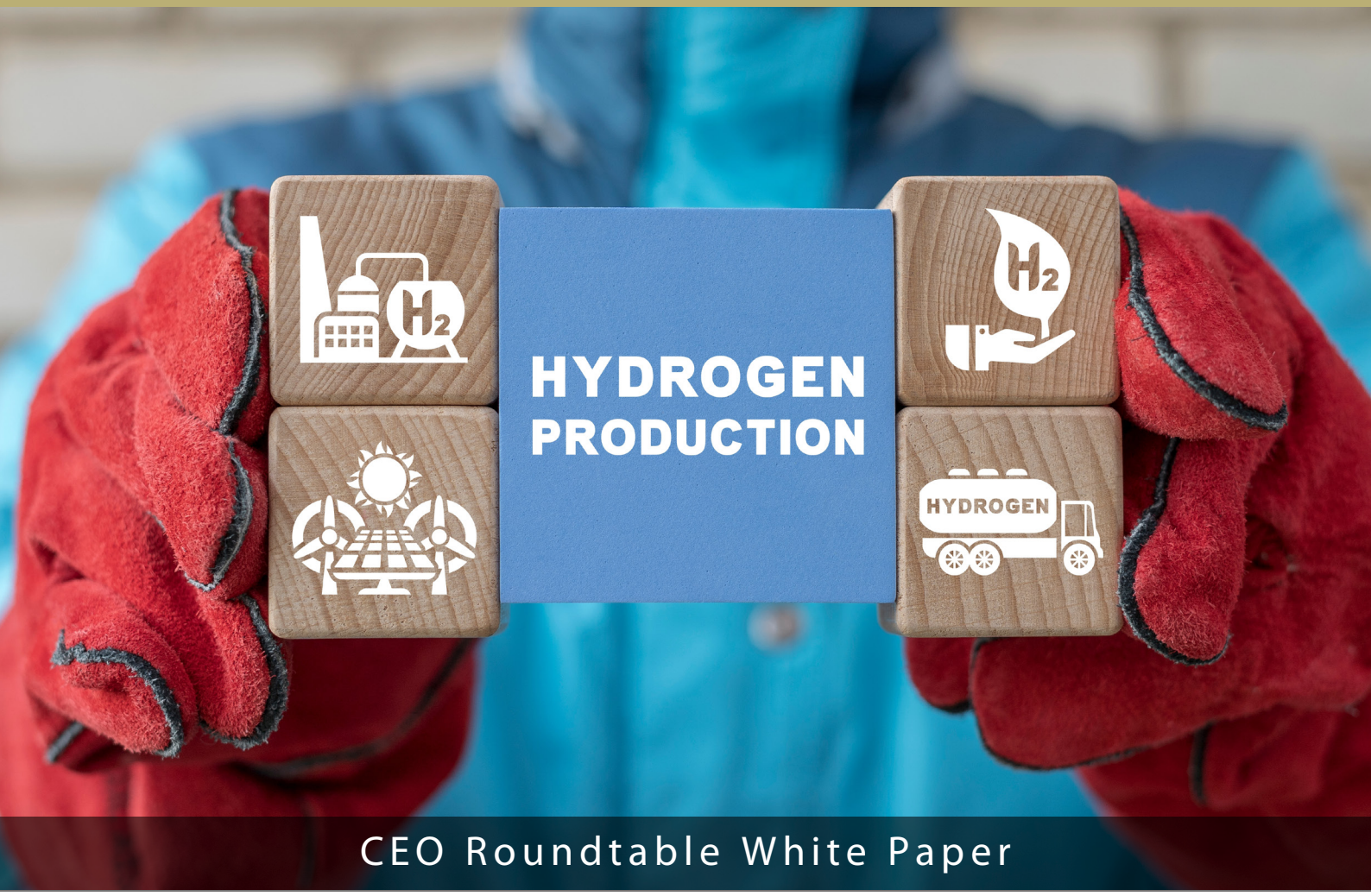
2023

September

Hydrogen Technology - From Strategy to Delivery



CEO Roundtable White Paper

The Al-Attiyah Foundation

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Hydrogen is the most abundant element in the universe and also burns without producing carbon dioxide. Due to these properties, many experts have claimed that it is the "wonder fuel" and could play a major role in the race to net-zero emission by mid-century. However, hydrogen production technologies are nascent, expensive to implement and require further support from the public and private sectors for further implementation. At this CEO Roundtable, global experts, captains of Qatar's industry and esteemed guests examined the practical problems associated with using hydrogen as a fuel and the strategies that countries can adopt for hydrogen to play its part in the transition to low carbon fuel and low emission economies.

