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Article

# The important factors of Saudi Arabian policymaking in renewable energy resources

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**ABSTRACT**

There is no doubt that Saudi Arabia exports the most oil. The country has considered notable investments in Renewable Energy to diversify its economy and decrease dependence on oil export. The research aims to analyze the key factors that have influenced Saudi Arabia's renewable energy policy. The main question of our article is: What are the influential factors in Saudi Arabia's energy policy on renewable energy sources? In response, the research hypothesizes that the growing energy consumption of Saudi Arabia and its favorable geographical location for renewable energy production caused the country to invest in renewable energy for its energy mix, economy, and carbon emission reductions. To investigate the research hypothesis, we have used the theoretical framework of energy security by Benjamin Sovacool. The findings show that Saudi Arabia's capital investments in renewable energy provide opportunities for the government to create a modern industry that creates jobs and revenue with the support of the private sector. Furthermore, industries and residences use renewable energy for electricity. Therefore, renewable energy has decreased fossil fuel dependence and diversification of the country's energy mix consumption. Data are collected through the library method. The analysis method is descriptive.

## 1. Introduction

Renewable Energy resources in the Middle East region, like East Asia and Europe, have not developed enough for several reasons. First, the existence of enormous natural resources (oil and Gas), and second, the lack of sufficient knowledge and investments in the research sector and development of Renewable Energy. According to the BP Statistical Review of World Energy 2022, Middle Eastern countries collectively hold 31.3% of the world's oil production and 29.3% of the world's gas production. But the question arises, why should countries in the Persian Gulf Council see the future differently? Saudi Arabia's economy is the largest in the Arab region. For decades, Saudi Arabia has relied heavily on the oil industry to build and maintain its prominent position in world politics. A significant amount of $CO_2$ is released into the atmosphere by Saudi Arabia's reliance on crude oil for electricity production. Furthermore, the production of electricity from Renewable energy is at a low level. The country has a high energy consumption due to its growing industries and population and will be unable to produce energy for domestic consumption in the future. Thus, Saudi Arabian government has invested in renewable energy sources. The country aims to achieve 50% of its electricity consumption from renewable sources. There have been a lot of studies discussing renewable energy resources and policy in Saudi Arabia. Salam & Khan [1] have completed their analysis of Saudi Arabia would be able to export more natural gas and oil if it reduced its domestic use of fossil fuels. Solar energy can also be used as an alternative to fossil fuels in Saudi Arabia. Furthermore, this process will contribute to the stability and security of the Persian Gulf region. Waheed [2] analyzed the theoretical and empirical effects of non-oil exports and tourism on the economic growth of Saudi Arabia. He concluded an efficient strategy for sustainable economic growth in Saudi Arabia is increasing non-oil export, such as renewable energy technologies, which can be an alternative to oil production. Al-Saidi [3] analyzed the indicators, goals, and processes of the Saudi Arabian energy transition toward renewable energy. He concluded that Saudi Arabia's energy transition is primarily driven by economic pressures. Mosly & Makki [4] analyzed the Saudi government's benefits from developing renewable energy. They concluded that renewable energy resources help to decrease fossil fuel consumption for electricity generation and exports of fossil fuels. The residents, however, benefit from the lower energy bills and government subsidies.

Abubakar & Dano [5] analyzed Saudi Arabia's Climate change. Therefore, they concluded climate change is a threat to Saudi Arabia because of its sensitive ecosystems, limited freshwater reserves, and substantial coastal development. In this regard, Al-Douri et al. [6] in their studies concluded that green energy helped Saudi Arabia to overcome air temperature, humidity, and pollution. Amran et al. [7] analyzed the current status, growth, potential, resources, sustainability performance, and future prospects of renewable energy technologies in Saudi Arabia. They concluded utilizing and developing renewable energy technologies could play a significant role in KSA's future. In this regard, Tlili's research [8] concluded that solar and wind energy technologies contributed to reducing energy demand and creating efficient forms of energy. Barhoumi et al. [9] analyzed the energy resources in Saudi Arabia and their exploitation capabilities in terms of human resources. They concluded that a qualified workforce would be prepared using appropriate equipment and training. Research, development, and industrial production will be essential components of the energy production chain, as well as for the development of renewable technologies. Scholars emphasized the construction of universities and the training of specialized human resources. In addition, the different articles assume that renewable energy resources could be alternative choices to fossil fuels. The research aims to investigate the factors influencing Saudi policymaking regarding renewable energy. In this regard, the authors use the energy security theory by Benjamin Sovacool.

## 2. Theoretical framework

Energy is essential for sustainable economic growth. Industrialization and economic growth have increased energy consumption since the turn of the century. The scope of energy security assessments has expanded in recent years, now covering electricity reliability, oil and gas security, pipelines, LNG terminals, and the entire energy supply chain infrastructure [10]. Energy security within a consumer country means being able to provide energy services at reasonable prices without interruption. In contrast, major oil and gas producers aim to access new reserves and ensure the demand for their products. Saudi Arabia's energy security analysis is classified as energy producing country. Benjamin Sovacool defined energy security: "energy security should include the interconnected dimensions of availability, affordability, efficiency, and stewardship" [11]. In the following, "Energy Security" dimensions will be discussed.

### 2.1 Availability

Energy availability refers to the ability to secure "sufficient and uninterrupted supply" and the minimization of the dependence on imported fuels. Therefore, availability relates to ensuring relative independence and diversification of energy fuels and services [12].

### 2.2 Affordability

The affordability of energy is a reflection of the economic feasibility of supplying it. Affordability is defined as providing adequate and uninterrupted supply at a reasonable price. Energy affordability is also affected by the personal ability to pay [13]. Therefore, energy exporting and importing countries are sensitive to energy price volatility.

### 2.3 Efficiency

The concept of energy efficiency encompasses not just engineering but also management and policy [14]. To ensure energy security, it is often necessary to increase energy efficiency, manage demand, substitute fuels, change consumer behavior and reduce energy consumption levels through effective technology. The development of energy technology improves the quality of energy services by reducing the costs and externalities associated with energy delivery [15].

### 2.4 Stewardship

The concept of stewardship goes beyond protecting the environment; it also involves the governance of the energy system. Furthermore, the governance of energy has important in stewardship. As a measure of what countries have accomplished in reducing pollution, acid rain, greenhouse gas, and carbon dioxide emissions can reflect responsible environmental stewardship [16]. The following metrics can be used to measure the energy security dimension:

The availability of oil and natural gas is measured by import dependence. Affordability is measured by energy prices such as electricity, oil, etc. Energy efficiency is measured by electricity use per capita and the average fuel economy of passenger vehicles. Environmental stewardship is measured by carbon dioxide ($CO_2$) emissions [17].

