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King Abdullah Petroleum Studies and Research Center

Commentary

Saudi Arabia's Potential to Further Hydrogen Use in the Maritime Sector

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Introduction

The United Nations Climate Change Conference (COP 26) in Glasgow focussed on advancing low-carbon fuels to reach emissions abatement targets. The conference also reaffirmed the goals of the Paris Agreement: to secure global net-zero emissions by mid-century and limit the global temperature increase to 1.5 degrees Celsius above pre-industrial levels (UNFCCC 2021). A key highlight of COP 26 was the promotion of low-carbon fuels, such as hydrogen, to help hard-to-decarbonize sectors meet their net-zero emissions targets. Hydrogen has the potential to reduce global emissions by up to one-third if it is scaled up significantly (BloombergNEF 2020). Although not specifically mentioned in the Glasgow Climate Pact, hydrogen was at the front and center of much of the dialogue. As nations commit to net-zero emissions targets, many see low-carbon fuels as part of their future energy mix to help achieve their decarbonization targets.

Long-haul transport such as shipping is one of the hardest sectors to decarbonize given limited advancements in fuel technology

One potential use for hydrogen is in the maritime sector as it searches for a low-carbon alternative. Long-haul transport such as shipping is one of the hardest sectors to decarbonize given limited advancements in fuel technology. A fuel that is both high density and low weight that would allow for the seamless continuation of international trade has yet to be created. Shipping makes up about 75% of total freight activity, and the maritime sector contributes around 2% of the world's total carbon dioxide (CO_2) emissions (IEA 2019). The International Maritime Organization (IMO) is a United Nations agency that focuses on improving safety and security in the sector. It has set an objective to "reduce the total annual greenhouse gas emissions by at least 50% by 2050 compared to 2008" (IMO 2018). The IMO has adopted 15 regulations since 2011, including the Energy Efficiency Design Index (EEDI), Ship Energy Efficiency Management Plan (SEEMP), IMO Data Collection System (IMO DCS) and mandatory reporting of fuel oil consumption data within IMO DCS.

In particular, the IMO approved amendments to Annex VI in 2011, including new mandatory energy efficiency regulations to further reduce greenhouse gas (GHG) emissions from shipping and owner requirements to set efficiency targets (IMO 2022). Additionally, the IMO implemented a regulation at the beginning of 2020 to eliminate high sulfur fuels, such as heavy fuel oils (HFOs). It is currently developing further regulations to reduce maritime emissions. Approximately seven of these will come into effect between 2023 and 2050 (IMO 2022).

Many countries, including Saudi Arabia, Japan, Australia and the United Arab Emirates (UAE), have made commitments to invest in and produce hydrogen. Thus, the development of a low-carbon fuel for the maritime sector may be on the horizon.

Saudi Arabia's Potential to Support Maritime Shipping Decarbonization

In October 2021, Saudi Arabia hosted the first ever Saudi Green Initiative Forum, where it announced its commitment to achieve net-zero emissions by 2060 and several initiatives to help it reach this target. One of these was to become the largest producer of low-carbon hydrogen, targeting around 4 million tonnes of hydrogen production by 2030 (Saudi Green Initiative 2021). Saudi Arabia is among several countries pushing low-carbon hydrogen development. In September 2020, the Kingdom successfully exported the world's first shipment of carbon-neutral ammonia to Japan (Shabaneh, Al Suwailem and Roychoudhury 2020). Saudi Arabia will also be home to one of the largest green hydrogen projects, which are being built in the northwest coastal city of Neom. The country further pushed its commitment to hydrogen in January 2022, when the Minister of Energy, HRH Abdulaziz bin Salman, signed eight memorandums of understanding (MoUs) to further hydrogen development in the transport sector (Saudi Press Agency 2022). Saudi Arabia also signed a three-party MoU between the Saudi Public Investment Fund (PIF), Korean steelmaker POSCO, and Samsung C&T Corporation Engineering and Construction Group. The aim of the MoU is to develop projects to produce green hydrogen for export (Saudi Press Agency 2022).

