's oil sector officials have repeatedly confirmed the sector's commitment to maintaining the stability of the oil market. Under the OPEC+ agreement, Kuwait is currently producing 2.8 million barrels per day and has plans to increase its production capacity when markets need it.[25] Moreover, Kuwait will increase its non-associated gas production from 18.0 to 28.0 million cubic meters per day.[25] The essence of the policy "Sustain Stable Investment in the Oil and Gas Sectors" is to expedite the process of fully meeting the local oil products and gas demands even under global pressure to cut investments.

- Adopting Smart Energy Efficiency Measures. Energy demand management is the low-hanging fruit that most nations have not fully utilized. Energy efficiency is a significant card in maintaining national energy security. An example of utilizing this option may be found in Europe to counter the Russian oil and gas cut. In Kuwait, there has been some effort in this direction involving regulations, technologies, building envelopes, and consumer behavior. However, the per capita gross electricity consumption in Kuwait is about 17.8 MWh/year (see Chapter 1), which is among the world's highest figures. The primary drivers for high consumption are harsh local weather conditions and consumer behavior. The ambient temperature in summer seasons exceeds 50 degrees Celsius (usually in June-August). This high temperature is a health hazard to many people, especially the elderly, individuals with respiratory diseases, and children. Hence, air conditioning is a necessity and is the primary consumer of energy in buildings. Usually, consumer behavior can be improved through economic-related instruments (e.g., tariffs) and education. The former action, i.e., energy tariff reforms, is currently challenging to alter due to strong social and political resistance. This resistance is the outcome of the society's rentier culture and a conflation between societal rights and duties. Therefore, the policy "Adopt Smart Energy Efficiency Measures" needs to adopt active rather than passive energy efficiency measures by developing smart buildings and air conditioning systems. Regarding educational policies, awareness programs addressing consumer behavior need to be developed. For example, education and awareness campaigns should clarify the society's right to have clean and reliable access to energy, and its duties are to protect and

conserve its energy wealth for present and future generations. A stronger emphasis needs to be on protection and conservation.

- Accelerating the Deployment of Renewable Energy. Kuwait was one of the pioneering nations in the region that invested in renewable energy systems during the 1970s and 1980s. The Kuwait Institute for Scientific Research dedicated a department towards renewable energy. Subsequently, renewable energy research was stopped for about 15 years and revived in the mid-2000s. Since 2008, Kuwait has mobilized its institutions to develop plans, transfer knowledge and technologies, and establish demonstration renewable energy projects. It has aimed to install 15 percent of renewable energy systems out of the total electric power capacity by 2030. However, the pace toward achieving the goal is slow due to various factors.[22] Kuwait will not reach the renewable energy target on time under the present bureaucratic regulations, which might serve well for conventional power generation technologies. Even with conventional electricity generation and water desalination projects under the institutional bureaucracy of the public-private partnership (PPP), the execution pace is slow and sometimes stagnant. Track records of PPP awarded projects include only two, i.e., the Al-Zour North Phase 1 independent water and power plant (IWPP) and the Umm al-Hayman wastewater project. In October 2019, Kuwait Authority for Partnership Projects (KAPP) canceled the transaction advisory services contract for the planned Al-Zour North, phases 2 and 3, and Al-Khiran IWPPs, which the authority issued in December 2018. The contract has yet to be retendered.[26] The current financing instrument requires a fundamental overhaul to deal with unconventional power generation, such as renewables. Moreover, the concerned authority, i.e., the Ministry of Electricity, Water and Renewable Energy (MEWRE), is urgently required to develop (or modify current) transmission and distribution network topologies and related infrastructure master plan. The master plan should consider both central and distributed renewable energy generation stations. Furthermore, it ought to address the needed generation, transmission, and distribution network topologies counter-effecting renewable energy systems production variability. In addition, MEWRE needs to investigate the role of the GCC interconnection grid in facing local disruptions from renewable systems.

- Exploring the Feasibility of Alternative Clean Energies. At this phase, the authorities are advised to explore the inclusion of environmentally friendly systems, such as hydrogen in Kuwait's energy mix. A national hydrogen white paper was published recently[27] with a roadmap of milestones. To date, there has not been any official announcement by the concerned stakeholders launching related hydrogen production projects. However, if a hydrogen production commercial facility is to be established, blue hydrogen would be more feasible than green hydrogen. . Green hydrogen production relies on renewable energy sources and electrolysis technologies to extract hydrogen from water, while blue hydrogen is typically produced from natural gas with carbon capture and storage (CCS) to reduce its carbon emissions. Blue hydrogen can be more feasible due to the existing infrastructure and lower initial costs associated with utilizing natural gas resources. Fresh water is scarce in Kuwait, hence, producing green hydrogen would have relatively higher costs than blue hydrogen. Hydrogen is an additional means to reduce the local consumption of hydrocarbon fuels and mitigate GHG emissions.