## 3. Geography features of Saudi Arabia

### 3.1 Saudi Arabia on the sun belt

Most of Arabia is occupied by the Kingdom of Saudi Arabia. As shown in Figure 1, Saudi Arabia has access to the Persian Gulf and the Red Sea. Furthermore, The Rub Al-Khali, or the Empty Quarter of Saudi Arabia is the largest continuous sand desert in the world. Its oil region is also in the Eastern Province along the Persian Gulf. Saudi Arabia's latitude is equal to 24° 16' 0.86" N, indicating that the country lies on the equator. Saudi Arabia's longitude is equal to 45° 06' 28.26" E, showing that the country lies in the eastern hemisphere of the world [19]. Solar resources are abundant in sunbelt countries at 40 degrees from the equator. Furthermore, five sun belt regions receive the majority of long-term direct solar radiation. Sunbelt regions include the Mediterranean and Northern Africa, South Africa, China and India, Latin America, and Australia [20]. Figure 2 shows Saudi Arabia's Sunbelt located in the west and southwest of the country. Saudi Arabia's average insolation in ranges from a maximum of 7.004 kWh/m$^2$ in Bisha and a minimum of 4.479 kWh/m$^2$ in Tabuk. The southern regions of the country, including Bisha, Nejran, and Sulayyil, experience higher levels of insolation [22].

### 3.2 Saudi Arabia's wind energy resource

Wind power by using turbines generates electricity. Wind power can be an exciting alternative energy generating for Saudi Arabia. Figure 3 shows that Saudi Arabia has two regions for wind energy that include the coastal regions of the Persian Gulf and the Red Sea. Wind speeds are higher within the northeast, in the center, and near the mountains in the west. The average wind speed of the east is equal to 7.5-8 m/s and on the west coast is equal to 7-7.5 m/s.


