KAPSARC
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King Abdullah Petroleum Studies and Research Center

Facilitating the Low-Carbon Hydrogen Market: Opportunities, Challenges, and Pathways

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About KAPSARC

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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Key Points

The hydrogen industry is at a turning point, as regulatory frameworks and incentive schemes begin to take shape. However, there are still barriers for market participants to commit to production projects and infrastructure, as they face the chicken-and-the-egg dilemma. The King Abdullah Petroleum Studies and Research Center (KAPSARC) recently held a workshop with more than 40 experts to discuss recent developments and whether the existing incentives and guidance around carbon accounting are sufficient for creating a business model to propel this industry forward. The following are key points to be considered:

> A strong policy framework, supported by laws and regulations, is crucial for the development of the hydrogen market. Initially, bridging the cost gap by implementing well-designed support mechanisms to increase production capacity and essential infrastructure was essential. Additionally, incentivizing the demand for hydrogen in sectors and applications where it is best suited has become crucial.

> In the absence of committed buyers, financing hydrogen projects poses challenges. Customized interventions, including robust business models, are necessary to derisk investments and enable the large-scale expansion of the clean hydrogen market. Price transparency, liquidity, legal security with clear rules, and limited market barriers are some essential aspects of a well-functioning market.

> Creating a market reference price or index is crucial for enabling the commercial trade of hydrogen and for using it as a benchmark for the allocation of government subsidies. However, there is currently a lack of consistency in how the reference price for hydrogen is determined, with different methods being used or proposed in different locations.

> Drawing from past experience in developing the natural gas and liquefied natural gas (LNG) market, hydrogen will likely take a long time to establish itself as a commodity. During the early phase of market development, hydrogen project developers are inclined toward a fixed price with relevant escalation factors and long-term off-take agreements. These agreements enable them to recuperate their projected production costs, secure reasonable returns on their investments, reduce the degree of risk, and secure debt financing.

> The development of hydrogen hubs can offer many benefits. Achieving the desired objectives requires the establishment of clear pricing, standardized production definitions and contracts, data formats for information exchange, and fair and transparent access to hubs' infrastructure and supply.

> Positioning physical hubs as "virtual trading hubs," where hydrogen can be traded through tradable certificates independent of the underlying physical commodity, can provide more value to participants of these hubs and help achieve policy goals. However, a definition of clean hydrogen must be agreed upon to facilitate this situation.

> Building a hydrogen economy requires not only the necessary production capacities but also the development of enabling infrastructure. Hydrogen, which is light and corrosive and has a low volumetric density, faces challenges in terms of its storage, transport, and distribution. Thus, overcoming these infrastructural and logistical challenges is crucial for the advancement of the hydrogen economy.

Summary

The clean hydrogen market is still in its infancy. Governments are highlighting the importance of hydrogen through national strategies to decarbonize difficult-to-abate sectors and are putting in place the regulatory framework and incentives to jumpstart the industry. For a market to emerge, it needs to be liquid and have clear rules, and market barriers need to be overcome. However, today, none of these characteristics are found in the current stage. There is currently no clear price for clean hydrogen, and it is not known what the market is willing to pay for it.

Hydrogen hubs can facilitate market development. Hubs require the large-scale production of hydrogen, along with available consumers, adequate infrastructure (such as pipelines, harbors, and storage), and rules that provide nondiscriminatory and transparent access to the infrastructure to allow the trade or transfer of ownership to occur. When this situation is combined with transparent pricing and standardized products and definitions, it can lead to substantial benefits. Business models using instruments such as contracts for difference schemes can introduce a price discovery mechanism, providing a benchmark of what end users are willing to pay through bidding processes. Certificates for hydrogen are also important, as the value of hydrogen lies in its ability to reduce emission levels. The "greenness" of a commodity carries value, as seen in electricity markets with renewable energy certificates, which incentivize companies and end users to make their power procurement environmentally friendly.

The development of the hydrogen market will take a considerable amount of time, similar to the natural gas industry. The process of liberalizing the gas industry in Europe began in 1996, and it took approximately 20 years for the market to be established. Given several similarities, the development of the hydrogen market may follow a similar timeline but can be facilitated by the existing infrastructure that can be repurposed for transporting hydrogen. A practical approach that prioritizes the carbon intensity of hydrogen, regardless of its production method, is needed to create a tradable commodity.

Background of the Workshop

Interest in exploring the role of low-carbon hydrogen as an energy carrier in driving the global energy transition from unabated fossil fuels to clean energy has increased over the past few years. Policymakers consider low-carbon hydrogen a new energy vector and a strong contender for reaching their net-zero emissions goals. However, the cost premium of low-carbon hydrogen has often been cited as the main reason for inhibiting demand, and fewer projects are undergoing financial investment decisions. Other market risk factors, broadly characterized by demand, regulatory, and technology uncertainties and a lack of associated infrastructure, are significant and can pose a barrier to the development of a future hydrogen economy if left unaddressed.

On May 29, 2024, KAPSARC held a workshop titled "Facilitating the low-carbon hydrogen market: Opportunities, challenges, and pathways." This workshop aimed to gather input from a diverse range of local, regional, and global players and stakeholders who are actively involved or interested in the development of low-carbon hydrogen. This workshop was intended to discuss the following three core issues:

> The design and efficacy of various support mechanisms being considered to improve the cost competitiveness of hydrogen.

> Business models and regulations needed to support market formation.

Potential pricing mechanisms for a global low-carbon hydrogen market.

