ENABLING BUSINESS FOR THE ENERGY SECTOR

SPECIAL EDITION

Energy OMAN

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NEW ONE-STOP NET ZERO THINK-TANK FOR OMAN

The Oman Sustainability Centre has a comprehensive mandate to formulate strategies, policies and regulations in support of the nation's carbon emission reduction goals.

OMAN'S ENERGY TRANSITION PATHWAY

CCUS and Clean Hydrogen will ensure that Oman's current advantage as a competitive energy producer and exporter can be safeguarded.

SPEARHEADING OMAN'S GREEN HYDROGEN PUSH

OMAN'S HISTORIC AND BURGEONING GREEN HYDROGEN QUEST IS WELL AND TRULY OFF THE STARTING BLOCKS UNDER THE AUSPICES OF HYDROM, THE ORCHESTRATOR OF THIS NEW LOW-CARBON INDUSTRY.

GREEN HYDROGEN SUMMIT OMAN 2022

Three-day conference and exhibition foregrounding the Sultanate's increasingly promising role in the decarbonisation of global economies.

POWERING A THRIVING FUTURE

TAQA'S PURPOSE, VISION AND MISSION ARE ROOTED IN OUR AMBITION TO BE LEADERS IN THE ENERGY TRANSITION AND A CHAMPION OF LOW CARBON POWER AND WATER IN ABU DHABI AND BEYOND:

- A Global Clean Energy and Water Powerhouse
- Deep Commitment to Decarbonization and Growth

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ENABLING BUSINESS FOR THE ENERGY SECTOR
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Chairman's Message

Dear Readers,

Oman is on the cusp of transformational change. Landmark decisions adopted by the Omani government in recent months are set to steer the nation firmly on the path to decarbonization, culminating in the achievement of carbon neutrality by 2050. These are pathbreaking steps for a country that has relied majorly on hydrocarbons for its economic development for over half a century.

But as affirmed by HE Salim bin Nasser Al Aufi, Minister of Energy and Minerals, during a recent TV interview, the pivot to planet-friendly green energy, particularly hydrogen, will be gradual. This is aimed at averting potential energy shocks, as well as secure the needs of energy-deficient economies that lack the wherewithal to plug into the emerging green hydrogen ecosystem.

Birba Energy is proud to be associated with this promising new low-carbon economy that awaits the nation in the coming years and decades. The Green Hydrogen Summit Oman 2022 conference and exhibition, organised by Birba with the support of the Ministry of Energy and Minerals, serves as a powerful platform to foster the growth of the hydrogen ecosystem in Oman interconnected with the nascent global network.

Building on the success of the GHSO brand, Birba is now preparing to launch a series of similar events across the Middle East to strengthen networking across the clean energy industry. The underlying goal is to put Oman front and centre of this industry in the region with the continuing support of the growing number of energy sector stakeholders that have backed our efforts over the past two years. This edition of Energy Oman features many of these patrons who have allied with us in positioning Oman strongly for the future.

Abdullah Al Harthy

BIRBA ENERGY PRESENTS

GREEN HYDROGEN SUMMIT MEA

CONFERENCE - MIDDLE EAST & AFRICA

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Spearheading Oman's green hydrogen push

Speaking to Energy Oman, Dr. Firas Al-Abduwani, Acting Managing Director of Hydrom, provides exclusive insights into the Sultanate's strategy to jumpstart the growth of a nascent green hydrogen industry based on a unique and globally path-breaking regulatory model.

Oman's historic and burgeoning green hydrogen quest is well and truly off the starting blocks.

Since the start of the Round 1 auction process on 6th November 2022, registrations for qualification for the first two green hydrogen blocks in Duqm have been streaming in from prospective bidders from around the world.

Hydrogen Oman LLC (Hydrom), the state-owned company assigned the role of orchestrating the growth and development of the Sultanate's green hydrogen industry, has confirmed that the initial results from the competitive bidding process have been heartening.

"The public auctions are progressing quite well," said Dr. Firas Al-Abduwani, Acting Managing Director – Hydrom. "So far (17th November 2022), we have had more than 160

registered parties expressing interest, of which around 30 are renowned bidders. Looking at these figures and where we are in the auction process we have a healthy number to kick off this round."

Up for grabs in this round – one of two that constitute Phase A of the public auctions programme – is a pair of blocks, each of around 320 sq kilometres, in Duqm, not far from a massive Special Economic Zone (SEZ) in Oman's Al Wusta Governorate. Awards for these blocks are due to be announced in March 2023.

Oman has earmarked, in all, a total of around 50,000 square kilometres of land, distributed across the country, for green hydrogen projects over the long term. Delineated at this stage into blocks of 320 sq kilometers each, these plots will be awarded to successful bidders against 47-year project and land agreements.

Significantly, investor interest in the Round 1 auctions has been geographically widespread, says Dr Al-Abduwani. "It's from across the board, and they include the usual suspects – those we expected and are pleased to see participate. We have participants coming from five geographical regions - Europe, Southeast Asia, India, the GCC and the United States."

The competitive auctioning process itself is subject to a "compressed timeline" – in part to harness a groundswell of investor interest in Oman's green hydrogen industry, but also to position the Sultanate among the global frontrunners in this emerging sector.

Explaining the accelerated timeline underpinning this competitive process, Dr. Al-Abduwani said: "Bidders in the first round will be running on a very compressed and aggressive timeline to prepare and submit their bids by the set deadline.

A process that would typically take around 10 months, end-to-end, is being conducted in a five-month period through to March 2023, more or less. Yes, there is pressure on both sides – on the side of Hydrom as the auctioneer, and on the bidders' side. Nonetheless all involved so far have been taking it in a very positive and optimistic spirit."

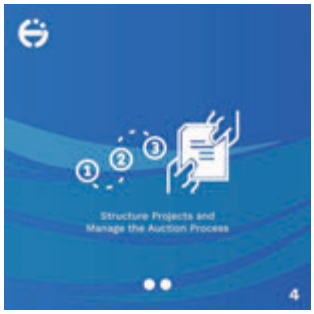
Based on this timeline, interested bidders have roughly five months – spanning the November – March period for Round 1 – to submit their qualifications as well as their final proposals. No cutoff is stipulated for the submission of qualifications, but any delay would essentially eat into the allotted time for submission of final proposals – part of a rolling process designed to give a degree of flexibility to the bidders, Firas points out.

Proposals received for the acreage on offer will be evaluated against different criteria, such as project concept and feasibility, financial viability or bidders' credentials.

As the evaluation of offers for Round 1 (Phase A) of the auction programme progresses, Round 2 – covering two to four blocks located in Dhofar Governorate – is being primed to go live for auction in April 2023. Awards are expected before the end of 2023.

Project-sized blocks

Importantly, each block of around 320 sq kilometres is large enough to accommodate a full-fledged project with a capacity to produce around 150,000 to 180,000 metric tonnes per annum of green hydrogen or roughly 1 million metric tonnes per annum of green ammonia in case that is the proposed derivatives over its operational life. This includes the upstream (renewable



energy in the form of solar and wind farms), midstream (electrolyzer capacity) and downstream components (conversion of hydrogen into other green molecules). The choice of end-product – whether green hydrogen or its derivatives in the form of green ammonia, methanol, synthetic fuels or even green steel as an example of a hard-to-abate heavy industry – remains at the discretion of the developers.

Eligible to bid are either individual companies with demonstrable capabilities to deliver an end-to-end hydrogen project or a consortium of companies led by a primary lead member. In terms of the equity distribution in a consortium, a certain minimum threshold is specified for primary members, and a lower threshold for secondary members.

"We want to ensure we have the right mix of companies with firm commitments as members of a given consortium. We've designed the qualification criteria to deter "develop and flip" participants. We are at a stage where we seek serious bidders who will carry their proposals on award forward into construction and then into operation."

While acknowledging that auctioning timelines are somewhat accelerated when compared with sector norms, the official conveys that the compressed timeframe is partly in response to burgeoning interest among international investors to explore green hydrogen project opportunities in Oman.

"There are nations that are ahead of us in the project and sector development cycle. Nonetheless Oman is well positioned to be a market leader. Oman began its green hydrogen journey quite early on – in 2019. What Oman lacked back then is a central party to receive the international developers who had been knocking on our doors. With the launch of Hydrom in October, the government provided this nascent industry a systematic approach to grow. We are confident that the developers who have been seeking entry into Oman will now find a simpler and cleaner process. Those who invested early on exploring Oman for green hydrogen will find that Round 1 delivery timelines are achievable."

For Hydrom, the accelerated timelines also represent an opportunity to demonstrate to the stakeholders, and the private sector in particular, that it can help achieve Oman's vision to ignite the growth of a new industry around green hydrogen – a sector that will power the nation's energy transition as well as its future economic growth. A sizable proportion of this new industry's output will also help fuel the decarbonisation goals of importing countries.

Delivery milestones

Come April 2023, the first two successful bidders are expected to hit the ground running with their development plans once the awards for Round 1 are announced. Actual

implementation is envisioned in three distinct phases, encompassing Development, Construction and Production, according to Dr Al-Abduwani.

"During the development phase, spanning roughly three and a half years, the successful developer will start working on assessing the area's solar and wind resources, embarking on their feasibility study, assessing permitting and bankability requirements and so on. We have some clear milestones that we expect them to achieve during this period. And one of the key deliverables of Hydrom is to make sure that the timelines are transparently visible to all stakeholders – government and international. Incentives have been incorporated into the process to encourage developers to move through the

phases on to production."

To incentivize the expeditious delivery of the development and construction phases, Hydrom has slashed land fees for the allocated block to just 20% of the stipulated levy during the development phase. The fee is completely waived during the construction phase, ensuring sizable savings for the developer.

With a total of around seven years allotted for the development and construction phases, the first output of green hydrogen or its derivatives from the Round 1 blocks in Duqm is anticipated in 2030. And as successive blocks are awarded and developed, production is projected to rise to between 3.25-3.75 million tonnes per year in 2040 before climbing to a peak of 7.5-8.5 million tonnes per year by 2050.

As for the decision to carve up blocks of 320 sq kilometres apiece, the rationale is simple, says the official. "Blocks based on this size help the project company achieve the economies of scale necessary to be commercially successfully. We're talking about investments of anywhere between $3– 5 billion to achieve the full potential of a block. These are sizable investments that are suitable for a certain category of players."

Furthermore, the blocks have been delineated to allow for common infrastructure. Corridors have been earmarked between the blocks for the construction of common infrastructure, such as hydrogen and water pipelines, and electricity overhead lines, he said.

Dr Al-Abduwani shared that project developers have expressed their eagerness to expand beyond the initial blocks they are bidding for. As a baseline Hydrom is designing the blocks to be suitable for expansion of existing blocks or as new standalone blocks. At this stage Hydrom is considering that new expansions would proceed through the ascribed auction process.

"We believe the existing developers will intrinsically have some advantage when they bid for new blocks, as they can put forward projects that can tie into their existing ones. Of course, there's also the prospect that newcomers will come with substantially new and attractive project proposals as well. We have designed the blocks in a way that projects can be expanded or awarded as standalone. One thing we have designed the process to avoid is for parties to come in and take huge blocks of land and sit on it for unacceptably long periods."

Going forward, however, Hydrom sees the potential for establishing larger blocks of around 1,000 sq km for cluster size projects. These options are being weighed in undeveloped parts of the country and could be offered up for public auction only when they have the basic infrastructure in place.

Hydrogen Aggregator

Hydrom's role as orchestrator and aggregator of Oman's new hydrogen industry is set to be unique in the region and perhaps globally as well. Its mandate encompasses market supply and demand assessment, proposing Oman's green hydrogen phasing, delineating lands, setting up the auction process, running it and awarding lands, orchestrating common infrastructure, oversight of the execution of awarded projects, ensuring in country value maximization, and being the data repository of the sector.

While broad-based, Hydrom's mandate does not include investment or development of hydrogen projects, according to Dr Al-Abduwani. "We will not be participating with any equity in these projects."

For now, however, Hydrom's immediate task is to facilitate investment inflows into

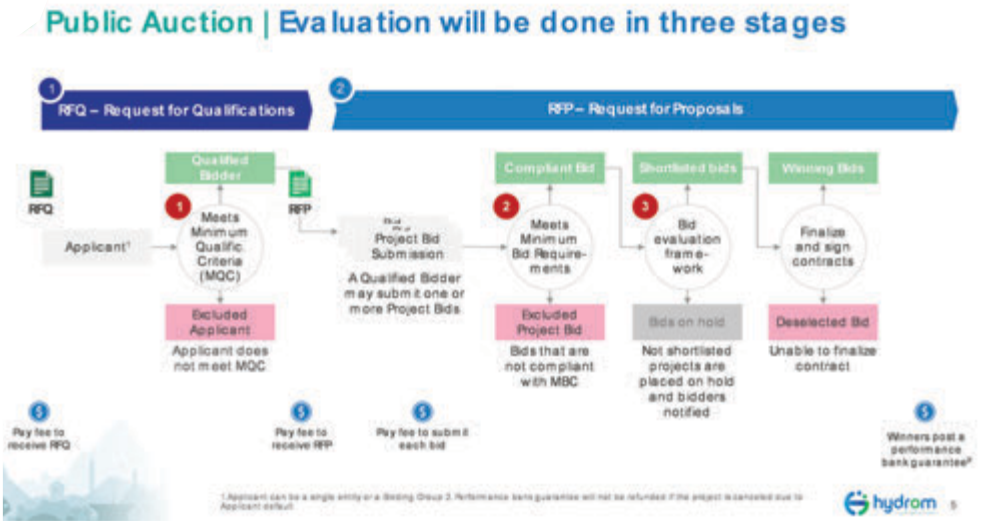
Oman's green energy industry, and enable successful bidders to develop their projects in a timely manner. But going forward, the state-owned entity could also play possible roles, for example, in the local distribution of hydrogen – green or blue – on behalf of producers. Further, a possible role for the company in the financing, development and operation of the common infrastructure is yet to be assessed. Any such decision, however, has to be balanced against Hydrom's primary role as a neutral industry orchestrator, says Firas.

National Champion

But one state-owned company that is set to have an equity presence in most, if not all of, the hydrogen projects planned for development over the foreseeable future is OQ Alternative Energy – part of OQ Group. As the government's designated 'national champion', OQ Alternative Energy is entitled to a minimum 20% equity stake representing the government's back-in rights in all new hydrogen projects when they come into operation.

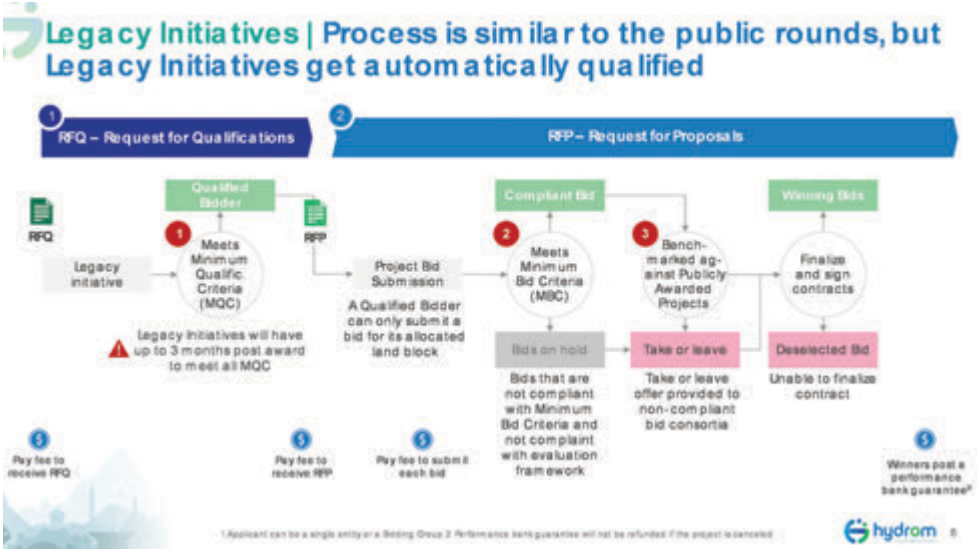
OQ, says Dr Al-Abduwani, is uniquely placed to assume the role of 'National Champion' on behalf of the government. "Today, OQ has a lot of operating experience upstream and downstream of a project, as well as in the operation of gas networks. It also has a stake in a large renewable energy project and is Oman's designated renewable energy champion. The company has very strong teams focused on clean energy, green molecules, decarbonization and energy efficiency. In addition to these elements, they also have asset ownership, and operations and maintenance experience, particularly with regard to the gas networks. From our perspective, OQ ticks most of the boxes as the national champion."