**Figure 1**. Geographical location map of Saudi Arabia [18]

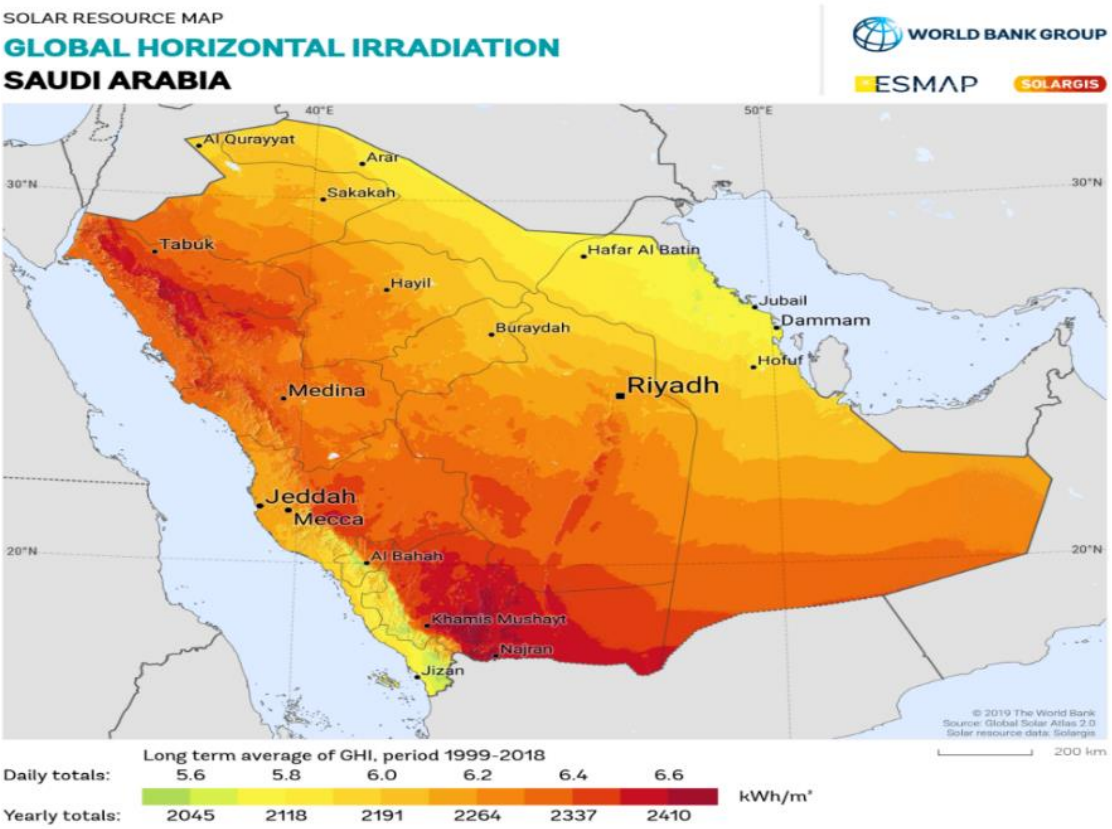



**Figure2.** Saudi Arabia solar irradiation [21]

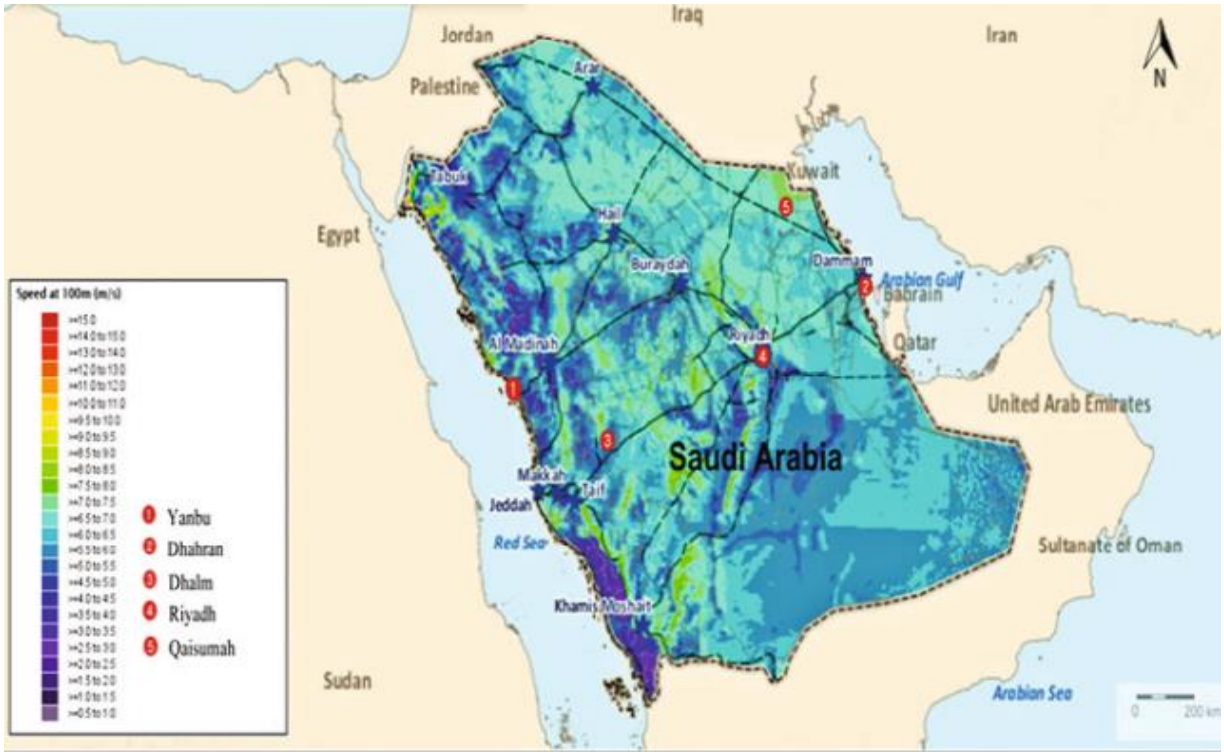



**Figure 3.** Saudi Arabia's wind speed [25]

Furthermore, the average wind speed of the central region is equal to 5-6.5 m / s [23]. "King Abdullah City for Atomic and Renewable Energy (KACARE) has established ten metering stations: in Sharurah, Hafar Al Batin, two sites in Yanbu, and two sites in Aljof, Traif, Jeddah, and Riyadh [24].

### 3.3 Geothermal energy of Saudi Arabia

Geothermal energy is heat within the earth. The Geothermal word origin includes two Greek words geo (earth) and thermal (heat). Due to the continued production of heat within the earth, geothermal kind of a renewable source. Governments use geothermal energy for industry, to heat buildings, and to generate electricity [26]. The most significant use of geothermal energy is electricity generation. The Kingdom is rich in geothermal energy, mainly distributed in the west and south. Saudi Arabia is one of the most active geothermal countries in the Middle East. Geothermal resources of Saudi Arabia can be divided into three levels: Low, medium, and high enthalpy resources. Sources of Medium enthalpy on the western and southwestern coasts (especially in the areas of Al Lith and Jazan) and shallow surface waters are represented by hot springs. In the geothermal region of Saudi Arabia, the temperature varies from 150 to 300 degrees Celsius [27]. Based on Figure 4, high-enthalpy sources, it is located in the Red Sea, west of Saudi Arabia.

## 4. Results and discussion

### 4.1 Energy availability

Security supply in Saudi Arabia is not monitored as it is in energy-importing countries. The country isn't worried about supplying energy to run its economy, at least for now.

The government instead is concerned about how to protect its domestic oil assets against security threats and ensure that future generations will be able to use them successfully. Saudi Arabia owns 17% of the world's proven oil reserves [29]. Therefore, a large share of Saudi Arabia's fiscal revenue is derived from oil, which is an important part of its economy. In 2010, oil revenues accounted for 75 percent of budget revenues, with high volatility, peaking at 93 percent in 2011 and failing to 53 percent in 2020, as the Covid-19 crisis reduced global oil demand. Therefore, government budget balances have also fluctuated with oil prices, with large surpluses during boom times and deficits when oil prices are depressed [30]. Aside from oil, Saudi Arabia also has natural gas, iron ore, gold, and copper. The country's manufacturing sector has also grown at an average annual rate of 75% until 2018 [31]. The country ranks as the largest energy consumer in its fuel production [32]. By 2038, Saudi Arabia will become a net oil importer if it does not reduce oil consumption in the energy sector [33]. The role of energy in human lives and economic activity cannot be overstated, both as a scale of development and as a primary need of humanity [34]. Therefore, energy consumption per capita is the measure of economic progress in a country. For sustainable economic growth, Saudi Arabia must search for alternative fuels for its industry. Economic growth and industrial development are closely tied to electricity consumption and production. According to British Petroleum statistics, Saudi Arabia has grown by 4.7% in its electricity production in the last decade. Furthermore, in 2021, a total of 356.6 terawatt hours of electricity was generated, which was a significant portion of the energy used to generate electricity from oil and gas.