The workshop included three sessions, with the first session focusing on critical issues in the hydrogen market and its regulation. The regulatory framework and incentive schemes for hydrogen necessary to initiate investments in low-carbon hydrogen at its early stage have begun to take shape in some regions. However, to unlock state provisions and fulfill cross-border hydrogen trade requirements, investors and project developers also need to meet a set of sustainability criteria to ensure that the use of hydrogen results in lower emission levels. Striking a balance between promoting investments in a nascent market and lowering emission levels can be challenging for policymakers but is needed to ensure the significant role of clean hydrogen as a decarbonization solution. In our efforts to transition to a hydrogen-based economy, assessing the effectiveness of emerging incentive schemes and regulatory frameworks to attract investments in clean hydrogen is crucial. We must also identify key barriers that hinder investments across the hydrogen value chain and determine how to overcome them.

The second session was intended to discuss the hydrogen business model and its role in market formation. The key objective was to understand the type of market design approach that can be conducive to the development of clean hydrogen. Additionally, the session aimed to explore the role and necessity of regulatory tools in regulating and accelerating the creation of a sustainable hydrogen market and how off-take issues should be handled. Can the lessons learned from the power and gas markets be applied to guide the development of a hydrogen economy?

As the hydrogen industry grows from pilot projects to commercial-scale projects, financing becomes more critical for creating large-scale projects. However, the absence of an established hydrogen market and market reference price, such as that of LNG, can present challenges for project proponents. Therefore, it is crucial to have a robust pricing mechanism to support market development in the early years of hydrogen deployment. The third session focused on gaining better insights into potential pricing options for a global low-carbon hydrogen market and how the experience and progress made in other sectors can be used to consider various available pricing mechanisms. The workshop aimed to provide valuable input for developing the low-carbon hydrogen market, both locally and globally, and guide KAPSARC's future research in the hydrogen arena.

Policy Support Necessary to Shape the Hydrogen Market

Hydrogen is now considered a crucial element in achieving net-zero targets. Estimates suggest that meeting these goals will require almost five to seven times more hydrogen than the current level of 95 million tons (Mt) (IEA 2023). The International Energy Agency (IEA) projects a fivefold increase in hydrogen demand, whereas the Hydrogen Council projects a sevenfold increase in hydrogen demand. The appropriate policies, standards, and processes could expand the clean hydrogen market.

Several countries have implemented policies to support their national objectives related to the role of hydrogen in decarbonization and economic development. Currently, the focus of the emerging policy landscape is on scaling up the supply side by bridging the cost gap, with a few exceptions where efforts are being made to create demand for low-carbon hydrogen. The European Union (EU), United Kingdom (UK), and United States (U.S.) are driving such policy development, while other countries are also working to offer support, albeit at a slower pace. The discussions held during the workshop produced the following observations and suggestions on policy design and effectiveness:

Europe has introduced various support mechanisms for different parts of the value chain, including subsidies for electrolyzer manufacturers and end users. It is likely to be the first major market to set up hydrogen pipelines and green ammonia import facilities. The strong commitment to decarbonization (e.g., Renewable Energy Directive, FuelEU Maritime initiative, RefuelEU Aviation initiative, and EU Emissions Trading System), along with targets for low-carbon hydrogen (producing 10 Mt and importing 10 Mt of renewable hydrogen by 2030) and a stable investment climate, has been instrumental in driving the adoption of low-carbon hydrogen. Its current frameworks (Delegated Acts) support hydrogen, which is produced only from renewable fuels of nonbiological origin (RFNBO). However, a greater degree of acceptance of blue hydrogen could accelerate such progress and drive its uptake. On the demand side, specific quotas for green hydrogen in certain sectors (transport and industry) have been proposed, but the values of the associated penalties and credits have yet to be determined. The EU's plan to level the playing field on carbon costs for imports will have wider impacts on global commodities, including low-carbon hydrogen, and shape carbon policies. Mandatory carbon pricing systems and carbon border taxes will encourage countries to decarbonize hydrogen production to enable them to export low-carbon hydrogen to the European market. Europe's other initiatives to promote the hydrogen industry include the following:

- European Hydrogen Bank (EHB) – a financing instrument with an objective to unlock private investments in domestic hydrogen production and to secure diversified imports of hydrogen (derivatives) from outside the EU. The EHB aims to use H2Global as a vehicle for international auctions and to make a visible contribution to international hydrogen imports.

- EU Innovation Fund (IF) – the world's largest funding program for the deployment and commercialization of low-carbon and innovative technologies.

