White Paper

Towards a Hydrogen Strategy for Kuwait

Executive Summary

(Short Version)

January 2021

Forward

The global energy supply chain is undergoing a major transition to net-zero energy resources, accelerated by the adoption of the Paris Agreement in 2015 by 198 countries, which aims to limit global warming to below 2°C, preferably to 1.5°C, compared to pre-industrial levels. The transition to clean, low-carbon energy systems will need to rely on all low emission technologies and pathways, and will require robust energy transition measures, involving technologically feasible and economically affordable solutions. This transition is now driven by the electrification of the energy supply chain with an increased proportion of electricity being generated from renewable energy resources.

The energy transition and de-carbonization of energy sources represents both a risk and an opportunity to oil and gas producers, such as Kuwait. The growth demand for fossil fuels, albeit will continue for decades to come, is subject to the high risk of demand peak which could be fast approaching within 1-2 decades, followed by a decline rather than a plateau. Therefore, it is imperative that for oil producing countries, such as Kuwait, to take a robust stance and response to the energy transition, for failure to do so, will lead to risking a sizable amount of these resources becoming potentially stranded. A more central role for blue hydrogen technologies, to counter balance the stringent global response away from fossil fuels, could mitigate those risks by decarbonizing the vast low-cost hydrocarbon reserves in Kuwait and other major OPEC producers, and substituting for traditional fuels in various sectors with large GHG emissions.

Hydrogen has been considered a source of energy by scientists since the early 1800s, and is known to have the highest energy storage density among all liquid fuels. It can be produced through various resources, such as fossil fuels, biomass, waste material and by splitting water molecules. Incorporating blue hydrogen, which is produced from fossil fuels but with the associated carbon dioxide emissions captured and stored underground or consumed in other processes, into the energy transition mix will allow for a low carbon option for transportation, electricity, and manufacturing and provide oil and gas producers the opportunity to play a central role in energy transition.

There are several sources of hydrogen that should be considered strategically, as countries and governments continue to develop national, and perhaps regional, plans for energy transition to enhance the security, reliability, and resilience of their energy infrastructures. Both blue and green hydrogen can be a powerful alterative to existing energy sources, should viable business plans and strategy be developed to eliminate the cost gap between the different hydrogen sources, and drive the transition of fossil fuel exporters to clean (green and blue) hydrogen economies. Ongoing innovation and technology development are reducing the cost of generation of both blue and green hydrogen, though the pace of the latter is faster. Many leading oil and gas producing countries (e.g. Australia, Canada, Norway,

Saudi Arabia) have developed their own hydrogen strategies and mega-scale projects; similarly, major energy consumers (Japan, EU, etc.) have also developed and are already rolling out their hydrogen strategies and mega scale projects.

To respond to the demands of the energy transition, Kuwait possesses the requisite resources for the production of both “blue” and “green” hydrogen and has conducted feasibility studies on carbon capture, storage, and utilization (CCUS), a pre-requisite for “blue” hydrogen production. Hence, this white paper outlines the need for a comprehensive National Hydrogen Strategy and Roadmap, highlighting key aspects of production to transport to distribution to end-use consumption. The strategy and roadmap entail dedicated policy tools and key stakeholders to carve a competitive position for Kuwait in the energy transition by using low-carbon hydrogen for structural and transformational changes. The roadmap also emphasizes the importance of parallel strategies to scale up the production of “blue” and “green” hydrogen, which would foster local demand for hydrogen, facilitate financing for hydrogen and CCUS-related projects, and lead to investments in demonstration projects in pre-competitive technologies that have the potential to reduce the costs and improve the sustainability of hydrogen production. However, the window of opportunity is limited and closing; thus, the time for action is now, especially for producing countries with great potential for low-cost blue hydrogen, like Kuwait.

I am grateful to the diligent, dedicated, and exemplary efforts of the Hydrogen Task Force in preparing this white paper. This work would not have been possible without the encouragement and guidance of the Board of Directors of the Kuwait Foundation for the Advancement of Sciences (KFAS). Our gratitude to the leadership of the Kuwait Petroleum Corporation and its Subsidiaries, especially KPC CEO, Engineer Hashem Sayed Hashem, for their continued support and collaboration on the completion of this work. It is my sincere hope that this White Paper on Hydrogen would be embraced producing quickly a robust and practical hydrogen strategy that pave the way for the launch of mega scale hydrogen production and export projects, including the establishment of a regional hydrogen HUB in partnership with local and international investment and industry leaders.