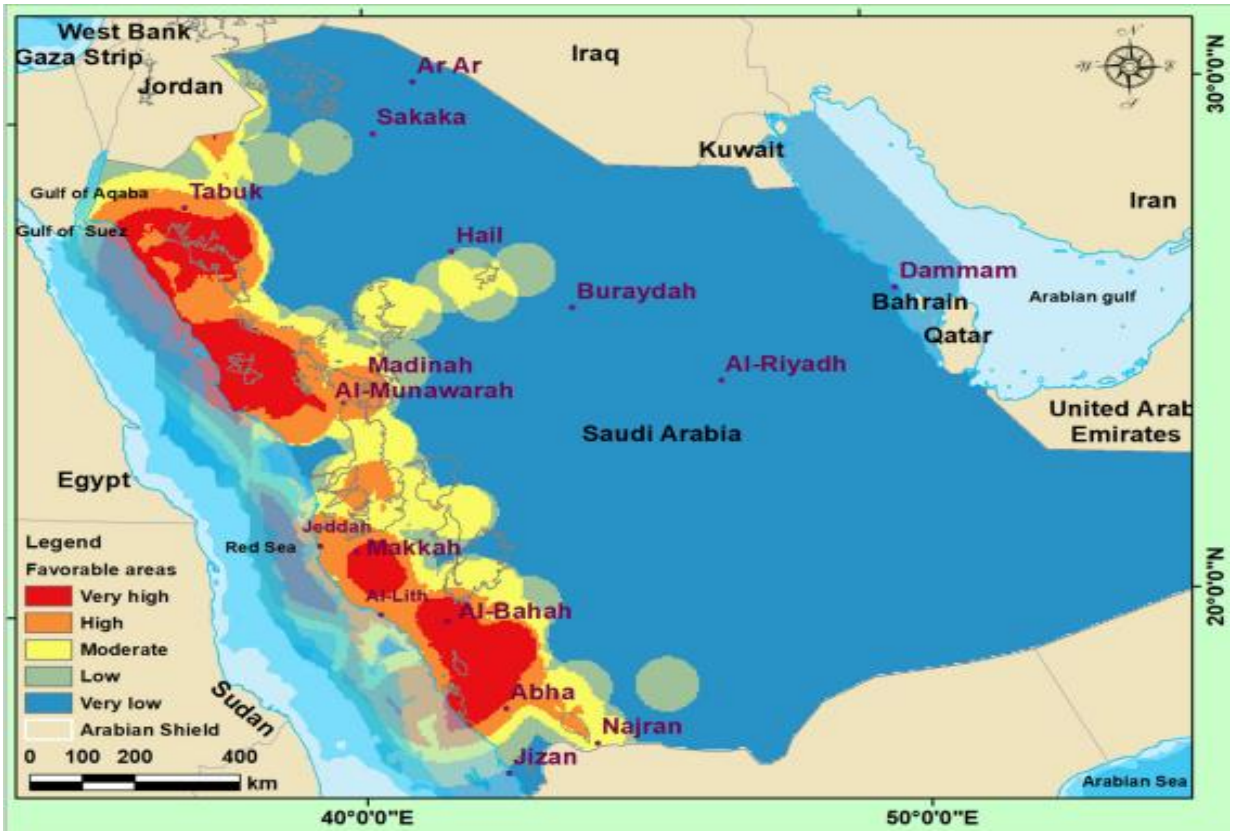



**Figure 4.** Saudi Arabia's geothermal map [28]

Figure 5 illustrates that Saudi Arabia has less diversity in its electricity production than Iran and the United Arab Emirates. Saudi Arabia generates half of its electricity from oil, which is higher than its two neighbors. Diversification of its electricity production is also important for the country's economy and industry.

### 4.2 Energy affordability

Population growth and industrialization have increased the energy demand, putting additional pressure on Saudi Arabia's economic and environmental sectors. Despite its vast oil reserves, Saudi Arabia faces different structural problems due to its fixed rate of oil production per citizen, which is aggravated by rapid population growth and high unemployment. The population of Saudi Arabia in 2000 was 20,600,000 people, to reach 35,700,000 people in 2022 [36]. Domestic energy prices have been set by the Saudi government below international market prices for a long time. Subsidies on energy help low-income households and keep prices stable. Energy subsidies, however, can lead to high energy demand and wasteful consumption while limiting incentives to invest in energy efficiency [37]. Government energy subsidies help make energy affordable for domestic and industrial use, but cheap energy causes energy waste.

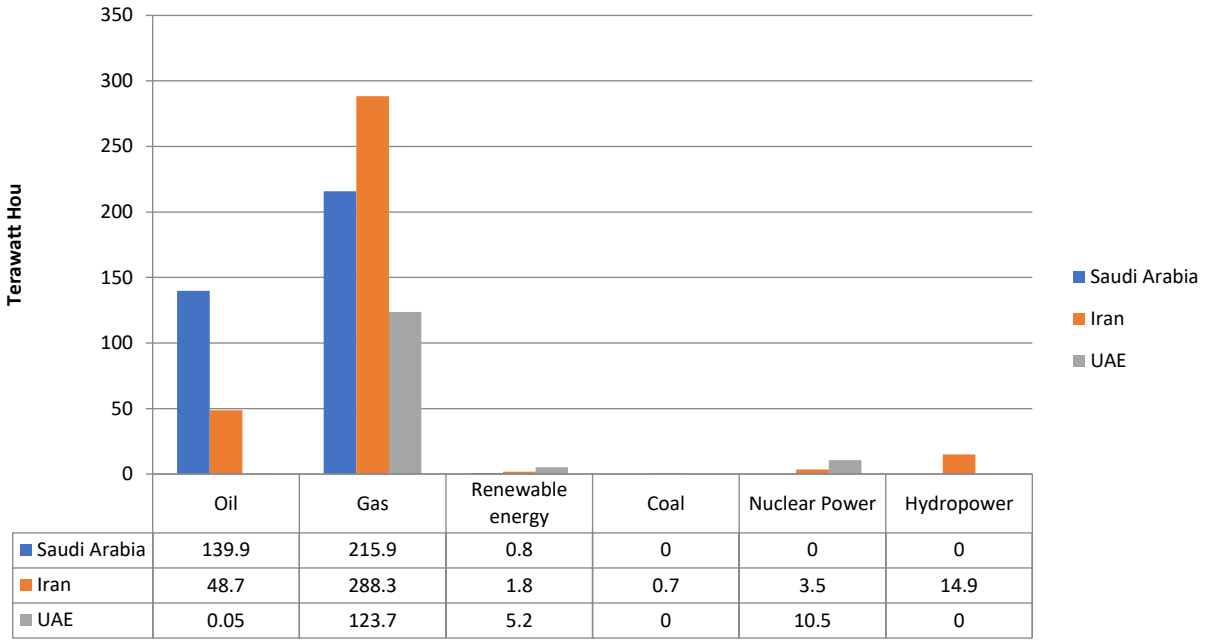
### 4.3 Energy efficiency

A rapidly growing population is a significant reason for the increasing energy consumption growth. Energy subsidies and policies to attract investment for energy sectors such as aluminum and petrochemicals are also factors contributing to Saudi Arabia's increasing energy consumption per capita.

Furthermore, due to the lack of fresh water, the country uses much energy for desalination to meet its basic water needs [38]. It is estimated that Saudi Arabia's transportation sector consumes a million barrels of oil each day, which accounts for 21% of the country's total energy consumption [39]. Figure 6 shows that Saudi Arabia's electricity consumption has increased over the years. Therefore, from 2010 to 2021, household and industrial consumption have grown significantly compared to other consumption. For efficient energy consumption in industries it is possible to contribute to efficient energy consumption by investing in technology and advanced industrial machines. In addition, improving households' energy consumption methods leads to greater efficiency.

