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Use of hydrogen in the transport sector: the case of the Arab region

Summary

Today, the transport sector functions solely on fossil energy carriers, meaning that the sector cannot be considered sustainable. In 2019, the transport sector was responsible for almost 27 per cent of global greenhouse gas emissions, mostly from road transport. The idea of decarbonization of energy supply is therefore gaining traction, so as to provide sustainable and renewable energy and ensure global security.

This situation has triggered a search for alternative fuel solutions, with increasing attention on hydrogen. The main challenges facing a fully renewable-energy transition are technical adaptation, and balancing supply and demand. Having hydrogen, which is transportable, storable and usable, as the main energy source can address these concerns. In the Arab region, hydrogen capacity is modest. However, countries such as Saudi Arabia and the United Arab Emirates have started developing hydrogen production facilities, with several others exploring their capacity. Switching to a hydrogen-based economy, especially in transport, would not only have environmental benefits but would also position countries as main hydrogen producers, attracting foreign investments and revenues. The Committee on Transport and Logistics is invited to review the information provided in the present document and discuss opportunities presented by the use of hydrogen in the transport sector in the Arab region.

Contents

Introduction

1. Fuel sources have become a worldwide concern, with a direct impact on technology choices and government regulations. The need to provide sustainable energy to economies supports the consensus that greenhouse gas emissions must be managed efficiently. To date, hydrocarbons have been the primary energy source, leading to their depletion and limited by extraction challenges and geographical distribution. The use of fossil fuels since the Industrial Revolution has caused a considerable elevation in carbon dioxide (CO_2) levels and other greenhouse gases emitted into the atmosphere, contributing to climate change. The idea of decarbonization of energy supply is therefore gaining traction, so as to provide sustainable and renewable energy and ensure global security.

2. Anticipated shortfalls in oil supply, accompanied by an increase in global energy demand, are raising concerns about the sustainability of energy sources in the near future, which is expected to impact the transport sector the most owing to its high dependence on oil. Today, the transport sector functions solely on fossil energy carriers, meaning that the sector cannot be considered sustainable. In 2019, the transport sector was responsible for almost 27 per cent of global greenhouse gas emissions, mostly from road transport. Thus, the idea of decarbonization of energy supply nowadays is gaining more importance as a solution to provide sustainable and renewable energy in addition to global security.

3. This situation has triggered a search for alternative fuel solutions, with increasing attention on hydrogen. The main challenges facing a fully renewable-energy transition are technical adaptation, and balancing supply and demand. Having hydrogen, which is transportable, storable and usable, as the main energy source can address these concerns. Hydrogen can be produced using various technologies and from different resources, such as fossil fuels, renewable energy, and natural gas. A hydrogen-based energy system comprises three stages, namely production, transportation, and storing.

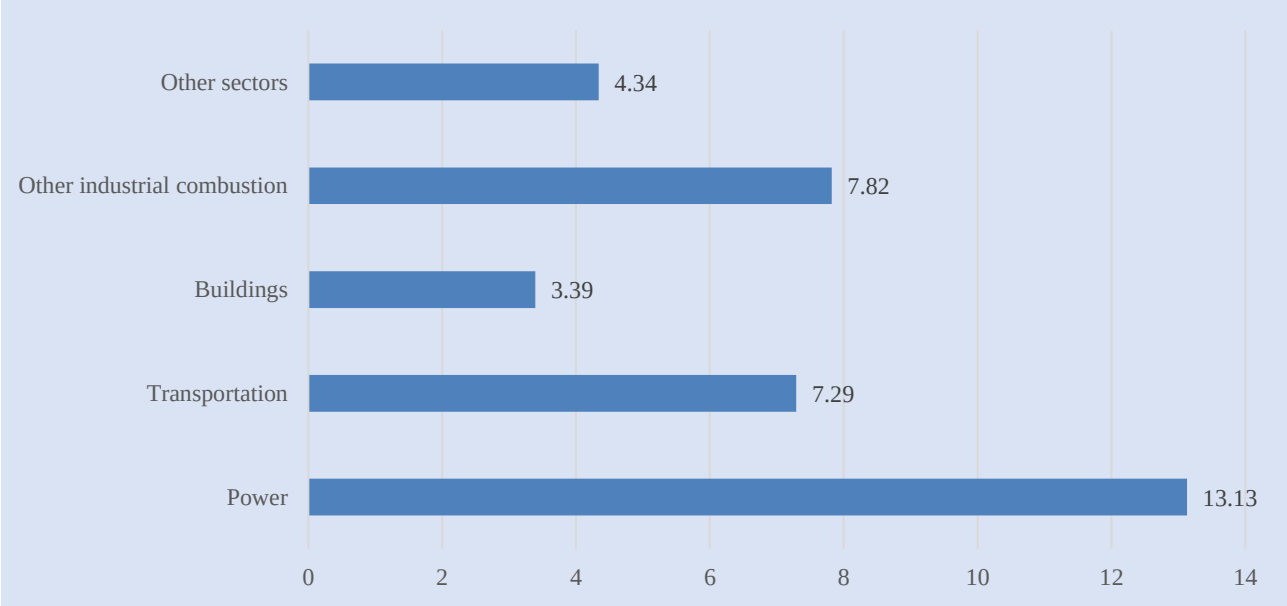
4. The Arab region has been rethinking its energy sources, with almost every Arab country developing a sustainable energy strategy for 2030 and 2050. In 2018, the region's main energy sources were mostly fossil-based, with only 4.6 per cent of renewable energy in use. Hydrogen capacity in the region remains modest. However, countries such as Saudi Arabia and the United Arab Emirates have started developing hydrogen production facilities, with several others exploring their capacity. Switching to a hydrogen-based economy, especially in transport, would not only have environmental benefits but would also position countries as main hydrogen producers, attracting foreign investments and revenues.