Dr. Adnan Shihab Eldin
Director General

Acknowledgment

This visionary White Paper was prepared as a result of ongoing discussions between Kuwait Foundation for the Advancement of Sciences (KFAS) and the Kuwait Petroleum Corporation (KPC), along with its subsidiaries, on addressing the challenges in the global energy transition for oil exporting countries, including Kuwait. This paper explores the potential impact and opportunities in the shift from fossil fuels to hydrogen as a future clean fuel, as well as the advantage and viability in adopting a national hydrogen strategy and roadmap in positioning Kuwait to become a leader in this emerging industry.

Jointly, KFAS and KPC organized two international workshops in preparation for the white paper. The first workshop on **Carbon Capture Utilization and Storage (CCUS)** was held on 22 October 2019 and the second workshop, titled the **Kuwait Blue Hydrogen Symposium**, was held on 12 December 2019. Both workshops were attended by more than 200 national, regional and international energy experts from academia, research institutions, and industrial companies, as well as policy makers.

This document was prepared by the Kuwait Hydrogen Committee chaired by Dr. Salem Alhajraf, Deputy Director-General at KFAS, and composed of (in alphabetical order by last name): Mr. Ahmad Al-Baghli (KNPC), Mr. Ali Al-Herz, (KOC), Dr. Faisal Al-Humaidan (KISR), Mr. Ahmad Al-Mazeedi (KNPC), Mr. Wael Al-Mazeedi – lead author of the paper (Avance Labs), Dr. Mohammad A. Al-Ramadhan (KFAS), Ms. Dalal Al-Sirri (KPC), Dr. Mamun Halabi (KISR), Mr. Fawzi Hamadah (KOC), and Dr. Essam Omar (KFAS).

This work would not have been possible without the encouragement and direction of the Board of Directors of the Kuwait Foundation for the Advancement of Sciences (KFAS), and the leadership of the Kuwait Petroleum Corporation and its Subsidiaries, especially KPC CEO, Engineer Hashem Sayed Hashem. The Committee would also like to express their gratitude to Dr. Adnan Shihab Eldin, Director General of KFAS, for his vision, support and guidance that led preparing this paper.

KFAS is grateful to several individuals and institutions who generously contributed their time to peer review the initial draft of the White Paper, namely (in alphabetical order by last name): Dr. Bassam Fattouh, Director, Oxford Institute for Energy Studies (OIES); Dr. Noé van Hulst, Chairman, International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE); Dr. Masakazu Toyoda, Chairman, Institute of Energy Economics Japan (IEEJ); and Dr. Colin Ward, Senior Researcher, King Abdullah Petroleum Studies and Research Center (KAPSARC).

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1. Background

In its efforts to promote environmentally responsible energy resources, Kuwait Foundation for the Advancement of Sciences ("KFAS") in collaboration with the Kuwait Petroleum Corporation ("KPC") is evaluating hydrogen as a clean energy opportunity to maintain Kuwait position in the future energy market derived by international energy transition strategies. In July 2019, KFAS initiated the Kuwait Hydrogen Committee ("KHC") and entrusted it with conducting an evaluation of developments affecting the emerging hydrogen supply chain and preparing a White Paper that would provide the basis for a national hydrogen strategy and roadmap for Kuwait, including identifying the role that hydrogen can play in assisting Kuwait to address national economic challenges and climate change risks. Initially KHC was comprised of energy experts from KFAS, Kuwait Institute for Scientific Research ("KISR") and the private sector. In February 2020, KPC appointed additional members to the KHC, representing KPC, Kuwait National Petroleum Company ("KNPC") and Kuwait Oil Company ("KOC").

Members of KHC contributed to the organization of two major hydrogen-related international events organized jointly by KPC and KFAS and held at the KPC auditorium in Kuwait City. First, the **Carbon Capture Utilization and Storage (CCUS) Workshop** organized in partnership with the British Embassy in Kuwait was held on 22 October 2019 and featured presentations by Kuwait Oil Company, Wood Group, Royal Dutch Shell, Mott MacDonald, Kuwait University, Imperial College and Heriot Watt University. Second, the **Kuwait Blue Hydrogen Symposium** co-organized in partnership with the Japan Cooperation Center Petroleum (JCCP) was held on 12 December 2019 and featured presentations by KPC, JCCP, KFAS, OPEC, International Energy Agency, The Netherland's Ministry of Economic Affairs and Climate Policy, Saudi Aramco, King Abdullah Petroleum Studies and Research Center, Oxford Institute for Energy Studies, Kyushu University, Chiyoda Corporation, JGC Corporation, Kawasaki Heavy Industries, Toyota Motor Corporation, Shimizu Corporation and JXTG Nippon Oil and Energy Corporation.