Although Saudi Arabia's hydrogen focus has mostly been on production and exports, the country can play an important role in galvanizing hydrogen demand by becoming a key contributor to maritime sector decarbonization. Saudi Arabia's hydrogen investments, coupled with its strategic location along the East-West shipping lane, present opportunities for the country. It can produce hydrogen for export and create demand for hydrogen or its derivatives as an alternative fuel source for shipping. Since IMO regulations on sulfur content went into effect in 2020, more shipping companies have begun to explore alternative fuel sources to meet the 0.5 sulfur content restriction and additional regulations aimed at reducing emissions in the sector. Several contenders for clean fuel alternatives have emerged that could help to reach the IMO's decarbonization objective. Of these, hydrogen and its derivatives are seen as a clear leader (Reinsch and O'Neil 2021). A study conducted by the Global Maritime Forum in March 2021 found that half of the 106 projects focussed on achieving zero emissions in maritime shipping involved hydrogen (Fahnestock and Bingham 2021). The Global Maritime Forum's study on the Nordic Green Ammonia-Powered Ship project also indicates the potential for ammonia synthesized from green hydrogen to be a credible long-term, zero-emissions fuel (Global Maritime Forum 2021). Saudi Arabia's continued investments in ship and port infrastructure to help the demand-side (exports) of hydrogen enables the country to become a key contributor in the decarbonization of the maritime sector.

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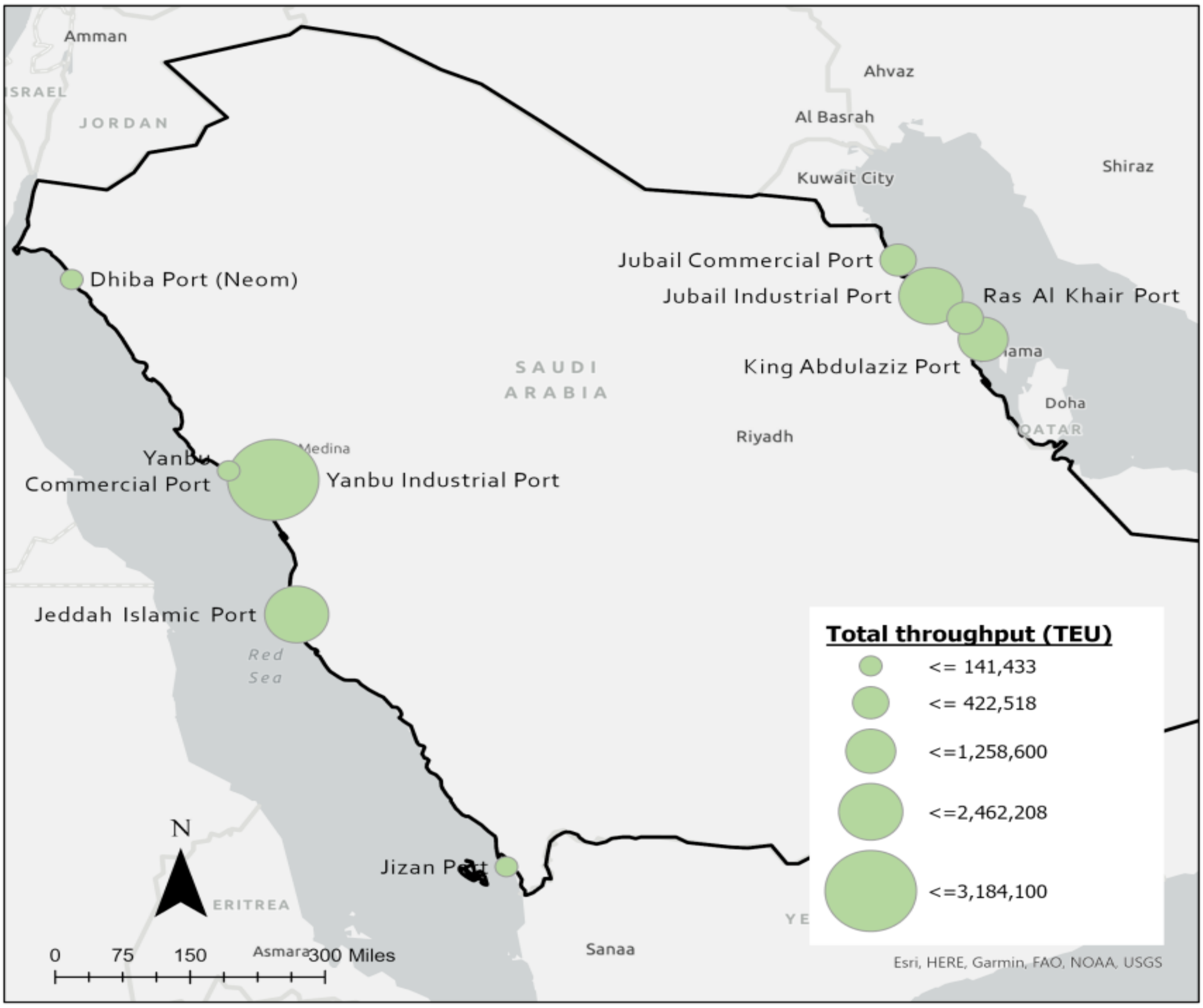
Overview of Saudi Arabia's Maritime Sector

