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Hydrogen for Energy Security: Fragile Dream or Opportunity?

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Topic: What are the implications of a higher use of hydrogen (and its derivatives) for energy security in a hydrogen importing country?

I. Introduction

Over the past few years, hydrogen gained a reputation as a versatile energy carrier that can play a significant role in decarbonization. Many governments and industries are betting on hydrogen, hoping that it will bring more flexibility and security to energy systems and reduce their reliance on fossil fuels. Coincided with the drastic fall of renewable energy prices, there are unprecedented amounts of investments and policy actions to develop the hydrogen economy. Still, it remains an open question whether hydrogen will actually bring more security to a decarbonized future.

Reflecting on this controversy, this essay looks into the implications of hydrogen on energy security, especially for the countries that will see increasing imports of hydrogen from overseas. It will provide a perspective on global hydrogen trade and explain why some countries would rely on hydrogen imports. It will then introduce the security implications of hydrogen imports using the "4A framework" which breaks down energy security questions into environmental acceptability, economic affordability, supply accessibility and availability which will frame an analysis of different use cases for hydrogen and its derivatives. This essay argues that the energy security implications for hydrogen importing countries will greatly vary depending on the type of security that is considered and that the type of fuel hydrogen imports will replace as well as general considerations about the future of the energy economy.

II. Context

A. How will global hydrogen trade be shaped?

Currently, most of the hydrogen is produced from coal and natural gas and is consumed domestically as an industrial feedstock. It can be produced in almost any region of the world, but regional trade is expected to cover a quarter of the global hydrogen demand by 2050[1]. 65% of global hydrogen demand is concentrated in North America, Europe, and East Asia, with a five-fold difference between highest- and lowest-cost production locations[2]. Thus, the global hydrogen trade will be shaped by several factors such as differences in the levelized cost of hydrogen production, the region's investment attractiveness (market efficiency, workforce availability, or country risk factor), and local public acceptance of hydrogen infrastructure[3].

[1] IRENA (2022a)
[2] Hydrogen Council (2022)
[3] Ibid.

B. Why import hydrogen?

Low carbon hydrogen will be exported from regions with low production costs to demand locations where cheap supply is limited or unavailable. It could be transported via pipelines or shipped depending on the distance and geographical conditions. However, hydrogen transportation is costly due to the light volumetric density of hydrogen, and requires costly treatment and conversion processes which will increase the price of imported hydrogen. Despite this, high domestic costs will force multiple countries to nonetheless decide to import hydrogen.

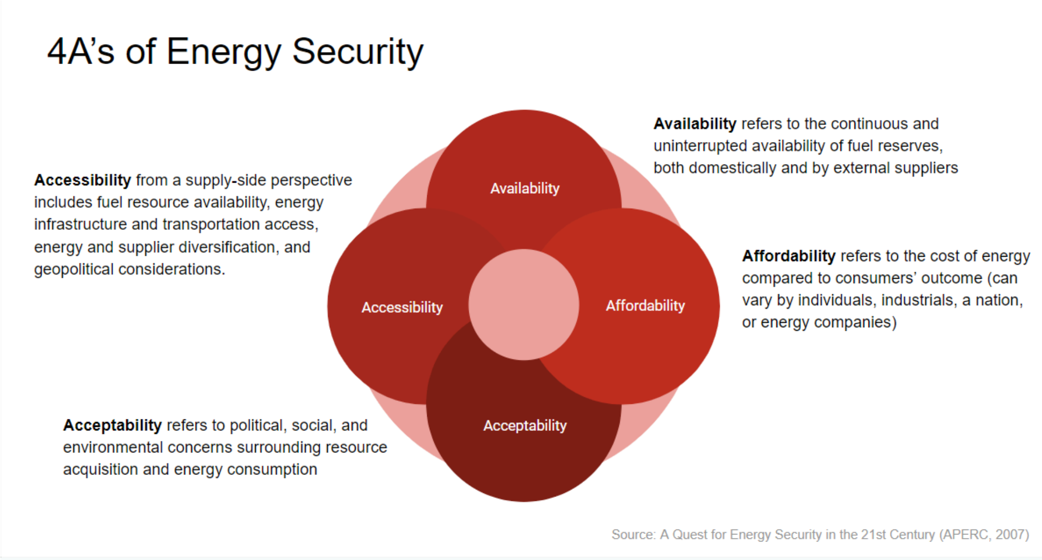
C. Who are the main hydrogen importers?