CEO WHITE PAPER

H.E. Abdullah bin Hamad Al-Attiyah created the Foundation as a platform for knowledge exchange and to support the global community in the quest towards a sustainable energy future.

The CEO Roundtable is an opportunity for CEOs, Foundation members and partners to meet in one room and examine pertinent energy and sustainable development topics.

The discussion focused on hydrogen's "Energy Trilemma," which is defined as the need to find balance between energy reliability, affordability, and sustainability and its impact on everyday lives.

SUMMARY OF KEY POINTS RAISED

- The balance between supply and demand for hydrogen is a dilemma that requires external intervention from governments, such as new policies and laws, tax incentives or subsidies.
- Hydrogen production technology for electrolysis or from natural gas is well established. It is generally a question of price.
- The production and transportation of ammonia is well established. The use of ammonia for power generation has been demonstrated to be feasible but is not currently undertaken.
- There could be opportunities for Gulf countries to produce 'green commodities' such as Liquified Natural Gas (LNG), fertilisers, steel, cement, and aluminium. However, demand for these products has yet to be established. Neither has it been established yet that a "green premium" exists!
- There are projects in development to use hydrogen in hubs. Moving high temperature industrial processes away from coal to hydrogen appears feasible. However, replacing grey hydrogen with blue in refineries will only increase prices of refined products.

CEO SPEAKERS

Moderator:

Nawied Jabarkhyl, Broadcaster and Director – Head of International Media Relations at APCO Worldwide

Speaker

David Hart, Partner, ERM: Environmental Resources Management

Speaker

Gagan Porwal, Head of International Market Partnerships – Carbon Solutions, GE Vernova

Speaker

Joe Seifert, CEO, Vertex Hydrogen Limited

Speaker

Mohannad T. Al-Suwaidan, Chief Middle East and Africa Analyst, ESAI Energy

At the start of the Roundtable, His Excellency Abdullah bin Hamad Al-Attiyah welcomed members and the guest speakers. H.E. expressed his pleasure at seeing many distinguished individuals and colleagues in attendance. H.E. remarked that the Roundtable was well timed as interest in hydrogen to reduce CO2 emissions is high.

Joe Seifert shared insights about his live hydrogen venture in the United Kingdom. Serving as the CEO of Vertex Hydrogen Limited, Mr Seifert said his company will produce blue hydrogen in Carrington, Manchester, forming a crucial component of a planned hydrogen hub in the area. This undertaking stands as one of the most sophisticated projects worldwide on a production scale and is set to generate an equivalent of 1 GW of hydrogen.
Additionally, there is contemplation of a smaller project geared towards producing 20 to 30 MW of green hydrogen.

Initially, the venture will cater to two nearby glass factories located in an industrial centre. The captured carbon dioxide will be stored in salt deposit reservoirs situated in Morecambe Bay. The elevated temperatures required for glass production render blue hydrogen as an optimal choice, and the easily recyclable nature of glass further bolsters the project's credentials for the "circular economy." Notably, the project enjoys funding from the UK government, mirroring the successful business model employed for the country's wind farm initiatives. Under this model, the actual half-hour price of grid electricity (referred to as the System Marginal Price or SMP) is closely monitored, and the discrepancy between the hydrogen production cost and the SMP is then calculated. This differential amount is then paid to the hydrogen producer (a so-called Contract for Difference). Under this model, the hydrogen off-taker suffers no penalty for using hydrogen.

Gagan Porwal is the Head of International Market Partnerships which forms part of the Carbon Solutions activity at GE Vernova. GE Vernova endeavours to "electrify the world while simultaneously working to help decarbonise it". He noted that about 40% of the world's carbon dioxide emissions derive from the power industry and that there are approximately 800 power plants active globally. He also observed that the power plants, and hence the emissions, are concentrated in specific areas so that projects to tackle emissions in such areas are highly feasible. GE has significant experience in the deployment of generation resources. Current experience with gas turbines (a GE product) is that hydrogen can be easily introduced into current gas turbines up to about 20%. The concentration of generation plants means that Carbon Capture could be more feasible than previously expected but grid reinforcement measures will be needed in all major industrialised nations.