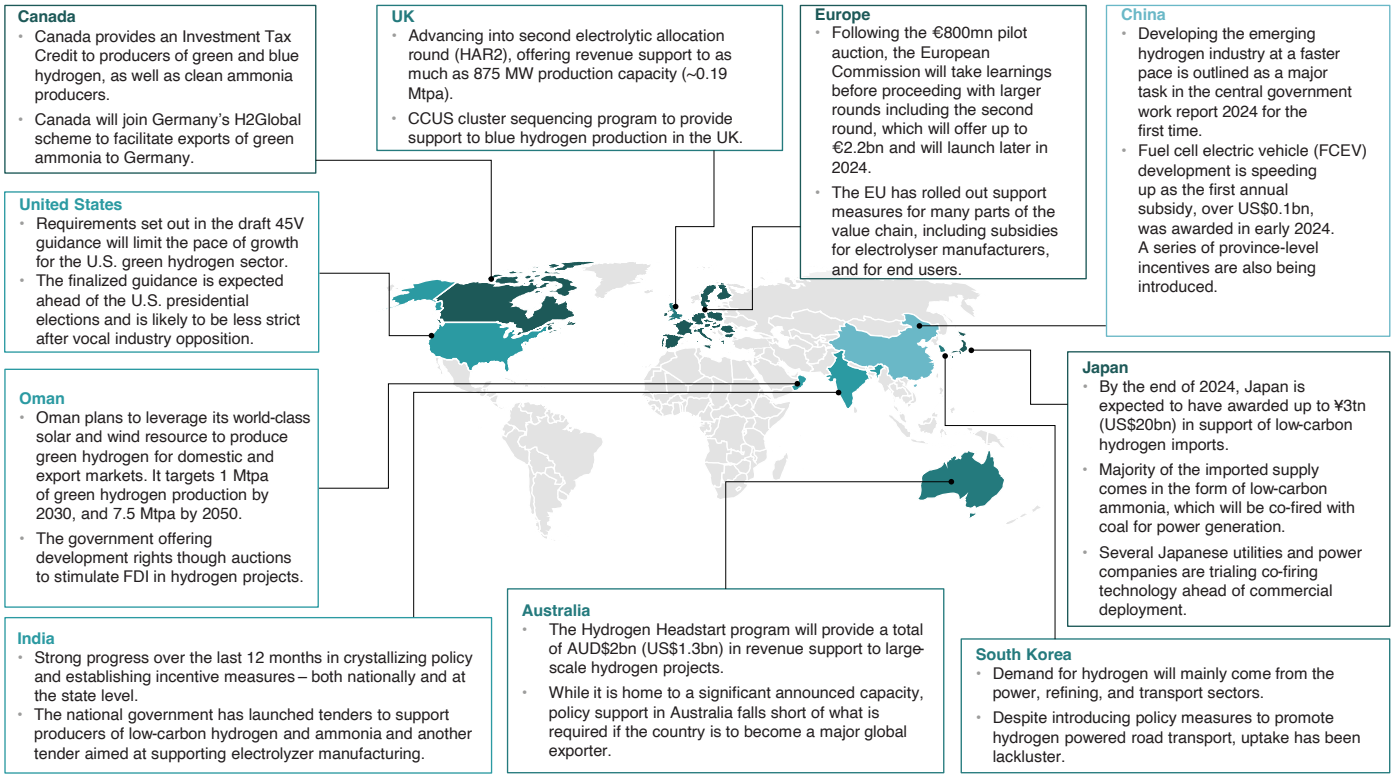
In the **U.S.**, the Inflation Reduction Act (IRA) has provided strong incentives for the domestic production of clean hydrogen, including tax credits such as the investment tax credit and production tax credit (up to US$3/kg of hydrogen

under Section 45V of the IRA). Despite creating excitement in the industry, there is a debate around the qualifying requirements, especially concerning the additionality-related clause in the US Treasury's proposed guidance on low-emission hydrogen. This debate has led to regulatory uncertainty, which may slow the adoption or development of low-carbon hydrogen. The U.S. is seeking to align its definitions of clean or renewable hydrogen with those of the EU. Nevertheless, the incentive calculation under 45V focuses on carbon intensity and does not differentiate between green and blue hydrogen, unlike in the EU, where the tax credit is available only for green or renewable hydrogen. The hydrogen hub policy aims to create demand through the cluster effect. The Regional Clean Hydrogen Hubs Program (H2Hubs) provides up to US$7 billion in support to create a network of clean hydrogen producers, consumers, and connective infrastructure while supporting the production, storage, delivery, and end use of clean hydrogen.

In **Japan**, the Green Transformation (GX) Promotion Act, Hydrogen Promotion Act, and Green Transformation Promotion Strategy provide legal and strategic support for advancing hydrogen and ammonia in 16 key economic sectors. The new law also aims to increase Japanese firms' degree of competitiveness in terms of hydrogen production, transportation, and utilization technologies. On the supply side, the country seeks smaller domestic hydrogen production targets but is positioning itself as an importer. On the demand side, the government plans to utilize contract for difference (CfD) as a financial mechanism through which to fully or partially compensate for the difference between the reference price (market price of the counterfactual fuel) and the strike price (cost of supply) for Japanese importers of green and blue hydrogen. The reference price will be linked to LNG for hydrogen and coal for ammonia as fuel in the absence of the Japanese Emissions Trading Scheme (ETS), which is expected to start in 2026. The details of the subsidy allocation system have not yet been announced, but eligible projects are expected to be competitively selected to receive government support. A threshold of carbon intensity of 3.4 kg CO_2 per kg H_2 on a well-to-gate basis has been set for hydrogen, while 0.84 kg CO_2 per kg NH_3 on a gate-to-gate basis has been set for ammonia. Low-carbon-intensity projects are likely to receive more policy support than are other projects. The CfD support will be provided for 15 years. However, applicants will be required to commit to an additional 10 years of supply after the initial 15-year period expires.

The momentum for rolling out various support mechanisms for hydrogen production is also increasing in other countries (Figure 1). However, nothing is currently in place at a scale that can support projects and the midstream investments necessary to produce the hydrogen needed for Europe; moreover, no infrastructure to deliver this hydrogen exists.

Figure 1. Evolving policy support for the role of hydrogen in decarbonization and economic development.



Source: Presentation by Claude Mourey, KAPSARC workshop – May 29, 2024.