Another major challenge is maintaining demand for Kuwait's hydrocarbon products in the international markets. Several factors affect the stability of the demand, including the global economy, geopolitics, and climate change. The first two factors are beyond the control of the nation. The latter factor, climate change, is mainly associated with the energy transition and can be handled with the following policies:

- Expand Gas Supply Sources. Until domestic gas production levels meet local demand, a short- to medium-term plan would be that Kuwait expands its gas supply sources in addition to those shown in Figure 3.2. Despite the political challenges and conflicts, Iraq and Iran could be among the gas supply sources. Given their proximity, Iraq and Iran could relieve the gas supply risks from outer regions, e.g., Africa and North America. In 2018, an agreement was being prepared

on importing gas from Iraq and developing shared border fields. The deal involved piped gas delivery from southern Iraqi fields to Kuwait with an initial supply of 1.4 million cubic meters per day, with volumes gradually rising to 5.7 million cubic meters per day.[28] However, the gas agreement had been on hold over disagreement on the pricing of the Iraqi gas. Kuwaiti authorities are recommended to continue negotiating with their Iraqi counterparts, especially after having the electricity interconnection between the Iraqi Al-Faw station and the Kuwaiti Al-Zour station. The line length between these stations is approximately 220 km, of which 140 kilometers are inside Kuwait, and the remaining distance is in Iraq.[29] Kuwait can reach a just and reasonable agreement with Iraq, which would sell Kuwait natural gas, and in turn Kuwait would sell electricity through this interconnection. Negotiations between Kuwait and Iran were intermittent between 2008 and 2015 to export Iranian natural gas to Kuwait through Iraq via underwater pipelines in the Arabian Gulf. The proposal was to export 45.5 million cubic meters per day to Kuwait at the international market price.[30] However, the cyclic tensions between GCC countries and Iran have reduced possibilities of such an agreement. GCC countries and Iran could count on geostrategic, geo-economic, demographic, and cultural common factors and interests to establish a healthy relationship based on a new strategic framework. Yet, the Iranian gas option is excluded within the short- to medium-term due to a lack of trust with the current Iranian regime. Another option could include re-negotiation with Qatar and Saudi Arabia regarding the extension of the Qatar-Kuwait gas pipeline project. Currently, the Dolphin pipeline project connects Qatar with the UAE and Oman. An extension to Kuwait would require Saudi permission to access and use its territorial waters. Any direct pipeline from Kuwait's neighbors would greatly decrease the price of natural gas.

- Integrate Clean Technologies with the Nation's Oil Industry. This policy aims at transforming national oil industry products into "near-clean" hydrocarbon commodities. In this way, hydrocarbon products are more appealing in international markets that apply restrictive environmental rules. Carbon capture, utilization, and storage (CCUS) can lead the role in decarbonizing the national industry in Kuwait. The first carbon capture unit in Kuwait was established by Equate Petrochemical Company. The unit can capture up to 450 tons of CO_2 per day from its existing facilities. Certainly, Kuwait needs to expand the utilization of CCUS across its industries. Oil and petrochemical industries are recommended to mobilize toward CO_2 removal from their operations.

- Invest in Clean Energy and Technologies. Kuwait Investment Authority (KIA) is recommended to explore the feasibility of establishing national clean energy companies. These companies would have global commercial activities associated with renewable energy and clean technologies (examples of such national companies in the GCC region are ACWA Power, Masdar, and Nebras Power). Furthermore, KIA may consider expanding its equity positions in international companies with activities that involve clean project development, operation, maintenance, and technology in order to best position itself in the emerging market. This strategy braces the country's soft power foreign policy in protecting hydrocarbon assets and marketing its products by accumulating carbon credits.

- Establish Carbon Credits. The main outcome of the policies mentioned above, i.e., "Integrate Clean Technologies with the Nation's Oil Industry" and "Invest in Clean Energy and Technologies" is carbon emissions savings. The carbon savings eventually become carbon credits that can be traded to facilitate the marketing of "non-clean" hydrocarbon products.

Table 3.2 summarizes the policies addressing national energy security concerns, facing global energy transition threats, and exploiting transition opportunities.

Table 3.2 | Policy implications addressing national energy security concerns and dealing with global energy transition.