He noted that significant policy measures, such as the Industrial Reduction Act (the IRA) in the US which is starting to make an enormous difference in investments for projects, are required from governments across the world.

Mohannad T. Al-Suwaidan is the Chief Middle East and Africa Analyst for ESAI Energy (Market Analysis, Forecasts & Consulting) and a Fellow of the Middle East Council on Global Affairs. He commented on the plethora of "hydrogen colours", noting that the debate and descriptions have deviated from the simple blue or green choice. Now the situation is much more complex and there is a need for more useful measures such as the "carbon density of the means of production". Through this method, the metric that measures what really matters - the amount of carbon produced- is described fully.

David Hart, the Managing Director of Energy Intelligent Solutions, spoke of new hydrogen developments and new exporting regions. Mr Hart touched on initiatives from Latin America, Africa, and the Middle East, highlighting Oman, Saudi Arabia, and the UAE as potential large-scale producers. However, he expressed concerns as to where these potential exports will be transported to, their intended use and carbon emissions. Mr Hart noted that the best ways forward have not been clearly identified for hydrogen projects. There are very likely to be geographically specific optimal solutions, he said. One technology which may come to the fore is methane pyrolysis. The end production waste of this process is solid carbon which is more easily and cheaply disposed of than carbon dioxide.

The floor was then opened to other participants at the Roundtable for comments, questions, and discussion. The following were some highlights from the session:

- Not every country has excess hydropower to use for hydrogen production. If other non-green electricity sources are used, then the carbon intensity will rise. If grid electricity is used to produce hydrogen, then how green the grid is will determine the carbon intensity of the hydrogen.
- Concerns remain over the transporting of hydrogen over long distances. Liquid hydrogen transportation by ship is expensive due to the very low temperatures required. Venting of liquid hydrogen to maintain these low temperatures by using the latent heat of evaporation (similarly process to that used by LNG shipping) is also dangerous.
- It was noted that long distance transportation by pipeline may be subject to leakages particularly with compression pumping stations (as is the case with natural gas). There are many advocates for hub solutions to avoid such problems (as is the case with Vertex Hydrogen in the UK). It was highlighted that town gas was distributed locally for decades in many urban areas to domestic users. Town gas was 60% hydrogen and about 35% methane, with some carbon monoxide (a toxic fossil fuel), making it an early example of hub distribution.
- Significant hydrogen developments are taking place in both Rotterdam, Huston, and Hull (in the UK). In these potential hubs, hydrogen would be used to provide hydrogen to refineries. This will help reduce the use of grey hydrogen and hence lower carbon dioxide emissions. However, this will only serve to increase the cost of refined products as it will presumably use grey methane from the same refineries to make blue hydrogen.
- Guests discussed how poorer nations would be able to use hydrogen, moving from cheap coal to more expensive fuels. This question will hopefully be addressed at COP28, it was noted.
- One critical challenge revolves around fostering the demand necessary to stimulate a corresponding increase in supply. Potential remedies, such as tax incentives, government aid, and carbon taxes, were deliberated as viable options.

- The utilisation of Ammonia as a hydrogen carrier underwent extensive discussion. This method boasts established efficiency in both production and transportation stages. Although the production costs associated with ammonia are relatively modest, the ultimate factor hinges on how ammonia is used. If it undergoes cracking back into hydrogen for specific purposes, additional expenses would be incurred. However, if it's directly employed in power generation, this cost would be avoided. Currently, China is conducting trials involving ammonia as a supplement to coal-fired electricity generation facilities, enhancing the calorific value of the fuel inputs.
- The discussion also delved into technological advancements and the potential attainment of economies of scale for electrolysers. Emphasis was placed on the fact that numerous components of electrolysers serve multiple functions, thus limiting the scope for achieving complete economies of scale. Nevertheless, it was observed that deploying electrolysers in extensive complexes proves notably more cost-effective per MW compared to smaller installations. Additionally, a noteworthy point was made regarding the substantial savings in economies of scale demonstrated by solar panels.

CONCLUSIONS

H.E. Abdullah bin Hamad Al-Attiyah provided a summary of the discussion, noting that hydrogen is a versatile energy carrier and with significant investment in the coming decades could help tackle various critical energy challenges. He also speculated that the Gulf region may become a major producer and exporter of hydrogen in addition to fossil fuels.

In closing, H.E. thanked members, speakers and guests for their attendance and contributions and said he is very much looking forward to the next CEO Roundtable that is scheduled for December 2023.