Saudi Arabia is endowed with a strategic geographic location along the East-West shipping lane, where around 13% of international trade passes through the Suez Canal. Six of the Kingdom's 10 ports are located on its Red Sea coast: Jeddah Islamic Port, Dhiba (Neom) Port, Yanbu Commercial Port, Yanbu Industrial Port, Jizan Port and King Abdullah Port (the only private port in the country). Total throughput reported in 2019 by the Saudi Ports Authority (MAWANI), excluding crude oil, was 262 million tonnes or 9.98 million twenty-foot equivalent units (TEUs) for its nine public ports. Figure 1 highlights the distribution of total throughput across the individual public ports. The Jeddah Islamic Port, a major container port, handles approximately 63% of the country's container throughput, with 1.76 million container TEUs in 2019. Yanbu Industrial Port handles approximately 61% of the country's liquid bulk throughput (excluding crude oil), with 3 million TEUs. Four ports are located on the Arabian Gulf coast: King Abdulaziz Port in Dammam, Ras Alkhair Port, Jubail Industrial Port and Jubail Commercial Port. Jubail Industrial Port, a major liquids bulk port, handles around 37.4% of total liquids bulk throughput (excluding crude oil), with 1.85 million TEUs in 2019.

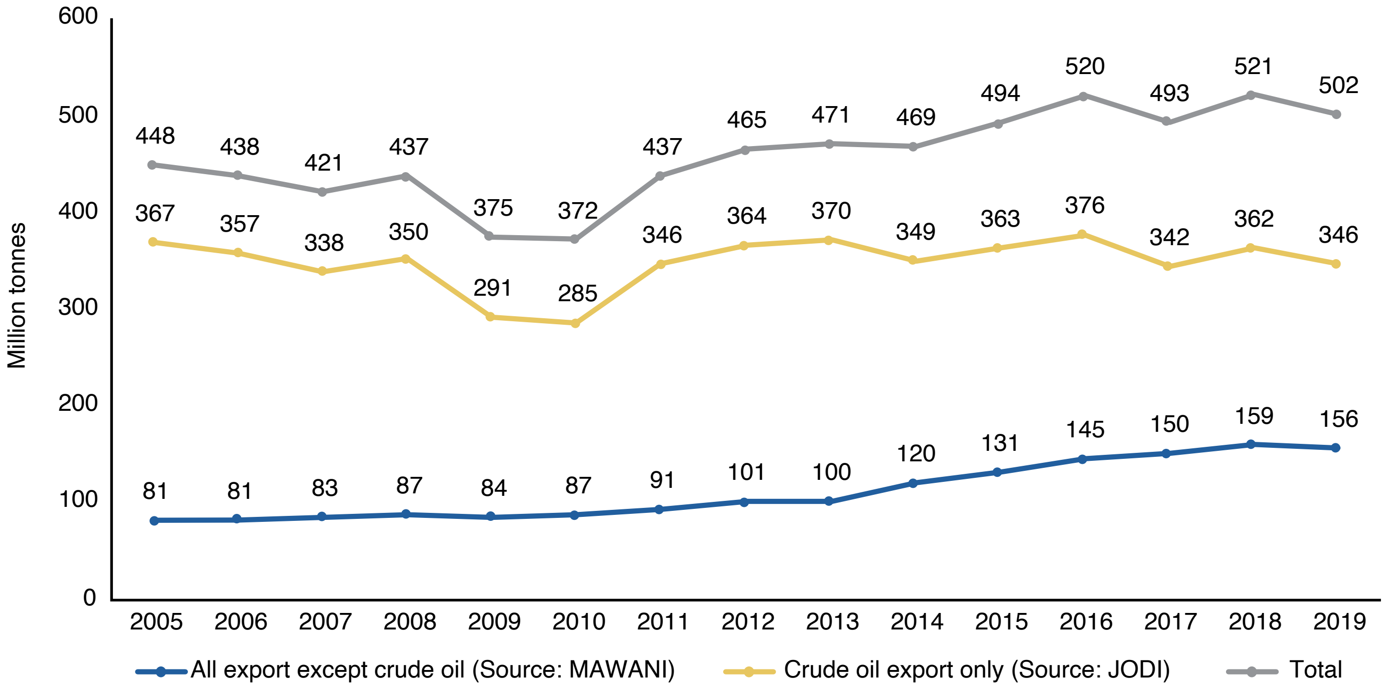
Figure 1. Throughput in Saudi Arabia by port, 2019.