New End-Use Sectors Will Scale Up the Market

The ongoing issues surrounding the demand and supply of hydrogen create a situation where it is unclear which should come first, similar to the age-old question of the chicken and the egg. Building the necessary infrastructure for hydrogen production is crucial for transitioning to hydrogen energy. However, without sufficient demand, investing in large-scale hydrogen production carries significant risks. Promoting the use of low-emission/renewable hydrogen will require carefully crafted policy and regulatory interventions, especially at the infancy stage of hydrogen energy deployment, when hydrogen energy is prohibitively more expensive than are the currently used fossil fuels in energy-intensive industries. Therefore, it is important to focus on incentivizing the creation of demand for hydrogen in sectors and applications that are best suited to the transition from fossil fuels to low-carbon hydrogen. The discussions during the workshop resulted in the following observations and suggestions regarding the challenges involved in scaling up hydrogen demand:

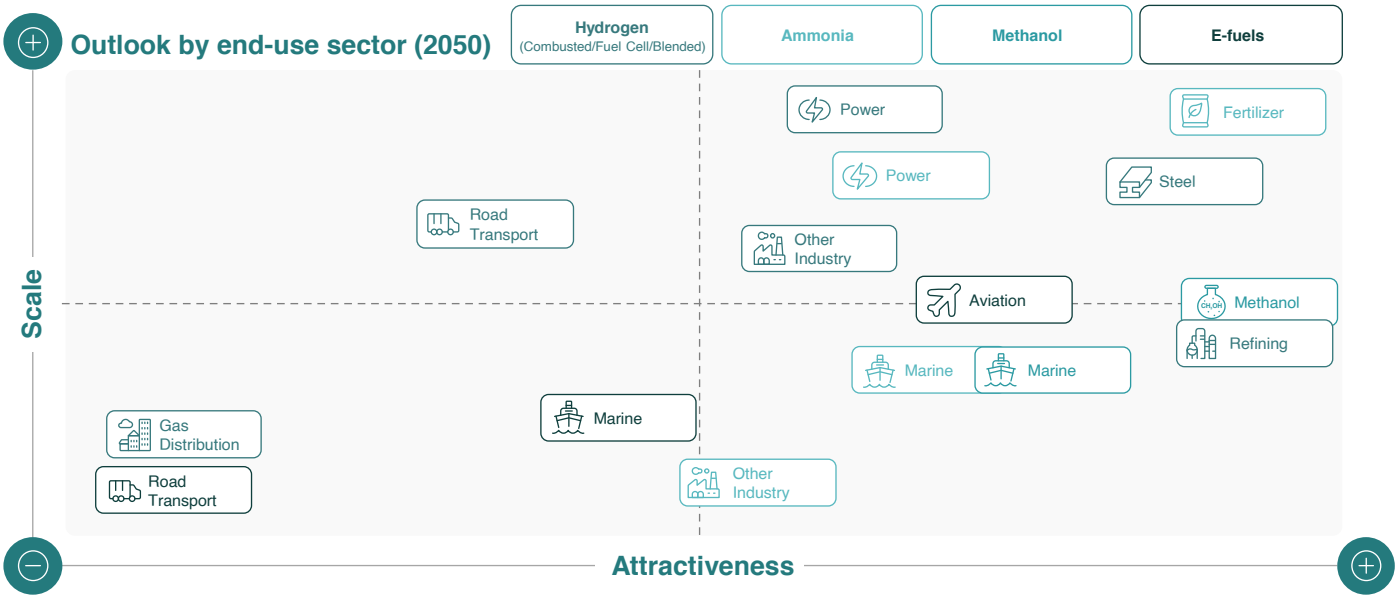
> The global production of hydrogen is currently approximately 95 Mt. Most of this hydrogen is used in traditional applications such as refining (40 Mt), the production of ammonia (34 Mt), methanol (15 Mt), and direct reduced iron (DRI) in the steel industry (5 Mt) (IEA 2023). In 2022, the demand for hydrogen in new applications, such as the heavy industry, transport, shipping, power generation, and building sectors, and the production of hydrogen-derived fuels were at low levels, at approximately 40 kilotons (kt). However, it is expected that the market for hydrogen in these new sectors will grow in the long term due to policy incentives and technological advancements.

> The complexity of the hydrogen value chain stems from its numerous industrial applications. As a result, different industries may have varying levels of willingness to pay to pass on the additional cost of using low-emission or renewable hydrogen to their end customers. For example, in fertilizer production, almost 80% of the total cost results from the use of hydrogen as feedstock. Passing on the additional cost of hydrogen production for ammonia directly to end users will make hydrogen use very price sensitive. However, other sectors may be less sensitive depending on how they use hydrogen energy to achieve their decarbonization goals. Therefore, a closer examination of this aspect is necessary to obtain a better understanding of the future demand levels of different end-use sectors (Figure 2).

> Many countries have set hydrogen targets in their policy or strategic visions. While these actions demonstrate government ambitions, the 2030 targets appear unattainable and less likely to be achieved. Meeting these targets is expected to be challenging because of factors such as the high cost of low-carbon hydrogen, lagging demand, lack of infrastructure development, and regulatory uncertainties, including carbon intensity standardization. The EU is leading the way in creating demand for renewable hydrogen by providing timely and robust support to the hydrogen industry. However, due to financial and regulatory challenges, domestic supply is likely to grow more slowly in the future. Consequently, the hydrogen targets outlined in the EU's RePowerEU plan, which aims to import 10 Mt and produce another 10 Mt within the EU by 2030, may be overly ambitious and difficult to achieve. Furthermore, infrastructure improvements are

New End-Use Sectors Will Scale Up the Market

Figure 2. Future outlook of hydrogen in traditional and new applications.



Source: Presentation by Claude Mourey, KAPSARC workshop – May 29, 2024.

needed to support the proposed import demand. Given the generous supply-side incentives provided to producers under the IRA of 2022, some U.S. manufacturers may choose to export their RFNBO-compliant green hydrogen to the EU.

Several large-scale, blue hydrogen projects are being developed in industrial clusters in the UK. Blue hydrogen is expected to support the scale-up of UK supply, with green hydrogen likely to account for the majority of supply only after 2036.