I. Overview

A. Carbon dioxide missions

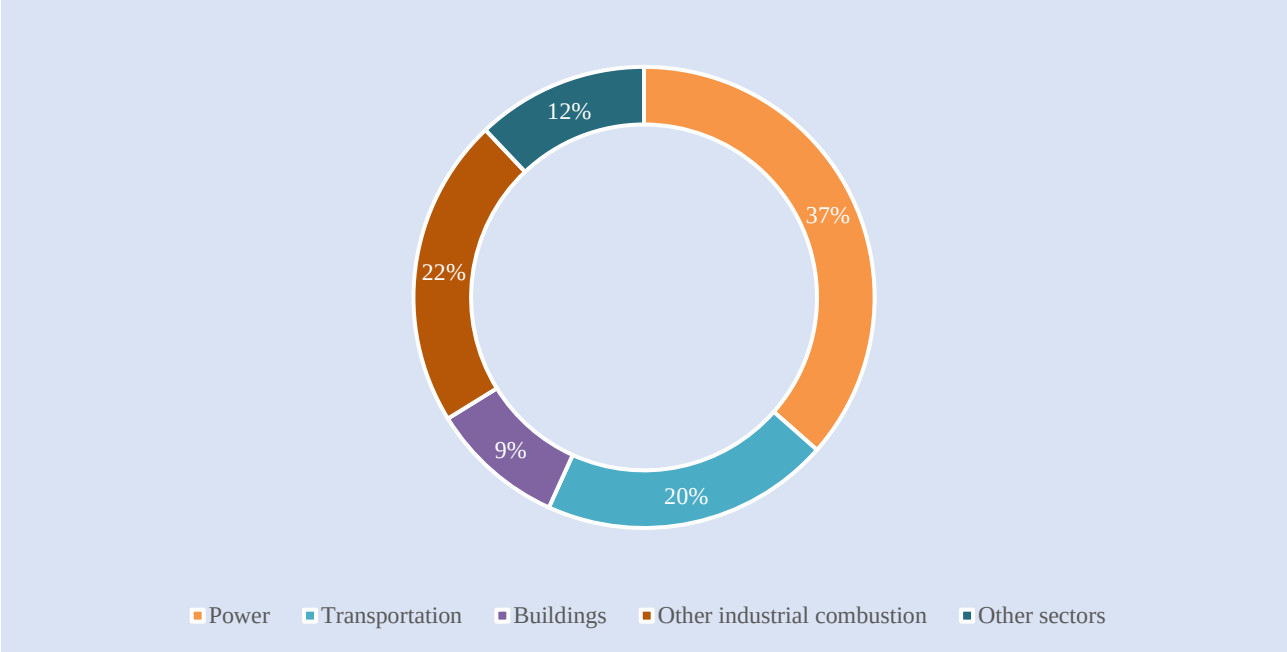
5. One of the primary sources of global fossil-fuel combustion-related CO_2 emissions is the transport sector. The sector was responsible for 7.29 billion metrics tons of CO_2 produced globally in 2020 (figure1), with a negative impact on public health, including respiratory problems and allergies, and the environment in the form of global warming, air pollution and acid rain, among others. Global climate change due to CO_2 emissions is one of the most pertinent issues facing humanity today.

Figure 1. Global carbon dioxide emissions in billion metric tons



Source: European Commission, Emission Database for Global Atmospheric Research.

Figure 2. Global carbon dioxide emissions by sector, 2020



Source: European Commission, Emission Database for Global Atmospheric Research.

B. Hydrogen

1. *Definition*

6. Clean hydrogen has been attracting considerable attention recently, especially in the transport sector, because it is a clean fuel source that only emits water when used. It can be produced using almost any energy source, including renewable energy sources available locally, and it functions well with fuel cells that can contribute to sustainable energy supply.

7. Hydrogen is a light, colourless, odourless, and non-poisonous gas. It has the most elevated explicit energy content of all ordinary fuels, and is the most abundant element known to mankind. It has a high energy yield of 120 MJ/kg, which is around 2.75 more than hydrocarbon power, yet the density of fluid hydrogen is significantly less than gasoline. This means that hydrogen stores around 2.6 times more energy per unit mass than gasoline, implying that hydrogen has higher warming or calorific worth than gas. However, because of its lower volumetric energy density, it requires multiple times more volume than gasoline to store similar energy.

8. The most common types of hydrogen include the following:

- **Green hydrogen:** Green hydrogen is produced using clean energy sources, such as solar or wind power, in a process called water electrolysis. The process is designed to split water into two main components, hydrogen and water, with no CO_2 emission during production.
- **Blue hydrogen:** In general, blue hydrogen production requires the use of natural gas and heated water in the form of steam. However, this process usually also emits carbon dioxide. CO_2 emissions are typically managed using carbon-capture equipment to reduce their dispersal in the atmosphere.
- **Grey hydrogen:** Grey hydrogen is the most common type of hydrogen produced today. It is derived from natural gas and produced from fossil fuels, making it one of the least clean options.

2. *Hydrogen in transport*

9. The energy-powered transport sector consists of various components, from small motor scooters to large container ships. Today, the majority of these components rely heavily on traditional fuel sources, with consumption determined by the engine payload and range.[1]

10. Hydrogen is an energy carrier and fuel that serves as a power source for trucks and vehicles, leaving no harmful discharges. Hydrogen can be stored as fuel in tanks. Cars that run on hydrogen-powered engines emit only heat and clean water through their exhaust pipes, resulting in no pollutants or greenhouse gas emissions.

11. Traditional fuel engines can make vehicles heavy and less efficient. In contrast, hydrogen-powered vehicles contain hydrogen fuel cells that convert energy into electricity two to three times more efficiently than internal combustion engines. Fuel cells also reduce noise caused by cars. Hydrogen has a longer distance range than ordinary fuel and requires fewer refuelling stops, meaning that it could be a better choice for heavy-duty trucks and public transport transit buses that travel hundreds of miles.

