مركز الملك عبدالله للدراسات والبحوث البترولية
King Abdullah Petroleum Studies and Research Center

The Saudi Move into Hydrogen: A Paradigm Shift

Hatem Alatawi and Abdulelah Darandary

Instant Insight

December 22, 2020

KS--2020-II32

About KAPSARC

The King Abdullah Petroleum Studies and Research Center (KAPSARC) is a non-profit global institution dedicated to independent research into energy economics, policy, technology and the environment across all types of energy. KAPSARC's mandate is to advance the understanding of energy challenges and opportunities facing the world today and tomorrow, through unbiased, independent, and high-caliber research for the benefit of society. KAPSARC is located in Riyadh, Saudi Arabia.

Legal Notice

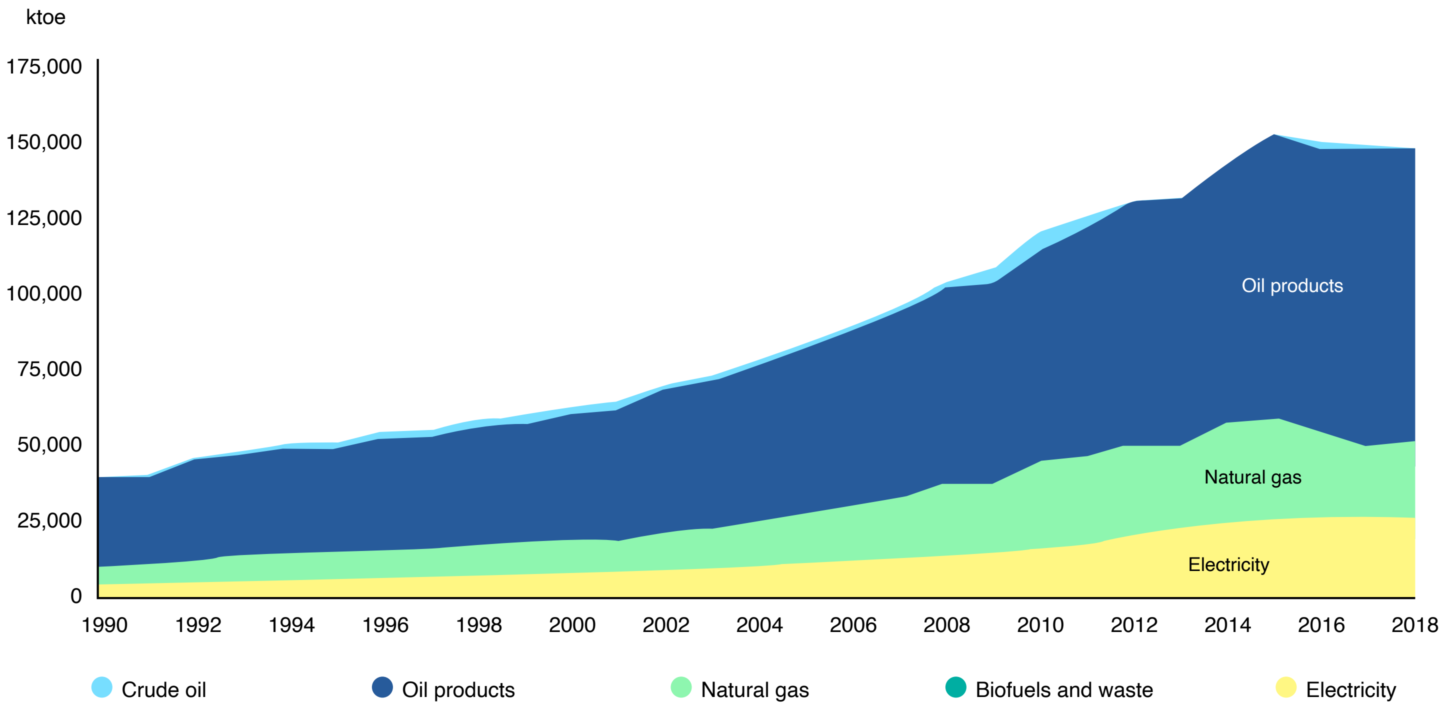
Introduction

Saudi Arabia is moving ahead with its diversification plan, Saudi Vision 2030, by adopting hydrogen. The Kingdom is keen to enable the circular carbon economy (CCE) by producing and utilizing clean hydrogen. On September 27, Saudi Aramco announced its first shipment of hydrogen from Saudi Arabia to Japan. The 40 tonnes of high-grade blue ammonia shipment, which is meant for use in zero-carbon power generation, marks the first of its kind worldwide (Ratcliffe 2020). The Saudi-Japan partnership, represented by Saudi Aramco and Mitsubishi Corporation, spans the whole supply chain, including capturing associated carbon dioxide (CO2) emissions, the conversion of hydrocarbons into hydrogen to ammonia, and ports used to ship the ammonia. Ahmad Al-Khowaiter, Chief Technology Officer of Saudi Aramco, said, “The shipment is considered the first around the world, and it represents a crucial opportunity for Aramco to introduce hydrocarbons as a reliable and affordable source of low-carbon hydrogen and ammonia” (Arab News 2020).