### 4.4 Stewardship

An enormous amount of energy is required to boost economic growth and income. Furthermore, economic growth leads to an increase in infrastructure and transportation activities, both require power to operate, and direct air pollution is expected. Due to Saudi Arabia's heavy reliance on fossil fuels for energy production, rising energy consumption could result in significant $CO_2$ emissions [41]. Figure 7 depicts the $CO_2$ emissions of Saudi Arabia. Therefore, the country's emission is equal to 588.8 million tons. Furthermore, the $CO_2$ emissions of Saudi Arabia increased from 47.02.2 million tons in 1971 to 588.8 million tons in 2020. The $CO_2$ emissions of Saudi Arabia have increased by 5.28% on average per year [42]. Aramco, the national oil company of Saudi Arabia, emits around 18 tons of $CO_2$ per person, making it one of the biggest $CO_2$ emitters in the world.




| | Oil | Gas | Renewable energy | Coal | Nuclear Power | Hydropower |
|---|---|---|---|---|---|---|
| Saudi Arabia | 139.9 | 215.9 | 0.8 | 0 | 0 | 0 |
| Iran | 48.7 | 288.3 | 1.8 | 0.7 | 3.5 | 14.9 |
| UAE | 0.05 | 123.7 | 5.2 | 0 | 10.5 | 0 |

**Figure 5**. Comparison of electricity production in Saudi Arabia, Iran and the UAE in 2021 [35]

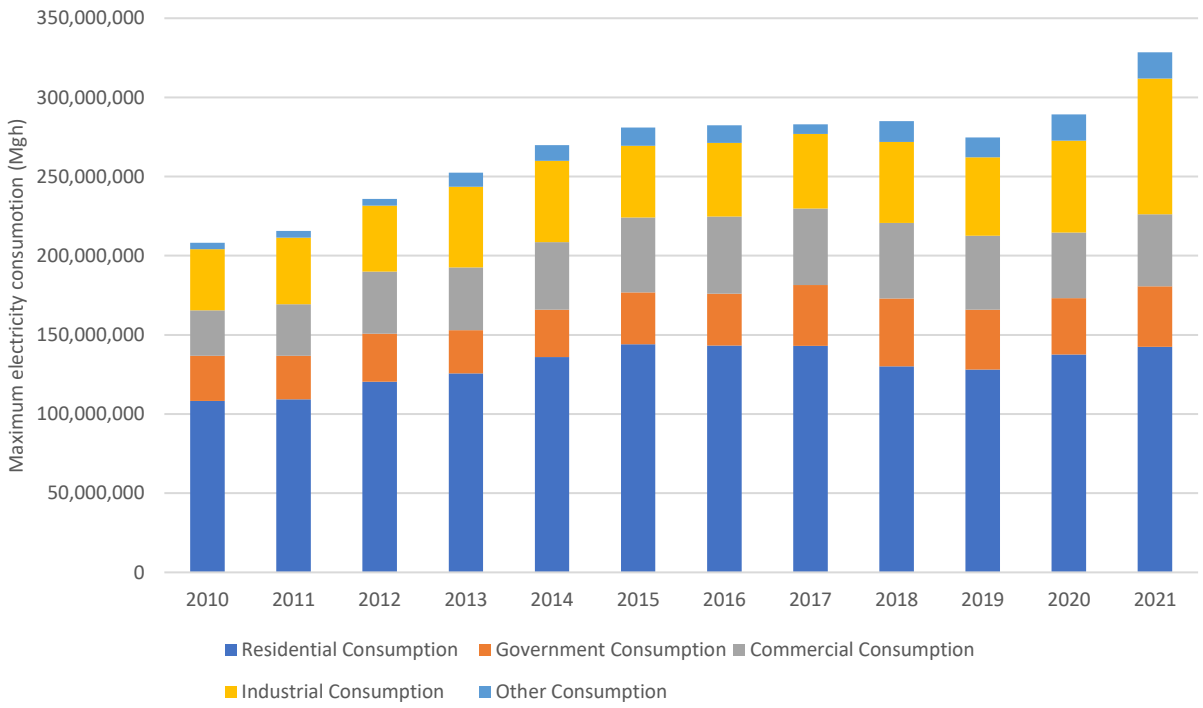



**Figure 6**. Electricity consumption in Saudi Arabia from 2010 to 2021 (in different sectors) [40]

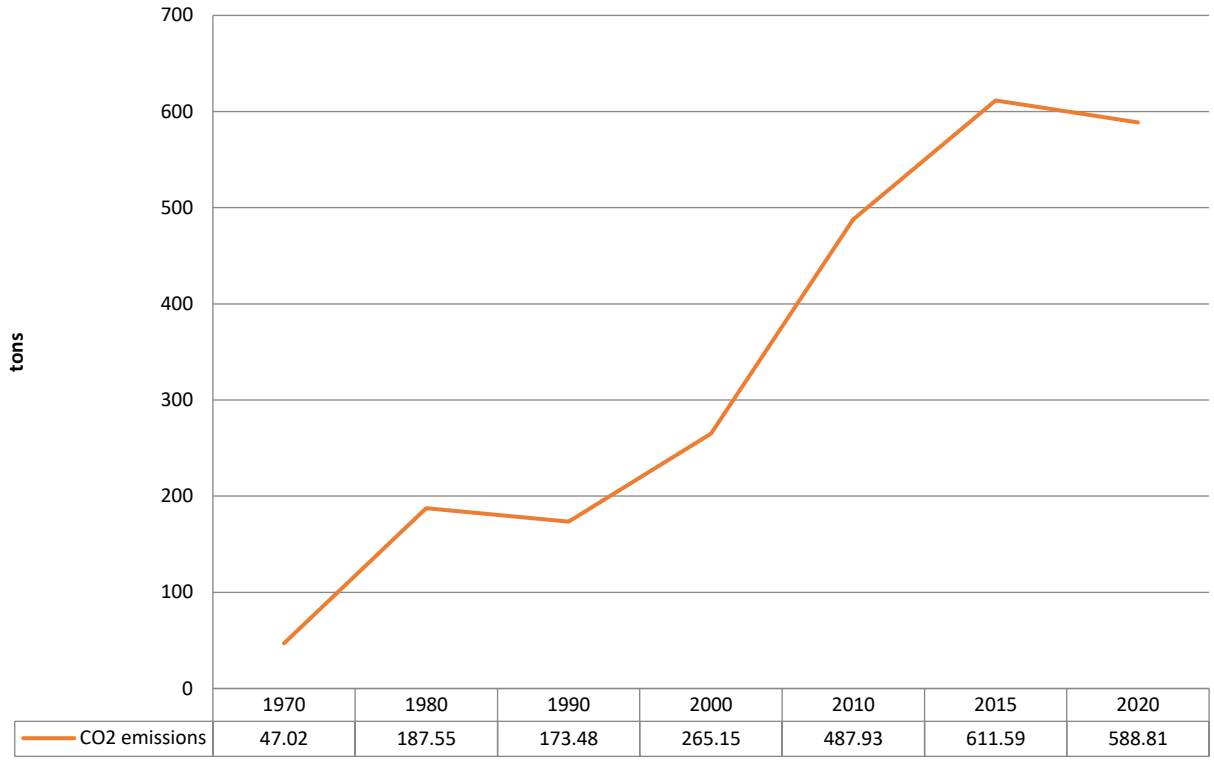



**Figure 7**. Saudi Arabia's Carbon dioxide emissions from 1970 to 2020 [43]

Saudi Aramco is the world's largest carbon dioxide emitter, producing over 60 billion tons since the 1960s.