1 kg of hydrogen	**=**	**1 gallon of gasoline**
Hydrogen		**Gas**
1 kg = 60 miles		**1 gallon = 25 miles**

12. Hydrogen is usually sold in kilograms. The energy in 1 kg of hydrogen is equivalent to one gallon of gasoline. As of 2019, the average cost of hydrogen in the Unites States of America is around $16 per kilogram.[2] However, with the emergence of hydrogen technologies, costs are expected to decrease, making it more affordable and accessible. Vehicles using hydrogen as a fuel source are able to travel long distances while

1. Hydrogen Council, Hydrogen scaling up, 2017.

2 California Energy Commission, Joint Agency Staff Report on Assembly Bill 8: 2019 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California, 2019.

consuming less energy. Today, 1 kg of hydrogen can cover almost 60 miles, compared with one gallon of gas which only covers 25 miles.[3]

3. *Heavy-duty vehicles*

13. The heavy-duty sector, which includes large truck fleets, is becoming a sector of interest for pursuing alternative fuel solutions. Due to their high demand for gas, decarbonizing this sector would be highly beneficial for the environment. Hydrogen has the potential to become a major player in this industry.

14. Using hydrogen to power heavy-duty trucks has the following benefits and constraints:

- Benefits:
  - Heavy-duty trucks have the capacity to hold large or small tanks suitable for storing hydrogen.
  - Depending on the journey, the potential to provide hydrogen refuelling stations in the corridors and routes taken by heavy-duty trucks is much higher than that of electric refuelling stations.
- Constraints:
  - The price of hydrogen needs to be reduced to make the technology cost-competitive.
  - Heavy-goods vehicles with non-routine routes will not have sufficient access to hydrogen refuelling stations, making hydrogen use less attractive until more refuelling options are available.

4. *Maritime transport and ports*

15. Ports are ideal for becoming hydrogen hubs, enabling hydrogen production and storage, and hosting vessels powered by hydrogen fuel cells. Hydrogen is already being used to reduce emissions in maritime operations. The shipping sector has also started using alternative power sources, such as ammonia and methanol. To date, around 15 methanol-fuelled ships are in operation, with more to come. Both ammonia and methanol can be produced from hydrogen, whether through reaction with nitrogen for ammonia, or through reaction with CO_2 for methanol.

16. Using hydrogen in the maritime sector has the following benefits:

- In the short term, hydrogen fuel cells are a suitable option for local ferries and water transport fleets.
- Ports have the capacity to establish hydrogen production and storage facilities, and to provide decarbonized compressed hydrogen fuel through pipelines or inland transport.
- The diverse geographical locations of ports present opportunities for developing hydrogen hubs.

17. Australia is set to become the first exporter of liquified hydrogen. The port of Hastings is being developed as a storage and loading facility that will convert gas hydrogen into liquid hydrogen. In December 2021, a Japanese carrier set sail from Kobe to pick up its first hydrogen shipment in Victoria, successfully converting gas hydrogen to liquid under the liquefaction process that cools gas hydrogen to -253°C and reduces its gaseous volume.[4]

[3] Office of Energy Efficiency and Renewable Energy, Hydrogen's role in transportation, 2022.

[4] PV Magazine, Australia to make world's-first liquefied hydrogen shipment to Japan (22 January 2022).

5. *Aviation*

18. While a few air terminals have managed to decarbonize some tasks, the carbon decrease venture for airplanes is both environmentally critical and highly challenging.

19. Many countries are actively looking for zero carbon solutions, such as the use of synthetic fuels produced from green hydrogen and CO_2, which has received considerable attention recently.

20. Using hydrogen in the aviation industry has the following benefits and constraints:

- Benefits:
  - Hydrogen can be utilized either straightforwardly (combustion or fuel cells), or as a component of flight fuel.
  - Hybrid airplanes are a significant innovation.
  - Green hydrogen could be embraced as an essential fuel, thus wiping out CO_2.
- Constraints:
  - Conversion to hydrogen-based aviation system requires major modifications to storage and supply arrangements, and to airport infrastructure and aircrafts.
  - Aircraft configurations may take time to be certified to introduce the new technology.
  - Cryogenic hydrogen may require more space on aircrafts, affecting available space.

21. GKN aerospace in leading a ground-breaking programme called H2GEAR, aimed at developing the first liquid hydrogen propulsion system for subregional aircraft in the United Kingdom of Great Britain and Northern Ireland.[5]

II. Potential uses of hydrogen in the transport sector in the Arab region

22. The transport sector is one of the main drivers of economic development, yet its impact from using traditional fuel sources raises concerns about air and water quality, and about the environment in general. The sector is responsible for a considerable share of greenhouse gas emissions, worsening the effects of global warming, thus highlighting the need for cleaner energy sources such as hydrogen. The Arab region's experience with using hydrogen as an energy source is currently limited; however, the region has revealed significant energy production capacity and infrastructure that are essential for a hydrogen economy. Rapid urbanization and increases in vehicle numbers per capita place additional pressures on countries' ability to meet energy consumption demands, thus stressing the need for adequate government policies and investments for switching to hydrogen.

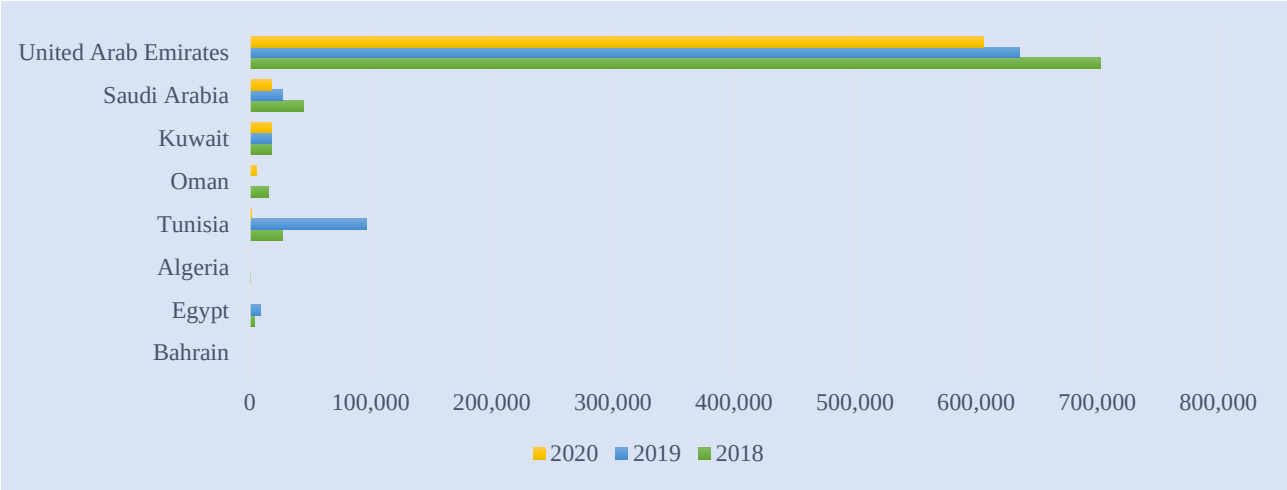
23. The region's rapid socioeconomic development caused a sharp increase in energy consumption, requiring new energy plans for environmental protection. Moreover, the region is highly dependent on fossil fuels, both as a source of energy supply and as revenue from oil and gas production. More than 95 per cent of the region's energy is supplied from natural gas,[6] making it one of the most fuel-dependent regions worlding. In addition, oil and gas are the main sources of revenue in the Arab region, accounting for 65-90 per cent of exports. These dependencies causing economic and fiscal vulnerability for the region.