In addition, members of KHC participated in a fact-finding mission to Japan (9-10 October 2019) where they visited a technology demonstration plant and met with senior government officials and corporate executives from JCCP; Ministry of Economy, Trade and Industry (Carbon Recycling Promotion Office); New Energy and Technology Development Organization (NEDO); Japan Hydrogen Mobility (JHyM), Institute of Energy Economics Japan; Green Ammonia Consortium; Chiyoda Corporation and Mitsubishi Hitachi Power Systems (recently renamed Mitsubishi Power). Prior to that, certain members of KHC attended the Hydrogen Energy Ministerial Meeting 2019, which was held on the sidelines of the G-20 Meeting convened in Japan later that year.

CCUS is featured prominently in this White Paper since it is a key pre-requisite for the production of "blue" hydrogen, a form of low-carbon hydrogen described in detail herein.

2. Executive Summary

The global energy supply chain is undergoing a major transition to zero-carbon energy resources. The pace of this energy transition was accelerated by the signing of 198 countries, including Kuwait, on the UN's Framework Convention on Climate Change (UNFCCC) commonly known as the Paris Agreement in 2015. The agreement calls for limiting global warming to below 2°C above pre-industrial levels and pursuing efforts to limit it further to below 1.5°C. Since then, over 70 countries committed to cutting carbon emissions to "net zero" by 2050.

The energy transition is currently being spearheaded by the electrification of the energy supply chain, with electricity generated from renewable energy resources such as solar and wind emerging as the energy vector of choice. Renewable energy resources are displacing fossil fuels on two levels. First, their share of the electricity mix is increasing. Second, as an energy vector, electricity in gradually displacing fossil fuels in the global energy mix.

Therefore, it is imperative for oil exporters such as Kuwait to respond to the energy transition and secure market position in the clean energy domain. Failure to do so could render a sizable proportion of their hydrocarbon reserves to become stranded. In fact, under pressure from investors, lenders, environmentalists and from within their own workforce, several international oil companies earlier this year announced "net zero" emission pledges. These include Total, BP, Shell, Repsol and Equinor, with others expected to follow. Some such as BP went further by announcing a 40% reduction in oil production by 2030.

Hydrogen Opportunity

Luckily, the energy transition holds a silver lining for oil and gas producers. Zero-carbon electricity on its own is not sufficient to decarbonize hard-to-abate sectors such as heavy industry, heavy-duty transport, aviation and shipping. Nor is it able to facilitate its own integration with the heating, industry, transport and the natural gas sectors, referred to later in this White Paper as "sector coupling". Both are required to attain the carbon emission reduction targets under the Paris Agreement. Emission-free "green" hydrogen and low-carbon "blue" hydrogen are able to achieve both objectives and therefore complement electricity in the energy transition context.

"Blue" hydrogen - produced from reforming hydrocarbons such as oil, gas and coal resources but with its carbon dioxide emissions captured and stored or consumed in other industrial applications, offers a valuable and potentially rewarding window of opportunity during the transition to emission-free "green" hydrogen produced from electrolyzing water using electricity generated from solar or wind energy sources. In many respects, investment in hydrogen may prove to be the most cost-effective response by oil and gas producers to the energy transition.

Countries around the world, accounting for 45% of global GDP, responded to the hydrogen opportunity by preparing and releasing national hydrogen strategies and roadmaps. Oil and gas producing countries such as Norway, Australia and the Kingdom of Saudi Arabia have also responded with their own national hydrogen strategies and multi-billion-dollar project announcements.

Kuwait possesses the requisite resources for the production of both "blue" and "green" hydrogen. In addition, oil sector in Kuwait possesses a strong track record in the production of both "grey" hydrogen and ammonia (an emerging hydrogen carrier and potentially an energy vector in its own right) and has conducted feasibility studies on carbon capture, storage and utilization (CCUS), a pre-requisite for successful "blue" hydrogen production. It is worth noting that hydrogen is categorized as being "grey" to reflect the relatively high carbon emissions associated with its production, hence the need to capture CO_2 for the production of "blue" hydrogen.