## 5. National Renewable Energy Program of Saudi Arabia

As a part of Vision 2030, Saudi Arabia aims to diversify beyond oil production. A long-term strategic initiative led by Saudi Arabia's Ministry of Energy Industry and Mineral Resources (MEIM); the National Renewable Energy Program (NREP) directly supports the Kingdom's 2030 vision. By implementing NREP, Saudi Arabia will reduce its oil reliance and reduce greenhouse gas emissions as a result of the Paris agreement. Also, new jobs will be created, stimulating economic development throughout the Kingdom, thereby ensuring long-term prosperity consistent with Vision 2030 [44]. The NREP is funded by Public Investment Fund (PIF). Acwa Power has plans to build 11.8 GW by 2025, fulfilling the government's aims to generate 50% of electricity from renewable sources by 2030 and the rest from natural gas [45]. One of the most successful projects of renewable energy resources is the Sakaka project. The Sakaka project is a 300MW photovoltaic (PV) solar. In April 2021, the Sakaka project was commissioned by its developers, ACWA Power (70%) and AlGihaz Renewable Energy Company (30%) [46]. Another project is the wind farm. The Dumat Al Jandal wind farm is the first wind power plant in Saudi Arabia and the largest plant in the Middle East. The wind farm capacity is equal to 400MW. The plant is being developed by a consortium led by EDF Renewables (51%) and Masdar (49%) [47]. The construction of the wind farm started in 2019, and the first wind turbines were installed in 2020.

Dumat Al-Jandal's first stage of wind electricity generation began in August 2021 [48]. Furthermore, the Saudi Ministry of Energy is advancing renewable energy projects with a total capacity of 7.1 gigawatts (GWs), which are in different stages of development. Under NREP a further 15 GWs are expected to be installed in 2022 and 2023, bringing the current capacity of renewable energy projects in the Kingdom to 700 MW [49].

## 6. The Line City

Mohammed bin Salman, Crown Prince, Chairman of the Neom Company's board, unveiled the idea of a linear city. Neom Company distributes announcements stating that Line city will be a revolution in urban living, a $500 billion cross-border city in Saudi Arabia's Tabuk Province. The Linear City project is 100 miles long and located in the west of the country [50]. The line will be a smart city in the country. It is expected that Neom will become a hub for the generation of renewable energy derived from wind, solar and green hydrogen, as well as a development ground for advanced technologies as part of a shift to a low-carbon economy. The Line City is a future city powered by renewable energy. The use of Artificial Intelligence (AI) technology can provide all the energy it needs from geothermal, wind energy, solar PV, and batteries. Furthermore, AI technologies can improve energy efficiency and renewable energy integration in a smart city and create cost-effective and environmentally friendly solutions for the city. Upon completion, the city will create thousands of jobs for Saudi Arabia's residents and diversify the country's economy [51].

## 7. Challenges for Widespread Renewable Energy Development in Saudi Arabia

Renewable energy investment has faced many challenges worldwide, including financial, technical, and small market challenges. The cost of renewable energy technology, maintenance, and training still outweighs that of conventional energy sources. In general, wind turbines and solar PV are more costly to invest in but are less expensive to operate and maintain [52]. The Saudi Arabian shift to renewable energy is costly and challenging compared to fossil fuel technology. Furthermore, PV and Concentrated Solar Power (CSP) technologies are ineffective in Saudi Arabia due to high temperatures and significant dust levels. High temperatures reduce PV efficiency, while dust reduces CSP output, especially on reflectors. In order to solve these problems, PV systems need cooling and washing systems, which increase their maintenance costs [53]. Since the country's economy depends heavily on fossil fuels, nonrenewable energy dominates current energy markets. Renewable energy must compete with fossil fuels. There is massive government support for fossil fuels, even though the government offers rebates and incentives for solar energy [54]. Oil and gas operations in Saudi Arabia are controlled by Aramco, the country's national oil company. It is the second-largest producer of oil in the world. Saudi Arabia's investments in natural gas and nuclear power indicate that these sources can be integrated into its future energy mix consumption and affect its investment in renewable energy. As long-term electricity sources, natural gas and nuclear power offer low fuel costs and high-capacity factors. The mix of energy sources should be taken into consideration by decision-makers and government entities in light of these facts [55]. Therefore, the competition for renewable energy with the second-largest oil company is challenging. Due to the cheapness of fossil fuels and their market dominance, the renewable energy market remains small and underdeveloped.

## 8. Conclusion

Energy is the main factor in economic and industrial growth. The countries try a lot for the security of supply at an affordable price. With an annual economic growth of 7.5 percent, Saudi Arabia needs enormous energy. Furthermore, population and industry growth caused energy consumption to increase, especially oil and electricity for domestic use. The industrial sector in Saudi Arabia is regarded as a promising area for business growth that could provide more private-sector jobs for citizens in the coming decades. Saudi Arabia has also discovered that its abundant crude oil inputs and cheap foreign labor aren't enough to generate wealth for its growing population. Saudi Arabia, therefore, is investing in renewable energy to diversify its economy and reduce its dependence on crude oil. The country's location in the sunbelt and between the Persian Gulf and the Red Sea has made it a significant advantage in geothermal, solar, and wind energy production. Further, Saudi Arabia is seeking to attract capital to the renewable energy sector. Through private sector investments and public-private partnerships, Saudi Arabia can develop a new industry for renewable energy technology. Thus, the country is encouraging private investments in renewable energy. As a result of Saudi Arabia's investment in renewable energy, domestic oil consumption and pollution can be reduced. Furthermore, Saudi Arabia's commitment to the Paris Climate Agreement has caused the country to turn to new energies to reduce carbon dioxide emissions. The infrastructures of Saudi Arabia are very energy-intensive, and a lot of energy spend on their use. Therefore, Saudi Arabia has taken different steps to reform its energy prices to prevent energy wastage. The country must also encourage collaboration between science, technology, and innovation to accomplish its renewable energy goals. Several challenges are facing renewable energy development, such as technological issues, high initial costs, low efficiency, funding shortages, and small market share. The government can solve these problems by establishing renewable energy projects with long-term power purchase contracts, which will provide stable revenues for investors. Furthermore, the power purchase contracts could also protect buyers from future volatility in electricity.

### Ethical issue

The authors are aware of and comply with best practices in publication ethics, specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. The authors adhere to publication requirements that the submitted work is original and has not been published elsewhere in any language.

### Data availability statement

Datasets analyzed during the current study are available and can be given following a reasonable request from the corresponding author.

### Conflict of interest

The authors declare no potential conflict of interest.