Source: KAPSARC analysis based on Saudi Ports Authority (MAWANI) 2019 data.
Note: TEU = twenty-foot equivalent units.

In Saudi Arabia, seaborne trade makes up an estimated 94% of the volume of all goods transported and 77% of all value. In 2019, MAWANI indicated that the throughput at all Red Sea coast ports, including the private King Abdullah Port in King Abdullah Economic City (KAEC), was an estimated 6.4 million TEUs. The throughput at the Arabian Gulf coast ports was an estimated 4.4 million TEUs. As indicated in Figure 2, non-oil exports have grown in Saudi Arabia over the last decade from approximately 22% to 31% of total exports.

Figure 2. Saudi Arabia's seaport exports.



Source: KAPSARC analysis based on Saudi Ports Authority (MAWANI) and Joint Organisations Data Initiative (JODI) data.

Saudi Arabia's commitment to becoming a logistics hub is reflected in the Ministry of Transport's (MoT) National Transportation and Logistics Strategy (NTLS), a Vision Realization Program of Saudi Vision 2030. It aims to tackle several factors that are currently holding back the country from being a leader in the maritime sector. Some key strategic investments include port expansion to accommodate more than 40 million TEUs by 2030, from 9.98 million TEUs in 2019. This will enable further transshipment and re-export of goods (MAWANI 2022). Saudi Arabia has taken the initiative in developing its hinterland network, serving its ultimate goal of becoming a logistics hub. One such project is the Al Khumra Zone, a free trade zone located near the Jeddah Islamic Port. The development of a second free trade zone is expected in the private King Abdullah Port in KAEC.

As part of its efforts to become a global player, MAWANI has prioritized efficiency, safety and environmental sustainability by establishing clear targets under the NTLS. Saudi Arabia is ranked 65th in the 2018 World Bank Logistics Performance Index on efficiency of customs and border clearance. Saudi Arabia is actively working on improving its efficiency ranking through notable projects handled by the Transport General Authority (TGA). In terms of sustainability efforts, MAWANI is working to establish a baseline for all its ports to achieve environmental sustainability and safety levels. Although it does not currently have a port sustainability strategy, MAWANI is developing key performance indicators that focus on important environmental benchmarks. These include the level of CO_2 emissions per tonne of cargo, the percentage of port electrification, the diversification of energy sources for port operations (equipment, vehicles, buildings, etc.), water conservation and sustainable dredging, among others.