[5] GKN Aerospace, GKN Aerospace leads development of ground-breaking hydrogen propulsion system for aircraft.

[6] E/ESCWA/SDPD/2019/TP.5.

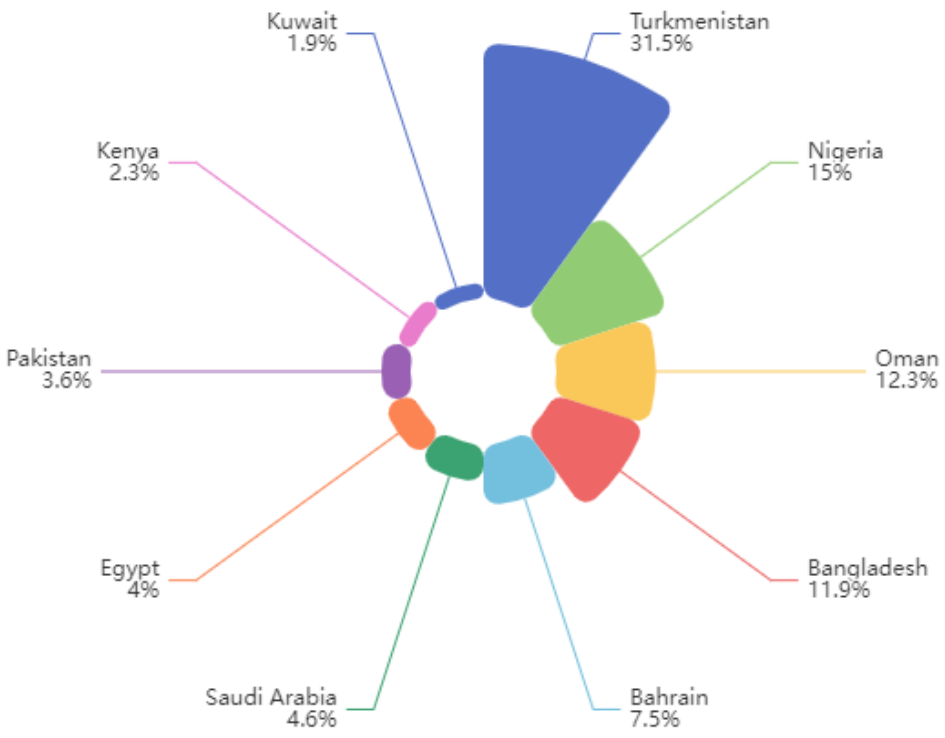
A. Hydrogen trade

Figure 3. Hydrogen exports in the Arab region (Dollars)



Source: ESCWA, External Trade Data Platform for the Arab Region, 2020.

Figure 4. Share of hydrogen exports from the Arab region

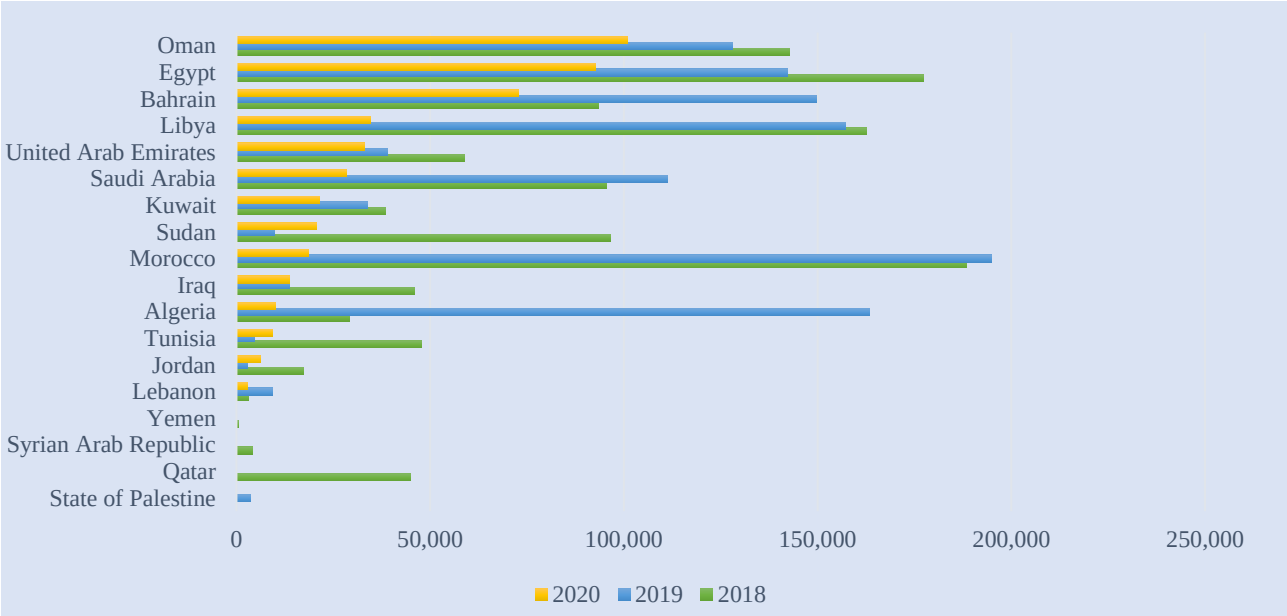


Source: ESCWA, External Trade Data Platform for the Arab Region, 2020.