- Conrad Prabhu

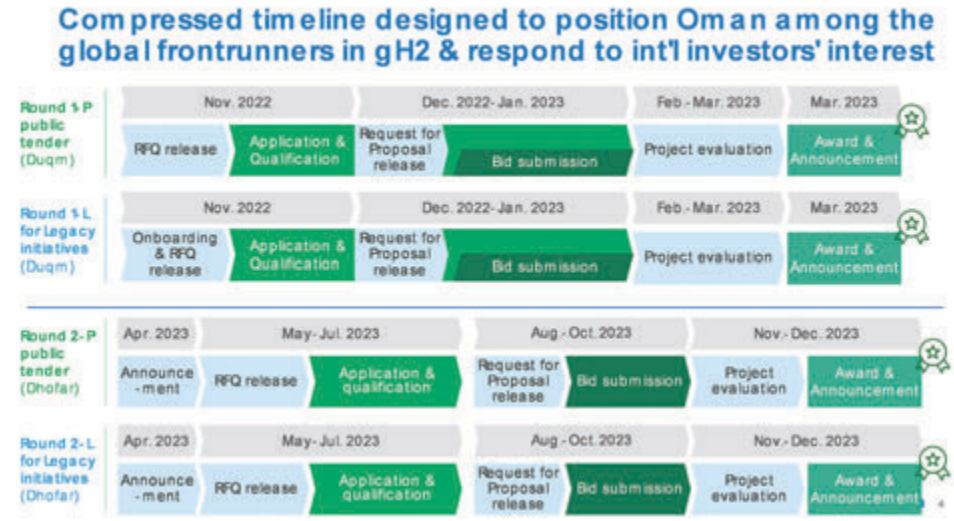


Legacy Initiatives

As for the so-called 'legacy initiatives – the roughly six-odd green hydrogen projects that were announced before the launch of Hydrom on 23rd October 2022 – they will be mapped against the qualification criteria set out by the government for the development of hydrogen ventures in Oman. The processes adopted for public auctions and legacy first dibs running in parallel are presented below respectively:



According to Hydrom, the respective consortia comprising legacy initiatives will be given an opportunity to rejig their ventures and bring them into alignment with the new regulatory regime for the hydrogen sector unveiled in October, and to bid for the plots they have been given first dibs opportunity to. ■



New one-stop Net Zero think-tank for Oman

The Oman Sustainability Centre has a comprehensive mandate to formulate strategies, policies and regulations in support of the nation's carbon emission reduction goals.

HE Salim bin Nasser Al Aufi, Minister of Energy and Minerals

The newly established Oman Sustainability Center, set up in accordance with the Royal directives of His Majesty Sultan Haitham bin Tarik, has been tasked with spearheading the delivery of the Sultanate's Net Zero strategy. The centerpiece of that strategy is a solemn commitment by the Omani government to achieve carbon neutrality by 2050 – a target that also aligns with that of the majority of advanced economies.

According to Eng. Faiza al Harthi, Head of Energy, Environment and Natural Resources Priority Support at Oman Vision 2040 Implementation Follow-up Unit, the new facility will serve as a hub of the following four centres: (1) Think-tank, Advisory and Follow-up Support Centre (2) Business Environment Centre (3) Centre for Technological Advancement, Innovation & Scientific Research, and (4) Net Zero Socioeconomic Centre. In delivering its mandate, the Center will be supported by the Ministry of Energy and Minerals, Oman Vision 2040 Implementation Follow-up Unit, Environment Authority and the Civil Aviation Authority (CAA).

"Its primary task is to ensure the implementation of the Net Zero national plan in line with the follow-up methodology to achieve the objectives of Oman Vision 2040," said Eng. Faiza. "I will also facilitate the obtainment of the necessary approvals from the relevant decision-makers to achieve the targeted goals in a timely manner," she stated.

In its role as a Net Zero think-tank, the centre will formulate strategies, policies and regulations in support of Oman's carbon emission reduction goals. Besides

providing technical and advisory services, it will monitor progress in the reduction of greenhouse-gas emissions (GHG).

Further, in its role as a Business Environment Centre, the new entity will support the development of sustainable finance and circular economy programmes. Also as part of its remit, it will ensure infrastructure readiness for investment.

Importantly, innovation and scientific research will be a key objective of Oman Sustainability Centre. Towards this end, the centre will make recommendations on the financing of research and development activities, while also enhancing and accelerating scientific research and innovation. Additionally, it will support the initiation of demo projects for energy transition technologies.

Finally, as a Net Zero Socioeconomic Centre, it will conduct awareness and educational programmes in support of rationalized energy consumption and sustainability. It will also support local content development and capacity building within this emerging sector, she added.

Carbon Management Lab

The idea behind a one-stop nodal agency to drive Oman's carbon neutrality strategy has its origins in the Carbon Management Lab – a three-week-long brainstorming session attended by dozens of veterans from a cross-section of sectors with a stake in the decarbonization of the Omani economy. As with all such labs held in recent years, the Carbon Management Lab was organized by the influential Oman Vision 2040 Implementation Follow-up Unit in collaboration with the Ministry of Energy and Minerals.

The Lab identified the most important projects that will contribute in reducing greenhouse gas emissions and promote renewable energy sources (solar, wind, green hydrogen). It also put the focus on tapping biofuels, recycling waste, and improving energy efficiency of the electricity supply chain from production to transmission to distribution and consumption.

In the oil and gas sector, emphasis was on enhancing the efficiency of production and use of gas, reducing the routine combustion of natural gas, green testing of gas wells, reducing diesel use, sequestration of carbon and emissions control. As for the industrial sector projects, the aim is to optimally use energy consumption, electrification of processes, deployment of renewable energy and hydrogen, emission control, waste recycling and promoting circular economy.

A statement issued by the Lab upon its conclusion warned that inaction on global warming and climate change would exact a heavy toll on the Omani economy and society as a whole. It alluded to the disastrous extreme weather events that have occurred over the previous decade in Oman.

Carbon neutrality and climate change are the most important components of Oman Vision 2040, it stressed. Industry, urban planning, energy, transportation, agriculture and health sectors have factored in these components in their strategies. It aims to achieve economic growth by sustainable use of natural resources and mitigate impact of climate change.

Achieving carbon neutrality will contribute to diversifying sources of income, creating opportunities for sustainable economic and social growth, reducing the repercussions of climate change, building a knowledge economy, benefiting from clean technology and creating a diversified mix of energy sources.

Carbon neutrality pledge

At the 27th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP27) 2022, HE Eng Salem bin Nasser Al Aufi, Minister of Energy and Minerals, affirmed the Sultanate's commitment to the decarbonisation of the economy in line with the goals enshrined in the Paris Accords.

Oman's participation in COP27, he said, stems from its conviction in the significance of endorsing coordinated measures in partnership with the world to reduce global warming to levels below 2 degrees Celsius, namely the endorsement of the Paris Agreement by 196 countries, which

Eng. Faiza al Harthi, Head of Energy, Environment and Natural Resources Priority Support at Oman Vision 2040 Implementation Follow-up Unit

> **"The idea behind a one-stop nodal agency to drive Oman's carbon neutrality strategy has its origins in the Carbon Management Lab – a three-week-long brainstorming session attended by dozens of veterans from a cross-section of sectors with a stake in the decarbonization of the Omani economy."**

became effective 4 November 2016 at a time the world is set to reach the peak of global greenhouse gas emissions.

He added that the pact also aims to achieve a climate-emission-neutral world by mid-century, as various countries have pledged to provide nationally-determined contributions in order to ensure energy transition and mitigated emissions.

HE Al Aufi outlined steps adopted by Oman towards cutting down carbon emissions, including its solemn declaration to achieve carbon neutrality in 2050.

Overseeing this effort will be the Oman Sustainability Centre which is mandated to formulate a national strategy for an orderly transition to carbon neutrality. This strategy will complement the existing National Environmental Policy for Energy, he said.

The Minster also shed light on the start of the pre-qualification phase for investors wishing to participate in the first round of green hydrogen projects via an online platform launched by Hydrogen Oman (Hydrom) – the new state-owned orchestrator of this future industry.

Alongside its pledge to transition away from fossil fuels, Oman is also working to promote local value-added policies, localise industries related to the renewable energy and hydrogen sector, enable strategic studies, research and development and to enhance community awareness of clean energy. ■

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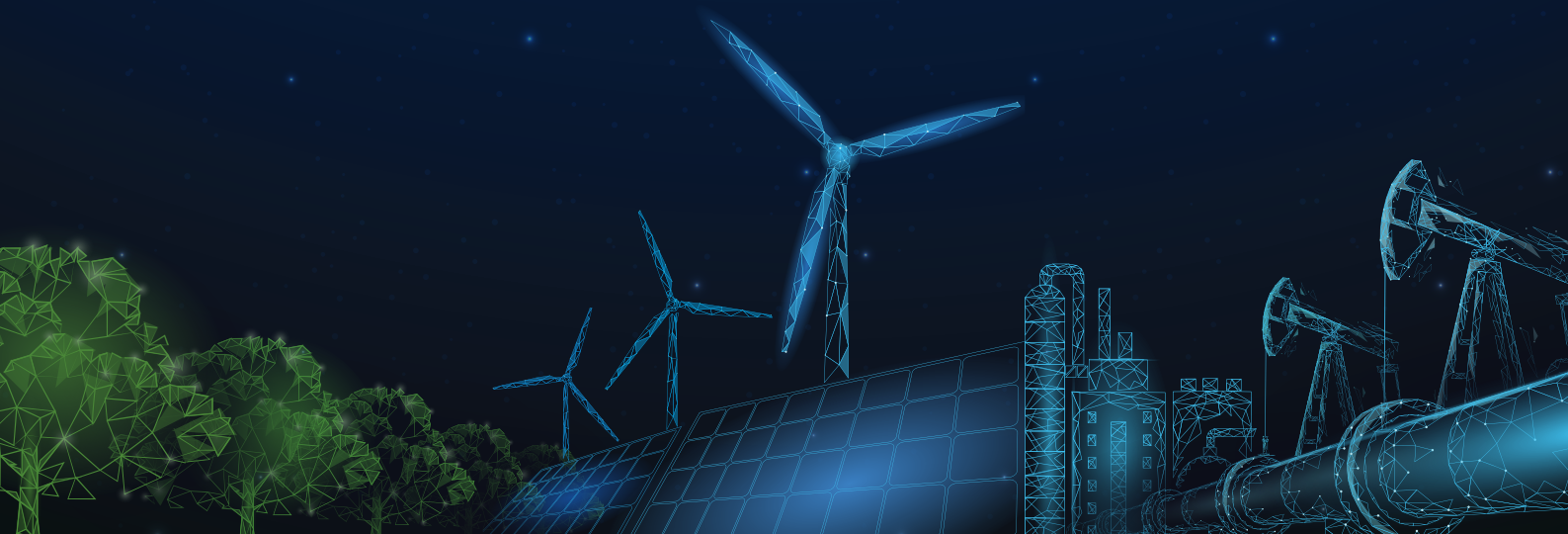
Petroleum Development Oman

WORKING TOWARDS SUSTAINABLE DEVELOPMENT



The global energy crisis may be accelerating decarbonisation efforts

The executive director of the IEA believes Russia's war in Ukraine has created new incentives to go green

Russia's invasion of Ukraine has changed energy markets and policies around the world, not just for the time being, but for decades to come. The energy crisis set off by Moscow's war is giving a short-term lift to fossil fuels in some cases. More coal has been burned in Europe, for example, because natural-gas prices have been extremely high. But I think this lift is likely to be temporary. The crisis is also driving powerful structural changes that are set to accelerate the transition to clean energy. These promise to be positive for our climate and for our energy systems in the long run.

Our data at the International Energy Agency (IEA), where I am executive director, suggest that many governments are responding to the economically damaging spikes in fossil-fuel prices by doubling down on clean-energy technologies. America's Inflation Reduction Act, the EU's Fit for 55 package and rePowereu plan, Japan's Green Transformation programme and ambitious clean-energy targets in China and India are all helping. Consider America's legislation. It should drive a decline in carbon-dioxide emissions from the country's electricity sector this decade by using tax credits to boost the deployment of solar and wind power. At the same time it is supporting research and development into batteries and extending the lives of nuclear plants.

The latest analysis from the IEA shows that governments' policies are now strong enough to deliver a distinct peak in fossil-fuel use within ten years. Fossil fuels have made up 80% of the global energy mix for decades. We see their share falling to 60% by 2050. Given that fossil-fuel use has grown alongside global GDP since the start of the Industrial Revolution in the 18th century, reversing this rise will be a pivotal moment in energy history. Yet the expected decline in fossil fuels brought about by current policies, and in associated greenhouse-gas emissions, will come too slowly to avoid severe impacts from climate change.

I am confident that governments will continue to strengthen their clean-energy policies, however, because they are no longer driven primarily by environmental concerns. The economic arguments in favour of affordable clean technologies are increasingly compelling. Solar and wind are the cheapest options for new power facilities in most parts of the world, even without taking into account the exceptionally high prices seen in 2022 for coal and gas. And countries also need to ensure their domestic clean-energy industries can compete internationally.

Security concerns are also increasingly driving the transition to clean energy. Russia's invasion of Ukraine and subsequent use of its gas supplies to pressure Europe

show the risks of relying heavily on fossil-fuel imports. Clean and energy-efficient technologies such as wind, solar, electric vehicles and heat pumps enable countries to produce more energy domestically and reduce the need for fuel imports. And we're seeing governments, notably in Europe, acting to accelerate their adoption. New energy-security risks are emerging alongside. Countries need ample, diverse supplies of critical minerals and of manufacturing supply-chains for technologies such as solar panels and electric-vehicle batteries.

Despite my overall optimism about the direction in which we are headed, there is one area that causes me significant concern. Amid the current geopolitical upheaval, I see a real risk of fractures emerging around energy and climate between some advanced and developing economies, which could lead to damaging dividing lines globally.

Take infrastructure. Emerging and developing economies often face much higher financing costs for clean-energy projects than developed economies do. For example, the cost of capital for a solar power plant in 2021 in key emerging economies, such as in Brazil or Indonesia, was between two and three times higher than in advanced economies. And this gap is in danger of increasing as central banks around the world tighten interest rates, increasing the cost of borrowing.

To prevent these divisions from becoming entrenched, the world's leading economies need to work hard to tackle their causes. First, they need to ensure that Russia's role in triggering today's energy crisis is well understood by everyone. There is a false narrative circulating that clean energy and climate policies are to blame for it. But IEA analysis finds scant evidence for this misleading claim, which only serves to draw attention away from Russia's responsibility.

Second, the rich world needs to do much more to enable emerging and developing economies, particularly those in Africa, to massively scale up clean-energy technologies. We need to take an empathetic and morally coherent view on transforming energy systems and boosting economic growth in the places that need it most. Just

Energy Transition Partnerships, such as the one currently being negotiated between the rich democracies of the G7 and Indonesia, are a way forward. They offer a chance for co-operation on both policy and investment.