Hydrogen as a Marine Fuel: Options and Challenges

Because hydrogen is carbon free, it does not emit CO_2 when burned. However, the current hydrogen production process must be decarbonized either by using renewable electricity for the electrolysis of water (green hydrogen) or using carbon capture, utilization and storage (CCUS) technologies to manage CO_2 emissions from steam methane reformation (blue hydrogen). While low-carbon hydrogen (blue and green hydrogen) has strong potential as an alternative fuel in the maritime sector, it does come with a set of challenges. Hydrogen is highly flammable and embrittles various metals. Although safety standards for handling and storing hydrogen are well established for industrial use, safety continues to be a key area for research and development, particularly for new applications, including shipping. Further, hydrogen has a much lower volumetric energy density than traditional marine fuels, i.e., it provides fewer miles per unit of volume than residual fuel oil or marine gasoil (MGO). As shown in Figure 3, to achieve the same propulsion power from a liter of fuel oil or MGO, ship owners would need to accommodate almost seven to eight times the storage volume of compressed hydrogen (at 700 bar). Liquefying hydrogen slightly improves energy density but requires a significant amount of energy. Higher quality insulation onboard vessels would also be needed. Finally, the ‘cleanness’ of hydrogen depends on its source. It is important to use low-carbon hydrogen that ensures the removal of emissions either by coupling traditional hydrogen production with CCUS or utilizing renewables.

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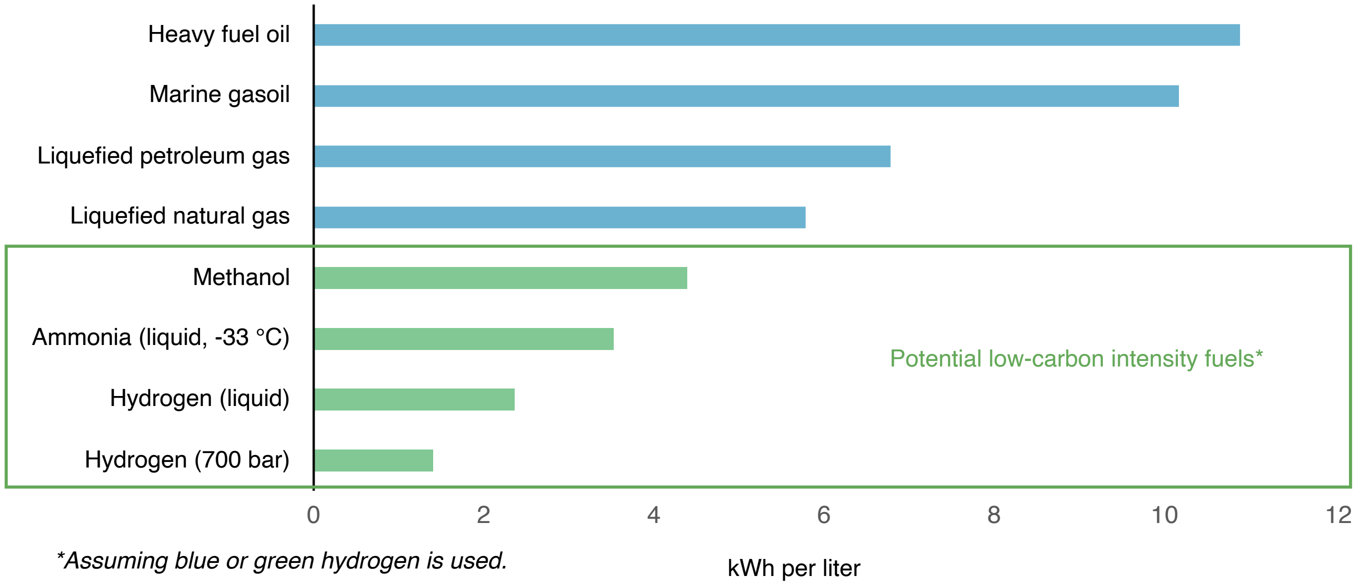
Figure 3. Comparison of the volumetric energy density of fuels.



Source: Authors' depiction using data from The Royal Society (2020) and The Engineering Toolbox (2003).
Note: kWh = kilowatthour; °C = degrees Celsius.