The biggest markets for hydrogen trade are likely to be Europe, Japan, and South Korea. These regions will face significant increase in hydrogen demand as their climate plans will push them to use hydrogen to decarbonise hard to abate sectors, such as their steel and chemical industries, heavy-duty transport, shipping, and energy storage[4]. However, these regions suffer from low potential for renewable or natural gas production of low carbon hydrogen which will thus see them resort to overseas imports. These plans are already taking shape such as the European Commission's plans to import 10Mt of hydrogen from overseas and expand partnerships[5] or Germany's recently signed agreement with Norway to import green hydrogen. Japan has also completed a pilot project to import hydrogen from Australia[6]. Overall, these regions have signed numerous MOUs with potential hydrogen exporting countries, laying the foundations for a future international hydrogen market.

III. Framework: The 4A's of energy security

Energy security is defined as "the ability of an economy to guarantee the *availability* of energy resources supply in a sustainable [*acceptable*] and timely [*accessible*] manner with the energy price being at an *affordable* level that will not adversely affect the economic performance of the economy"[7]. Also known as the 4A's of energy security, these indicators provide a useful framework for policymakers to identify potential risks and opportunities in the energy sector and develop appropriate strategies to address them. By providing a flexible and adaptable approach to energy security, the 4A's framework ensures that energy security remains relevant and effective in the face of changing geopolitical and technological landscapes. In particular, this paper seeks to provide a meaningful analysis of the impact of hydrogen and its derivatives on the energy security of importing countries, and to identify the factors that shape this relationship.

[4] IEA (n.d.)
[5] European Commission (n.d.)
[6] Reuters (2023)
[7] APERC (2007)



IV. Analysis: Will hydrogen and its derivatives provide more energy security to importing countries?

This section examines whether and to what extent hydrogen and its derivatives can contribute to the energy security of hydrogen-importing countries. Since the beginning, hydrogen advocates have widely touted the hydrogen economy as a clean and self-sovereign system that is free from the dependence on fossil fuels and its complicated geopolitics. However, as more detailed plans are developed, incresign imports of hydrogen and its derivatives will have complex security implications for the economy of an importing country in terms of supply availability, price affordability, system accessibility, and socio-environmental acceptability.

A. Supply availability

While fears of depletion of fossil fuel reserves used to be an important worry[8], these fears of 'peak-oil' supply have generally disappeared and it is now expected that demand for these fuels will peak before supply does[9]. Furthermore, estimating the actual reserves of fossil fuels is very difficult and will only result in highly imprecise estimates of relatively little analytical value. Nonetheless, while the availability of the resources themselves is not a current concern, structural decline in investment in fossil fuel exploration and infrastructure may make fossil fuel supplies exposed to availability insecurity due to a structural lack of infrastructure to exploit them. If fossil fuel demand does not decrease equally fast, then supply availability may become a concern due to market mismatches[10].

In this scenario, hydrogen would be a source of increased energy security by being an alternative to fossil fuels in sectors like power generation (coal and gas) and transportation (oil). Especially thanks to green hydrogen, traditional energy importing countries can quickly phase out fossil fuels and reduce the dependence on fuels that are

[8] APERC (2007)
[9] RMI (2022)
[10] National Review (2023)

increasingly scarce as they will not be exploitable anymore. The reserves of renewable energy to produce hydrogen, while limited in some countries, are relatively abundant in many regions and could technically provide enough energy to meet global energy demand, making availability of green hydrogen less of a concern.