Third, rich countries should immediately fulfil the promises made to poorer ones on climate finance. At the COP15 conference in Copenhagen in 2009, they pledged to raise $100bn a year by 2020 to help developing ones adapt to climate change. It is shocking that this promise has still not been met. But we also need to go well beyond that level now to fill the huge clean-energy investment gap between the haves and the have-nots.

The COP27 UN climate conference in Egypt is an important opportunity. But if leading economies do not build bridges with developing economies, or if they take an overly prescriptive approach, they run the risk of widening divisions. Countries everywhere are facing brutal shocks from the energy crisis. The last thing we should do is turn away from supporting each other. Advanced economies have the means and the moral duty to act.

Fatih Birol is the executive director of the International Energy Agency.

[This article appeared in the By Invitation section of the print edition of The Economist]

Oman Shell: Powering Oman's Net-Zero Transition Goal

With a comprehensive sustainability agenda and a strong energy transition strategy as well as a committed target of net-zero emissions by 2050 in line with the society, Oman Shell's sustainable business is leading the energy transition journey and engagements on renewables with relevant stakeholders.

As the world progresses boldly towards the larger goal of making energy more sustainable, available, affordable, and cleaner, local companies are altering their business narratives to fit the title. His Majesty Sultan Haitham bin Tarik in a recent meeting of the Council of Ministers at Al Barakah Palace reviewed domestic, regional, and international developments to this effect. As part of Royal attention to improve environmental performance and alleviate the impact of climate change, the year 2050 has been set as a date for net zero carbon emissions in the

Sultanate of Oman. A national plan has been drafted to achieve this goal, along with the setting up of Oman Sustainability Centre to undertake the supervision and follow up of zero carbon emission plans and initiatives.

In line with Oman's Net Zero objective, Oman Shell is setting a strong example in the country, steering its developmental axis towards the target of net zero emissions by 2050.

With local authorities incorporating sustainability measures into policies and plans of national interest, the responsibility is on every sector, most importantly energy, to develop and execute strategies that have the interests of the nation, the region, and the world at large. On its part, Oman Shell has and continues to be an active player in the country's energy spectrum. It is working towards delivering more renewable and low-carbon energy options for customers through investments in wind, solar, electric vehicle charging, and hydrogen.

Sustainability at Shell

At Shell, the values of sustainability span through all of its business operations. While the need to provide essential energy to power homes and fuel transport for an ever-growing population with a rising standard of living is essential, Shell strives to meet this demand by deriving energy from lower-carbon sources through constant innovation and advancement in technology. Processes and procedures are devised to minimise adverse environmental and social impacts while respecting the interest and safety of the communities.

Shell's three-layered approach to sustainability begins with a keen focus on safety, efficiency, and responsibility as the three fundamental pillars to run an ethical and profitable business. The organisation adheres to the highest global standards of environmental consciousness and community involvement as well as ethics and compliance. With its operations being planned for the long run, Shell believes that it is imperative to play a role as responsible members of the community. This is done by contributing to the development of local economies whether it is by creating jobs, sourcing from local suppliers, or paying taxes and royalties. Home-grown projects that provide sustainable benefits to the local communities and are in alignment with Shell's line of business are duly encouraged.

By focusing on cleaner energy sources, reducing emissions, and increasing energy efficiency, Oman Shell will continue to advocate the importance of creating a more sustainable energy future.

Energy Transition and Decarbonization

The challenge of transitioning to a low-carbon energy future to combat climate change risks, while meeting the growing demand for energy and extending access to life-changing, reliable energy to everyone on the planet is daunting. The onus is on how oil and gas companies operate their businesses to meet the target, which is why Oman Shell has accelerated its transition drive and leveraged its decarbonisation program to become a partner of choice for electric mobility in Oman. A case in point is the Memorandum of Understanding with Oman Airports Management Company signed earlier this year, to provide 15 hydrogen cars for the Oman Airports' corporate usage, which will entail development of hydrogen production units that will be powered by photovoltaic solar plants, installed at fuelling units related to the project. This is commensurate with Oman's concerted efforts to build a hydrogen-centric economy, with an annual production of green and blue hydrogen of around 30GW by 2040. On the anvil are several green hydrogen projects, including a 14GW facility powered by 25GW of wind and solar energy.

Government regulations, rightly, play a vital role in accelerating energy transition, as set out in Oman's Vision 2040, explicitly addressing the need to move beyond hydrocarbons and decarbonise the energy sector. This plan resonates with the global shift to cleaner energy solutions to power the world, while significantly reducing carbon emissions. Shell's global experience, technological capability, operational experience and market expertise has enabled it to be at the leading edge of this transition and meet its customers' evolving energy needs.

Today, customers are seeking bolder paths towards decarbonisation through innovative, cleaner and reliable energy solutions to drive

> **Today, customers are seeking bolder paths towards decarbonisation through innovative, cleaner and reliable energy solutions to drive their growth and achieve their sustainability goals.**

their growth and achieve their sustainability goals. Shell is committed to helping them navigate the complex energy environment by designing innovative energy solutions for their businesses. It is developing and investing in new technologies to decarbonise its energy system.

The future of mobility in Oman is about creating diverse choices that increase customer convenience. As a leading player committed to contribute to the energy transition journey and support Oman's Carbon Control Target Plan, Oman Shell is working with its partners and key stakeholders to create innovative mobility solutions with enhanced efficiency. This will directly contribute to the country's sustainability goals and help the company drive towards a lower-carbon future.

Carbon Neutral Lubricants

Of particular significance to this goal is its recent introduction of a range of carbon neutral lubricants across its Helix Ultra brand (0W viscosity grade) for passenger cars. Shell has announced that its recently launched portfolio of carbon neutral lubricants is now available for customers in Oman.

As per the set target, the global lubricant company expects to offset annual emissions of more than 200 million litres of advanced synthetic lubricants, thereby compensating around 700,000 tonnes of carbon dioxide equivalent emissions per year - which is comparable to taking as many as 340,000 cars off the road, for one year. This goal of global significance will have Shell Lubricants play a critical role in not just supporting the company's larger objective of net-zero emissions, but also aiding customers in doing their part to reduce carbon footprints.

Oman Shell owns and operates Oman's only ISO certified lubricants blending plant, which generates in-country value by producing made-in-Oman Shell lubricants. These lubricants not only meet the local demand, but they are also exported to countries in the Middle East, South Asia and Africa. Besides, as part of its ICV and HSSE framework, it had previously moved its base-oil storage facility to Sohar Port, thus enhancing its contribution to sustainable development by supporting SMEs and, successively, helping create more in-country value.

Moreover, with the launch of its first solar-powered Service Station in Oman, Shell Mukhaizna Service Station, more than 5 years ago, the company has been demonstrating its leadership and commitment to more and cleaner energy solutions for Oman.

EV Charging Stations

While the success of electric vehicle charging stations is dependent primarily on customers, the responsibility of making it a conveniently available option lies on energy businesses. Towards this end, Shell has taken a bold stance to incorporate EV charging stations into its growth strategy, making travel choices more exciting, with efficient internal combustion engines.

Efficient and effective electric vehicles are

the main catalysts in global energy transition, however, the possibility of utilizing 100 percent sustainable fuels has set in motion the need for critical investments towards energy solutions. Shell has been producing very high-quality differentiated fuels, most importantly high-end fuel for the Ferrari 1 Formula team, which is a second-generation biofuel. It is produced from the leaves of the non-edible parts of leftover sugarcane. Shell has a huge ethanol company in Brazil and this will help it achieve the target of producing 100 per cent sustainable fuels – a combination of different bio fuels and synthetic fuels - for Ferrari by 2026. While this will provide consumers with an alternative fuel option, it will open newer avenues to produce energy efficient cars.

Oman Shell has initiated the process of reducing emissions from its operations, including the production of oil and gas by increasing energy efficiency, as well as by capturing/offsetting any remaining emissions. At present, emissions from its operations make up less than 10 per cent of its total emissions. But what sets the benchmark for excellence is its goal of including emissions not only from the energy it produces and processes itself, but also from all the energy products that others generate and sell to its customers. Oman Shell will continue to drive innovation to provide the cleaner energy that its customers need.

Powering Progress

Oman Shell's sustainable business success has endowed its clients and partners with cutting-edge technology, reach and technical experience. It continues to provide pioneering technologies and expertise in the business of energy, ensuring an added value for the community. The organisation's values are not just aligned to Oman Vision 2040, but it contributes to and is in service of the vision. Oman Shell has undertaken various social investment initiatives that span from environmental conservation to the development of the youth workforce. It is dedicated to supporting economic development in Oman while remaining committed to sustainable development and making a lasting difference in society.

By partnering with the Ministry of Energy and Minerals, Oman Shell believes in powering progress through providing more and cleaner energy. Shell also aims to reduce the carbon intensity of its portfolio globally and in Oman by improving energy efficiency. While access to clean energy has always been a goal, it ensures that it is safe, reliable, and affordable for all.

An active contributor to economic growth, Oman Shell offers direct employment opportunities through its supply chain activities. They also work with governments and partners to help create jobs while supporting the development of local businesses or suppliers. Through Oman Shell's Intilaaqah programmes, it has offered additional training to improve the level of skills and technical know-how of business owners.

Oman Shell will continue to remain invested in community health and the promotion of educational initiatives reaffirming its belief that these form the backbone of any country.

In a nutshell, Powering Progress is Shell's strategy to accelerate the transition of its business to net-zero emissions. Designed to create value for the giant's shareholders, customers and wider society, it has four main goals: achieving net-zero emissions, powering lives, respecting nature and generating shareholder value.

To conclude, its essential to note that as the world navigates an era of transition in the way business is carried out in terms of deals, marketplace, supply and demand, it requires everyone to be ahead in the energy transition journey addressing the different challenges and capitalizing on the opportunities. Oman Shell has already started deploying resources, expertise, and best practices to meet the Sultanate's growing energy demands in an economically, environmentally, and socially responsible way, while creating sustainable benefits for the society. Through its fuel, and lubricants business Oman Shell has worked on commercial and technical advancements to enhance mobility in Oman, helping the growth of various industries that have underpinned the country's economic development. ■

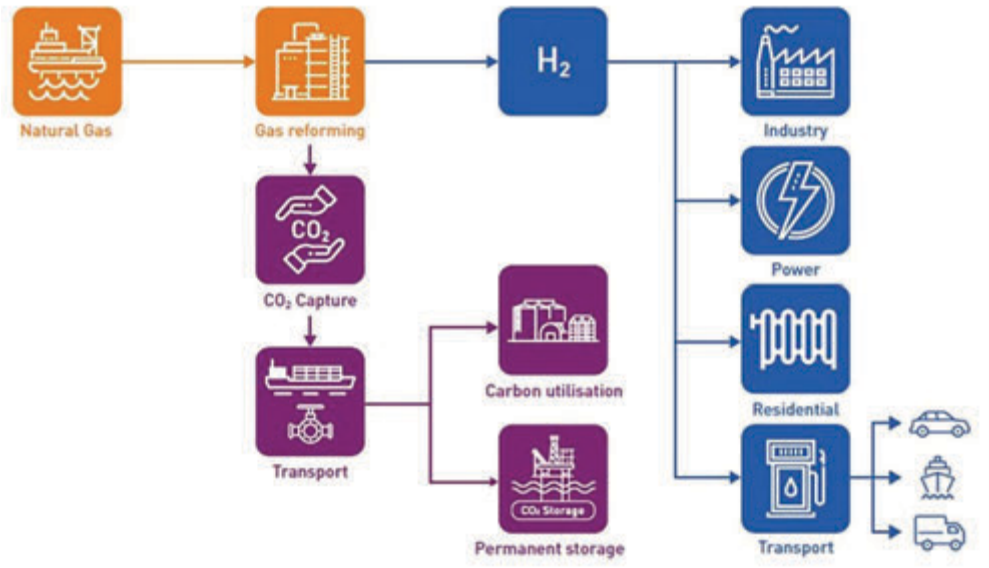
Oman's Energy Transition Pathway: The Role of CCUS and Clean Hydrogen

Dr. Khalil Al Hanashi
Snr. Energy Renewal Advisor
Petroleum Development Oman LLC

Never before has energy transition and decarbonization been the focus of cross sector national discussion and deliberation in Oman. In October of this year, the National Carbon Lab organized by Oman Vision 2040 Implementation Follow-up Unit gathered experts from across multiple sectors to discuss one common item, the decarbonization agenda. The gathering aimed to draw a collective national net zero ambition for Oman. At the same time, the Ministry of Energy and Minerals continued its detailed work into shaping the energy transition policy framework. In both avenues and across multiple sectors, clean hydrogen and Carbon Capture Utilization and Storage (CCUS) emerged as common decarbonization levers that could help Oman navigate the energy transition towards the aspiration of Vision 2040.

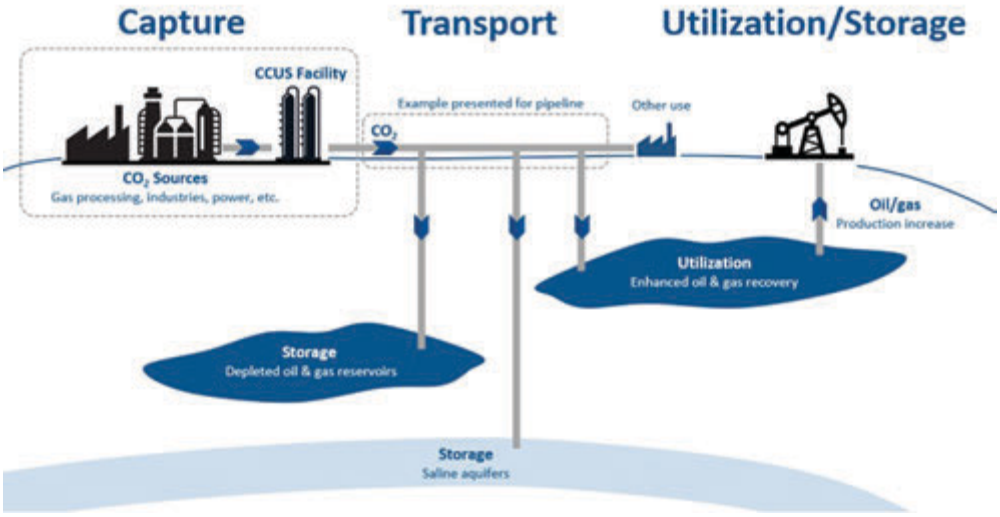
Today, considerable emissions are attributed to fossil fuel energy consumption in industrial activities. While fossil fuel energy in the form of heat or electricity is used to drive many industrial processes, grey hydrogen is used as feedstock in the petrochemical and fertilizer industry in Oman to produce various chemicals including ammonia and methanol. In addition, it is also used as a desulfurization agent in refineries. However, this hydrogen (grey hydrogen) is produced from natural gas and not only does it result in some considerable emission of CO2, it also consumes a considerable amount of natural gas at a time when the growth of other sectors is delayed due to constraints on gas

Hydrogen and CCUS value chain options



Source: International A association for Oil and Gas Producers

CCUS Schematics



Source: Institute for Energy Economics and Financial Analysis

availability. The current plans to produce clean hydrogen in Oman, both blue and green, could be a lever for decarbonizing one of the hard-to-abate sectors in Oman (chemicals and fertilizers industry) and could at the same time free up gas to be directed towards sectors where hydrogen is not attractive or not practical at this early stage of the hydrogen economy.

CCUS and Clean Hydrogen provide two pathways to transit the current hydrogen-based chemical industries into low-carbon industries and eventually kick-start a new clean products industry. The former involves transitioning existing grey hydrogen production to low carbon hydrogen by capturing the emissions from its production site. Such emissions normally have high CO2 purity and concentration supporting a highly efficient capture process. A CCUS upscale could also open doors for decarbonizing the gas-based power sector that needs to remain part of the power mix to provide a clean stable baseload to ensure the resilience of the power system for future scenarios where renewable share of the power production is set to increase.