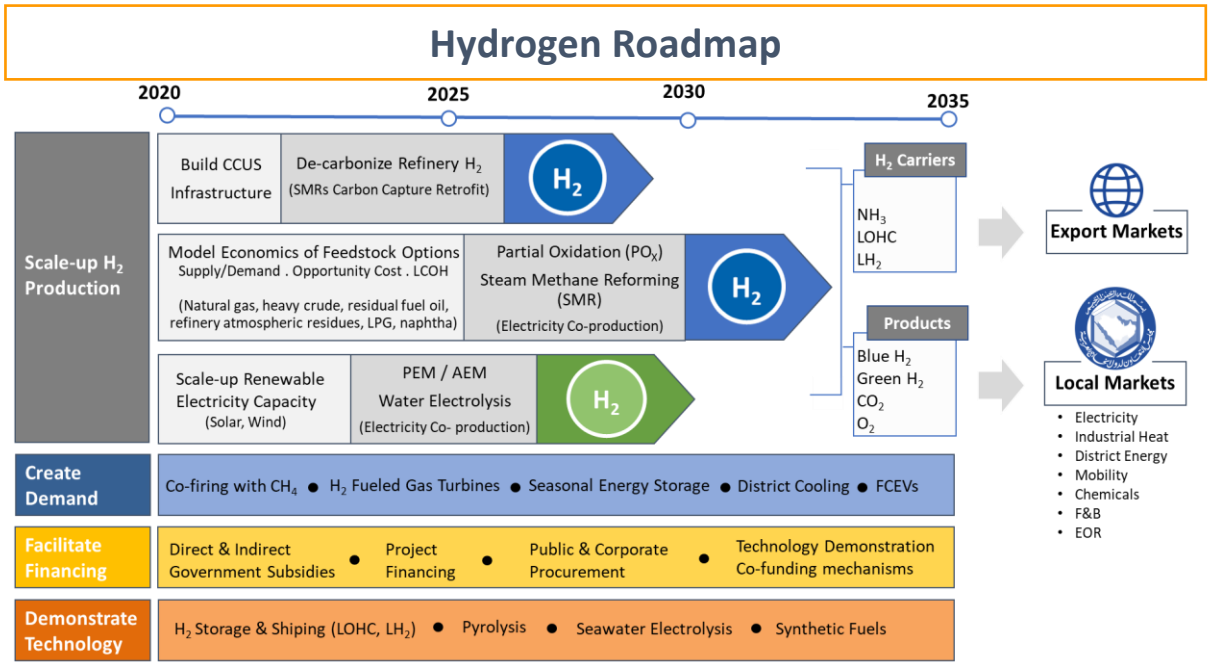
low-carbon hydrogen provides Kuwait with a unique opportunity to achieve several strategic objectives.

Hydrogen's Value Proposition to Kuwait

- Supply, to the extent possible, low-carbon or carbon neutral energy products to end-use energy consumers around the world, reducing the aggregate carbon footprint of its energy exports.
- Incentivize investments in carbon capture, utilization and storage (CCUS) and kickstart the use of captured CO_2 in enhanced oil recovery (EOR), which would:
    - Maximize recovery of its oil reserves.
    - Extend the life of its oilfields.
    - Attain (potentially) carbon-neutrality for its petroleum exports (provided a disproportionate amount of CO_2 is injected for every barrel of oil recovered).
- Facilitate its participation in the circular carbon economy (CCE).
- Reaffirm its commitment to addressing climate change challenges and potentially achieve net zero emissions targets ahead of its peers.
- Invigorate its nascent renewable energy industry.
- Transform the role of the private sector in the economy and potentially create world-class companies that can compete on the global stage.
- Carve a proactive role for itself in the ongoing energy transition.
- Create job opportunities for its citizens in the emerging hydrogen and CCE economy.

Hydrogen Strategy

It is proposed that Kuwait develop a roadmap to carve a competitive position for itself in the energy transition using low-carbon hydrogen as a change agent. The roadmap would include parallel strategies to scale up the production of "blue" and "green" hydrogen; create local demand for hydrogen; facilitate financing for hydrogen and CCUS-related projects; and demonstrate key pre-competitive technologies that have the potential to reduce the costs and improve the sustainability of hydrogen production.