24. Hydrogen is the 3,755th most traded product worldwide. Between 2018 and 2019, hydrogen exports grew by 6 per cent. The Arab region's total hydrogen exports in 2020 totalled $649,451, representing only 0.38 per cent of the global hydrogen trade.

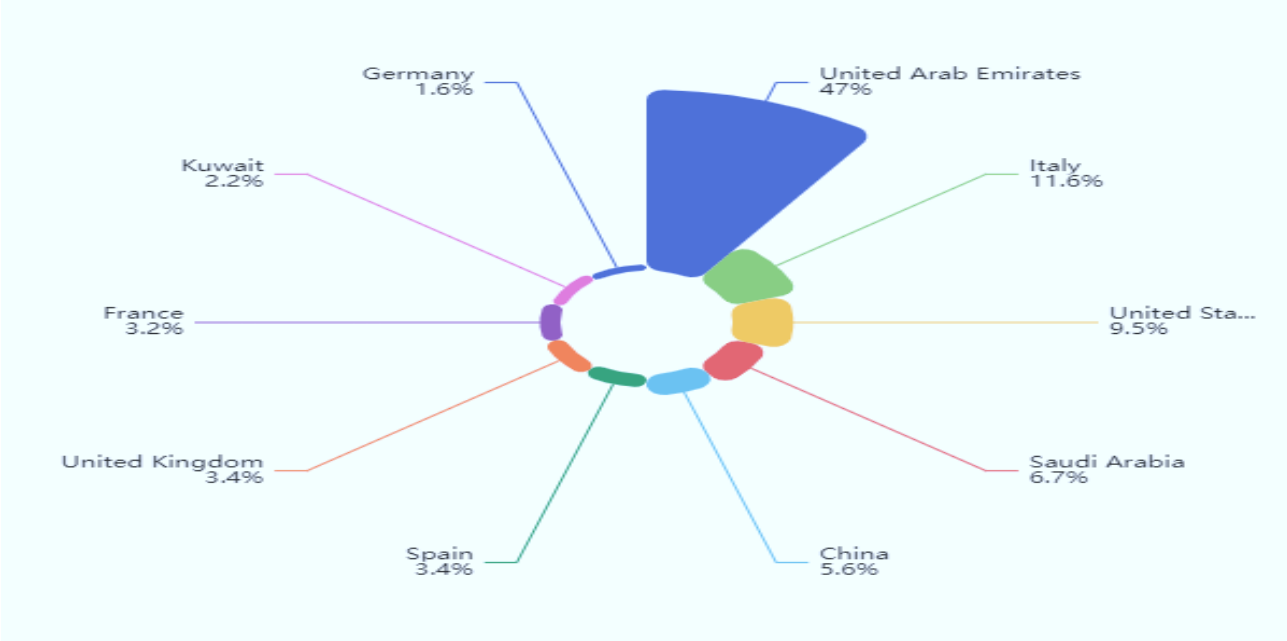
25. Figure 3 shows that the United Arab Emirates is the top hydrogen exporter among Arab countries, totalling $606,000 USD, or roughly 93 per cent of the total hydrogen exported in the region. Saudi Arabia and Kuwait come second and third, with small shares of around 2.8 per cent of the region's hydrogen exports valued at around $18,000 in hydrogen exports.

Figure 5. Hydrogen imports to the Arab region (Dollars)



Source: ESCWA, External Trade Data Platform for the Arab Region, 2020.

Figure 6. Share of hydrogen imports in the Arab region



Source: ESCWA, External Trade Data Platform for the Arab Region, 2020.

26. The region's hydrogen imports for 2020 totalled $465,271, equalling 0.27 per cent of hydrogen traded globally. The main import countries for hydrogen were Oman at 21.7 per cent of total hydrogen trade in the region, Egypt at 19.9 per cent, and Bahrain at 15.66 per cent. Figure 6 indicates that 47 per cent of the region's hydrogen imports are from the United Arab Emirates, explaining the positive hydrogen trade balance of the region.

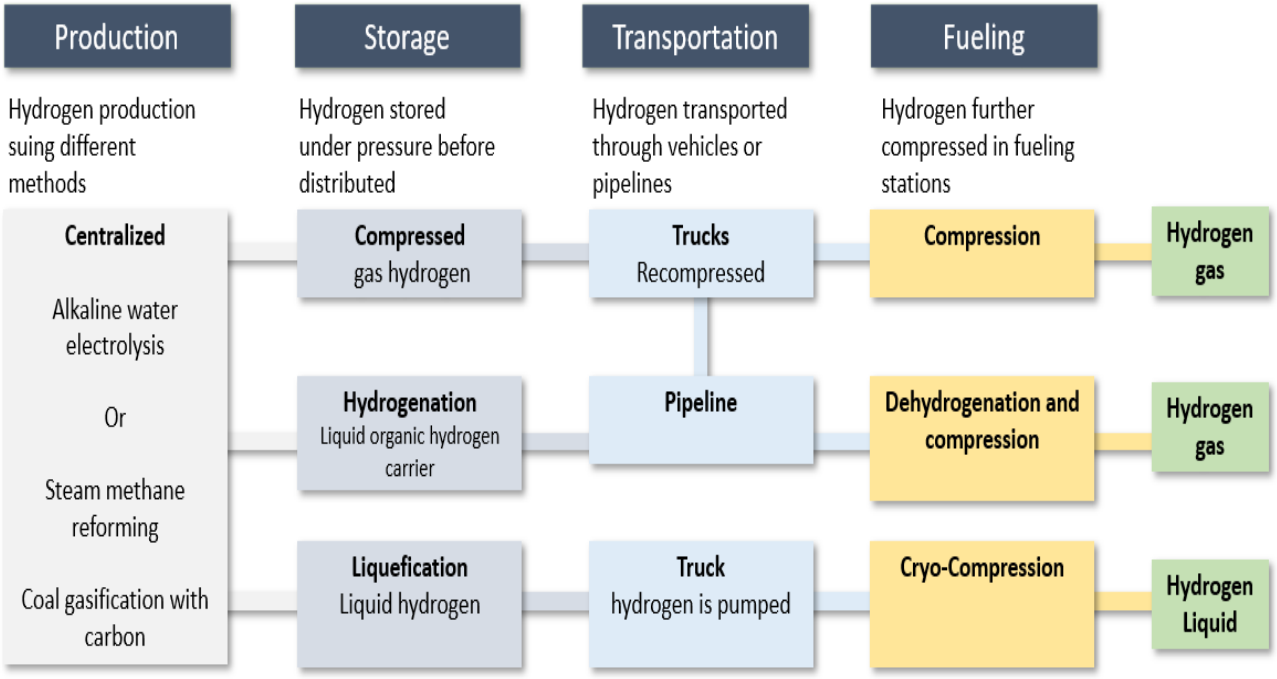
27. Data indicate that the region is in need of effective hydrogen strategies that reduce imports and increase production capacity for self-use in domestic sectors, while distributing to foreign markets.