The second pathway, Clean Hydrogen, involves kick-starting new green products and clean chemicals sectors through enabling local consumption of clean hydrogen in tandem with its production ramp-up in Oman. Albite small in volume now, the clean products and industries sector is witnessing a big growth rate worldwide. The decision to be an early mover in clean hydrogen production in Oman should be accompanied by a similar one for clean products as well.

As the global energy transition moves at unprecedented and sometimes unpredictable speed and scale driven by the various geopolitical and technological uncertainties, readiness in both CCUS and Clean Hydrogen will ensure that we safeguard Oman's current advantage as a competitive energy producer and exporter and at the same time provide an avenue for new energy growth. Such growth, in the long run, will balance out the future decline in fossil fuel. However, we need to act now before external transition forces are too fast or too big to keep up with.

Certification of Oman's Sustainable Energy Developments

Michael Tsang, Ph.D., LEED-AP
Founder and Principal Consultant at Three Pillars Consulting
Director of Life-Cycle Assessment at Avance Energy Labs LLC

Significance of the Amin Renewable Energy Company certification? Benefits of certification for the project, end-user of the energy, and for Oman?

Earlier this year, Oman completed a significant milestone with the registration of Amin Renewable Energy Company's (AREC) 105 MWac utility-scale solar photovoltaic system with the International Renewable Energy Certificate (I-REC) Standard Foundation's renewable energy tracking standard known as I-REC(E). An I-REC(E) Certificate relates to each MWh of energy produced by a energy power plant and is completely factual and verifiable (e.g. location of the plant, energy source used). Trading certificates make it possible to link the ownership rights of electricity from the place of production to the place of consumption, which leads to more transparent markets through which reliable claims can be made about one's electricity consumption.

Such a system will be a strong component of Oman's transition towards integrating more renewable energy into its energy supply mix as the certificates create an additional income stream for in-demand, largely renewable, energy plants. End-users are willing to pay for this additional income stream as they are looking for reliable ways to report their emissions. Disclosure programs like the CDP (formally known as the Carbon Disclosure Project) and standards like the Greenhouse Gas Protocol (GHG-P) require such evidence as an I-REC Certificate be provided by companies who want to report that their Scope 2 electricity emissions come from renewable sources. Companies might also use I-REC(E) Certificates for complying with renewable energy targets that are set internally by their company or to comply with other decarbonization goals that the company might have in place.

Moreover, international regulations and policies such as those related to green hydrogen, are moving towards similar requirements when demonstrating how their products are lower carbon compared to others. Since Oman is setting itself to be a significant producer of green hydrogen in the coming decades, certification of renewable energy in the grid provides a basic foundation needed to support that goal. Thus, any country that wants to be a global 'export' country for hydrogen will need to have an international mechanism in place such as I-REC(E) that is accepted by 'importing' countries.

How is certification done and validated? Is I-REC now the main provider of certification services in Oman?

In each country, the I-REC Standard Foundation accredits an entity for validating project registrations and verifying renewable energy production. In Oman, our company, Three Pillars Consulting, has been accredited and is fulfilling this roll since January of 2021. Each project must demonstrate adequate evidence to fulfill the administrative and technical requirements for registration with the I-REC Standard. We then audit this information to ensure it meets quality control requirements and specifications of the standard. Similarly, when a project wants to issue I-REC(E) Certificates for energy it produces, it must go through a similar round of documentation submission, data verification, and auditing before the certificates are generated.

These types of certificates provide robust, transparent, and reliable tracking of renewable

energy in the grid. The I-REC Standard Foundation is a standard that has a reliable track-record and is being implemented in over 50 countries globally, while its I-REC(E) Certificates are being purchased by RE100 member companies such as Apple, Nike, Microsoft, Google, and others.

Gearing up for green hydrogen certification

The I-REC Standard Foundation is also expanding its list of product codes, many of which are already in beta-deployment such as for the C-Capsule Code for Carbon Dioxide Removals and a separate code for Hydrogen. The Hydrogen Product Code, in particular, is being developed by Avance Energy Labs LLC based out of Abu Dhabi, U.A.E.

The entire premise of hydrogen playing a role in the ongoing energy transition relates to its potential to be produced (and ultimately consumed) with very little (to no) carbon footprint attached to it. This means that throughout its entire life cycle, a hydrogen-product (or a hydrogen-derivative) must be able to demonstrate what carbon emissions are associated with it. Currently, 97% of hydrogen globally is produced using fossil fuels or high-carbon production pathways (including by-product hydrogen). When looking at the conventional production of hydrogen using fossil fuels, production is the most carbon intensive process of the product's entire life cycle as compared to other components within the life cycle such as procurement of the fossil fuel or downstream transport of the hydrogen-based product to the end-user. Production typically involves the reformation of a fossil fuel such as natural gas into hydrogen via steam methane reforming or autothermal reforming. Along the way, copious amounts of carbon dioxide are given off in the process.

Therefore, producers are currently developing alternative pathways to generate hydrogen, one of which is electrolysis of water using sources of electricity that are powered by renewable energy. With this method, there would be little (to no) GHG emissions during the production of hydrogen. However, to ensure such claims, producers will need to provide evidence that they produced and consumed their own renewable electricity. If a producer does not have their own renewable energy systems, then they will need to demonstrate that they procured renewable electricity from the grid either with certificates such as I-REC(E). It is also worth noting that electricity is an input to all hydrogen production pathways and is not just relevant for renewable energy related production.

Any other issue of relevance

There are of course other aspects that will need to be implemented to ensure that Oman has the appropriate systems in place, allowing for robust tracking and reporting of its sustainability initiatives. For example, producers, consumers, and other entities that wish to report their carbon emissions need up-to-date and reliable information that they can rely on when preparing their GHG reports. National databases relating to things such as Residual Emissions Factors for the grid and sector-specific emissions factors for Scope 3 GHG reporting will help to improve the process of reporting from development of one's GHG inventories to the validation and verification of those results.

With our support, the Environment Authority's Climate Affairs Department has recently developed two such databases. One is for tracking Oman's commitments to the Paris Agreement (as well as the Montreal Protocol for Ozone Depletion Substances). The other database is for carbon reporting for companies that require a climate affairs license. The hope is that such transparent and reliable data will support further development, planning and research for integrating sustainability in Oman's economy. ■

Direct Sales to unlock new renewables-based investment opportunities in Oman

The first phase of a Direct Sales initiative -- a keenly anticipated endeavour by the country's power sector regulator to open up the market to competition for access – has been launched in the Sultanate of Oman.

The Direct Sales initiative, representing a further step in the ongoing liberalisation of Oman's power sector, is now a reality. A regulatory framework underpinning this important project came into effect from 1 October 2022 with the Authority for Public Services Regulation (APSR) outlining a phased timeline for its implementation.

Announcing the introduction of the framework, the Authority said: "Article 22 of the Electricity and Related Water Sector Law stipulates that the Authority shall review the conditions of the electricity market in order to measure the readiness of the market for further liberalization. The outcomes of the studies carried out by the Authority during the past period showed that the electricity market in the Sultanate of Oman has become ready for further liberalization. Accordingly, the Authority decided to implement the direct sale mechanism between the electricity producing companies licensed by the Authority and among major consumers other than the Oman Power and Water Procurement Company SAOC."

Significantly, the Direct Sales Framework enables 'bilateral arrangements' agreed directly between generators and major customers, bypassing the state-owned monopoly offtaker OPWP, which is currently the sole buyer of all electricity output under the sector law.

Work on the initiative began last year with assistance from an international consultant that was tapped by the Authority to develop the appropriate regulatory framework in accordance with the requirements of the direct sale mechanism. The framework also specifies conditions, rules and requirements that must be met by prospective generators seeking licenses to enter into direct sales arrangements with customers.

Beneficiaries will include power plants that have fallen out of contracts and those engaged in the captive power generation business. The Authority explained: "The implementation of the direct sales mechanism, at the first stage, will be limited to generators with expired contracts (PPA) with OPWP and companies that rely on self-production and have an exemption license from the Authority. Moreover, it is necessary for the regulatory and legal framework for direct sales to consider the technical aspects - mainly to ensure that all economic and technical requirements are met such as: connection to the network, the effects of operating power units on the network, consumption calculation and settlement, ancillary services, and electricity losses."

Besides contributing to system cost savings, the Direct Sales Legal Framework is also expected to incentivize investments in large-scale renewable and green hydrogen projects, which the Omani government is banking on to support its transition away from hydrocarbons.

Market liberalization

A Guidance Document recently issued by APSR outlines the scope of Phase 1 of the Direct Sales initiative. It explained: "Direct Sales are a means of introducing competition for access to eligible customers – typically the largest customers. Direct Sales will be introduced though a staged implementation, with the first stage, Phase 1, eligibility for Direct Sales participation will be limited to the following: (a) Large customers with their own captive generation1 (Buyer); and (b) Generators with PPA expired (Seller)."

According to the Authority, the Phase 1 Direct Sales arrangement aims to use as much of the existing market systems, processes, and frameworks as possible so that Phase 1 Direct Sales contracts are a logical subset of the broader range and scope of market-based contracts that the end point liberalised market design can support. This allows focus on what change contribute both to expanding Direct Sales applications and progressing the liberalisation efforts further.

However, a range of pre-conditions must be achieved, the Authority has pointed out. These include certain technical criteria designed to ensure that physical connections, dispatch implications, and metering data and settlement implications are all catered for. Additionally, there are commercial and economic implications related to the price signals that direct

sales proponents and eligible customers see and to which they respond. These signals determine the extent of interest by potential sellers (generators) and the value proposition anticipated by eligible customers.

Technical enablement is also key element in establishing the legal and regulatory framework for direct sales, says APSR. However, commercial and economic aspects will then drive uptake and perceptions of benefits. Electric power systems have a high degree of fixed costs. An important part of a Direct Sales regime involves determining a level of non-bypassable costs to continue recovering from customers connected to the system as they shift to being 'Direct Sale' customers.

Current arrangements allow a generator to sell to OPWP via the Oman Electricity Market (the Spot Market) or through PPA contracts with OPWP. But the Direct Sales Framework introduces a new facility, dubbed a Direct Sale, to allow a generator to sell directly to a customer.

The primary technical enablement requirements for Direct Sales are two-fold: (a) To be able to determine what physical quantity generation output from a direct sales generator is being sold to a customer; and (b) To be able to bill the customer and pay the generator for the combination of direct sales generation output, use of system to support direct sales generation reaching the customer, and any other purchases by the customer of electricity from the system (in addition to those from the direct sales generator).

Importantly, Direct Sales customers will be CRT (cost-reflective tariff) customers as the CRT is cost-reflective and not subsidised. Even though the tariff is not fully unbundled, the CRT covers all relevant and attributable costs, the Authority has stressed in the Guidance Document.

Further, the Eligible Generator may offer into the Spot market any capacity that is not contracted for Direct Sales with the Eligible Customer(s). This capacity shall be offered on a cost-reflective basis, in accordance with the Oman Electricity Market Rules. But in order to be able to offer capacity into the Spot market, the Eligible Generator shall sign the Accession Agreement for the Market Rules with the Market Operator.

Besides, Eligible Customers are also required to pay Transmission Use of System Charges (TUoS) like other transmission grid connected customers. An Eligible Customer who is supplied by an Eligible Generator, even one 'right next door', still uses the grid, especially at any time the Eligible Generator is not generating whilst the Eligible Customer is still using electricity. ■

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OFFICIAL MAGAZINE:

Hydrogen safety
Hydrogen handling and key process safety steps

Hydrogen use is expected to grow enormously in the coming years, both for storing and transporting energy and as a carbon-free fuel. To do this safely, a few crucial points are important to consider and act upon.

Introduction

Safe operations – regarding workers, plant & equipment, communities and the environment – should be the foundation of any industrial or commercial process. With hydrogen gaining widespread attention as an energy carrier for a growing range of applications in both industry and transportation, it is vital that any company working with hydrogen, or planning to work with it, is well aware of the safety hazards involved.

This ABB mini-brief is intended to provide a basic outline of key safety points to be considered when expanding the use and application of hydrogen.

Of course different companies and plants will be at different stages on their hydrogen journey, with some just getting started while others have been using hydrogen safely for many decades.

"Risk" is normally defined as the combination of "likelihood" and "consequences or hazards" of an event occurring, and the improper handling or processing of hydrogen can lead to serious negative outcomes. If a company doesn't understand the consequences of an hydrogen release, and the likelihood of it being released, then handling hydrogen could become a very high risk activity.

In this area ABB is well equipped to help because, based on our long hydrogen processing experience, we understand how to control these risks. Thus with hydrogen applications expected to grow exponentially in the near future – both at mature operating companies as well as at newcomers entering the hydrogen sector – we feel these safety points are worth communicating.

We believe this overview will provide both a good starting point as well as a timely refresher for interested readers such as: safety managers, designers, process engineers at energy and chemical companies, EPC firms and electrolysis technology companies, and analysts and policy-makers.

The current market situation

The potential that hydrogen offers to act as a flexible energy vector, particularly for renewable but intermittent energy sources like solar and wind power, has created huge amounts of interest as the cost of installing photovoltaic (PV) and wind turbine generation has decreased. Therefore worldwide there is an increasing number of projects to generate, store, transport and use hydrogen – fueled further by the urgent need to decarbonize.

Many green hydrogen projects are being undertaken both by numerous newcomers with no prior safety experience of handling hydrogen, as well as by existing companies

moving from grey to ultimately green hydrogen. The existing companies already handle hydrogen and are mature in their Process Safety Management (PSM) journey but are needing and requesting specific hydrogen safety knowledge for their expansions. This widespread scaling-up of industrial production volumes for hydrogen, as well as rapid growth of smaller off-grid operations, all involve safety risks that must be addressed.

For either category - newcomer or mature – any serious safety incident could have catastrophic consequences for the employees, local communities, the environment and the company's reputation and potentially its future. If an incident were to be serious enough, it could also damage the public perception of the entire and promising hydrogen sector for a long time into the future. An example of this is the explosion at the Uno-X hydrogen refueling station at Kjorbo near Oslo, Norway in June 2019 which had a severe impact on the fuel cell vehicle sector, since drivers could not refuel their vehicles.

Of course, many industries and companies have very safe and successful experience of using and generating hydrogen over many decades, such as chemical plants using reforming for hydrogen production or cracking furnaces generating ethylene and propylene with hydrogenation reactors. But as the pace of growth increases, safety must not be overlooked.

3 Key Steps for Safe Handling of Hydrogen

To make sure that hydrogen is safely handled, systematic Process Safety

Management procedures must be understood and practiced from day one. Years and decades of experience here at ABB have shown us that there are three crucial steps that need to be prioritized to help ensure hydrogen safety.

1. First of all, build on the right foundations and ingrain safety culture by starting at the top. There is no alternative: The leadership team must be totally committed to the highest level of process safety management regarding hydrogen adoption or expansions. If you lead from the top – with some individual on the company board responsible for PSM – that helps drive the process safety culture and sets you up for success. Many of the most successful players already working with hydrogen, and who are good at managing their process safety, have a company director responsible for PSM.

   New entrants into the promising hydrogen market must recognize that it is extremely important to have this 'top led safety culture'. Safety underpins sustainability and is the foundation of any good operating company. Keeping people safe and alive is certainly the most basic first step in any sustainability program. Also, safe operations usually reinforce efficient operations, and that means reduced emissions, another key sustainability factor.

2. The second key step is: Identify all credible hazards in the early stages of the design process, even at the concept stage. If you can spot hazards early and design them out or mitigate them, it costs a lot less to alleviate them at that stage of the design process rather than later on. Even simple things, like minimizing the number of flanges in the design or the installation of hydrogen flange guards where flanges are unavoidable, are important to do early on.