Legend: CCUS: Carbon Capture Utilization & Storage / SMR: Steam Methane Reforming / PO_X: Partial Oxidation / RE: Renewable Energy / LCOH: Levelized Cost of Hydrogen / LOHC: Liquid Organic Hydrogen Carriers / LH_2: Liquid Hydrogen / FCEVs: Fuel Cell Electric Vehicles / EOR: Enhanced Oil Recovery / F&B: Food & Beverage / CH_4: Methane / NH_3: Ammonia / CO_2: Carbon Dioxide / NG: Natural Gas

Strategic Scenario Perspectives

To capitalize on the hydrogen opportunity, Kuwait can pursue one of two scenarios. It can follow the scenario of "observe, wait-and-see" until the hydrogen market matures while undertaking minimum investments to acquire a foothold in the emerging supply chain. Alternatively, it can "embrace" the hydrogen economy and commit to becoming a key industry player.

The former may prevent Kuwait from capitalizing on the potentially valuable and sizable transitionary role of "blue" hydrogen since "green" hydrogen is expected to reach price parity with "blue" by 2030 supported by a disproportionate number of public subsidies due to its emission-free credentials and by massive investments by OECD and other countries to support innovation and development of cheaper electrolysis technologies. The latter would gradually grow the local know-how, transfer new and emerging hydrogen production, storage and utilization technologies and attract regional and international partners to Kuwait, which

would reduce investment risks and open up end-use markets for hydrogen imports from Kuwait.

Industry Risks and Country Challenges

Irrespective of which scenario Kuwait chooses to pursue, it would need to assess the financing, regulatory, market and technology risks typically associated with an emerging industry such as hydrogen. However, it should derive comfort from the solar and wind industries of the early 2000s, which initially struggled to gain traction but within less than 20 years have become pillars of the energy transition.

Kuwait would also need to overcome some challenges of its own. For "blue" hydrogen, alternative hydrocarbon feedstocks to natural gas would need to be made available in a cost competitive manner. Moreover, investments would be needed to demonstrate and commercialize promising technologies that convert crude oil and petroleum products into low-carbon hydrogen. For "green" hydrogen, the capacity of electricity generated from solar and wind resources would need to be increased significantly from current low levels in order to convert surplus renewable energy to green hydrogen.

Cross-cutting challenges include, capital constraints caused by the high level of indebtedness within the oil sector and what might become a persistent low oil price environment; absence of a country-wide energy regulatory framework; lack of precedent for granting public subsidies to energy projects; limited capacity to attract foreign direct investment at the scale that is required; and the lack of appetite and expertise within the local private sector to assume and manage risks associated with developing large-scale capital-intensive projects.

Solutions to overcome these challenges include, facilitating a larger role for local private companies (including SMEs) and treating them as key stakeholders; improving and streamlining public private partnership (PPP) frameworks; stepping-up current efforts to promote foreign direct investment, expanding the role of sovereign wealth funds in the local economy, establishing an independent energy regulatory authority; initiating public procurement programs; and developing economic free zones, complete with their own independent regulatory frameworks and incentive mechanisms.

In many respects, forging strategic partnerships with key potential importers of "blue" and "green" hydrogen and making such partnerships a cornerstone of its market entry strategy would go a long way in assisting Kuwait to mitigate industry risks and address national challenges.

Action Plan

Going forward, it is proposed that Kuwait pursue an action plan comprised of the following local, regional and international elements:

Action Plan

Locally

- ✓ Prepare an adaptable Kuwait National Hydrogen Strategy (KNHS).
- ✓ Formulate concrete ambitious targets for "blue" and "green" H_2 production for domestic demand and exports for the next 10-15 years.
- ✓ Secure necessary fund for hydrogen production projects with emphasis on oil-based "blue" H_2.
- ✓ Expedite implementation of CCUS projects currently under study.
- ✓ Conduct comprehensive modeling of the economics of the H_2 supply chain (production, storage, transportation), including levelized cost of hydrogen (LCOH) production for hydrocarbon feedstocks and electricity inputs based on available technologies and decarbonization options.
- ✓ Identify early win projects and build business cases around them to justify the investment.
- ✓ Support promising novel technologies and technology solutions that would enhance the competitive positioning oil-based "blue" H_2 post 2030.
- ✓ Conduct a by-invitation workshops and seminars to ensure stakeholder buy-in and proactive participation in the implementation of the NHS.