28. Hydrogen production can be costly, especially if inputs used in production are not accessible in a country. Hydrogen can be produced in various, such as renewable energy for green hydrogen, natural gas for blue hydrogen, and oil and fossil fuels for grey hydrogen. Countries should consider their specific endowments and best strategic fit, based on available technologies, resources, capacities and demand centres (both domestic and foreign).

29. Arab countries' have different energy sources. For example, Egypt and Morocco are two of the region's most capable countries in terms of solar power and wind capacity, which in turn can be used to produce green hydrogen. Iraq and Qatar, in contrast, possess an abundance of oil and natural gas reserves, making grey and blue hydrogen a better choice.

B. Fuel and refuelling infrastructure

Figure 7. Hydrogen process

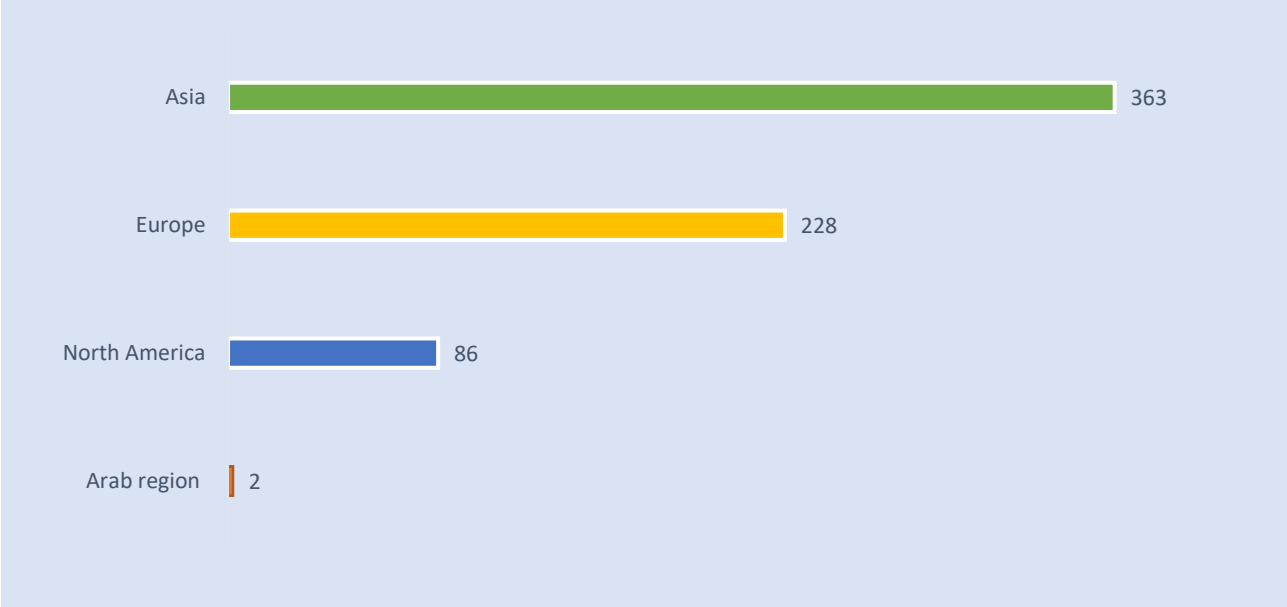


Source: Aurecon, Hydrogen for transport report, 2019.

30. Several approaches exist for hydrogen fuelling, as shown in figure 7. Transporting hydrogen to fuelling stations across the country depends on its nature. For gas and organic hydrogen, the material can be transported using either trucks in a compressed form, or using pipelines. Liquid hydrogen is usually also transported by truck. The transported hydrogen is then stored in a refuelling station.

C. Hydrogen refuelling stations

Figure 8. Number of hydrogen refuelling stations by sector



Source: H2stations.org.

31. In 2021, approximately 685 hydrogen refuelling stations were in operation worldwide,[7] with only two stations in the Arab region compared with 363 in Asia, 228 in Europe, and 86 in North America.

D. National plans for a hydrogen transport sector

1. *Saudi Arabia*

32. In 2019, an agreement was signed by Saudi Aramco and Air Products to build the first hydrogen fuel cell electric vehicle (FCEV) fuelling station in Saudi Arabia. The fuelling station became operational in late 2019. A pilot fleet of FCEVs will be built as part of the agreement, dispensing high purity compressed hydrogen at the new fuelling station. King Abdullah University of Science and Technology is also implementing several research and development initiatives on hydrogen and fuel cell technologies that will benefit the Saudi transport sector.

33. In 2020, ACWA Power signed a $5 billion agreement with NEOM to build a production facility in Neom, powered by renewable energy, to produce and export green hydrogen to global markets. This world-scale green hydrogen-based facility is one of the largest hydrogen production facilities worldwide. The main energy sources used will be solar, wind and storage, producing over 650 tons of hydrogen every day using Air Products technology, and approximately 1.2 million tons each year using Haldor Topsøe technology. Air Products is a key player in ammonia, and exports it globally for green hydrogen production used in the transport sector. This is the first international partnership for NEOM, which will make it a global centre for renewable energy and hydrogen. This will place Saudi Arabia as the lead producer of green hydrogen and ammonia globally, revolutionizing the transport sector.