However, in the current reality of carbon-intensive hydrogen production, the decreasing availability of fossil fuels may threaten hydrogen supplies in the short term, as mass deployment of green hydrogen is only expected by 2050. Especially following a scenario of progressively limited availability of fossil fuels on the market, imports of blue hydrogen (produced from natural gas) may themselves suffer from a lack of supply availability. This could lead to a situation where uncertainties in hydrogen supply send negative signals to market participants, preventing further demand creation for hydrogen. Even if renewable hydrogen eventually dominates the market in the long-term, uncertainties still lie within the supply chain as the availability of critical minerals and its processing is likely to be concentrated on a handful of regions. Furthermore, other technologies, such as batteries, may be in competition with electrolysers and fuel cells over available quantities of critical materials[11]. In other words, the new dependence on raw materials poses potential risks for resource-poor countries that hope to scale-up their demand for green hydrogen in the long term. Overall, supply availability may be an important risk in the short-term as the current underinvestment in fossil fuel could limit the availability of blue hydrogen in the medium-term while competition for critical minerals may slow down the deployment of green hydrogen. However, a swift shift to green hydrogen is likely to shield importing countries from potential market bottlenecks for fossil fuels.

B. Price affordability

While the costs of producing low-carbon hydrogen will decline in the future, decarbonizing hydrogen production is nonetheless expected to come with a green premium. This premium will not, however, impact all actors equally. Hydrogen will mainly be used in the processing of primary commodities, such as steel, the price of which makes up a small share of the price of final goods. For example, while hydrogen could increase costs of steel production by 40%, the impact of steel in the final cost of manufactured goods is relatively small, for cars it may represent less than 1% of added costs. There is thus a distinction to be made between cost affordability for industry actors and price affordability for consumers, the latter being, generally, less affected by an increase in price due to hydrogen imports.

The security implications for industry in terms of energy affordability will also depend on the global market context. Considering that energy affordability for industry must be understood in relation to energy prices for competitors, a synchronized switch to hydrogen of the main industry actors will lower the price exposure that an early adopter may face. Furthermore, if the main export markets for the industry are protected by a carbon levy such as the EU's Carbon Border Adjustment Mechanism (CBAM), then a switch to hydrogen could, in fact, increase the price affordability for the industry compared to carbonized competitors considering that many industries are likely, other things equal, to favor green

[11] IRENA (2022b) p.89 *"Rapid growth of hydrogen will underpin rising demand for nickel and zirconium for use in electrolysers and platinum-group metals for fuel cells (IEA, 2021g). Because hydrogen will trigger increased deployment of renewable technologies like solar and wind – and because it will go hand in hand with stringing new electric lines and installing batteries – it will also raise demand for the minerals used in those technologies"*

steel[12]. Nonetheless, hydrogen importing countries will face structurally high prices for hydrogen as it will always be more affordable to consume it where it's produced. This could make domestic industries relying on hydrogen at risk of relocating where hydrogen is abundant and cheaper.

While industry will be the main actor exposed to higher prices due to imports of hydrogen, depending on which sectors shift to hydrogen, final consumers could also be impacted by an increase in energy costs. The aviation industry is likely to resort to hydrogen to decarbonise which will result in an increase in ticket prices for customers. Additionally, households could see a rise in utility bills if hydrogen is implemented in power generation and heating**.** Some potential hydrogen importing countries such as South Korea and the United Kingdom are considering using hydrogen to decarbonize domestic heating. Yet, the increase in energy costs that a shift to hydrogen would cause in the heating sector has been estimated to be as high as 90%[13]. Increasing imports of hydrogen are thus likely to harm energy security from the point of view of its affordability. While industrial activity is the most exposed to this, households may also have to shoulder an increase in the cost of energy associated with higher imports of hydrogen.

C. System accessibility

Accessibility in an energy security context refers to the extent to which the energy system is vulnerable to interruption. If energy supplies are imported from a handful of producers, the system is more exposed to availability insecurity than in cases where multiple producers are available and the country can easily switch between them, or if it benefits from a reliable domestic production. Additionally, concentration of energy supplies in a handful of countries can also increase vulnerability to geopolitical instrumentalization of energy flows. Furthermore, the ability to store a fuel improves energy accessibility as it can shield countries from relatively long supply interruptions.