   To help accomplish this, there is a hazard study suitable for every project stage. HAZOP (hazard and operability study), one of the most common techniques, involves a structured, team-based assessment of a firm's design to ensure that the

consequences of design deviations are fully understood. This study also determines if suitable and sufficient protective measures have been incorporated into the design.

However there is more than just Hazard Study 3, with the techniques going from Hazard Study Zero all the way through to 7. Zero is the interesting one because it covers inherent safety, so it asks you crucial questions very early in the concept stage, potentially helping to design out hazards from the start of a project. Then these studies and solutions roll on to support further layers of safety pillars, as you pass through the design process into the next stages.

3. A third more specific step is to make sure any hydrogen hazards that are identified are fully controlled. One of the main reasons hazardous area classification and controls are important is hydrogen's low ignition energy. As hydrogen use expands – particularly green hydrogen from electrolysis of water using renewable energy – electrolyzers will become more commonplace. Electrolyzers involve very high electrical demands, which is another potential ignition source, in close proximity to potential leaks.

Electrolyzers are typically located inside buildings. This means that if there are hydrogen releases from the process the concentration can rise rapidly and very easily enter the flammable region, if there isn't adequate ventilation. This occurrence, combined with the potential ignition sources, presents a very significant explosion hazard. These factors need to be considered in the early specification and location of electrical equipment.

As hydrogen fuel cells are increasingly applied to transport, hydrogen refueling points for ships, buses, trains, HGV-trucks and even automobiles are becoming more widespread, bringing people into closer contact with hydrogen. The unique properties of hydrogen and this increasing proximity to people needs to be considered in the design phase of a project, as well as in the operations – when humans can do unpredictable things.

Many countries are exploring the addition of hydrogen to their natural gas networks, and industrial sites are also considering the implications of the use of pure hydrogen. Generally the natural gas networks do not operate at elevated temperatures and therefore the hazard of hydrogen embrittlement would not be an issue for reuse of equipment. However where repurposing of equipment in the presence of hydrogen at elevated temperatures occurs, the impact on materials of construction needs to be fully considered.

We can support your Process Safety Management

Although there are more aspects to making hydrogen generation, handling, storage and use as safe as possible, by following these key steps you will be well on the road to hydrogen process safety:

1) Building a committed, top-leadership-driven corporate process safety culture
2) Making sure hazards are identified at the earliest stages in design and mitigated cost effectively
3) Thoroughly controlling any operational hydrogen hazards that are identified, you will be well on the road to hydrogen process safety

With this as a foundation, you'll be well placed to implement hydrogen safety in the most effective manner and avoid the worry and sleepless nights that can occur when handling hydrogen.

If and when needed, our capable ABB Process Safety Team, which has both broad and deep experience in hydrogen, would be happy to guide and support you in these areas.

To learn more about ABB's hydrogen offering and ways we can work with you on your hydrogen journey, get in touch with us at these links:

ABB hydrogen site

https://new.abb.com/process-automation/energy-industries/hydrogen

Consulting services web pages

https://new.abb.com/process-automation/processautomation-service/engineering-and-consulting

Hydrogen – the key to a low-carbon future

We are now at the start of the age of hydrogen. Produced using renewable resources, this versatile element could well prove to be the key to meeting the most important challenge of our time – the decarbonization of our economy.

Hydrogen's many potential uses, directly as a carbon-free fuel or for storing and transporting renewable energy, make it extremely valuable for lowering man-made CO_2 emissions. It provides an efficient way to integrate renewable energy into industrial value chains, and also into the transportation, power and building sectors, all over the world. ABB is already today deploying technology and solutions to support the new hydrogen value chain as we transition to a cleaner energy future.
solutions.abb/hydrogen

ADVARIO

Creating positive impact

We are convinced that by setting highly ambitious ESG standards, we will achieve 'better business' for our partners, society and ourselves. This means that besides ambitiously growing our business, an equally important priority will be to operate our business with the highest care for our people, the communities we work in and the environment we live in.

2040

Net zero operations

SUSTAINABILITY AT THE CORE

Our brand-new company is focused on growth in petrochemicals, gases and new energies and we put sustainability at the heart of what we do. We are committed to achieving **net zero operations by 2040.**

With a team of 1200 highly committed employees, our global network of terminals and our legacy in the industry, we are well-placed to take up a frontrunner role in transforming our industry, together with our partners.

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ASYAD

ASYAD GROUP, OMAN'S HYDROGEN LOGISTICS PROVIDER

Asyad Group provides integrated logistics solutions across ports, free zones and shipping. It comprises three deep ports, two free zones and an economic zone supported by Oman's five airports, and a world-class road network. In addition, Asyad operates full maritime services with one of the largest drydock in the middle east and a diversified fleet of more than 60 vessels, supported by a sea transport network that connects Oman to key ports across the region and the globe.

The Group offers integrated logistics services to meet market needs and support Oman's economy. This allows optimal use of its diverse and powerful support assets, including its renowned Asyad Express service that spans from the 3,000m^2 world-class fulfilment centre to the last mile delivery, serving finance, e-commerce, manufacturing, and other businesses.

asyad.om

Bank Nizwa: Promoting Sustainable Growth

Khaled Al Kayed
Chief Executive Officer,
Bank Nizwa

Bank Nizwa is dedicated to assisting Oman in its transition to a low-carbon, more resource-efficient, and sustainable economy, by being at the forefront of initiatives to create a financial system that promotes sustainable growth.

In fact, Islamic finance and sustainability go hand in hand. Therefore, being an Islamic bank ourselves, we adopt a strategic approach to being sustainable in all our systems, processes, products, and services. The Bank is reaffirming its commitment to assisting with the energy transition in a variety of ways, including by funding government initiatives in the industries with the highest carbon emissions.

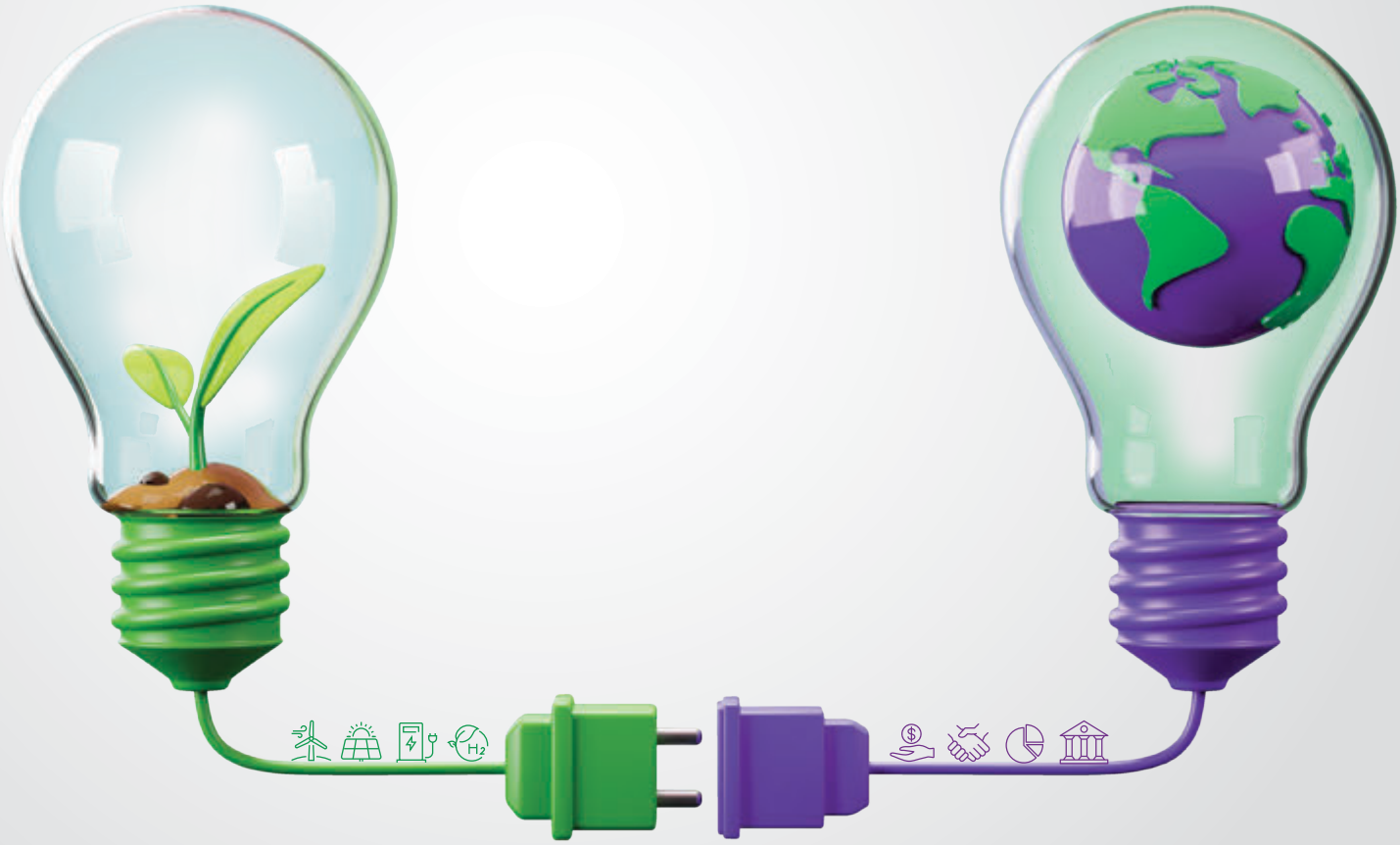
It is adopting a strategy of supporting renewable energy projects as part of the energy transition agenda.

The Do No Significant Harm (DNSH) principle and the minimum social protections are both included into the bank's robust eligibility framework, which serves as the foundation for its ESG products.

By offering innovative financial products and services, Bank Nizwa aids in the ecological transition of both its customers and the economy as a whole. In order to allow other investors who are ESG sensitive to invest in Green Sukuks, Bank Nizwa actively seeks for opportunities to issue Sukuk (Islamic Bonds). By partnering with the providers of alternative energy sources, Bank Nizwa is able to fund their potential clients. ■

UNLOCKING SUSTAINABLE DEVELOPMENT

Bank Nizwa now offers preferential rates for sustainable businesses



Enjoy superior benefits:

- Preferential rate on financing
- Innovative products to help the customer to move to low carbon, more resource-efficient business.
- Helping clients who are into Renewable energy by financing their clients.

24 950 500 Follow us on

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Bank Nizwa

Equinor: A leader in the energy transition

Every day Equinor delivers oil, gas and renewable power to more than 170 million people. For fifty years, Equinor has been pushing the boundaries of imagination and technology, taking the company to deeper waters and new frontiers. Today, we are the largest operator in Norway, one of the world's largest offshore operators, and a growing force in renewables and low carbon projects.

The energy industry is experiencing fundamental challenges. In Equinor, the approach is to turn these into opportunities, seeking new ways to utilise its expertise to the growing new energy arena as well as driving innovation in oil and gas around the world.

Equinor supports the Paris Agreement, and the ambition is to become a net zero energy company by 2050. Guided by its strategy - always safe, high value, low carbon - it will create value as a leader in the energy transition, in renewables, carbon capture and storage, and hydrogen. It is also a leader in sustainable development, receiving a number of recognitions for its sustainability performance.

To reach its ambitious goals Equinor seeks to remain at the forefront of digitalisation, implementing and creating value from new digital tools which enable improvements and optimisations in day to day operations, in combination with remotely controlled and automated designs.

In renewables Equinor has successfully applied its oil and gas expertise to Dogger Bank, the world's largest offshore wind farm, and Hywind Tampen, the world's largest floating offshore wind farm.

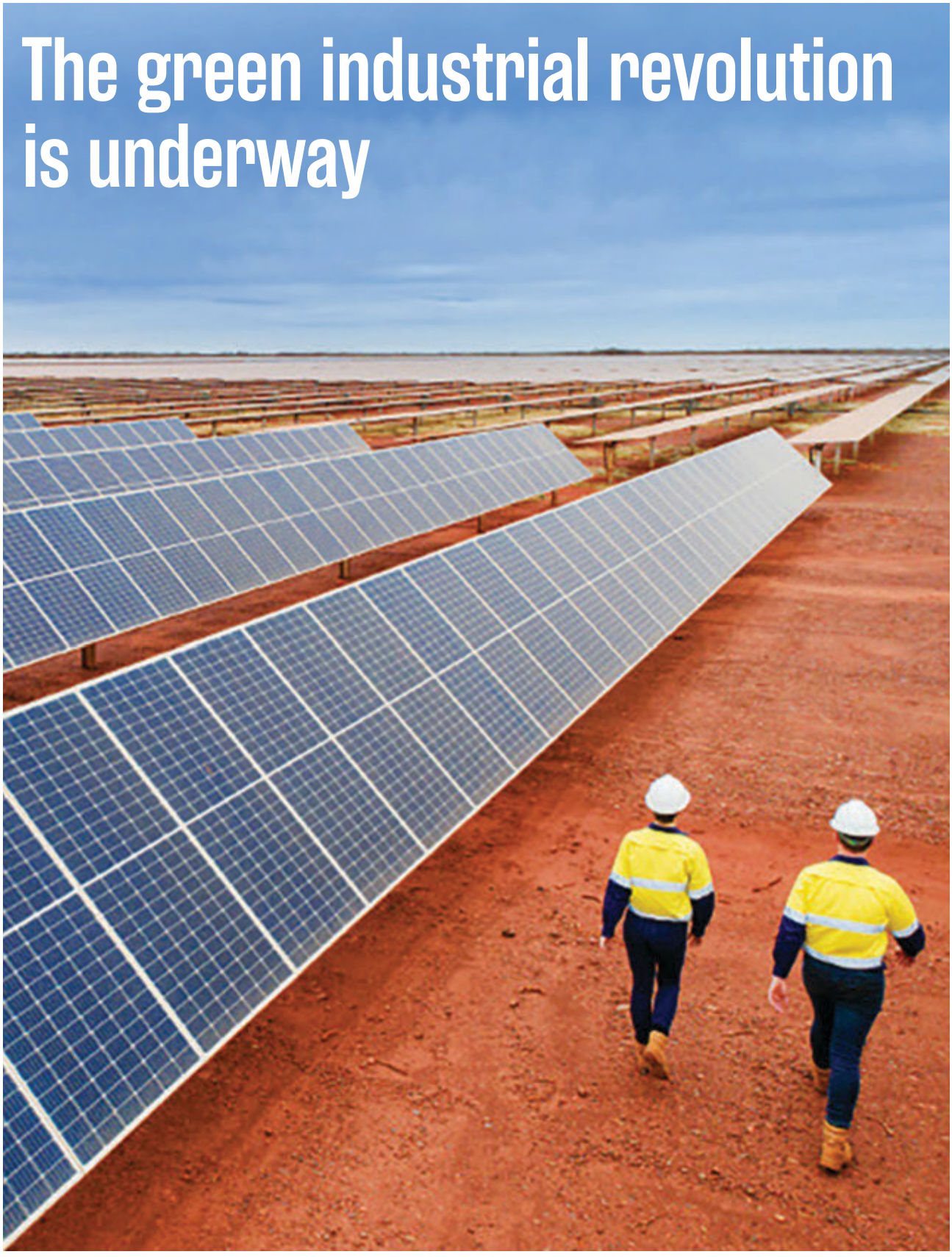
Equinor is developing the world's first carbon capture and storage network (Northern Lights), and is progressing with several low carbon hydrogen projects. Carbon capture enables near-term, large-scale emissions abatement while preserving reliable energy, high-value industries and highly skilled jobs.

Equinor believes societies will continue to need oil and gas in the future. That is why it continues to look for and produce oil and gas at industry-leading emissions levels, less than half the global industry average, using electrification, energy efficiency and digital technologies.

Ahmed Osman, Middle East Business Development Manager in Equinor, emphasized that the company is glad to be working with local entities in both the gas sector as well as in the renewable arena. "Oman has great ambitions for the energy transition and Equinor is hoping to be part of this journey."