The Asia-Pacific (APAC) region is expected to experience a significant increase in demand levels, largely due to early upticks in China, Japan, and South Korea. Compared with Europe and North America, the more relaxed carbon intensity standards in the APAC region will likely contribute to its higher growth in hydrogen production.

Unlocking Investment Poses Many Challenges for Governments and Developers

Encouraging infrastructure investment presents many challenges for governments and developers, with one of the most urgent and complex challenges being how to finance such infrastructure. The financing of hydrogen projects is particularly challenging due to the absence of committed off-takers in need of hydrogen for decarbonization and demand uncertainties. These unique challenges make attracting much-needed investments difficult in this capital-intensive sector. As different markets may face varying levels of market challenges, several unique interventions are being taken to reduce these risks and encourage investment. Below are some of the prominent support measures and the issues associated with them.

Japan and South Korea are becoming key players in establishing a hydrogen market. Both countries are taking substantial steps to support the import of low-carbon hydrogen. In 2024, Japan passed the Hydrogen Promotion Act, which provides a legal framework for promoting hydrogen as a clean energy source to achieve carbon neutrality goals. The Act extends subsidies aimed at attracting investments in projects within Japan and globally. As these subsidies can help bridge the price gap between clean ammonia and other alternative fuels, the move has attracted the interest of Japanese investors in participating in numerous projects worldwide.

In Europe, the EHB, established in 2022, serves as a financial tool to generate investment security and business prospects for producing renewable hydrogen in Europe and worldwide. Its primary goal is to facilitate private investment in hydrogen value chains in the EU and globally. Within the European Economic Area (EEA), the EHB focuses on scaling up the hydrogen production market and linking renewable energy supply with demand to address the initial investment hurdles. Funding is awarded as a fixed premium in €/kilogram (kg) of verified and certified RFNBO hydrogen produced over a 10-year period and is capped at €4.5/kg of hydrogen produced. This subsidy support is expected to make renewable hydrogen cost competitive and speed up its integration into the market. However, a strong certification and verification system is needed to maintain the climate-friendly credentials of hydrogen. Additionally, prioritizing the appropriate use cases (i.e., difficult-to-abate industries) will ensure that hydrogen funding is directed to where it is most urgently needed for rapid decarbonization.

- The recent EU-wide auction allocated approximately €720 million to seven renewable hydrogen projects across Europe. The winning bidders are expected to produce 1.58 Mt of renewable hydrogen over the next 10 years. This means that achieving the EU's 10 Mt domestic target by 2030 will depend on private-sector funding to bridge the investment gap, potentially leading to increased project risks and costs. Although the budget for the second auction, scheduled for late 2024, has been increased to €1.2 billion by the European Commission, it may not be adequate on its own to fully realize the growth goals outlined in the EU Hydrogen Strategy.

The IF is a financing instrument established by the European Commission to support innovative flagships and first-of-a-kind projects

that have advanced beyond the research stage but are not yet bankable. Its primary aim is to assist businesses in investing in clean energy, promoting economic growth, generating employment opportunities, and enhancing European technological leadership. The fund shares risk with project promoters by supporting highly innovative projects that are the first of their kind. The fund provides support in the form of regular grants for proposals, auctions, project development assistance, and financial instruments such as the EHB. For the hydrogen industry, the IF can provide support across the value chain from hydrogen production to transmission, distribution, and end use. The IF covers up to 60% of the costs linked to innovation. The subsidies can be complemented by other funding sources by member states at the national level, but more than 100% of overall funding is not allowed, and items and expenses cannot be doubly funded. While the current focus is on developing and deploying cutting-edge technologies, more mature technologies with greater potential to combat climate change could also be included in such funding support.

In the U.S., the support for clean hydrogen is being bolstered by the Bipartisan Infrastructure Law (2022) and the Inflation Reduction Act of 2022. These laws significantly promote the economics of hydrogen production by implementing provisions for the development and scaling of climate-friendly technology. However, developers are reportedly encountering challenges due to the following three strict criteria outlined in the draft rules: additionality, time matching, and deliverability. The clarification of these criteria is essential for developers to access clean hydrogen tax credits.

A range of regulatory approaches that are somewhat more stringent on the green hydrogen side and easier on the blue side are swinging the focus from the European to the Asian market, which is driving investment worldwide. The blue hydrogen supply chain is likely the current storyline in relation to the clean hydrogen market in the U.S., the Middle East, and Asia.

Hydrogen Value Chain Needs a Market and Business Model but Not One-Size-Fits-All Options

The lack of arrangements to derisk investments in hydrogen projects is a major issue, which includes the absence of robust off-take agreements to buy the produced hydrogen for various end-use applications, inadequate access to renewable energy for producing the required volume of renewable hydrogen, and a shortage of infrastructure for transporting and distributing hydrogen to its end users. In recent years, several countries have introduced policies, strategies, processes, and standards to promote decarbonization via hydrogen. While these steps are important, the widespread adoption of hydrogen energy in the energy sector still faces many market uncertainties. As a result, financing clean hydrogen projects requires innovative business models to help reduce risks, alleviate uncertainties, and enable the large-scale expansion of the clean hydrogen market. The importance of business model innovations becomes even more crucial when considering that an estimated US$4 trillion will be needed globally by 2045 for investment in addition to other infrastructure. In contrast, only US$100 billion in public subsidies are available in all Organisation for Economic Co-operation and Development (OECD) countries and China. According to Bloomberg data, over 1,400 clean hydrogen projects have been announced globally, with fewer than 4% reaching the financial investment decision stage. Hence, there is an enormous degree of mismatch between ambition and reality, which underscores the need to create markets that can attract private capital for these projects. Discussions about the business model topic produced the following observations and suggestions:

The key attributes of a well-functioning market include price transparency, liquidity, legal security with clear rules, and limited market barriers. Unfortunately, these attributes are not present in the current stage of the hydrogen economy market. It is assumed that hydrogen production costs will decline over the next few decades because of economies of scale and learning, setting the scene for market creation. Given the need for timely actions on climate change, waiting for this moment to create a market will only delay the integration of hydrogen to achieve decarbonization goals. Therefore, it is crucial to prioritize the development of a market with the necessary frameworks over increasing the hydrogen production capacity to transition toward a hydrogen economy.