There are two distinct methods of producing hydrogen:

1). By electrolysis of water i.e., where water molecules are split into hydrogen and oxygen, capturing, and storing the hydrogen for use as fuel. This process was discovered by English chemist William Nicholson, (born 1753, London, England—died May 21, 1815). The problems of electrolysis are two-fold. The electricity must be "green" i.e., produced by a renewable source otherwise the use of hydrogen as a fuel is no longer "green". The second problem is that hydrogen must be produced "at scale" to make an effective contribution to the energy transition. The vessel in which water is electrolysised is known as an electrolyser. Scaling-up electrolysers is not easy or cheap. Production economies of scale may reduce the price of electrolysers, but this is yet to proven.

2). By chemically separating a hydrocarbon, usually methane, into its constituent parts namely hydrogen and carbon or a carbon containing compound using the steam-methane reforming process. In this process, high-temperature steam (700°C–1,000°C) is used to produce hydrogen from a methane source, such as natural gas. Methane reacts with steam under 3–25 bar pressure in the presence of a catalyst to produce hydrogen, carbon monoxide, and a relatively small amount of carbon dioxide. Steam reforming is endothermic - that is, heat must be supplied to the process for the reaction to proceed. Subsequently, in what is called the "water-gas shift reaction", the carbon monoxide and steam are reacted using a catalyst to produce carbon dioxide and more hydrogen.

In a final process step called "pressure-swing adsorption", carbon dioxide and other impurities are removed from the gas stream, leaving essentially pure hydrogen. Steam reforming can also be used to produce hydrogen from other fuels, such as ethanol, propane, or even gasoline. The problem is that for every molecule of hydrogen produced, one of carbon dioxide is also produced:

Steam-methane reforming reaction

$CH_4 + H_2O$ (+ heat) → $CO + 3H_2$

Water-gas shift reaction

$CO + H_2O \rightarrow CO_2 + H_2$

Consequently, to make the hydrogen "blue", Carbon Capture, Utilisation and Storage (CCUS) is required. This extra stage of hydrogen production adds to production costs.

Hydrogen as a source of fuel has a few significant questions to answer, as per the "Energy Trilemma".

For sustainability then the questions of "blue" or "green" come to the fore. Battery technology may become important as a storage medium to use "off peak" electricity in the same way as pumped storage hydropower is used. Indeed, all energy storage developments may become a rival to hydrogen.

Due to global events over the past couple of years, energy security is a recent trilemma concern. Here hydrogen appears to have an advantage. Though it must be pointed out that cargoes of all types out of the Middle East have hardly been disrupted since the end of World War II.

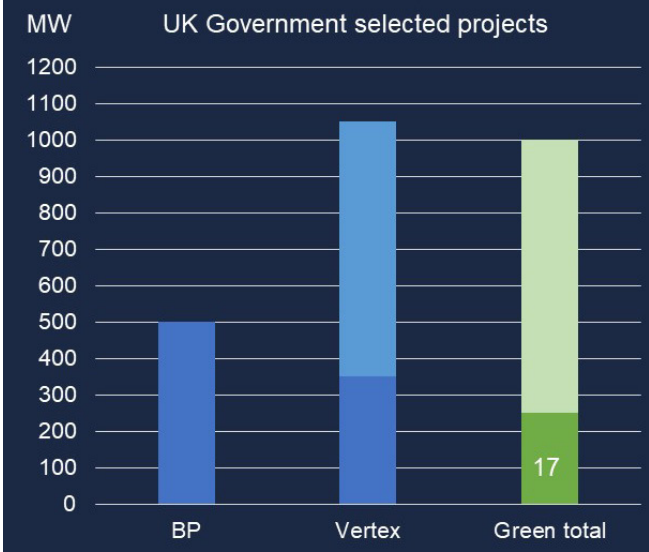
Affordability is another key issue. Both routes to hydrogen are expensive when delivered to export customers. Of course, grey hydrogen is produced extensively for use in refineries worldwide, so a part of the affordability problem is already solved. The use of hydrogen boils down to affordable exports or by close production in hubs coupled the use of suitable electricity.