[7] H2stations.org.

34. According to the International Renewable Energy Agency, the cost of producing 1kg of hydrogen currently costs a little under $5. However, the competitive advantage of Saudi Arabia will likely place it as a global leader in terms of costs per 1 kg of hydrogen, which is expected to only be $1.50 by 2030.

2. *Morocco*

35. Morocco is considered a regional energy-transition pioneer. The country has expressed its ambitions to increase its renewable energy shares by 52 per cent in 2030. The success of Morocco in achieving renewable energy encouraged it to explore its hydrogen capacity. In 2021, the International Renewable Energy Agency and the Moroccan Ministry of Energy agreed to strengthen the country's knowledge of green hydrogen. The country's ambitions to become a major green hydrogen producer will be backed by these two parties working closely together on hydrogen studies, and actively exploring policy instruments to engage the private sector at the national level in the green economy.

3. *United Arab Emirates*

36. In 2017, Al-Futtaim Motors in collaboration with Air Liquide, successfully built the first hydrogen station in Dubai, to be used by FCEVs.

37. Masdar Abu Dhabi, Siemens Energy, the Abu Dhabi Department of Energy, Etihad Airways, Lufthansa, Marubeni Corporation and Khalifa University have partnered to develop an electrolysis facility to produce green hydrogen for the transport sector.[8] Hydrogen for road transport will be initially tested, while constructing a plant that will convert the majority of it into sustainable aviation fuel. A more advanced step will include the decarbonization of maritime fuel.

4. *Egypt*

38. Currently, there are over 330,000 vehicles in Egypt that use compressed natural gas as their main fuel source, with the aim of expanding the use of natural gas in the transport sector because of its environmental advantages.

39. In the long run, green hydrogen is considered a better and cleaner alternative than compressed natural gas in the transport sector. Several streps are needed before this transition can be achieved, starting with blending hydrogen with gas transported through the national gas grid, then repurposing existing infrastructure to accommodate green hydrogen, and building hydrogen refuelling infrastructure.

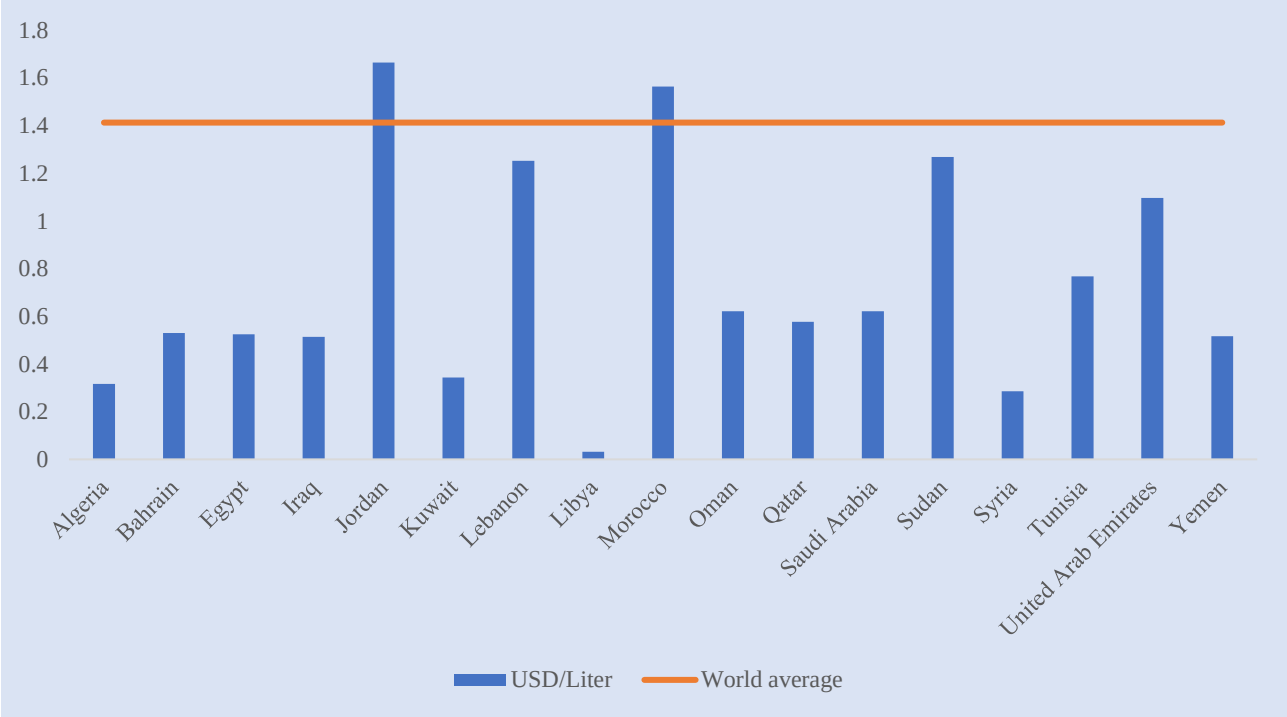
III. Barriers to adopting hydrogen in transport

A. Petroleum pricing strategies and subsidies

40. The introduction and growth of hydrogen use in transport remains unclear in the region. Many Arab countries have expressed their readiness to contribute to cleaner transport fuel. However, some factors, such as subsidized liquid petroleum products, are affecting the growth of this sector. Domestic subsidies on liquid petroleum fuels and the lack of environmental regulations to use cleaner fuels are leading to more unclean energy consumption in a highly inefficient way. Despite the benefits behind this transition, converting to a hydrogen-based transport economy would burden on Arab countries' treasuries. However, recent oil price drops have forced some Arab countries to rethink their energy-price subsidy policies.

[8] Watson Farley and Williams, Hydrogen in the United Arab Emirates, 2021.