Considering the number of countries that have shown interest in clean hydrogen production and export compared to the number of potential importers, it may seem like the hydrogen market might see an oversupply. This is highly unlikely as initial production plans will most likely only reach the production stage if they manage to secure purchase commitments from importing countries. This may lead to a market initially dominated by relatively rigid long-term contract structures with important commitments from the importing countries. This makes it unlikely that a liquid hydrogen spot market, resembling the current LNG market, will appear in the early stages.

Furthermore, the accessibility of hydrogen for the importing country will depend on its mode of transportation. Pipelines are asset-specific, meaning that they serve no alternative purpose than transporting hydrogen, and are largely dominated by a single supplier. In the natural gas market, the rise of LNG shipping alleviated some of the security issues that asset-specific trade relations, such as imports of Russian gas via pipeline into Europe caused[14].

[12] EnergyPost.eu (2022)
[13] The Guardian (2022)
[14] Peter Zweifel, P. Z., Aaron Praktiknjo, A. P., & Georg Erdmann, G. E. (2017).

However, shipping hydrogen may not translate into a similar increase in energy security. It is currently unclear under what form hydrogen will be traded over long distance. Different technologies and carriers are currently being considered such as ammonia (NH4), liquid hydrogen (LH2) or liquid organic hydrogen carriers (LOHC)[15]. These different methods require specific infrastructure to handle and integrate them into the domestic energy system. Thus, when importing countries choose between different hydrogen transport technologies, their infrastructure can become fragmented and eventually stranded, making it difficult to shift to different suppliers if these do not have the necessary infrastructure to produce the right type of carrier. Therefore, because the market will be relatively rigid and balanced, dominated by pipelines and may be fragmented by different long-distance carriers, the supply accessibility of hydrogen may be relatively limited, particularly compared to fossil fuels such as coal and oil. Nonetheless, it should be noted that importing countries can leverage the current enthusiasm for producing hydrogen to carefully select and diversify their hydrogen suppliers to prevent exposure to geopolitical pressure and unreliable hydrogen suppliers.

Finally, hydrogen storage potential is another dimension shaping the energy access of hydrogen importing countries. While most of the future hydrogen importing countries have extensive experience storing natural gas, hydrogen storage will be different for two reasons. Firstly, natural gas is primarily used for seasonal variations of heating demand, while hydrogen storage will be needed more consistently throughout the year and will mainly serve as a buffer for variations in supply availability[16]. Secondly, hydrogen has a lower energy density than natural gas, meaning that for similar volumes, hydrogen storage will provide around a quarter of the energy gas could store[17]. Therefore, although different methods are being developed to improve the storage of hydrogen[18], but as it stands, the lower capacity of hydrogen storage may further contribute to the vulnerability to supply shocks of hydrogen importers.

D. Socio-environmental acceptability

Acceptability of a fuel or technology in the energy system is tricky to conceptualize because “what is [environmentally] acceptable varies widely among different actors: local population, environmental NGOs, industries, and nation states”[19]. Controversies over safety and sustainability are still ongoing for certain energy sources. For example, although nuclear energy is agreed as a low-carbon energy source, many countries have decided that the potential socio-environmental consequences of nuclear-related disasters are simply not acceptable. Likewise, the use of hydrogen was limited and strictly controlled for decades, as it was widely perceived as a dangerous molecule that can cause explosions. However, with improvement in safety management and storage technologies along with a momentum for decarbonization, hydrogen is promoted by policymakers and industries more than ever before. Despite this, there are safety concerns associated with the handling of hydrogen and its derivatives that may make the population reluctant to adopt it. Germany's decision to

[15] Robinius, M., Cerniauskas, S., Madlener, R., Kockel, C., Praktiknjo, A., & Stolten, D. (2022)
[16] IRENA (2022b)
[17] Ibid.
[18] Tergea (2023)
[19] Cherp, A., & Jewell, J. (2014)

replace nuclear power with hydrogen for power generation presents an interesting case study on the impact of acceptability of a particular energy source or technology on the security of an energy system.