The Kingdom has the world’s cheapest solar power. In August 2020, Neom announced a $5 billion Saudi green hydrogen plant powered by 4 gigawatts (GW) of renewable energy, which will be the world’s biggest hydrogen project announced so far. The plant, jointly owned by Saudi Arabia’s ACWA Power and Air Products, aims to produce 650 tonnes of hydrogen by 2025 and export it to the global market. Neom CEO Nadhmi Al Nasr said in a statement, “This is a pivotal moment for the development of Neom and a key element in Saudi Vision 2030 contributing to the Kingdom’s clean energy and circular carbon economy strategy” (Parnell 2020).

These developments signal Saudi Arabia’s commitment to transitioning to cleaner and more sustainable energy systems. This is particularly important as Vision 2030 mandates the development of new industrial sectors and leveraging existing sectors’ supply chains to increase the country’s local content provision. It also mandates the further diversification of its exports through developing new high-value-added manufacturing. Energy is an essential input into most production processes in the industrial sector, and economic diversification will undoubtedly require energy for either export diversification and/or import substitution strategies. It would also improve the total energy efficiency use of all customers, including residential, governmental, and agricultural sectors, which has been dampened due to regulated energy prices. This is especially important as the population is young and expected to grow in the coming decades, further increasing demand from residents and businesses for energy. Figure 1, below, highlights the time profile of total energy consumption by energy source in Saudi Arabia from 1990-2018. The data is provided by the International Energy Association (IEA) and is in kilotonnes of oil equivalent (ktoe). The largest energy source is oil, followed by natural gas and electricity.

Figure 1. Total final consumption by source, Saudi Arabia, 1990-2018.



Source: IEA.

Why hydrogen? And how could Saudi Arabia capitalize on it?