		Domestic Level	International Level
Policies	Sustain Stable Investment in the Oil and Gas Sectors	Invest in local non-associated gas production to meet local demand. Invest in local oil chain production, especially, upstream sector, to meet local demand.	Prepare to meet the demand of global markets.
	Adopt Smart Energy Efficiency Measures	Encourage the development of smart buildings. Develop educational and campaigning programs to adjust consumer behavior.	Support joint research and development programs with international institutions in the field of smart buildings and systems.
	Accelerate the Deployment of Renewable Energy	Modify the current financing tool taking into account renewable energy's special nature. Develop generation, transition, and distribution networks to deal with the targeted installed renewable capacity.	Investigate the role of the GCC interconnection grid in facing local disruptions from renewable systems.
	Explore the Feasibility of Alternative Clean Energies	Investigate the local demand for hydrogen and develop a business model.	Study the potential for joint venture projects with regional and international entities.
	Widen Gas Supply Sources	Support local think tank institutes to study current affairs and develop strategies for the Gulf region gas trade.	Follow up to potentially revive the Iraqi gas deal. Propose a GCC-Iran gas trade initiative. Renegotiate Dolphin pipeline extension.
	Integrate Clean Technologies with the Nation's Oil Industry	Mobilize clean technology installations in oil and petrochemical industries.	Develop marketing strategies for international trading.
	Invest in Clean Energy and Technologies	Explore the feasibility of establishing national clean companies.	Invest in abroad clean energy and technologies projects for market positionality.
	Establish Carbon Credits	Support local think tank institutes to identify opportunities in carbon credit markets.	Develop a strategy for carbon credit trading in international markets.

Annex A

Acronyms

A/C	Air conditioning
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAU	Business as usual
Bcm	Billion cubic meters
CC	Carbon credit
CCGT	combined cycle gas turbine
CCUS	Carbon capture, utilization and storage
CO_2	Carbon dioxide
CSB	Central statistical bureau
CSP	Concentrated solar power
ETSA	enhanced technical service agreements
EU	European union
FY	Financial year
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GECF	Gas Exporting Countries Forum
GGFR	Global Gas Flaring Reduction
GHG	Greenhouse gas
GW	Giga watt
GWh	Gigawatt hour
IEA	International energy agency
IMF	International monetary fund
IPP	independent power producers
IWPP	independent water and power producers
KAPP	Kuwait Authority for Partnership Projects
KEC	Kuwait Export Crude
KEO	Kuwait energy outlook
KFAS	Kuwait foundation for advancement of science
KGOC	Kuwait Gulf Oil Company
KIA	Kuwait Investment Authority
KIPIC	Kuwait Integrated Petroleum Industries Company
KISR	Kuwait Institute for Scientific Research
km	kilometer
KMHC	Kuwait Medium-Heavy Crude
KNPC	Kuwait National Petroleum Corporation
KOC	Kuwait Oil Company
KPC	Kuwait Petroleum Corporation
KSLC	Kuwait Super Light Crude
Ktoe	Kilo tonne of oil equivalent
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
MED	Multi-effect distillation
MEWRE	Ministry of Electricity, Water, and Renewable Energy
MIG	million imperial gallons
MSF	Multi-stage flash
Mtoe	million tonnes of oil equivalent

MW	Mega watt
NDC	Nationally Determined Contribution
NGL	natural gas liquids
OCGT	Open-cycle gas turbines
OPEC	Organization of the Petroleum Exporting Countries
PACI	Public Authority for Civil Information
PMV	predicted mean vote
PPP	public-private partnership
PV	photovoltaic
REC	renewable energy certificates
RO	Reverse osmosis
SAC	Saudi Arabian Chevron
SCM	Standard Cubic Meter
SMART	South Korea for the Korean-designed small modular reactor
SREP	Shagaya Renewable Energy Park
SSDD	Systems & Software Development Department
TWh	Terawatt hour
UAE	United Arab Emirates
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USA	United States of America
USD	US dollars

General Conversion Energy Conversion Factors

To convert to	TJ	GWh	MBtu	Mtoe
From		Multiply by:		
TJ	1	0.2778	947.8	2.338×10^{-5}
GWh	3.6	1	3,412	8.6×10^{-5}
MBtu	1.0551×10^{-3}	2.931×10^{-4}	1	2.52×10^{-5}
Mtoe	4.1868×10^{4}	11,630	3.968×10^{7}	1

Annex B

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Annex C

The following tables are the energy balance tables constructed from the aggregation data received throughout the duration of the project. This includes data received from the K-companies, MEWRE, CSB, and PAI. Data gaps were either filled in from data from the Joint Oil Database Initiative. For more years, IEA energy balances were utilized. Data such as those presented in the tables below allow for such analyses presented in this report.