Figure 9. Pump price for gasoline, 2022 (Dollars per litre)



Source: Globalpetrolprices.com.

41. Fuel pump prices in the region are way below the global average of $1.41 $USD per litre, except in Jordan and Morocco (figure 9).

B. Need for international standards

42. A major hinderance for switching to a hydrogen-based transport sector is a lack of international standards on hydrogen. Since hydrogen technology is still in its preliminary phases, there are no unified international standards on its production and use, leaving individual countries and companies to develop their own standards.

43. Developing a common international framework is essential to avoid unfair competition practices. For instance, several countries have adopted different definitions for the same term, causing confusion.

44. Moreover, for better cross-border cooperation when dealing with hydrogen, it is important to set the ground for unified safety standards and operational rules, and promote the development of common methodologies.

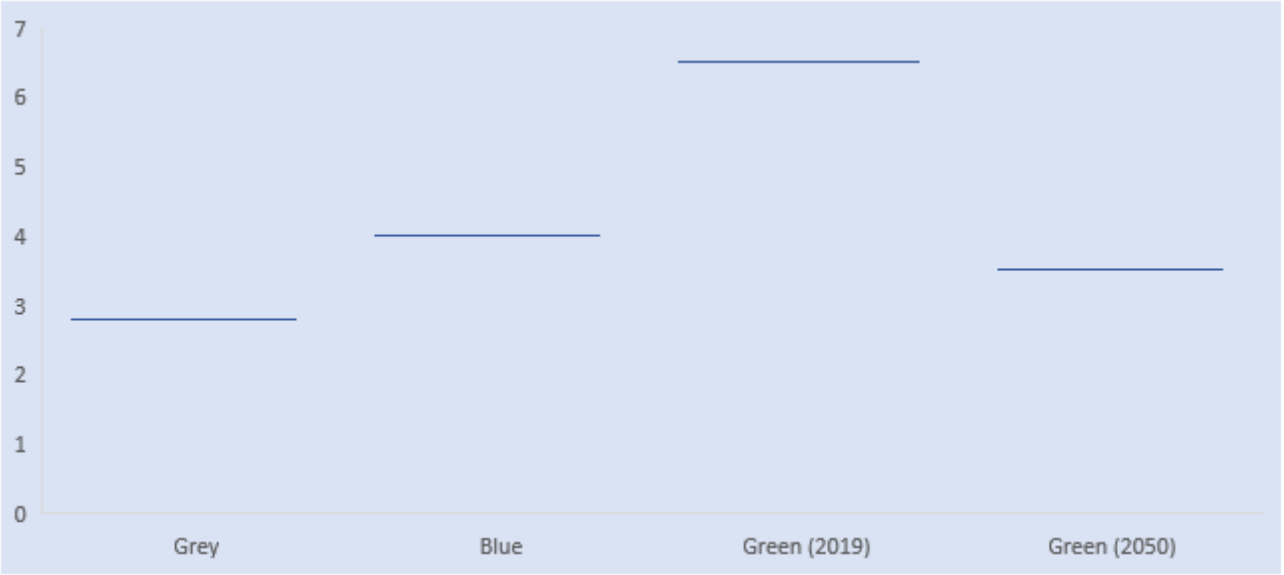
45. To date, it is not yet clear how the hydrogen market will expand, but implementing international standards is a big step toward ensuring a fair and smooth-functioning global market.

C. Cost of hydrogen

46. The cost of producing hydrogen remains a major barrier to developing a clean hydrogen market. According to the International Energy Agency, producing hydrogen from fossil fuels is currently the cheapest alternative globally. Costs range from 0.5 to 1.7 USD per one kilogram (KG), in addition for the technologies required to reduce CO_2 emissions from the production, increasing the cost to around 2 USD.

47. The cost of producing hydrogen from renewable energy ranges from $3 to $8 per kilogram. There is potential for cutting productions costs through several technologies, where producing hydrogen from renewables is expected to drop to around $1.3 per kilogram by 2030, in regions with an abundance of renewable energy sources. In the longer run, costs are expected to fall as low as $1 per kilogram, making hydrogen from renewable sources more competitive.

Figure 10. Cost of green hydrogen production from water electrolysis, $/kg



Source: KPMG, The hydrogen trajectory.

48. In the short term, the cost of green hydrogen from water electrolysis is reported at around $2.6-6 per kilogram. As shown in figure 10, innovations and technologies should be able to decrease the price of green hydrogen in 2050 by around 50 per cent, making it cost competitive with grey hydrogen.

D. Lack of refuelling stations

49. There are currently 685 hydrogen refuelling stations worldwide. However, in the Arab region, only two stations exist, located in Saudi Arabia and the United Arab Emirates. It would therefore be unreasonable to switch to hydrogen-based transport system at this time, indicating the necessity of developing an effective hydrogen transport strategy, and ensuring that a specific number of refuelling stations are built across countries within the reach of commercial vehicles and transport trucks.

IV. Conclusion

50. Adopting hydrogen as the main source of fuel in the transport sector is a big step towards decarbonizing the sector. However, the presence of strong subsidies for oil and gas in the majority of Arab countries, along with high levels of water scarcity (water is essential for green hydrogen production), the technology has yet to be widely implemented and is in need of significant strategies and government policy. Several Arab countries have essential resources that are key to hydrogen production, including natural gas in Iraq and Qatar for blue hydrogen, and solar and wind capabilities with Egypt and Morocco for green hydrogen.

51. Many countries have already stated their intentions to move towards a clean hydrogen economy, but progress is still in preliminary phases. Policies and national plans must therefore be put in place to provide the appropriate infrastructure for this transition.

52. Infrastructure development is essential for the transport, storage and distribution of hydrogen (gas and liquid). Several transport options are available, such as road tankers, vessels and pipelines, which should be tailored based on a country's usage, existing infrastructure, and location.

53. Investments in hydrogen value chains for production, storage, transport and distribution should take into consideration several aspects, such as the cost, delivery times, and the impact of local conditions on fuel strategies. For example, for personal transport, individuals will require relatively smaller amounts of hydrogen, compared with heavy-duty trucks that require a significant number of refuelling stations worldwide.