Regionally

- ✓ Work collaboratively with neighboring countries (especially GCC) to identify and develop projects of common interest based on the success of a similar framework (Important Projects of Common European Interest) adopted by EU countries to expedite the energy transition.

Bilaterally

- ✓ Launch feasibility studies for 2-3 flagship export projects to Asia (Japan/Korea) and Europe (Germany/Netherlands) in partnership with these countries and with industry players.
- ✓ Engage with strategic industry players operating at the technological frontiers of low-carbon H_2 (e.g. Equinor) and ports that are active in promoting H_2 trade routes (e.g. Port of Rotterdam).

Internationally

- ✓ Participate in the creation of an international guarantee of origin (GO) scheme to certify hydrogen production, a precondition to trading hydrogen.
- ✓ Apply for membership in international hydrogen associations and stakeholder groups.
- ✓ Participate in technical committees of international standards setting organizations.
- ✓ Leverage KPI's network and presence in end-use markets to obtain first-hand knowledge of latest industry regulations and business models.
- ✓ Integrate H2 used domestically as well as CCUS projects and strategies into Kuwait's national determined contributions (NDC).

Stakeholder Engagement (Illustrative Examples/Not Exhaustive)

Category	Applied Research	Demonstration Projects	Blue H_2 Production	CCUS	Green H_2 Production	PCI
Kuwait	KFAS, KISR, Q8	KFAS, KNPC, Kuwait Oil Company, PETROCHEMICAL INDUSTRIES COMPANY K.S.C., Q8, EnerTech Holding Company	KNPC, Kuwait Oil Company, PETROCHEMICAL INDUSTRIES COMPANY K.S.C., KIPIC, QURAIN, Boubyan Petrochemical Company, KUT	KNPC, Kuwait Oil Company, PETROCHEMICAL INDUSTRIES COMPANY K.S.C., greencarbon, Gulf Cryo, KUWAIT GULF OIL COMPANY (K.S.C)	Ministry of Electricity & Water, IPP Developers, Alternative Energy Projects Co., ACWA POWER, Q8	Kuwait Petroleum Corporation, ADNOC, Saudi Aramco, Qatar Petroleum, Petroleum Development Oman
Foreign		OECD	IOCs: Shell, bp; OFS; IGCs	IOCs: Shell, bp; OFS; IGCs	IPPs	
Other Government		KDIPA, THE NATIONAL FUND FOR SMALL AND MEDIUM ENTERPRISE DEVELOPMENT			KAPP	
Finance		KFH Capital, NBK CAPITAL, KAMCO INVEST, Gulf Investment Corporation, APICORP, KUWAIT INVESTMENT AUTHORITY, Wafra				

Legend: *IPP: Independent Power Producers / IOCs: International Oil Companies / OFS: Oilfield Services / IGCs: Industrial Gases Companies / PCI: Projects of Common Interest*