### References

[1] Salam, M. A., & Khan, S. A. (2017). Transition towards sustainable energy production – A review of the progress for solar energy in Saudi Arabia. Energy Exploration & Exploitation, 36(1), 3–27. At: https://doi.org/10.1177/0144598717737442

[2] Waheed, R., Sarwar, S., & Dignah, A. (2020). The role of non-oil exports, tourism and renewable energy to achieve sustainable economic growth: What we learn from the experience of Saudi Arabia. Structural Change and Economic Dynamics, 55, 49–58. At; https://doi.org/10.1016/j.strueco.2020.06.005

[3] Al-Saidi, M. (2022). Energy transition in Saudi Arabia: Giant leap or necessary adjustment for a large carbon economy? Energy Reports, 8, 312–318. At: https://doi.org/10.1016/j.egyr.2022.01.015

[4] Mosly, I., & Makki, A. (2018). Current Status and Willingness to Adopt Renewable Energy Technologies in Saudi Arabia. Sustainability, 10(11), 4269. https://doi.org/10.3390/su10114269

[5] Abubakar, I. R., & Dano, U. L. (2019). Sustainable urban planning strategies for mitigating climate change in Saudi Arabia. Environment, Development and Sustainability, 22(6), 5129–5152. https://doi.org/10.1007/s10668-019-00417-1

[6] Al-Douri, Y., Waheeb, S. A., & Voon, C. H. (2019). Review of the renewable energy outlook in Saudi

Arabia. Journal of Renewable and Sustainable Energy, 11(1), 015906. https://doi.org/10.1063/1.5058184

[7] Amran, Y. A., Amran, Y. M., Alyousef, R., & Alabduljabbar, H. (2020, February). Renewable and sustainable energy production in Saudi Arabia according to Saudi Vision 2030; Current status and future prospects. Journal of Cleaner Production, 247, 119602. https://doi.org/10.1016/j.jclepro.2019.119602

[8] Tlili, I. (2014). Renewable energy in Saudi Arabia: current status and future potentials. Environment, Development and Sustainability, 17(4), 859–886. https://doi.org/10.1007/s10668-014-9579-9

[9] Barhoumi, E.M., Okonkwo, P.C., Zghaibeh, M. et al. Renewable energy resources and workforce case study Saudi Arabia: review and recommendations. J Therm Anal Calorim 141, 221–230 (2020). At: https://doi.org/10.1007/s10973-019-09189-2

[10] Sovacool, B. K. (2012). Energy security: challenges and needs. WIREs Energy and Environment, 1(1), 51–59. At: https://doi.org/10.1002/wene.13

[11] Sovacool, B. K. (2010). The Routledge Handbook of Energy Security (Routledge International Handbooks) (1st ed.). Routledge. ISBN 9780415721639. Published February 5, 2014 by Routledge, 464 Pages

[12] Novikau, A. (2019). Conceptualizing and achieving energy security: The case of Belarus. Energy Strategy Reviews, 26, 100408. https://doi.org/10.1016/j.esr.2019.100408

[13] Fang, D., Shi, S., & Yu, Q. (2018). Evaluation of Sustainable Energy Security and an Empirical Analysis of China. Sustainability, 10(5). At: https://doi.org/10.3390/su10051685

[14] Shove, E. (2017). What is wrong with energy efficiency? Building Research & Information, 46(7), 779–789. At: https://doi.org/10.1080/09613218.2017.1361746

[15] Sovacool, B. K., & Brown, M. A. (2010, November 21). Competing Dimensions of Energy Security: An International Perspective. Annual Review of Environment and Resources, 35(1), 77–108. https://doi.org/10.1146/annurev-environ-042509-143035

[16] Brown, M. A., Wang, Y., Sovacool, B. K., & D'Agostino, A. L. (2014). Forty years of energy security trends: A comparative assessment of 22 industrialized countries. Energy Research & Social Science, 4, 64–77. At: https://doi.org/10.1016/j.erss.2014.08.008

[17] Paravantis, J. (2019). Dimensions, Components and Metrics of Energy Security: Review and Synthesis. SPOUDAI Journal of Economics and Business, 69(4), 38–52. Retrieved from https://spoudai.unipi.gr/index.php/spoudai/article/view/2755

[18] Infoplease. (2022, March 24). Saudi Arabia. Retrieved from https://www.infoplease.com/world/countries/saudi-arabia

[19] All Famous Faqs. (2022, March 23). What region of the world is Saudi Arabia in? https://allfamousbirthday.com/faqs/what-region-of-the-world-is-saudi-arabia-in/

[20] Wang, Z. (2019). Design of Solar Thermal Power Plants (1st ed.). Academic Press. At: https://doi.org/10.1016/C2017-0-03007-0

[21] Solargis. (2020). Solar resource maps of Saudi Arabia. Retrieved September 26, 2022, from https://solargis.com/maps-and-gis-data/download/saudi-arabia

[22] Almasoud, A., & Gandayh, H. M. (2015). Future of solar energy in Saudi Arabia. Journal of King Saud University - Engineering Sciences, 27(2), 153–157. At: https://doi.org/10.1016/j.jksues.2014.03.007

[23] Allhibi, H., Chowdhury, H., Zaid, M., Loganathan, B., & Alam, F. (2019). Prospect of wind energy utilization in Saudi Arabia: A review. Energy Procedia, 160, 746–751. At: https://doi.org/10.1016/j.egypro.2019.02.184

[24] AlGhamdi, S. A., Abdel-Latif, A. M., Abd El-Kawi, O. S., & Abouelatta, O. B. (2022). Analysis of Wind Speed Data and Wind Energy Potential for Seven Selected Locations in KSA. Journal of Power and Energy Engineering, 10(04), 1–26. https://doi.org/10.4236/jpee.2022.104001

[25] Abdelaziz Mohamed, M., & Eltamaly, A. M. (2017, August 4). Modeling of Hybrid Renewable Energy System. Modeling and Simulation of Smart Grid Integrated With Hybrid Renewable Energy Systems, 11–21. https://doi.org/10.1007/978-3-319-64795-1_2

[26] EIA (Energy Information Administration). (2021, December 21). Geothermal explained. EIA. Retrieved from https://www.eia.gov/energyexplained/geothermal/

[27] Zohbi, G. A., & AlAmri, F. G. (2020). Current Situation of Renewable Energy in Saudi Arabia: Opportunities and Challenges. Journal of Sustainable Development, 13(2), 98–119. At: https://doi.org/10.5539/jsd.v13n2p98

[28] OPEC. (2021). OPEC : Saudi Arabia. Organization of the Petroleum Exporting Countries. Retrieved from https://www.opec.org/opec_web/en/about_us/169.htm