Additionally, actors have mixed views on hydrogen's environmental impact. Importing hydrogen can reduce the energy system's carbon footprint, but the extent depends on the type of hydrogen and fuel it replaces. Both blue and green hydrogen are likely to be the subject of global trade, although blue hydrogen will mainly be deployed in the initial phase of global hydrogen trade, and green hydrogen will dominate in the long term. The environmental impact of blue hydrogen is higher due to its production's reliance on carbon capture and storage (CCS), which is currently at a 90% capture rate[20]. Methane emissions associated with natural gas used to produce blue hydrogen are also problematic. If the leakage rate is not substantially decreased, blue hydrogen could be worse for the environment than directly using natural gas[21]. Also, hydrogen leakages have recently been identified as a potential source of global warming[22]. Recent studies have highlighted that hydrogen leakages could extend the lifetimes of greenhouse gasses in the atmosphere and thus indirectly contribute to global warming. Therefore, while green hydrogen provides the most potential to increase the acceptability dimension of energy security, especially comparing to the carbon-intensive fuels it will replace, further research into its leakages will be necessary to avoid unnecessary climate warming.

V. Conclusion

This essay looked at the energy security implications of higher uses of hydrogen and its derivatives for hydrogen importing countries. To do so, this paper broke down the concept of energy security into four distinct categories that encompass the multiple dimensions of contemporary energy security: its economic implications (affordability), its environmental impact (acceptability), its potential for long-term exploitation (availability) and the resilience of its supply route (accessibility). Overall, the paper aimed to highlight that energy security implications of hydrogen demand vary depending on the dimension of energy security analyzed, and within this specific dimension, the impact of increasing imports of hydrogen further varies depending on the type of fuel that is replaced and on the assumptions we make about the future of energy markets.

More specifically, we argued that:

For availability, higher imports of hydrogen could be a source of greater energy security under a scenario where the current under investment in fossil fuel exploitation leads to a structural lack of supply of fossil fuels. However, hydrogen is less likely to contribute significantly to supply availability in the early stages considering that blue hydrogen, likely to be the first low-carbon hydrogen with significant market shares, still requires natural gas to be produced. However, as green hydrogen production develops, supply availability risks will

[20] LSE (2023)
[21] Howarth, R. W., & Jacobson, M. Z. (2021).
[22] Fan, Z., Sheerazi, H., Bhardwaj, A., Corbeau, A-S. & Longobardi, K. (2022). *"To date, however, very little attention has been paid to the potential contribution of hydrogen leakage to climate change, driven by hydrogen's indirect global warming effect through mechanisms that extend the lifetime of methane and other greenhouse gases (GHG) in the atmosphere"*

progressively disappear as hydrogen production can tap into the immense capacity potential of renewables.

Regarding the contribution of higher hydrogen imports to affordability concerns of energy security, hydrogen is less likely to contribute positively to the system security. We argued that while prices were likely to decrease, low-carbon is still likely to come with a green premium. Nevertheless, the impact of this price increase is not the same per actor, and we argued that while final users are less likely to suffer from higher energy costs, industrial actors may face structurally higher prices. While we argued that the consequences of these higher prices depend on the state of each market that converts to hydrogen, there are concerns that hydrogen importing countries face the risk of facing a relocation of some of their processing industries to countries where hydrogen is cheaper.

The accessibility of higher imports of hydrogen was also nuanced. The fact that the market is unlikely to be very liquid and flexible, that differences in the technology used for long-distance transport may isolate supply chains and considering the lower storage potential of hydrogen compared to alternative gasses, make hydrogen unlikely to significantly contribute to an increase in energy accessibility for an import country, even though importing countries are in the comfortable position of being able to select with whom and how to build a hydrogen supply chain.

Finally, the environmental acceptability of hydrogen is similarly complex to assess. Blue hydrogen is seen by many as an imperfect, but necessary intermediary between the current carbonized energy mix and a developed green hydrogen economy. While green hydrogen is seen as having the most potential to contribute to the environmental acceptability of a country's energy mix, recent concerns about the impact of hydrogen leakages highlight that much remains to be done to ensure the sustainability of the hydrogen economy.

Overall, the contribution of higher imports of hydrogen for an economy thus seems relatively ambiguous and can vary a lot depending on the assumptions made about future developments as well as the dimension of energy security considered.

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