Implementation Mechanisms

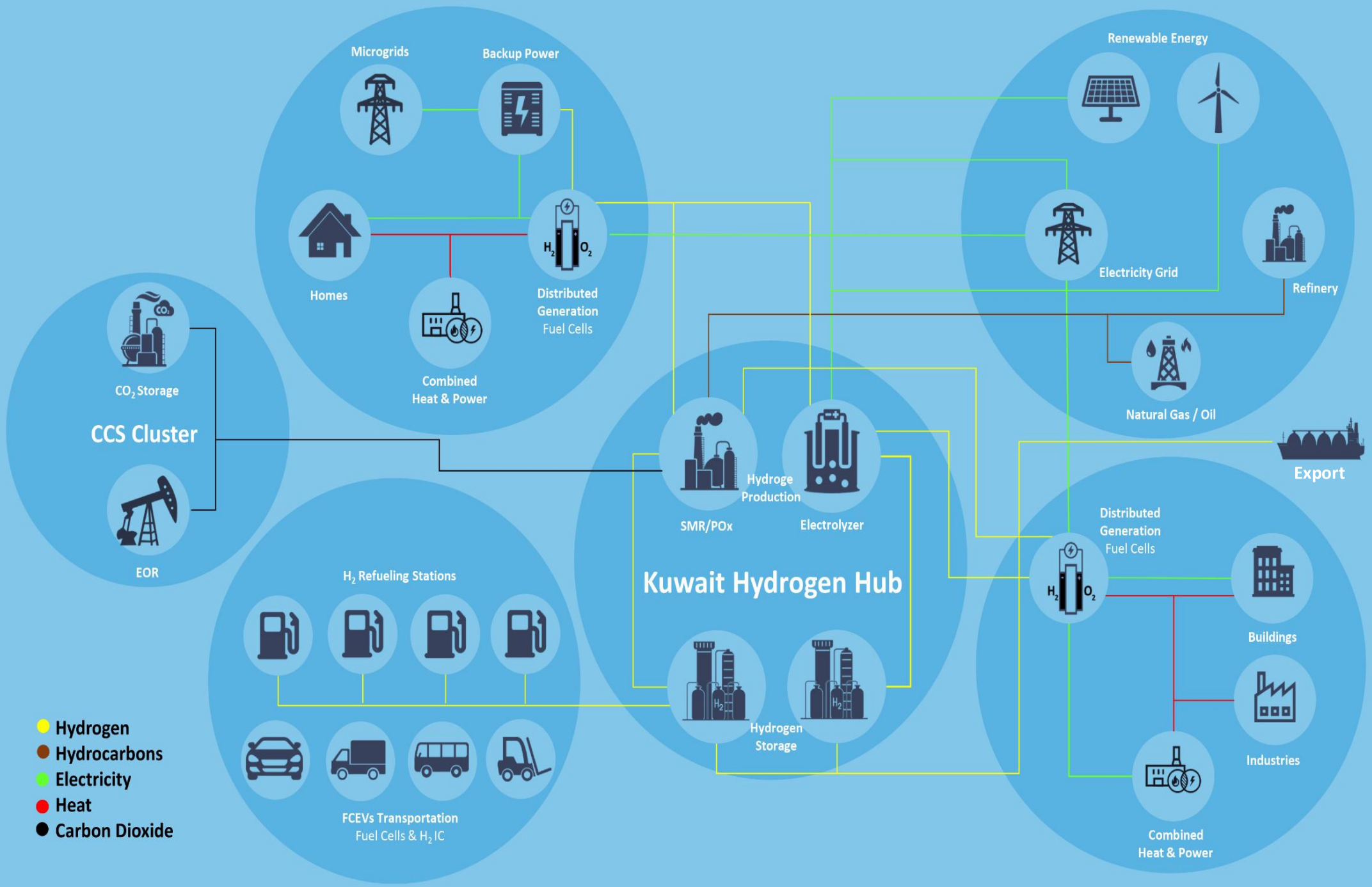
Last but not least, to ensure effective planning, follow up and implementation of Kuwait's National Hydrogen Strategy, it is proposed that Kuwait consider the following three implementation mechanisms, which are mutually exclusive:

I. **Transform and reconstitute the current technically oriented Kuwait Hydrogen Committee** into a multi-stakeholder national hydrogen task force to prepare the National Hydrogen Strategy and develop key performance indicators (KPIs) to assess the effectiveness in achieving strategy objectives, potentially forming part of the mandate of the Kuwait Higher Energy Committee.

II. **Establish an independent energy regulatory authority** to develop a legislative and regulatory framework for the energy sector, including hydrogen.

III. **Establish a project demonstration fund** to provide equity and debt finance to low-carbon hydrogen and CCUS projects that align with the National Hydrogen Strategy, with a focus on scaling up hydrogen production, developing export and domestic supply chains, establishing hydrogen hubs and creating local demand for hydrogen.

IV. **Develop a hydrogen hub** as an exclusive economic zone on a public private partnership (PPP) basis, governed by the independent energy regulatory authority, preferably located in Northern Kuwait, to facilitate and incentivize investment in the scale up of hydrogen production and associated CCUS infrastructure.


Microgrids
Backup Power
Homes
Distributed Generation Fuel Cells
Combined Heat & Power
Renewable Energy
Electricity Grid
Refinery
Natural Gas / Oil
Export
CO_2 Storage
CCS Cluster
EOR
Hydroge Production
SMR/POx
Electrolyzer
Kuwait Hydrogen Hub
Hydrogen Storage
H_2 Refueling Stations
FCEVs Transportation
Fuel Cells & H_2 IC
Distributed Generation Fuel Cells
Buildings
Industries
Combined Heat & Power
Hydrogen
Hydrocarbons
Electricity
Heat
Carbon Dioxide