[29] Aboud, E., Qaddah, A., Harbi, H., & Alqahtani, F. (2021). Geothermal Resources Database in Saudi Arabia (GRDiSA): GIS model and geothermal favorability map. Arabian Journal of Geosciences, 14(2), 1-10. At: https://doi.org/10.1007/s12517-020-06426-z

[30] Zeidane, Z. (2022, August). Country report: SAUDI ARABIA (No. 22/275). International Monetary Fund. https://www.imf.org/en/Publications/CR/Issues/2022/08/11/Saudi-Arabia-Selected-Issues-522192

[31] White, G. (2020, May 16). Is Saudi Arabia going to be the world's next big manufacturing destination? Manufacturing Digital. Retrieved from https://manufacturingdigital.com/smart-manufacturing/saudi-arabia-going-be-worlds-next-big-manufacturing-destination

[32] Tazay, A. (2020). Techno-Economic Feasibility Analysis of a Hybrid Renewable Energy Supply Options for University Buildings in Saudi Arabia. Open

Engineering, 11(1), 39–55. At: https://doi.org/10.1515/eng-2021-0005U.S.
[33] Salah, M. M., Abo-khalil, A. G., & Praveen, R. (2021). Wind speed characteristics and energy potential for selected sites in Saudi Arabia. Journal of King Saud University - Engineering Sciences, 33(2), 119–128. At: https://doi.org/10.1016/j.jksues.2019.12.006
[34] Esen, Ömer y BAYRAK, Metin.Does more energy consumption support economic growth in net energy-importing countries. Journal of Economics, Finance and Administrative Science [online]. 2017, vol.22, n.42, pp.75-98. ISSN 2077-1886.
[35] BP. (2022). BP Energy Outlook: 2022 edition. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2022-full-report.pdf
[36] Worldometer. (2022). Saudi Arabia Population (2022) - Worldometer. Retrieved from https://www.worldometers.info/world-population/saudi-arabia-population/
[37] Aldubyan, M., & Gasim, A. (2021). Energy price reform in Saudi Arabia: Modeling the economic and environmental impacts and understanding the demand response. Energy Policy, 148, 1-13 At: https://doi.org/10.1016/j.enpol.2020.111941
[38] Bambawale, M. J., & Sovacool, B. K. (2011). Sheikhs on barrels: what Saudi Arabians think about energy security. Contemporary Arab Affairs, 4(2), 208–224. At: https://doi.org/10.1080/17550912.2011.569466
[39] Howarth, Nicholas, Alessandro Lanza, and Thamir Alshehri. 2019. Saudi Arabia's 2018 CO2 Emissions Fall Faster Than Expected. KS--2019-II01. Riyadh: KAPSARC. Retrieved from https://www.kapsarc.org/research/publications/saudi-arabias-2018-co2-emissions-fall-faster-than-expected/
[40] Saudi Central Bank. (2022). Electricity Consumption of The Kingdom by Type of Consumption and Its Ratio to The Total. Saudi Central Bank. Retrieved September 20, 2022, from https://www.sama.gov.sa/en-US/EconomicReports/Pages/report.aspx?cid=126
[41] Mahmood, H., Alkhateeb, T. T. Y., Al-Qahtani, M. M. Z., Allam, Z., Ahmad, N., & Furqan, M. (2020). Energy consumption, economic growth and pollution in Saudi Arabia. Management Science Letters, 979–984. At: https://doi.org/10.5267/j.msl.2019.11.013
[42] Knoema. (2021, October 14). Saudi Arabia CO2 emissions, 1970–2021 - knoema.com. Retrieved from https://knoema.com/atlas/Saudi-Arabia/CO2-emissions
[43] Statista. (2021, November 12). CO2 emissions from fossil fuel & industrial purposes in Saudi Arabia 1970–2020. Retrieved from https://www.statista.com/statistics/486065/co2-emissions-saudi-arabia-fossil-fuel-and-industrial-purposes/
[44] KSA Climate. (2018, November 21). NATIONAL RENEWABLE ENERGY PROGRAM. Retrieved from https://ksa-climate.com/making-a-difference/nrep/
[45] IEA. (2022, January 22). Saudi National Renewable Energy Program (NREP) – Policies. Retrieved from https://www.iea.org/policies/14658-saudi-national-renewable-energy-program-nrep
[46] Power Technology. (2021, April 20). Sakaka Photovoltaic Solar Project. Retrieved from https://www.power-technology.com/projects/sakaka-photovoltaic-solar-project/
[47] Ellichipuram, U. (2021, August 9). Dumat Al Jandal wind farm in Saudi Arabia starts production. Power Technology. https://www.power-technology.com/news/dumat-al-jandal-wind/
[48] NS Energy. (2021, August 12). Dumat Al Jandal Wind Farm, Al Jouf, Saudi Arabia. https://www.nsenergybusiness.com/projects/dumat-al-jandal-wind-farm/
[49] Argaam. (2022, July 25). Saudi Arabia plans to add 15 GWs of renewable energy projects in 2022, 2023: S&P Global. ArgaamPlus. https://www.argaam.com/en/article/articledetail/id/1576240
[50] Paszkowska-Kaczmarek, N. (2021). The Line – The Saudi-Arabian Linear City Concept as the Prototype of Future Cities. Architecturae Et Artibus, 13(2), 33–46. https://doi.org/10.24427/aea-2021-vol13-no2-03
[51] Al-sayed, A., Al-shammari, F., Alshutayri, A., Aljojo, N., Aldhahri, E., & Abouola, O. (2022, March 14). The Smart City-Line in Saudi Arabia: Issue and Challenges. Postmodern Openings, 13(1 Sup1), 15–37. https://doi.org/10.18662/po/13.1sup1/412
[52] IEA (2020), Renewable energy market update, IEA, Paris https://www.iea.org/reports/renewable-energy-market-update
[53] Al Yousif, M. A. (2020, July 30). Renewable Energy Challenges and Opportunities in the Kingdom of Saudi Arabia. International Journal of Economics and Finance, 12(9), 1. https://doi.org/10.5539/ijef.v12n9p1
[54] Regen-Power. (2021, June 4). What are the problems faced by renewable energy? Regen Power. Retrieved September 16, 2022, from https://regenpower.com/articles/what-are-the-problems-faced-by-renewable-energy/
[55] Salim, A. M., & Alsyouf, I. (2020, April 4). Development of renewable energy in the GCC region: status and challenges. International Journal of Energy Sector Management, 14(6), 1049–1071. https://doi.org/10.1108/ijesm-07-2019-0012