Without a regulatory stimulus, there will be no/limited willingness to pay a “green premium.” Similarly, without supply security under price-comparable conditions, there will be no demand uptake. Regulatory changes such as carbon pricing, taxes, and quotas are likely to increase the willingness to pay. Initially, subsidies will be necessary to bridge the cost gap and establish a business and investment case for both supply and demand. The government needs to clearly define the amount of funding it will provide, the specific purposes for which it is intended, and the exact timeframe over which it will be made available. Competitively allocating these subsidies will enhance their effective utilization.

When subsidy programs are implemented on the basis of CfD, establishing a reference price is

essential. Since the willingness to pay for green or clean hydrogen per kg is unknown and may vary across uses, determining a reference price can be challenging. In such situations, the role of a physical intermediary between suppliers and buyers becomes crucial. To address the concerns of sellers and buyers, a competitive approach on both the supply and demand sides (referred to as a "double auction") by such an intermediary (or trader) could be beneficial. H2Global is one such emerging player, which provides long-term off-take agreements on the supply at clear terms and fixed prices over 10 years, making it easy for projects to enter a final investment decision (FID) stage. Examples include NEOM in Saudi Arabia, H2 Magallanies in Chile, and the HyVelocity Hydrogen Hub in the U.S. On the demand side, buyers are chosen on the basis of having the highest degree of willingness to pay to keep the cost difference to be recovered from the government at an absolute minimum. Examples include Thyssen in Germany, Port of Rotterdam in the Netherlands, and Brussels Air in Belgium. Additionally, a one-year contracting period for buyers does not obligate them to purchase hydrogen at today's price for an extended period. Such an arrangement represents a market-driven compensation mechanism to ensure the most efficient use of public funds for maximum impact and create a catalytic effect, moving market creation forward. More importantly, such an arrangement can be helpful in creating liquidity for hydrogen and pricing signals on the demand side, which is very important for market development. This business model can be customized according to the funder's objectives, such as price optimization, the promotion of green technologies, energy security, the decarbonization of specific sectors, and development policies in different geographic areas (e.g., global, regional, and national).

It is essential to form a consortium of competent companies with relevant industry expertise and a clear understanding of their components and roles. This consortium is crucial for instilling confidence among lenders when they are seeking financing for high-capital and riskier projects. Lenders may hesitate to support newcomers without relevant industry experience unless the projects are backed by off-take agreements. Collaboration between relevant companies and the government is likely to provide the necessary credibility and positioning to move forward with such projects. This situation could be an important differentiator for potential project developers to secure loans from potential lenders. Further clarity on project costs and earnings is essential for developing a viable project. Unsubstantiated assumptions may jeopardize a project's financial feasibility at a later stage.

Hydrogen is not currently considered a commodity. Furthermore, owing to the significant level of investment and the complexity of the value chain, it is unlikely that hydrogen will become a commodity similar to LNG in the near future. In regions where natural gas prices are low, it may be practical to convert natural gas to hydrogen for heat applications in industrial sectors, but this approach may not be practical in other areas. Hence, for a developer, having a portfolio that includes both blue and green hydrogen may offer more flexibility to meet the varying needs in different geographic locations. While the LNG market is expected to continue expanding, it is unlikely that hydrogen will directly compete with LNG. However, economics will play a large role in this situation.

When creating regulations for the hydrogen industry, especially in its early innovative stages, there is ongoing debate about how to achieve

regulatory consistency, particularly in a global market involving many countries. Striking the right balance between coherence and flexibility allowance is crucial for fostering innovation. The hydrogen market is unlikely to be driven by supply and demand at the beginning but rather by the aspiration of creating supply and demand through supportive regulations to achieve climate neutrality goals. Therefore, regulatory innovation will be key in driving down costs in various areas of hydrogen and scaling up the market. The regulations should create incentives to act and to invest. An investor interested in entering the hydrogen industry will examine the range of specific markets and available options. He or she will likely choose the market that offers the fastest payment, even if it is not necessarily the most lucrative, to kickstart his or her business and start trading.

An Orchestrator with Multiple Roles Needed to Drive a Low-Emission Hydrogen Ecosystem

To effectively utilize hydrogen as a fuel to reduce emission levels in difficult-to-abate industrial sectors and as an energy carrier, it is necessary to develop an ecosystem that encompasses the production, storage, distribution, and utilization of hydrogen. The low volumetric density of hydrogen and the need for compression and conversion create logistical difficulties in storing, transporting and distributing hydrogen. This situation requires a seamless connection between each step involved in using hydrogen as an energy source. Discussions on this topic yielded the following insights:

> The development of a clean hydrogen ecosystem will require coordinated efforts at the national level. Establishing a centralized entity that could act as an orchestrator to facilitate the development of a competitive and sustainable hydrogen ecosystem could help in several ways. Ideally, such an entity should be independent, with no ownership interests in private companies entering the hydrogen business. The main goal of this entity should be to promote the growth of a competitive market and accomplish other policy objectives instead of simply regulating the sector. Additionally, identifying developers on the basis of their capabilities will improve their chances of securing the necessary funding for their projects.