For more information visit - www.equinor.com

The green industrial revolution is underway



Right now, the world is fighting a battle on two fronts.

Countries are on the brink of a major energy security and supply crisis, and we are also already in the middle of a climate emergency.

We cannot wait until 2050, 2040 or even 2030 for solutions.

The solutions must start right now, today, and we must not let one problem exacerbate the other.

Instead, these problems should be the catalyst for change and opportunity, a chance for countries, like Oman, to take control of their future, create their own energy and export their sun and wind to global markets.

Decarbonisation can be a path to a stronger, more resilient economy.

It could mean construction jobs for decades.

It has the potentially to mean low-cost renewable energy right where you need it.

It could mean improving energy security.

It could mean global competitiveness, diversification of the economy and taking action in a carbon-counting world.

Oman is already planning for its lower carbon future, and it has a distinct advantage with a vast supply of renewable resources.

Fortescue stand to help with that transition, bringing the solutions, the technology, the supply chain, and the infrastructure to make the switch to renewable energy for a better future.

In September we made a major announcement in New York on the decarbonisation of our mining operations.

Fortescue emits more than 2.2 million tonnes of Scope 1 & 2 CO2 emissions each year, that's 60% more than Fiji.

We are a big carbon emitter, and we are doing something about it.

In fact, we are the first major heavy industry company to have a fully funded plan to eliminate terrestrial carbon emissions from our iron ore operations (Scope 1 and 2) and get to real zero by 2030.

Fortescue has a roadmap to do this and, more importantly, it is a very sound investment decision for us.

Our plan is to invest US$6.2 billion into our decarbonisation strategy and, in the process, save US$3 billion before 2030.

What we are doing is showing the world it is possible.

Our decarbonisation plan can help move us beyond fossil fuels and significantly de-risk our business.

To do this, Fortescue is partnering with Liebherr to build and supply hydrogen fuel cell and battery electric mining haul trucks to replace our existing diesel fleet.

These haul trucks, which will emit no carbon during operation, will be integrated with the power system technologies being developed alongside Williams Advanced Engineering. They will begin to enter Fortescue's fleet in 2025, working towards replacement of our existing diesel fleet by 2030.

It will have a significant impact on Fortescue's emissions, with truck haulage currently consuming about 200 million litres of diesel per year and accounts for 26 per cent of Scope 1 emissions.

Beyond haul trucks, we need drill rigs, excavators, and all other mobile equipment running on green hydrogen or renewable electricity.

We are also designing and building two, new battery electric locomotives.

The Infinity Trains will utilise gravitational energy from travelling downhill fully loaded, which are designed to recharge the battery electric systems and not require any additional charging for the return journey back to the mine sites.

This fully costed decarbonisation plan is not only helping to significantly reduce our emissions, but it's also preparing the business for the future.

It allows Fortescue to avoid an ongoing fossil fuel price risk, as well as avoid any future carbon pricing and carbon offset costs.

This is a significant milestone globally for an industrial company and we hope that we will set a great example for other heavy industry companies to do the same.

We want all investors, banks and customers to ask other companies the question: "if they can do it, why can't you?"

It is very clear that the capital markets are quickly moving away from fossil fuels and that customers are demanding fossil fuel free products.

> **"The Infinity Trains will utilise gravitational energy from travelling downhill fully loaded, which are designed to recharge the battery electric systems and not require any additional charging for the return journey back to the mine sites."**

Fortescue is leading the world in responding to these shifts which presents a significant opportunity for our business.

Key to that is Fortescue Future Industries, which will not only enable our decarbonisation plan, but also drive the evolution of Fortescue into a global green energy, technology, and resources business.

FFI is building a global portfolio of hydropower, geothermal, wind and solar resources to meet a significant and rapidly growing global demand for green hydrogen and renewable energy.

We are working rapidly to meet the needs of our partners around the world, including E.ON in Germany, who is seeking the supply of five million tonnes of green hydrogen per annum from FFI, from mid-decade.

In order to meet that demand, FFI is looking at projects to produce green hydrogen and renewable energy across Africa, the Middle East, Europe, the US, South America and of course Australia.

We have recently progressed planning to final stages with Incitec Pivot for the proposed conversion of a site at Gibson Island in Queensland to produce green hydrogen, and to make green ammonia.

We have also entered into a global strategic collaboration with energy infrastructure developer Tree Energy Solutions.

This will help accelerate the development of a world leading green hydrogen import facility in Germany.

Technology will be key to scaling up the green hydrogen economy and making it cheaper and more efficient.

To help, FFI has established a US Technology Hub, based out of Colorado, it includes a potential 10-year collaboration with the U.S. Department of Energy's National Renewable Energy Laboratory.

This collaboration is not only expanding FFI's U.S. presence, but it will also strengthen our position as a significant global developer of renewable energy and green hydrogen technology.

Where technology doesn't exist yet, we are investing to make it happen faster.

Where we think the supply chain might not keep up, we are investing in manufacturing capacity.

We are doing just that in Gladstone, Queensland, where our Green Energy Manufacturing centre is in the final stage of construction.

This will be one of the world's largest electrolyser manufacturing facilities and is due to start production next year.

Looking to the future, FFI hopes to strengthen its relationship and presence in Oman, and will be actively participating in the bidding for a number of blocks offered up by the Omani government for the establishment of green hydrogen projects.

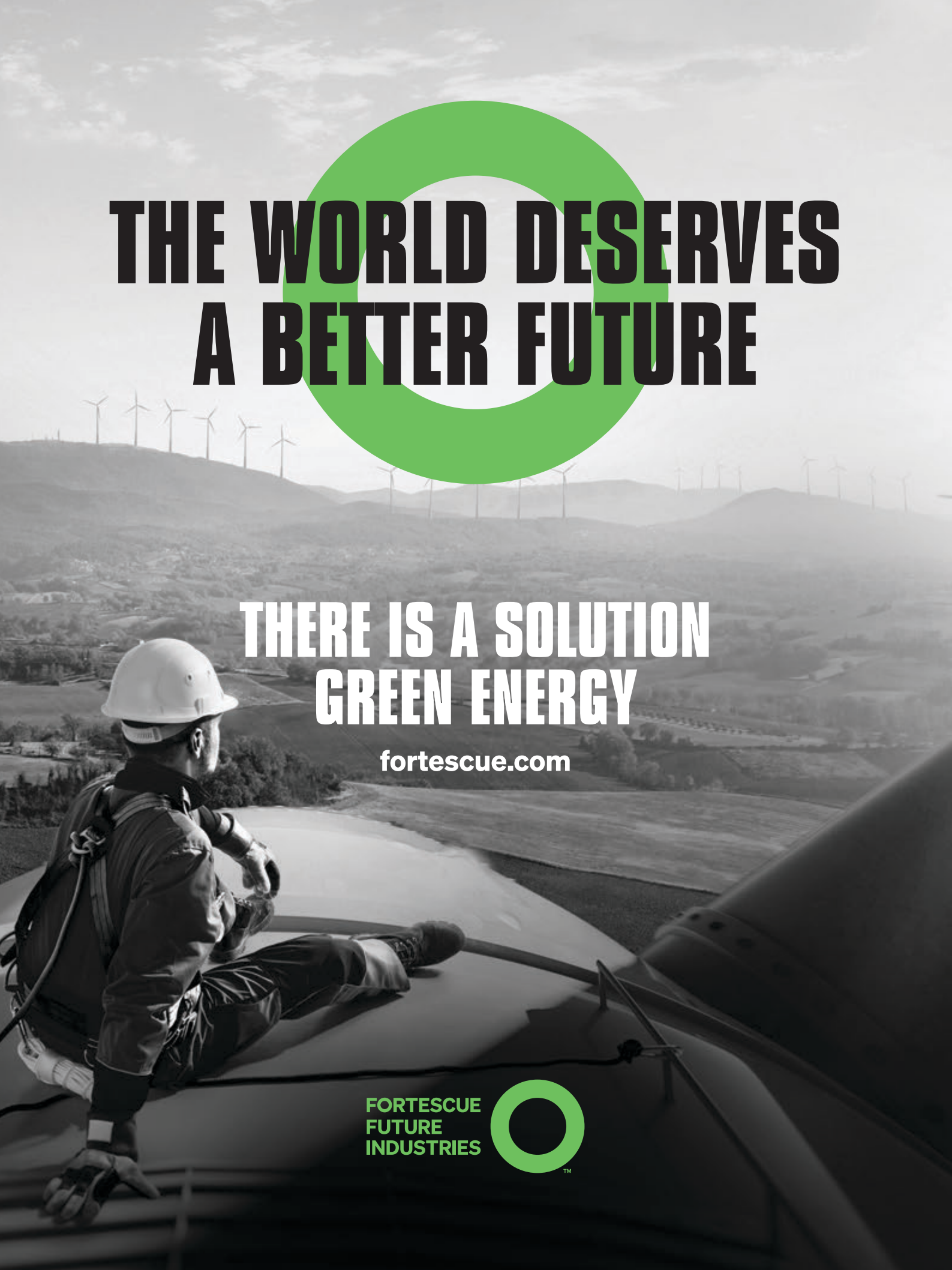
FFI will bring to Oman the same approach we have taken in Australia – with a sharp focus on adding value to the local communities and the national economy through employing and training Omanis and looking to build out down-stream manufacturing in Oman as well.

We are moving fast, because the planet needs us to.

It's time to speed up the world's energy transition and move on from fossil fuels.

The green industrial revolution is underway.

Join us. ■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A Low-Carbon Future for the Middle East and Central Asia

Under the Paris Agreement, countries in the ME&CA region have collectively committed to reduce annual GHG emissions in 2030 by 13 to 21 percent. This means that the region's per capita emissions would need to be reduced by 7 percent over the next eight years.

Almost all countries in the Middle East and Central Asia (ME&CA) region have joined the rest of the world in what is arguably the most ambitious and consequential global effort—the race to save the planet from the effects of climate change. To date, 31 out of the region's 32 economies have published their nationally determined contributions (NDCs) as envisaged by the 2015 Paris Agreement. Of these, 29 spell out explicit commitments for reducing or containing greenhouse gas (GHG) emissions in the coming years. As part of a broader strategy by the IMF to help member countries address climate change related policy challenges, this paper examines two questions:

What do ME&CA countries emission reduction commitments amount to? What will it take to achieve them?

Answering these questions is important both for the world and for the ME&CA countries themselves. Despite witnessing a rather rapid increase in emissions in recent decades, the ME&CA region is admittedly not the largest overall emitter of GHGs in the world, neither currently nor from a historical perspective. And reflecting its countries' stage of development—the region is populated by emerging and developing economies (EMDEs) including several low-income and conflict-affected countries—their mitigation objec¬tives can be expected to be more modest than those of the advanced economies (AEs). Nevertheless, for the global effort to succeed, achieving every region's mitigation target is critical. Moreover, ME&CA is one of the most vulnerable regions to the continued rise in global temperatures and achieving the goals of the Paris Agreement is of paramount importance to containing the region's climate adaptation costs and the habitability of many of its countries (Duenwald and others 2022).

The absence of explicit enforcement mechanisms in the Paris Agreement means that whether its goals will be achieved largely depends on the clarity of countries' emission reduction commitments, credibility of their mitigation policy strategy, transparency when it comes to monitoring progress, and periodic revisions of mitigation ambitions to ensure that individual commitments are on aggregate compatible with the overall goal of limiting the rise in global temperatures

to no more than 1.5°C–2°C relative to the preindustrial level by 2100. In any global coordinated effort, insufficient ambition or underperformance in some parts of the world would need to be compensated elsewhere for the overall numbers to add up. That is why it is important to understand what is entailed in each region's pledges, what they imply for the future trajectory of emissions, and how they fit into global mitigation efforts.

Aggregation of the ME&CA countries' mitigation commitments is a challenging task. Reflecting individual circumstances and priorities, countries have used a variety of definitions, methodologies, yardsticks, and reference points to specify their pledges. This paper attempts to aggregate them by using a common denominator in a unified framework with the help of the IMF-World Bank Climate Policy Assessment Tool (CPAT)—a country-specific climate model

> **"Reflecting individual circumstances and priorities, countries have used a variety of definitions, methodologies, yardsticks, and reference points to specify their pledges."**

that projects fuel usage and emissions across different sectors (see Annex 1). It finds that achieving the region's "conditional" climate mitigation pledges, that is those commitments that require some form of external support, would imply a level of GHG emissions in 2030 that is roughly equal to the volume of emissions expected to be produced by the region in 2022 and consti¬tutes a 21 percent decline relative to the business-as-usual (BAU) baseline projection in 2030. By contrast, unconditional commitments, that is those that rely on countries' own resources, amount to moderating the growth of GHG emissions to 16 percent between 2022 and 2030, relative to 32 percent in the BAU. Within the region, there is also significant variation in the degree of mitigation ambition. Some countries' stated emissions reduction commitments could be met without additional mitigation efforts, while others will need to work hard to fulfil their pledges in the coming years.

Nevertheless, the region as a whole has a mountain to climb, and it would be inaccurate to interpret its collective mitigation commitment as unambitious because of the strong underlying currents. Much of the region's recent growth in emissions owes to rapid expansion of populations which by far outpace the rest of the world, particularly in MENAP. This demographic trend is expected to continue and containing the region's aggregate emissions at their current level would require a reduction in per capita terms by 7 percent over the next eight years. This will be no mean feat given that only a few EMDEs have been able to achieve a similar reduction in emissions while maintaining economic growth over the same period.

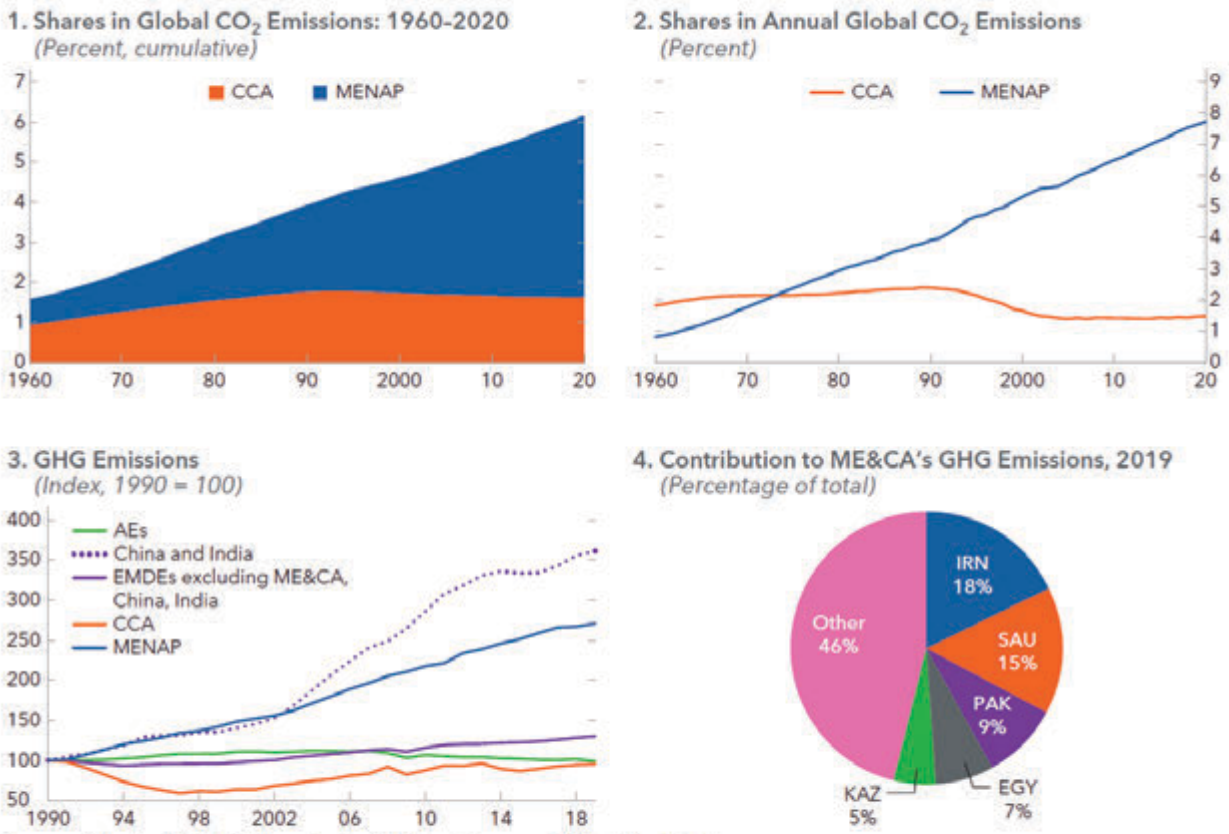
Therefore, crafting policies to meet countries' mitigation commitments while carefully balancing the associ¬ated socioeconomic consequences will be critical. The paper discusses how climate mitigation policies can be integrated into the broader macroeconomic policy framework. To do so in a tractable way, it focuses on two broad categories of policies to curb GHG emissions: those that increase public investment in renewable energy and those that raise the effective carbon rate (ECR), defined as emissions-weighted tax revenue from fossil fuels net of subsidies. Such a dichotomy emphasizes substitutability, albeit up to a point, between two alternative fiscal policy approaches to climate change mitigation and captures the key medium-term macro¬economic and long-term intergenerational trade-off that is arguably the most pertinent for the ME&CA region where governments are likely to play a leading role in the low-carbon transition.