Another key question is where can hydrogen be used at scale and if so, how can a market price be established? If hydrogen is to be used at scale, then there are two markets that must be tackled, including:

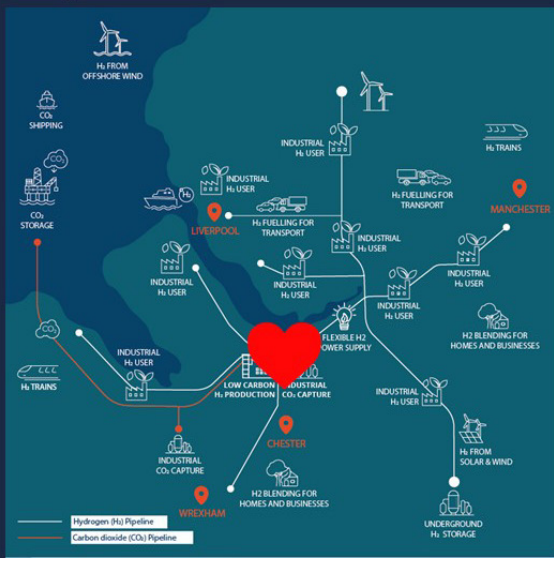
1). Main markets for natural gas i.e., electricity generation and space heating. In these markets technological developments are looking at the possibility of blending hydrogen into existing natural gas usage. Here the market size is such that even relatively small blends would establish a market for hydrogen.

2). There are some hard to decarbonise industrial processes where coal is used to generate high temperatures. Examples are iron and steel making and the production of cement. These again are large markets and technology solutions are being researched.

Vertex Hydrogen
The UK's leading hydrogen hub

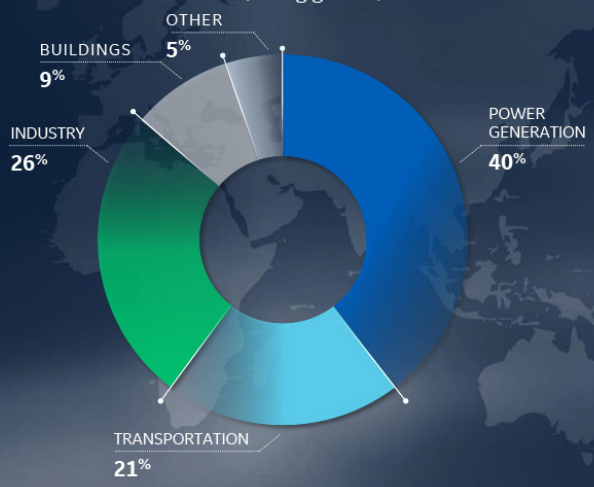


HyNet Cluster for Industrial Decarbonisation



The world today

Global CO_2 emissions
(34.2 gigatons)



Global electricity generation

27k TWh *of electricity*

770M people *w/out power*

13.5 *gigatons CO_2*

Decarbonization* of the power sector and electrification of **ENERGY-USE SECTORS** will have the most substantial impact on global carbon emissions

*Decarbonization as used herein is intended to mean the reduction of carbon emissions on a kilogram per megawatt hour basis | Source: IEA WEO 2021

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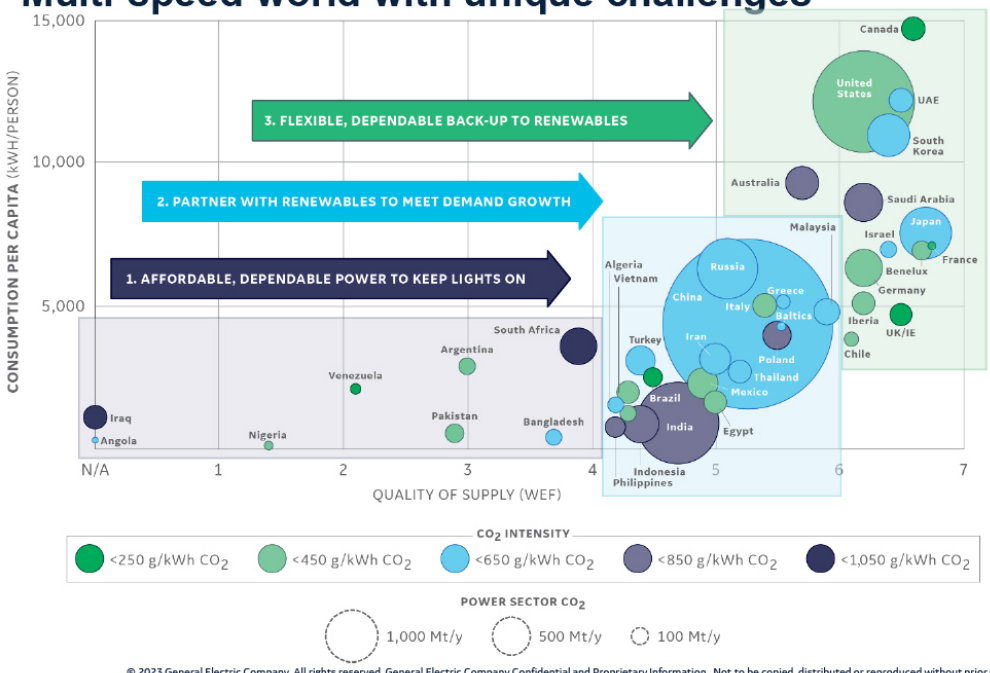
Multi-speed world with unique challenges