> The key roles that such an entity could fulfill include the following:

- Advising the government on policies and regulations related to the hydrogen industry and positioning the country as a leading global green hydrogen hub.
- Leading the development of strategy and conducting master planning activities.
- Coordinating with other relevant government entities to ensure the timely implementation of various components of the hydrogen ecosystem (e.g., developing a shared infrastructure, including electricity transmission, water, and hydrogen pipelines).
- Managing the auction process to competitively allocate land to project developers and transparently and effectively disburse any subsidy support.
- Providing logistics, including transport, storage and other enabling infrastructure for the clean hydrogen sector and developers.
- Supporting off-take agreements for clean hydrogen developers, including negotiating with clean hydrogen demand aggregators locally and globally.
- Capitalizing on the opportunity to localize the value chain, supporting the localization of hydrogen ecosystem facilities.
- Incubating some of the processes/activities that could be spun off as a new entity, especially on the logistics side and as demand aggregators.

Development of Hydrogen Hubs Offers a Multitude of Benefits

The idea of hydrogen hubs is gaining the attention of policymakers. Hydrogen hubs are areas where producers and users of clean hydrogen in the industrial, transport, and energy markets are situated close to one another. The main goal of promoting hydrogen hubs, also known as hydrogen clusters or valleys, is to facilitate the transition to a low-carbon economy. This strategy involves addressing risks and uncertainties related to the hydrogen supply and demand, as well as avoiding the challenges and costs related to hydrogen transport. Numerous initiatives focused on hydrogen hubs are underway in countries such as the U.S., Australia, Germany, France, Canada, Spain, the UK, Denmark, Greece, the Netherlands, Japan, China, Portugal, and Oman. These hubs can leverage existing infrastructure and industrial activities to reduce costs and enhance efficiency. Discussions on this topic resulted in the following insights:

> A clean hydrogen hub at the national or regional level could drive innovation in green technologies and solutions while helping project developers overcome the challenges of mobilizing finances for their projects. A successful hydrogen hub would need certain key conditions to be met. These include the sufficient production and consumption of hydrogen, efficient logistics for hydrogen transportation, nondiscriminatory and transparent access to the hub's infrastructure and supply, transparent pricing, standardized product definitions and contracts, and data formats for information sharing.

> The government may fully or partially support the development of hub facilities, such as shared infrastructure for the multiple companies involved in the entire hydrogen process, from unloading to final consumption. Moreover, the success of the hub would greatly benefit from a clear vision and strong leadership within the hub consortium, consensus among participants, and engagement with local communities. It would be highly desirable to competitively identify and select participating developers. Additionally, hubs should be designed with adequate infrastructure flexibility to accommodate future local demand growth or trade opportunities.

> While most hydrogen hubs under development or consideration are physical hubs aimed at creating an interlinked network of infrastructure covering the entire hydrogen value chain to meet local, regional, or global needs, it would also be beneficial to position them as "virtual trading hubs." In these virtual trading hubs, the potential for trading in the form of certificates (similar to the concept of emission trading or renewable energy certificate trading platforms), independent of the underlying tradable commodity, can be explored. Such an arrangement has the potential to deliver more value to hub participants. Additionally, such hydrogen hubs can facilitate importers of their hydrogen by arranging guarantees of origin and sustainability certificates, which are essential for future hydrogen trading.

Transparent Pricing will be Key to Developing the Hydrogen Economy

The push to create a global market for hydrogen raises the following key question: What pricing mechanism will best capture the value of hydrogen as a crucial decarbonization agent? As the hydrogen industry moves from small-scale test projects to larger commercial ventures, securing financing becomes crucial for launching large projects. However, because there is no established market for hydrogen and no standard market price, such as that of LNG, this situation presents challenges for project developers. Therefore, it is essential to establish a robust pricing mechanism to support the early stages of hydrogen deployment and market development. The discussions held during the workshop generated the following insights:

> At present, the price of hydrogen is determined through negotiations between sellers and buyers. Since there is no organized market for hydrogen and market reference price, pricing it as an energy commodity will be challenging in the early stages of market development and will vary widely, reflecting isolated markets. The price of clean hydrogen will depend on various factors, which, if addressed properly, could lead to the establishment of a strong and competitive hydrogen economy. Similar challenges were experienced with natural gas and LNG before market prices for them were established. However, past methods should be adapted for hydrogen pricing wherever relevant.

> In the absence of a market reference price or index for hydrogen, sellers and buyers are expected to adopt either a fixed price approach or a price formula that incorporates fixed and variable costs in their off-take contracts. Project developers are likely to prefer a fixed price, as it allows them to recover their anticipated production costs along with a suitable return on investment. However, committing to a fixed price prior to reaching an FID could also expose sellers to future cost overruns and input price increases.

> Creating a market reference price or index is crucial for enabling the commercial trade of hydrogen and for using it as a benchmark for the allocation of government subsidies. However, there is currently a lack of consistency in the approach used to determine the reference price for hydrogen, with different methods being used/proposed in various locations. For example, Japan's CfD scheme uses the market price of specific fuels as reference prices – LNG for hydrogen and coal for ammonia as a fuel. In the UK's first hydrogen allocation round (HAR1), the reference price represents the market value of hydrogen sold.

Reference

International Energy Agency (IEA). (2023). *Global Hydrogen Review 2023*. https://iea.blob.core.windows.net/assets/cb9d5903-0df2-4c6c-afa1-4012f9ed45d2/GlobalHydrogenReview2023.pdf.