At one end of this trade-off, a sizable increase of the ECR could achieve ME&CA's emissions reduction targets without any additional investment in renewables, for example, through a gradual removal of all

fuel subsidies and, in addition, a phased introduction of a carbon tax of $8 per metric-tonne of CO2-equivalent in MENAP and $4 in the CCA over the next eight years. Such an approach would prioritize raising the price of energy and amounts to making the current generation bear the brunt of the adjustment burden. Vulnerable house¬holds and the economic sectors reliant on cheap sources of energy could be particularly at risk. Though the additional fiscal resources generated by ECR-raising measures could be used to alleviate these side effects, an adverse impact on economic growth—at least in the medium term—would be difficult to avoid, and real GDP per capita in 2030 could decline by 5 percent in both MENAP and CCA relative to the BAU baseline. In the long term, however, such a transition would leave to future generations an economy that is not only cleaner but also more energy efficient and potentially more competitive, with fewer distortions and a more efficient allocation of resources.

An alternative way of reducing emissions is through public investments in renewable sources of energy. For example, additional investments of $770 billion in MENAP (20 percent of 2021 GDP) and 114 billion (27 percent of 2021 GDP) in the CCA between 2023 and 2030 would allow achieving the region's emission reduction targets with fuel subsidies reduced by two-thirds and without any carbon tax. Such a strategy implies a smaller increase in energy prices and would create more jobs and faster growth, raising the 2030 real per capita GDP by 4 percent in MENAP and 7 percent in CCA relative

Figure 1. Greenhouse Gas Emissions in the ME&CA Region



Sources: Climate Watch Database for the GHG emissions; and IMF staff calculations.
Note: GHG emissions exclude land use, land-use change, and forestry (LULUCF). AEs – Advanced Economies; EMDEs – Emerging and Developing Economies; ME&CA – Middle East, North Africa, and Central Asia.

to the BAU baseline. But it would also preserve the distortions in energy prices, limit energy efficiency gains, weaken fiscal positions and macroeconomic stability, and leave fewer resources available to future generations that would see the aggregate government debt in 2030 rise by 12 percent of GDP in MENAP and 15 percent of GDP in the CCA relative to the BAU baseline. Thus, a smoother transition for the current generation could set future genera¬tions on a path of slower long-term growth.

In between, other combinations of these fiscal options can be compatible with reaching the ME&CA region's NDC targets. Countries would need to choose a suitable policy mix based on the available fiscal space, socioeconomic fragilities, and political economy constraints. Non-fiscal mitigation policies—such as envi¬ronmental regulations or private climate finance initiatives—could play an important role in reducing the mitigation burden on fiscal policy, thereby improving the options outlined above. Global and regional initiatives to provide affordable financial support and technological assistance would be equally important in improving the ME&CA region's economic trade-offs. For individual countries, deciding on and rolling out the appropriate policy mix early will be critical. Delays will make achieving the mitigation targets more difficult, thus worsening the fiscal trade-off over time. On the other hand, an early start will allow an orderly adjustment by the private sector and timely gearing of other regulatory, fiscal, monetary, and financial sector policies and structural reforms to tread a smoother path toward a greener economy in the ME&CA region.

Conclusion

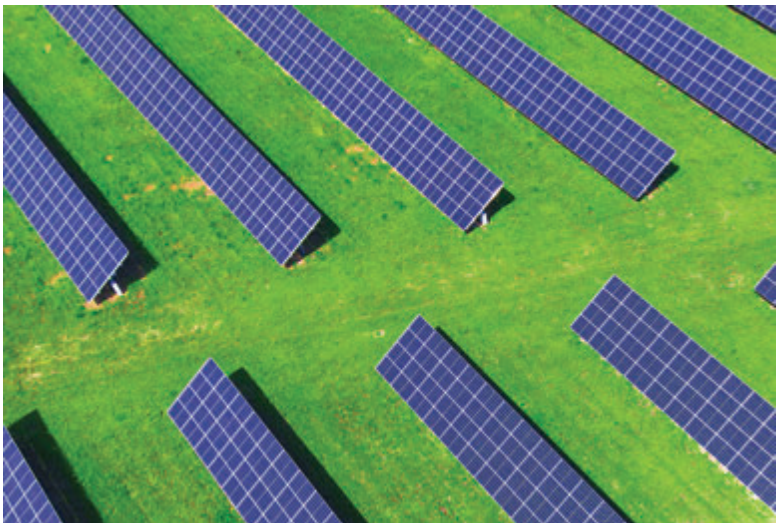
This paper estimates that, under the Paris Agreement, countries in the ME&CA region have collectively committed to reduce annual GHG emissions in 2030 by 13 to 21 percent, depending on the availability of external support, relative to current trends. This means that the region's per capita emissions would need to be reduced by 7 percent over the next eight years.

Fulfilling this commitment entails a significant economic challenge that is likely to grow over time as the deadline nears, while many other competing needs, such as meeting the SDGs and adapting to climate change, become more acute. Therefore, balancing the region's priorities while ensuring an adequate contri¬bution to the global climate mitigation effort requires full integration of emissions reduction policies into countries' economic strategies.

> **"The paper discusses how climate mitigation policies can be integrated into the broader macroeconomic policy framework."**

The discussion above lays out a framework to help countries do so and outlines the magnitude of the required policy efforts at the regional level. It focuses on the choice between two broad categories of fiscal policies to curb GHG emissions: public investments in renewable sources of energy and measures that raise the effective carbon rate. Such a choice involves important medium-term macroeconomic and long-term intergenerational trade-offs that are arguably the most pertinent for the countries in the Middle East and Central Asia where governments are expected to play a key role in the low-carbon transition.

On the one hand, the region's 2030 emissions reduction goals can be achieved through a gradual removal of all fuel subsidies and, in addition, a phased introduction of a carbon tax of $8 per metric-tonne of CO2-equivalent in MENAP and $4 in the CCA over the next eight years. Such an approach would set off a potentially challenging transition by the private sector toward a cleaner fuel mix and lower overall energy consumption that could temporarily weigh on economic growth. In the long term, however, such a transition would leave to future generations an economy with a stronger fiscal position, greater energy efficiency, and a more efficient overall allocation of resources.



Alternatively, additional public investments of close to $900 billion in renewable sources of energy between 2023 and 2030 would allow achieving the region's emission reduction targets with fuel subsidies reduced by two-thirds and without any carbon tax. Such a greening strategy implies a smaller increase in energy prices, improved energy independence, and faster economic growth during the transition. But a smoother low-carbon transition for the current generation could set future generations on a path of lower long-term growth due to higher debt, persistent distortions in the energy sector, and unabated emissions in many parts of the economy.

In between, many other combinations of these fiscal options can be compatible with reaching the ME&CA region's climate mitigation commitment, combined with other measures including regulations and sector-specific policies. How to share the economic burden of climate mitigation between current and future generations is arguably the most difficult and important decision that each government will need to make. Other mitigation policies could play an important role in alleviating the burden on fiscal policy and the trade-off outlined above. Examples of such policies include tightening building codes, mandating a transition to cleaner fuels and processes in manufacturing, reducing gas flaring from fossil fuel extraction, raising emissions standards in transportation, and mobilizing private investments in greening the economy.

A key takeaway from the discussion presented above is that, regardless of the choice, identifying the implied fiscal strategy and rolling it out early can help countries meet their mitigation pledges in time while mini¬mizing potential economic dislocations. If action is delayed, the measures required to achieve a given commitment would become larger and the trade-off less favorable. This is especially pertinent for countries which, in addition to their 2030 commitments, also pledged to reach net zero in the following decades and would therefore need to progressively raise their policy ambition. Increased external financial support, particularly concessional financing, could be used to ease the fiscal and growth trade-offs associated with climate mitigation policies.

There are other benefits to early identification of the fiscal strategy in support of climate mitigation. It would help countries arrive at credible estimates of potential external financing needs to inform both their own economic planning and the international dialogue on the needed external financial support. It would also provide sufficient time for domestic public discourse to take place, for the private sector to adjust to the expected policy changes, and for the authorities to implement other policies toward addressing the potential side effects—for example, by introducing measures to soften the distributional impact of mitiga¬tion policies, improving social safety nets, accelerating structural reforms to support the energy transition and offset potential growth effects, and strengthening financial sector regulations (IMF 2022). Finally, an early start will allow timely gearing up of other regulatory, fiscal, monetary, and financial sector policies and reforms, helping countries in the ME&CA region tread a smoother path toward greener economies.

(Prepared by Gareth Anderson, Jiayi Ma, Tokhir Mirzoev, Ling Zhu, and Karlygash Zhunussova)

Green Hydrogen: Harnessing the hope for a cleaner future

The climate change is a recognized phenomenon with temperatures already rising more than 1.1°C since pre-industrial levels and on a trajectory of rising beyond 3°C by 2050 if the world doesn't come together to act against it. Decarbonization has become a worldwide agenda with developed nations making a historic agreement at the recently concluded COP27 to help developing nations pay for the loss and damage due to climate change. Major economies have pledged to go carbon neutral by 2050 (e.g., EU, US) or 2060 (China) and have started taking measures to affect the same.

For leading companies in the world, sustainability and decarbonization has emerged as the imminent business challenge to address in the next decade. The need for companies to craft a definitive sustainability strategy and embark upon an implementation plan has never been more urgent. Global Steel majors too have set themselves specific and ambitious targets with clear roadmaps. Many steel companies have come up with specific climate action agenda and have released detailed publications outlining their targets and plans.

Steel is a basic building block of the global economy which factors into the production and operations of most industries, e.g., auto, aviation, construction, household appliances, etc. This also means it contributes to their carbon footprints. The steel industry represents up to 7% of global GHG (greenhouse gas) emissions and is also considered as one of hardest industries to decarbonize due to high heat requirements, low profit margins, high capital intensity, long asset life, and trade challenges. Approximately 88% of steel

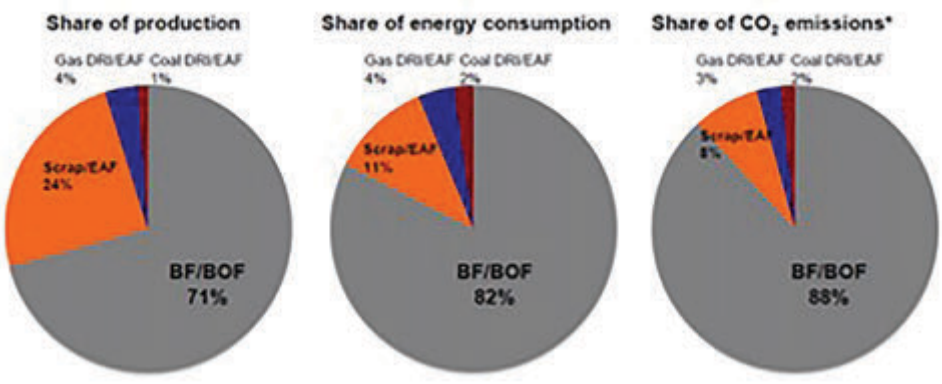


Figure 1: BF-BOF route accounts for ~88% of steelmaking emissions with >70% of world's production currently using

Figure 3: Reference image for Jindal Shadeed Iron & Steel facility

industry emissions stem from the use of BF-BOF (Blast Oxygen furnace) route in steel production. This route accounts for more than 70% of current steel production in the world. (Figure 1).

In comparison to BF-BOF route, DRI-EAF route with natural gas is a significantly cleaner technology with 40-50% less CO_2 emissions. While majority of steel producers around the world (including US, Europe, Japan) are yet to switch to the cleaner DRI-EAF route, the Middle Eastern steel producers are leading the way owing to the availability of natural gas in the region. Steel producers like Jindal Shadeed Iron & Steel are striving towards further reduction of CO_2 emissions through their gravity fed DRI technology.

Although natural gas-based technology offers emissions reduction, switching to hydrogen-based production offers a giant leap towards an environment friendly steelmaking. Using Green Hydrogen, hydrogen produced with the use of renewable energy (solar, wind, etc.), the H-DR-EAF production route holds a strong promise for reduction of more than 80% of CO_2 emissions as compared to existing emissions in steelmaking. (Figure 2)

“Although natural gas-based technology offers emissions reduction, switching to hydrogen-based production offers a giant leap towards an environment friendly steelmaking.”

With the development of Green Hydrogen, the world will move a step closer to

achieve the climate goals. The main cost drivers for green H2 - renewable power and electrolyzer efficiency, are expected to significantly reduce by 2030, thus boosting the Green Hydrogen market. Given the market landscape and improving economics, players from diverse sectors are increasingly moving towards green hydrogen generation. Utilities, Transmission system operators (TSOs), Oil & Gas companies & industry off-takers are few of the leading sectors entering the Green Hydrogen market in different capacities. Utilities can develop the storage solutions to match the renewable energy supply and electricity demand. TSOs possess access to distribution networks & vast knowledge on logistics infrastructure which can be leveraged to re-position core business in a de-carbonized market landscape. Green hydrogen paves a way for Oil & Gas companies to accelerate the phase-out of fossil fuels.

It is worth noting the effort on green hydrogen development already underway in Oman, a country rich in renewable resources. Oman Vision 2040 and the Government's push for National Hydrogen Strategy has created a very conducive atmosphere to attract investments in various green energy projects within the Sultanate.