GE VERNOVA
Our portfolio of energy businesses



We provide uniq value to each segment... affordable, dependable, flexible, cleaner.. with pathways to decarbonize*

*Decarbonization as used herein is intended to mean the reduction of carbon emissions on a kilogram per megawatt hour basis. Source: World Economic Forum, Executive Opinion Survey; GE Global Power Outlook 202

3

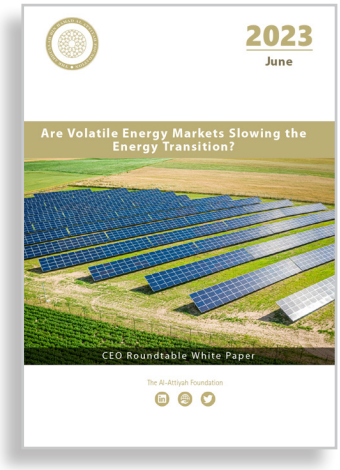
Decades of experience with hydrogen fuel

GE has more than 100 gas turbines with more than 8 million operating hours on fuels containing Hydrogen

4


GE VERNOVA

Do you want to keep up-to-date with the latest developments in energy? All past issues of the Al-Attiyah Foundation's Research Series, both Energy and Sustainability, can be found on the Foundation's website at www.abhafoundation.org/publications



June – 2023

Are Volatile Energy Markets Slowing the Energy Transition?

Various institutions within governments, academia, research institutions and the private sector are addressing the need for mitigating actions to either abate or counteract the effects of climate change. However, it is often observed that the prices of fossil fuels are volatile.

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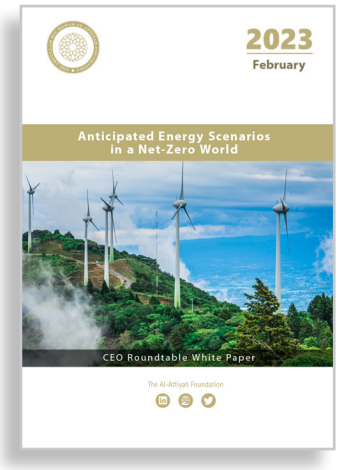

February – 2023

Anticipated Energy Scenarios in a Net-Zero World

Institutions within academia, research organisations, the private sector, and the energy industry have developed energy scenarios. While these organisations have different methodologies and varying assumptions, most of their scenarios are not optimistic about the world meeting targets set by the Paris Agreement.

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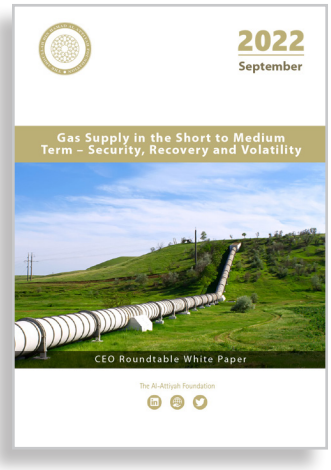

September – 2022

Gas Supply in the Short to Medium Term – Security, Recovery and Volatility

One may be forgiven for believing that the recent spike in gas prices and shortening supply are unheralded. However, some facets of the current situation could have been forecast with a quick analysis of trends from the previous decade.

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Our partners collaborate with the Al-Attiyah Foundation on various projects and research within the themes of energy and sustainable development.

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National Council on U.S.-Arab Relations

Gulf Times

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The Al-Attiyah Foundation

Tel: +(974) 4042 8000,
Fax: +(974) 4042 8099
www.abhafoundation.org

Barzan Tower, 4th Floor,
West Bay.
PO Box 1916 Doha, Qatar

AlAttiyahFndn
The Al-Attiyah Foundation
Al-Attiyah Foundation