Hydrogen-derived fuels such as ammonia and methanol are more promising options for the maritime sector compared to other forms of hydrogen (Figure 3). Both have relatively high energy densities and robust global supply chains that can be extended to bunkering capabilities. Burning ammonia does not release CO_2 but does emit nitrous oxide emissions, another GHG, which could be captured using special technologies such as selective catalytic reduction. Ammonia is also highly toxic, and shipowners would need to manage it with additional safety equipment such as emergency ventilation and gas absorption systems (Gallucci 2021). In contrast, methanol is easier to handle than hydrogen as, under normal pressures and temperatures, it is a liquid. Although methanol combustion releases CO_2, its lifecycle emissions could be significantly reduced if low-carbon hydrogen is used to manufacture the methanol. Ammonia and methanol are chemicals that have an established marine transport supply chain as they play a larger role in industry. Additionally, these hydrogen derivative fuels do not require a large investment for retrofitting because many existing pilot projects, including one using 29 vessels by the shipping giant Maersk, have dual-fuel engines that can operate both standard bunkers and hydrogen derivatives (Collins 2022).

The cost of low-carbon hydrogen is currently a barrier to its expanded use. Technologies to produce blue and green hydrogen are maturing but require significant scaling up to lower costs going forward. Saudi Arabia is well-positioned to produce the lowest cost low-carbon hydrogen in the world. Green hydrogen in Saudi Arabia is expected to fall from \$2.16 per kilogram (kg) today to \$1.48/kg by 2030, and potentially to \$1/kg in the long term (Shahid and Shabaneh 2022). In addition to the declining cost of technology, policy instruments such as carbon contracts for differences are essential to out-compete traditional marine fuels. Such policies provide opportunities to offset the operation and investment costs of using low-carbon technologies in heavy fuel industries (Energiewende Direkt 2020).

Moving forward, countries looking to promote the adoption of hydrogen (or its derivatives) as the marine fuel of choice will need to take advantage of existing shipping routes, such as the East-West shipping lane. They will also need to develop a shipping corridor in which participating ports are equipped to handle fuel bunkering and the retrofitting of vessels. This is an opportunity for Saudi Arabia to collaborate with other nations along this shipping lane to create a transition path for the maritime and other sectors.

Conclusion

Saudi Arabia's strategic geographic location along the global East-West shipping lane, coupled with its significant renewable energy resources and massive hydrocarbon reserves with access to underground geological pore spaces, makes it an ideal champion for decarbonizing the maritime sector.

Maritime shipping plays a significant role in the Saudi Vision 2030 goals. The country's investments to upgrade and develop its maritime infrastructure, along with the accompanying logistics infrastructure, demonstrates its commitment to diversifying its economy. Saudi Arabia is also well positioned (with the right investment in infrastructure) to produce low-carbon hydrogen, with costs expected to fall to an estimated $1/kg beyond 2030. Additionally, hydrogen-derived fuels such as ammonia and methanol have considerable potential for use in the maritime sector. Both have existing global supply chains and relatively high energy densities that can more easily be extended to bunkering capabilities than can hydrogen.

Although the discussion on hydrogen targets has focussed primarily on production, the utilization and penetration of hydrogen and its derivatives as alternative fuel options is key to meeting decarbonization targets. The maritime sector is one such example of creating demand for hydrogen as an alternate fuel. Moving forward, countries looking to promote the adoption of hydrogen (or its derivatives) as the marine fuel of choice will need to take advantage of existing shipping routes, such as the East-West shipping lane. They will also need to develop a shipping corridor in which participating ports are equipped to handle fuel bunkering and the retrofitting of vessels. This is an opportunity for Saudi Arabia to collaborate with other nations along this shipping lane to create a transition path for the maritime and other sectors. The International Energy Agency's Global Hydrogen Review 2021 suggests that developing an international shipping route for hydrogen-derived fuels is key, as these routes, given their high traffic, can expedite the adoption of such fuels. Saudi Arabia can thus become a leader in shipping industry decarbonization via investments in ship and port infrastructure to support the demand-side of hydrogen.

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About the Project

The KAPSARC Transport Analysis Framework (KTAF) studies and models global economic activity and freight transportation. For this, KTAF relies on open-source global data from satellites and the spatial distribution of different economic activities by broad sectors. The main objective of KTAF is to offer quantified insights into the effects of policy measures on transportation activities and energy consumption related to freight mobility.

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KAPSARC is an advisory think tank within global energy economics and sustainability providing advisory services to entities and authorities in the Saudi energy sector to advance Saudi Arabia's energy sector and inform global policies through evidence-based advice and applied research.

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