About the Workshop

The workshop took place in Riyadh on May 29, 2024, and brought together a diverse group of local, regional, and global players and stakeholders who are actively involved or interested in developing low-carbon hydrogen. Participants discussed the opportunities, challenges, and pathways for developing a hydrogen industry and included experts from the government, industry, hydrogen producers, off-takers, and intermediary organizations involved in facilitating hydrogen deployment, think-tanks, law firms, technology providers, and research institutions.

Speakers and participants

Abdullah Albanyan – Hydrogen & CCE Specialist, Ministry of Energy

Abdullah Aljarboua – Sr. Fellow, Energy Macro & Microeconomics, KAPSARC

Abdullah Fahad – Associate Programme Officer, IRENA

Abdulrahman Alanazi – Energy Expert, Ministry of Energy

Abdulrahman Almasri – Hydrogen and e-Fuel Policy and Regulation Lead, NEOM – ENOWA

Ahmad Albalawi – Fellow, Utilities & Renewables, KAPSARC

Amro Elshurafa – Executive Director, Utilities & Renewables, KAPSARC

Axel Pierru – Vice President, Knowledge & Analysis, KAPSARC

Bassam Dally – Professor, KAUST

Bassam Fattouh – Director and Head of Hydrogen Research, Oxford Institute for Energy Studies

Brian DaRin – Deputy Executive Director, Energy Futures Initiatives

Christof van Agt Ross – Director, International Energy Forum

Claude Mourey – Director of Hydrogen and New Energies, Wood Mackenzie

Dan Feldman – Global Head of Energy, King & Spalding

Ebubekir Koyuncu – Chief Executive Officer, Air Products Qudra

Elie Adaimy – Gulf Cryo Group

Faisal Al Qurooni – Sr. Specialist, Ministry of Energy

Ibrahim Alshankiti – H2 Expert, Ministry of Energy

Ilona Grzyb – Business Development Manager, H2SITE

Jan Haizmann – Chief Executive Officer, Zero Emissions Traders Alliance (ZETA), Global

Jitendra Roychoudhury – Principal Fellow, Utilities & Renewables, KAPSARC

Kholoud Alotaibi – Analyst, Ministry of Energy

Martin Wilhelm – Managing Partner, Geopolis Energy Partners

Mikail Aalmorabit – NEOM

Moaz Alshehri – Hydrogen Trainee, Ministry of Energy

Mousa Alqarni – Business Development Specialist, Thyssenkrupp Nucera

Mustafa Ahmed AlHakeem – Project Manager

Mustafa Alkhabbaz – Hydrogen & CCUS Expert, Independent

Nahla Abid – VP Strategy, Sales & Marketing Middles East, Caspian and Africa, Bureau Veritas

Nora Nezamuddin – Sr. Fellow, Transportation & Infrastructure, KAPSARC

Quentin Blommaert – Head, Hydrogen Diplomacy Office Riyadh, GIZ – German International Cooperation

Rami Shabaneh – Sr. Fellow, Oil & Gas, KAPSARC

Roberto Aguilera – Executive Director, Oil & Gas, KAPSARC

Rumaitha Al Busaidi – Business Development Manager, Hydrom, Oman

Sana Ben Kebaier – Head of Economic Research Department, Gulf Petrochemical and Chemical Association

Sarah Najm – Assistant Professor of Economics, King Saud University

Saumitra Saxena – Research Scientist, KAUST

Shahid Hasan – Principal Fellow, Utilities & Renewables, KAPSARC

Shatha Alwardi – Director, Wood Mackenzie

Timo Bollerhey – Chief Executive Officer, Hintco

Yoshikazu Kobayashi – Assistant Director, IEEJ

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About the Team

Shahid Hasan

Shahid is a Principal Fellow in the Utilities and Renewables program at KAPSARC. His current research focuses on exploring the opportunities and obstacles involved in establishing a hydrogen-based economy, implementing reforms in the electricity market, and addressing issues related to the integration of electricity markets in Gulf Cooperation Council (GCC) member states and the Middle East and North Africa (MENA) region. With over 25 years of research and consulting experience in South Asia, Southeast Asia, and the Middle East, Shahid specializes in identifying and addressing economic, policy, regulatory, technology, and sustainability issues relevant to the energy transition.

Before joining KAPSARC, Shahid worked with The Energy and Resources Institute (TERI), which is an energy policy think-tank based in India. During his time at TERI, he focused on electricity sector reforms in India and Southeast Asia. Shahid has also contributed to several government reports aimed at facilitating the transition of India's energy sector. He has worked closely with a diverse set of clients and stakeholders, including industry, industry forums, regulators, public and private utilities, governments, academia, international research institutions, and bilateral and multilateral organizations across different geographies.

Rami Shabaneh

Rami is a Senior Fellow who focuses on global gas and hydrogen markets. Rami has more than 15 years of research and industry experience in analyzing energy markets and energy policy. Before joining KAPSARC, Rami worked at Cenovus Energy as a market fundamentals analyst. There, he provided analytic support on specific issues affecting North American gas, natural gas liquids, and condensate markets. His work directly supported the company's hedging strategies. Before working at Cenovus Energy, Rami spent three years as an integral member of the fuels and power research team at the Canadian Energy Research Institute. He holds a Master of Science degree in Sustainable Energy Development and a Bachelor of Science degree in Actuarial Science from the University of Calgary.

About the Project

This workshop was organized as a part of the Regional Market Integration project within KAPSARC's Utilities and Renewables program. The project seeks to understand various aspects of electricity market integration, including the development of power pools in other regions and their potential application in the MENA region. Additionally, the project aims to provide insights into the ongoing energy transition by studying and learning from electricity markets worldwide, including their role in promoting clean hydrogen.

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