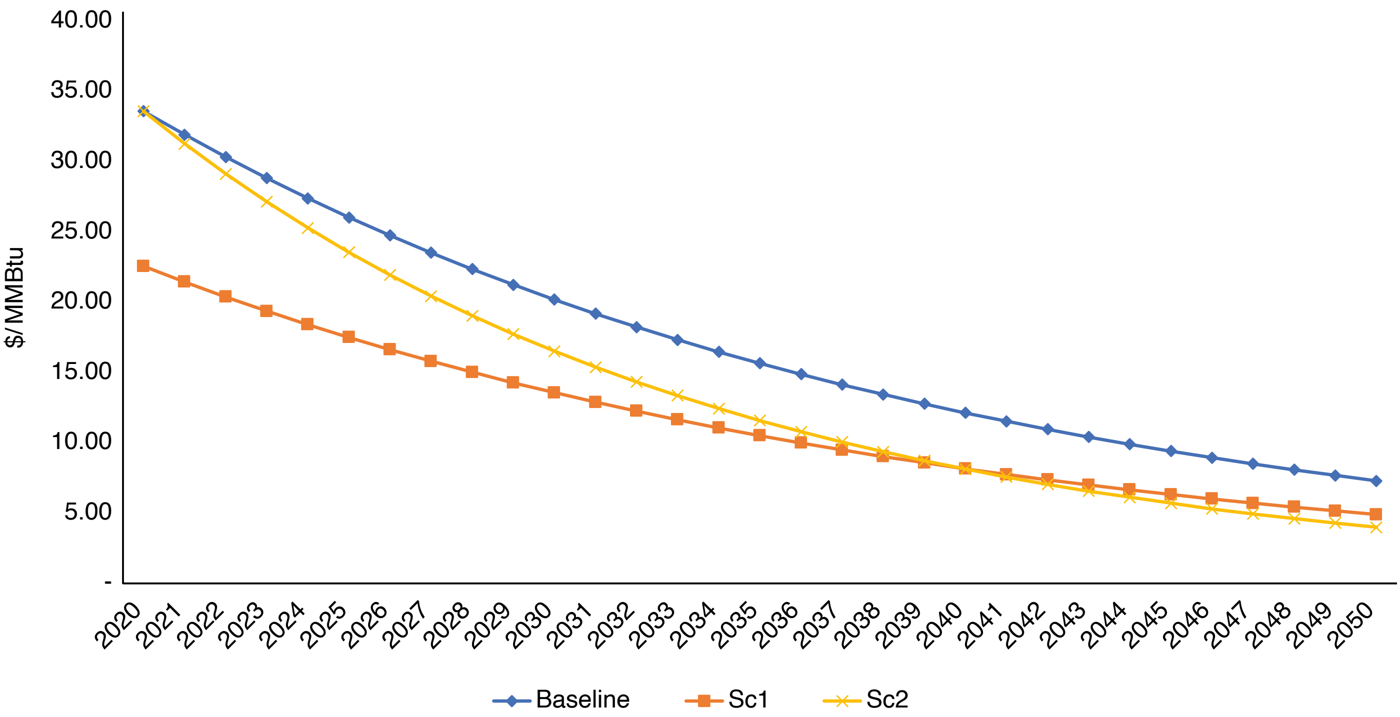
Hydrogen is a clean energy carrier; it could deliver or store enormous amounts of energy. Hydrogen fuel could be used to generate power, heat or electricity. However, the main use of hydrogen today is in fertilizer production (55%), petroleum refining (25%) and methanol production (10%). Transportation and utilities are emerging markets for hydrogen (DoE 2020; Hydrogen Europe 2020).

Hydrogen production will enable Saudi Arabia to be less reliant on domestic oil and will also be a source of income from global buyers. Domestically, hydrogen could be used in industry, transportation and electricity. For example, ammonia converted from hydrogen gas could be used as a feedstock for petroleum refining products, and hydrogen gas could be used as a fuel for fuel cell electric vehicles. The surplus energy from renewables would be converted to hydrogen gas through power-to-gas technology, which in return could be used to provide clean electricity to consumers. As global demand for green hydrogen increases, it could be exported from Saudi Arabia as ammonia.

The Kingdom is perfectly placed to capitalize on the production of green hydrogen as it has the lowest cost of solar photovoltaic generation globally, at 0.0162 U.S. dollars per kilowatthour (US$/kWh) (BNEF 2020). Furthermore, its abundantly available land for renewable energy deployment, and its optimal location with a high capacity factor for renewables, make an even stronger case for the country adopting green hydrogen.

However, hydrogen adoption is still in its early stages, and the growth in the development of green hydrogen is constrained by its cost. The recent drop in renewable costs significantly brightened the picture for green hydrogen production in the near future. According to Bloomberg New Energy Finance, the levelized cost of green hydrogen (from renewables) will drop to a range of 0.8-1.6 US$ per kilogram (US$/kg) in 2050 from 2.5-4.5 US$/kg in 2019 (BNEF 2020). As renewable prices drop, it will become more feasible to produce green hydrogen. Other factors, such as the prices of conventional hydrocarbon energy sources such as oil and natural gas, will contribute to the speed of hydrogen adoption. Since conventional energy sources are available, the hydrogen adoption rate will decrease if conventional energy sources remain in a low price regime. In contrast, global environmental protection policies and climate mitigation measures will further increase the cost of conventional energy sources, improving the outlook for hydrogen.

Figure 2. Relative cost of hydrogen.



Source: Baseline is from Bloomberg BNEF scenario; Scenario 1 and 2 are the authors' calculations.

Note: Sc = scenario.