Table C.1 | Kuwait Energy balances 2020, all units in Mtoe.

Kuwait Energy Balance 2020 (all units in Mtoe)	*Natural gas*	*Crude oil, NGLs, and feedstocks*	*Oil-derived products*	*Renewables (PV, CSP, & wind)*	*Heat for Desal*	*Electricity*	*Total*
Production (Oil, Gas, etc....)	14	142		0.05			156
Imports	4		1			0	5
Exports		-98	-23				-121
International Aviation& Navigation Bunkers							
Stock Changes		1	0				1
Total Energy Supply	**18**	**45**	**-22**	**0.05**		**0**	**41**
Statistical Differences		1	0				1
Transformation	**-9**	**-44**	**35**	**-0.05**	**1**	**6**	**-11**
Electricity Plants	-9	-4	-4	-0.05	1	6	-9
- Combined Cycle Generators	-6		-1		0	3	-3
- Open Cycle Generators	0		0			0	0
- Steam Turbines	-3	-4	-3		1	3	-6
- Renewables (PV, CSP, & wind)				-0.05		0	0
Oil Refineries & Gasification facilities		-40	38				-2
Energy Industry Own-Use	**-6**		**0**			**-1**	**-7**
- Oil sector own use	-6		0			0	-6
- Electricity Plants own use						-1	-1
Losses	0					-1	-1

Total Final Energy Consumption	3	12	1	5	21
Desalination			1	0	1
- MSF/MED			1		1
- RO				0	0
Industry	3			1	4
- Chemical and Petrochemical	3				3
- Non-specified industry	0			1	1
Transport		5			5
Service				1	1
Residential		1		2	3
Agriculture & Fishing				0	0
Non-energy use		6			6
- of which is chem. & petchem.		6			6

Table C.2 | Kuwait Energy balances 2019, all units in Mtoe.

Kuwait Energy Balance 2019 (all units in Mtoe)	*Natural gas*	*Crude oil, NGLs, and feedstocks*	*Oil-derived products*	*Renewables (PV, CSP, & wind)*	*Heat for Desal*	*Electricity*	*Total*
Production (Oil, Gas, etc....)	14	155		0.02			170
Imports	4		1				4
Exports		-106	-28			0	-135
International Aviation & Navigation Bunkers			-1				-1
Stock Changes		-1	0				-1
Total Energy Supply	**18**	**48**	**-28**			**0**	**38**
Statistical Differences	0	2	-2				0
Transformation	**-10**	**-46**	**37**	**-0.02**	**1**	**6**	**-11**
Electricity Plants	-10	-1	-6	-0.02	1	6	-9
- Combined Cycle Generators	-6		-1		0	3	-3
- Open Cycle Generators	0		0			0	0
- Steam Turbines	-3	-1	-6		1	3	-6
- Renewables (PV, CSP, & wind)				-0.02		0	0
Oil Refineries & Gasification facilities		-45	43				-2
Energy Industry Own-Use	**-5**		**0**			**-1**	**-6**
- Oil sector own use	-5		0			0	-5
- Electricity Plants own use						-1	-1
Losses	0					-1	-1
Total Final Energy Consumption	**3**		**11**		**1**	**5**	**20**
Desalination					1	0	1
- MSF/MED					1		1
- RO						0	0
Industry	3		0			1	4
- Chemical and Petrochemical	3		0				2
- Non-specified industry	0		0			1	2

Transport	6		6
Service		1	1
Residential	1	2	3
Agriculture & Fishing		0	0
Non-energy use	4		4
- of which is chem. & petchem.	4		4

Table C.3 | Kuwait Energy balances 2018, all units in Mtoe.