Figure 2 considers the expected marginal cost of hydrogen under different scenarios. The baseline case is taken from Bloomberg (BNEF 2020). Scenario 1 (Sc1) is a hypothetical cost curve that mimics the rate of technological progress, but it is shifted inward to accommodate other factors unrelated to price, such as a breakthrough in hydrogen technologies. Thus, Sc1 represents the cost curve of external factors that could dramatically reduce the overall cost structure, such as the impact of economies of scale arising from increasing demand. The reasoning here is that cost is a relative concept, which is especially true with regard to energy prices. On the other hand, scenario 2 (Sc2) represents a hypothetical curve in which rapid improvements in technological progress increase the rate at which the cost of producing hydrogen declines. The efficiency and the cost of electrolysis are the main components of determining the cost of green hydrogen, while carbon capture technology influences the cost of blue hydrogen. Electrolysis technology now has an efficiency of 65%-67%, and the maximum theoretical efficiency is 75%. Lastly, the cost of renewable energy, which has been steadily declining over the past decade, is another factor impacting the cost of green hydrogen adoption.

These scenarios illustrate the different factors and conditions that could lead to various breakeven points and profitability for Saudi Arabian hydrogen production. The developments of such factors impacting hydrogen should be closely monitored to signal further green hydrogen adoption.

Saudi Arabia and the Circular Carbon Economy

During its G20 presidency, the Kingdom of Saudi Arabia endorsed and promoted clean energy transitions through the Circular Carbon Economy (CCE), comprising **'4Rs'** (G20 2020). These 4Rs are:

- ***Reduce*** the amount of carbon entering the atmosphere through energy efficacy and using alternative energy supplies that do not emit carbon, such as renewables and nuclear power.

- ***Reuse*** carbon by capturing and converting it to another useful feedstock for use in industry, or injecting it back into oil and gas reservoirs to increase productivity.

- ***Recycle*** carbon through its natural process by transforming it into fertilizer or cement, or other forms of energy such as synthetic fuels.

- ***Remove*** carbon from the system and store it geologically or chemically.

The CCE was endorsed by G20 members (KAPSARC 2020). Considering Saudi Arabia's desire to encourage the production of hydrogen, it would be useful to closely monitor the development of factors impacting the cost of adoption and the consequent revenues from increased adoption. Assessing the progress of current and the prospects for the future deployment of renewable projects in the Kingdom would allow policymakers to detect windows of opportunity to achieve positive returns on investments in hydrogen technologies. It would also help give Saudi Arabia a first-mover advantage in its transition from a petrostate to an electrostate.

References

Arab News. 2020. "World energy supply must be sustainable, says Aramco officer." November 18. Accessed December 14, 2020. https://www.arabnews.com/node/1764706/business-economy

Bloomberg New Energy Finance (BNEF). 2020. "'Hydrogen Economy' Offers Promising Path to Decarbonization." March 30. Accessed October 08, 2020. https://about.bnef.com/blog/hydrogen-economy-offers-promising-path-to-decarbonization/

G20. 2020. "Energy Ministerial Communique." Accessed October 08, 2020. https://g20.org/en/g20/Pages/documents.aspx

Hydrogen Europe. 2020. "Hydrogen in Industry." Accessed October 12, 2020. https://hydrogeneurope.eu/hydrogen-industry

Institute for Energy Economics and Financial Analysis (IEEFA). 2020. "Saudi solar solicitation attracts ultra-low bids, with prices at $0.016/kWh." April 7. Accessed October 08, 2020. https://ieefa.org/saudi-solar-solicitation-attracts-ultra-low-bids-with-prices-at-0-016-kwh/

KAPSARC. 2020. "CCE Guide Overview." 27 Sept. www.cceguide.org/guide/

Parnell, John. 2020. "World's Largest Green Hydrogen Project Unveiled in Saudi Arabia." July 7. Accessed December 14, 2020. https://www.greentechmedia.com/articles/read/us-firm-unveils-worlds-largest-green-hydrogen-project

Ratcliffe, Verity. 2020. "Saudi Arabia Sends Blue Ammonia to Japan in World-First Shipment." Bloomberg, September 27. Accessed October 12, 2020. https://www.bloomberg.com/news/articles/2020-09-27/saudi-arabia-sends-blue-ammonia-to-japan-in-world-first-shipment

U.S. Department of Energy (DoE). 2020. "Hydrogen: A Clean, Flexible Energy Carrier." Office of Energy Efficiency and Renewable Energy. Accessed October 08, 2020. https://www.energy.gov/eere/articles/hydrogen-clean-flexible-energy-carrier

مركز الملك عبدالله للدراسات والبحوث البترولية
King Abdullah Petroleum Studies and Research Center

www.kapsarc.org