Kuwait Energy Balance 2018 (all units in Mtoe)	*Natural gas*	*Crude oil, NGLs, and feedstocks*	*Oil-derived products*	*Renewables (PV, CSP, & wind)*	*Heat for Desal*	*Electricity*	*Total*
Production (Oil, Gas, etc....)	15	154		0.00			169
Imports	4		1				5
Exports		-106	-27			0	-132
International Aviation & Navigation Bunkers			-1				-1
Stock Changes		0	1				1
Total Energy Supply	**18**	**48**	**-25**			**0**	**41**
Statistical Differences		1	-1				0
Transformation	**-9**	**-47**	**35**	**0.00**	**1**	**6**	**-13**
Electricity Plants	-9	-1	-7	0.00	1	6	-9
- Combined Cycle Generators	-6		0		0	3	-3
- Open Cycle Generators	0		0			0	0
- Steam Turbines	-3	-1	-6		1	3	-6
- Renewables (PV, CSP, & wind)				0.00		0	
Oil Refineries & Gasification facilities		-46	42				-4
Energy Industry Own-Use	**-6**		**0**			**-1**	**-7**
- Oil sector own use	-6		0			0	-6
- Electricity Plants own use						-1	-1
Losses	0					-1	-1
Total Final Energy Consumption	**3**		**11**		**1**	**5**	**20**
Desalination					1	0	1
- MSF/MED					1		1
- RO						0	0
Industry	3		1			1	4
- Chemical and Petrochemical	3		0				3
- Non-specified industry	0		1			1	2

Transport	5		5
Service		1	1
Residential	1	2	4
Agriculture & Fishing		0	0
Non-energy use	4		4
- of which is chem. & petchem.	4		4

Table C.4 | Kuwait Energy balances 2017, all units in Mtoe.

Kuwait Energy Balance 2017 (all units in Mtoe)	*Natural gas*	*Crude oil, NGLs, and feedstocks*	*Oil-derived products*	*Renewables (PV, CSP, & wind)*	*Heat for Desal*	*Electricity*	*Total*
Production (Oil, Gas, etc...)	14	150		0.002			164
Imports	4		1			0	4
Exports		-103	-28				-131
International Aviation & Navigation Bunkers			-1				-1
Stock Changes		0	2				2
Total Energy Supply	**17**	**47**	**-26**			**0**	**38**
Statistical Differences		1	-1				0
Transformation	**-9**	**-46**	**35**	**-0.002**	**1**	**6**	**-12**
Electricity Plants	-9	-1	-7	-0.002	1	6	-9
- Combined Cycle Generators	-5		-1		0	3	-3
- Open Cycle Generators	0		0			0	0
- Steam Turbines	-3	-1	-6		1	3	-6
- Renewables (PV, CSP, & wind)				-0.002		0	
Oil Refineries & Gasification facilities		-44	42				-3
Energy Industry Own-Use	**-5**		**0**			**-1**	**-6**
- Oil sector own use	-5		0			0	-5
- Electricity Plants own use						-1	-1
Losses	-1					-1	-1
Total Final Energy Consumption	**3**		**10**		**1**	**5**	**20**
Desalination					1	0	1
- MSF/MED					1		1
- RO						0	0
Industry	3		1			1	5
- Chemical and Petrochemical	3		0				3
- Non-specified industry	0		1			1	1

Transport	5		5
Service		1	1
Residential	1	2	4
Agriculture & Fishing		0	0
Non-energy use	3		3
- of which is chem. & petchem.	3		3

Table C.5 | Kuwait Energy balances 2016, all units in Mtoe.

Kuwait Energy Balance 2016 (all units in Mtoe)	*Natural gas*	*Crude oil, NGLs, and feedstocks*	*Oil-derived products*	*Renewables (PV, CSP, & wind)*	*Heat for Desal*	*Electricity*	*Total*
Production (Oil, Gas, etc....)	14	162					177
Imports	4						4
Exports		-109	-33			0	-142
International Aviation & Navigation Bunkers			-1				-1
Stock Changes		0	2				2
Total Energy Supply	**18**	**53**	**-32**			**0**	**39**
Statistical Differences		1	-1				0
Transformation	**-9**	**-52**	**41**		**1**	**6**	**-12**
Electricity Plants	-9	-1	-8		1	6	-10
- Combined Cycle Generators	-5		-1		0	2	-3
- Open Cycle Generators	0		0			0	0
- Steam Turbines	-3	-1	-7		1	3	-6
- Renewables (PV, CSP, & wind)							
Oil Refineries & Gasification facilities		-51	49				-2
Energy Industry Own-Use	**-5**		**0**			**-1**	**-6**
- Oil sector own use	-5		0			0	-6
- Electricity Plants own use						-1	-1
Losses	0					-1	-1
Total Final Energy Consumption	**3**		**10**		**1**	**5**	**19**
Desalination					1	0	1
- MSF/MED					1		1
- RO						0	0
Industry	3		1			1	5
- Chemical and Petrochemical	3		0				3
- Non-specified industry	0		1			1	1

Transport	5		5
Service		1	1
Residential	1	2	3
Agriculture & Fishing		0	0
Non-energy use	3		3
- of which is chem. & petchem.	3		3

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