The end-use industries such as steel have already started looking to replace the grey feedstock with green hydrogen to design sustainable end products that consumers now increasingly demand. An example of such initiative is the announcement by Jindal Shadeed for setting up a Green Hydrogen ready 5MT integrated steel complex at Duqm, Oman. ■

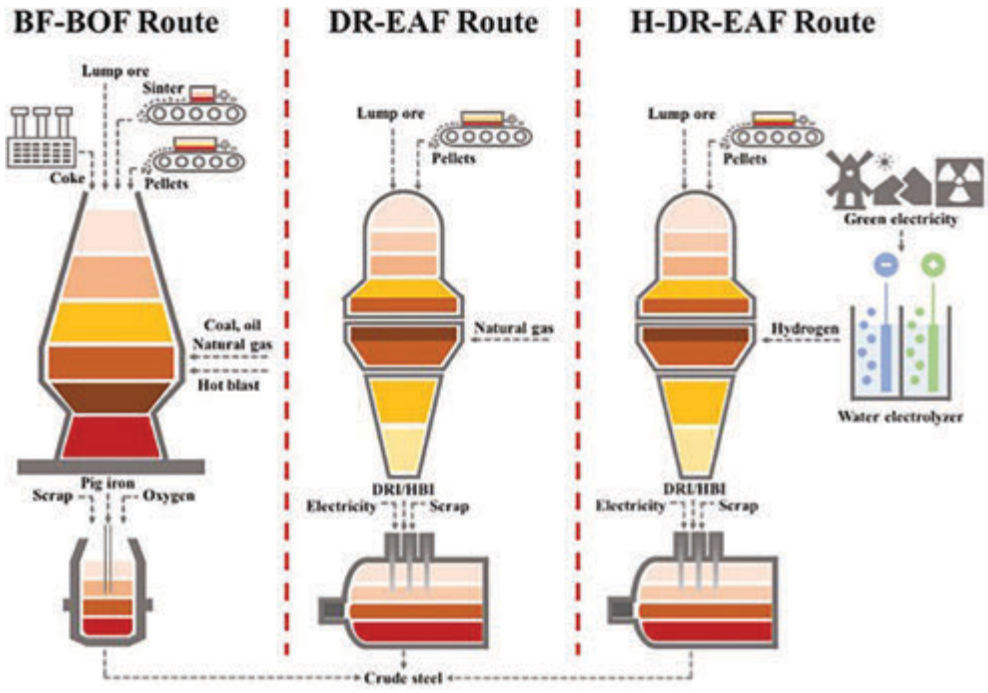


Figure 2: Comparison of different routes of steel production


علي الحبسي
THE STEEL OF OMAN
JINDAL

3 ways businesses can decarbonize and help reach net zero

By **Amy Barnes**
Head of Climate and Sustainability Strategy, Marsh

No organization will be untouched by climate change, and the transformation of the global economy it demands.

Risk managers must ask themselves two key questions: what is the impact of my organization on the climate? And on the flip side, what is the impact of the climate on my organization, both now and in the future?

Keeping global warming within the 1.5°C agreed in the Paris Treaty means almost halving CO2 emissions by 2030, underscoring the need to understand how every organization can play its part. While cutting emissions, businesses will also have to build resilience to a new reality that includes more extreme and costly natural disasters. In 2021 alone, ten of the world's most destructive events cost $170 billion in damages.

Oliver Wyman's Climate Action Navigator found that businesses across multiple key sectors need to take significantly more action to have emissions by 2030. This chimes with a recent Deloitte study, which revealed that while 97 percent of CEOs know their companies are already negatively impacted by climate change, just 19 percent have implemented 'needle-moving' sustainability actions.

Meanwhile, the risks of inaction are mounting. Managers will also need to gauge their organization's exposure to climate liability. A series of lawsuits against fossil fuel companies for causing climate change signals a growing desire for accountability.

To provide the momentum that is so urgently needed, here are three key ways companies can help cut greenhouse gas emissions to reduce their risk exposure, while gaining a competitive edge.

1) Prepare sustainable adaptations to extreme weather

The risk of destructive extreme weather events such as hurricanes, flooding, and heatwaves is rising. In addition to terrible human misery, these events disrupt global supply chains – the 2011 flooding in Thailand devastated many large industrial estates, causing a global shortage of hard drives. Fast forward to 2022, and Europe's heatwave has dried up the Rhine river to such an extent that only about 50% of the usual cargo is able to pass along this vital artery for everything from chemicals to car parts, according to a news report.

Despite the unpredictability of physical climate risks, companies can adapt with anticipatory strategies which identify relevant risks and put mitigation measures in place. They could make use of modeling techniques to understand their vulnerability to evolving weather patterns and build a bespoke risk-management toolkit.

Adapting to physical climate risks is an opportunity to implement sustainable practices, such as decentralization of supply chains. For instance, companies vulnerable to power outages could invest in rooftop solar panels and other low-carbon distributed power generation forms.

2) Decarbonize across the supply chain

More and more, businesses are scrutinizing the greenhouse gas emissions in their supply chains. In 2017, Apple laid out new, stronger sustainability criteria for its suppliers. In the same year, Walmart announced plans to cut one billion tons of greenhouse gas emissions from its supply chain by 2030.

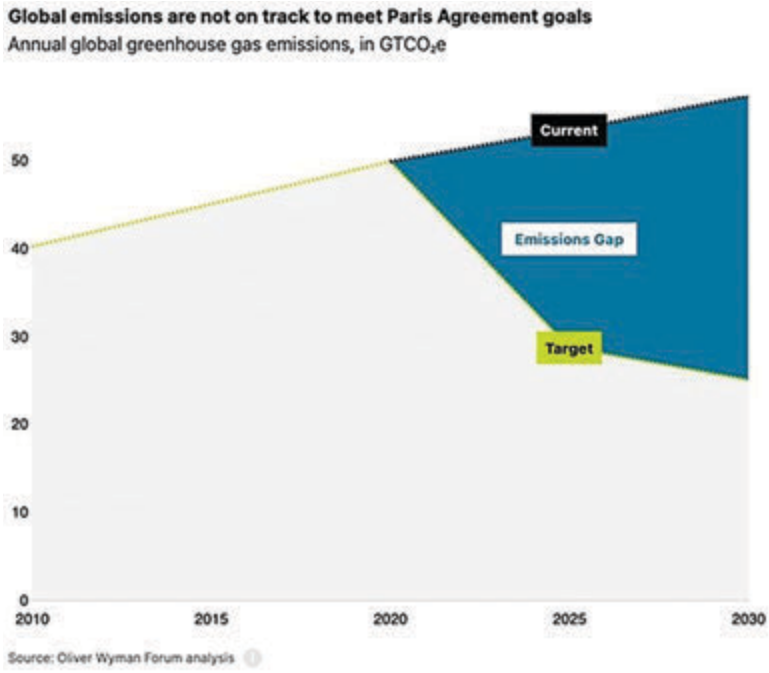
There is vast decarbonization potential in supply chains. Oliver Wyman's Climate Action Navigator shows that materials production alone accounts for 25 percent of global energy use and switching to a more sustainable use of materials has emissions reduction potential up to the equivalent of 1.6 gigatons of carbon dioxide annually by 2030. This could include adopting material recirculation and finding material efficiencies, supporting a company's climate resilience, particularly as access to raw materials like helium gas and lithium becomes less secure.

Businesses can also cut supply chain emissions by switching to low or zero-emissions transport options: 15 percent of greenhouse gas emissions are derived from transport, with more than half coming from trucks, trains, aircraft, and ships.

3) Proactively seek the opportunities of the net-zero transition

It is beneficial for businesses to stay one step ahead of regulation, investor concerns, and consumer attitudes to prevent being caught out in a world in which sustainability is taking center stage. This is why the most climate-resilient companies do not just defensively prepare for climate change impacts – they build offensive strategies which account for risk and embrace opportunity.

According to the 2017 report, How climate resilient is your company? Meeting a rising business imperative: "The shift to decarbonization will drive dramatic structural changes across the economy. Companies that proactively adapt to these changes will have powerful competitive advantages."



This means something different for every company, but requires leaders to overcome short-term thinking and invest in sustainable technologies, operations, and assets that have a clear future in the low-carbon economy: from hydrogen to carbon capture.

One of the biggest single changes a business can make to cut its emissions is switching to renewables and other sources of low-carbon power: scaling up low-carbon power accounts for around 30 percent of the 'emissions gap', with the potential to cut the equivalent of nearly 10 gigatons of carbon dioxide annually by 2030. Switching to a renewable energy supplier makes a business less vulnerable to volatility in oil and gas prices while building green credibility among investors and customers.

Fighting the climate crisis is not a zero-sum game. If companies make smart decisions to build resilience, they can prosper in the long term while playing a positive role in one of the biggest challenges of our time. ■

MENA's sustainability journey in light of COP27

The energy sector in MENA is undergoing structural changes with sustainability at its core to deliver on the region's climate pledges. These changes are accompanied by a comprehensive set of economic and regulatory reforms to maintain a certain level of socioeconomic development to attain climate targets while considering each country's energy security context, says the Arab Petroleum Investments Corporation (APICORP) in this new report.

Climate Justice: The North-South Divide

The main themes of COP27 are climate justice, balancing the trifecta of energy security, energy affordability and emissions reduction, as well as adopting a balanced approach between climate mitigation and adaptation finance.

A recent IMF article suggests that economies must collectively invest at least USD 1 Tn in energy infrastructure by 2030 and USD 3 Tn to USD 6 Tn across all sectors per year by 2050 to mitigate climate change, a formidable and unattainable sum for feeble economies already reeling from the impacts of COVID-19 repercussions. These countries are seeing themselves as having to pay for eradicating legacy GHG emissions that the

developed industrial nations have caused over the past century. Although the global south is prone to severe impacts of climate change, the ability of these nations to finance climate change mitigation/adaptation will be limited.

The MENA region has a vested interest in combating climate change. IPCC Climate models project that the average annual temperature could increase by almost 5°C in the region before the end of the century under the high emission scenario2. The World Bank's calculations also show that lower & middle-income populations in the region will take the largest hit from physical climate risks.

On the other hand, public debt burdens have been accumulating since 2020 where the gross public debt in MENA crossed USD 1.4 Tn. With continuing global inflation and interest rate hikes, the ability of MENA governments – with the exception of KSA, UAE and Qatar– to finance the energy transition is very low.

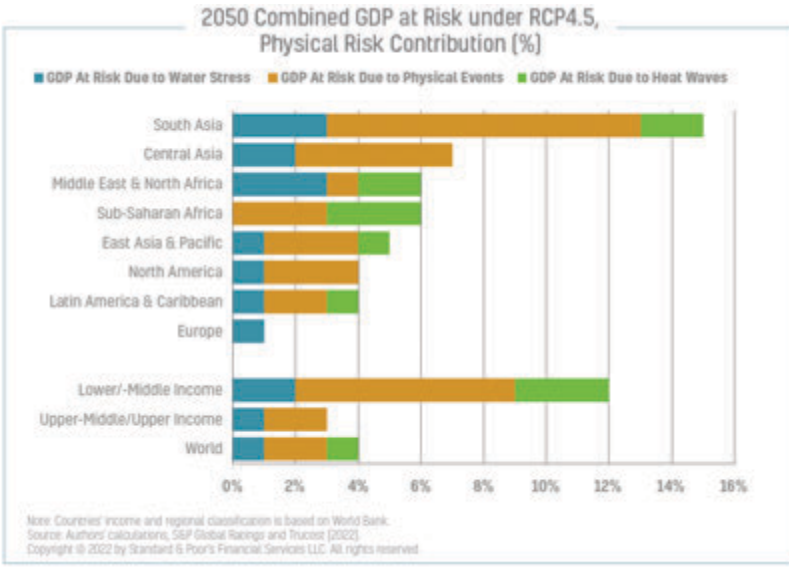
Balancing the Trifecta: Energy Security, Energy Affordability, and Emissions Reduction

Countries around the world are facing the greatest energy crises since the 1970s. In October 2022, the UN secretary general stated that emissions must fall by 45% in the next eight years to avoid a climate catastrophe. This comes in a year where countries around the world are switching back to burning coal for power generation (after the historic pledge of COP26 to phase down the usage of coal) - sending coal prices to record highs - as the spill-over from energy shortages affected fertilizer and food prices, raw material, and logistics costs.

In a volatile global economy battered by COVID, chronic global inflation, and the lowest agricultural productivity in a decade, developed economies have been hardly managing energy market tightness by paying more for their energy consumption, rationalizing energy consumption, bailing-out defaulting utility companies and subsidizing consumption. In developing economies, subsidy phase-outs had to be postponed and, in some countries, special social protection subsidies had to be injected to avoid destabilizing the entire state. In poor nations –where the energy crisis and its spillovers already jeopardized the entire social stability– governments had to ask for emergency aid from the international community. According to a 2022 study by the UN WFP, in just two years, the number of people facing acute food insecurity or at high risk increased by more than 200 million from 135 million in 53 countries pre-pandemic to 345 million in 82 countries today, mostly in developing countries.

For developing countries, the issue is much more complex, as they need to meet rising demand for affordable energy while simultaneously adapting to their vulnerability to adverse climate impacts, and above all of this, play their role in mitigating future climate change through decarbonisation.5 In this context, MENA countries' progress in energy transition has been exemplary for emerging and developing economies, and driven by the following realities:

First, MENA economies have been challenged –with varied degrees– even before Covid-19 crisis. The region is highly vulnerable to global warming effects mainly, rising sea levels, and desertification, and hence has a genuine interest in climate action. On the positive side, the region is blessed with an excellent profile of scalable & affordable renewables, particularly in solar and wind. MENA conventional energy exporters recognize their responsibility in meeting global energy security needs in a new decarbonized world, and are using hydrocarbons windfall to advance investments



Renewable Energy Targets in Selected MENA Countries

Country	RE policy targets	Progress '21
Saudi Arabia	10% of generation by 2025, 50% by 2030	< 1% of generation
UAE	44% of generation mix by 2050 (federal)	≈ 5% of generation (federal)
Oman	10% of generation by 2025, 30% by 2030	< 1% of generation
Qatar	20% of generation by 2030	< 1% of generation
Kuwait	15% of generation by 2030	< 1% of generation
Jordan	31% of generation mix by 2030	≈ 20% of generation
Iraq	5% of generation by 2025, 20% by 2030	< 1% of generation
Lebanon	30% of generation mix by 2030	≈ 7% of installed capacity
Egypt	20% of generation by 2022, 42% by 2035	≈ 11% of generation
Morocco	52% of installed capacity by 2025, 70% by 2040	≈ 40% of installed capacity
Algeria	37% of installed capacity by 2030	< 1% of installed capacity

Source: APICORP

in decarbonisation (e.g. CCUS). On the other hand, countries with no hydrocarbon resource significance are using renewables to decrease their energy import bill while still meeting their energy needs, and also eyeing clean energy export potential. The region –as a whole– targets capturing a strong future market share of renewable energy exports (Hydrogen, Ammonia, green electricity).

A Balanced Approach between Climate Mitigation and Adaptation Finance

Climate mitigation has been the focus of multilateral negotiations for decades over how to slow or arrest GHG emissions that contribute to climate change. Now, developing countries having long pressed for developed countries' financial assistance against severe storms, heat waves, floods, and other physical risks. Climate adaptation will be at the forefront of COP27 discussions after mitigation shortages have resulted in damages and even human losses. A 2022 Oxfam report shows that the average annual extreme weather-related emergencies rose more than 800% over the last two decades, with developed countries contributing only 54% of risk packages required. The economic cost of extreme weather events in 2021 alone was estimated to be USD 329 Bn globally, the third highest year on record.

This is nearly double the total aid given by developed nations to the developing world that year. Historically, fossil fuel extraction, industrialization, and greenhouse gas (GHG) emissions have been skewed toward a small number of countries. These "high-income" countries, as identified by the World Bank, are responsible for 44% of cumulative CO2 emissions from fossil fuel extraction, manufacturing, land use, and forestry since pre-industrial times. Their share of the current global population, by contrast, is just 14%.

Developing countries coming to COP27 with the aim of claiming right to compensation for tangible losses and damages from climate events, especially given the legacy failure of developed countries to meet their climate funding commitments to date. Calls for loss & damage obligations on the part of the global north will be stacked on top of pleas for financial assistance for emissions reductions.

The level of global adaptation funding committed in the context of the COP has so far inadequate in comparison to the scale of current and future needs. The official Adaptation Fund, created in 2001 to finance adaptation efforts in developing economies, has circa USD 1 Bn in funds available, mostly earmarked for initiatives to prevent loss of life, such as early warning systems.

The drive for adaptation carries a sense of urgency that mitigation never could, in that the associated physical risk is visible and quantifiable. The blended finance approach that received so much attention at COP26 was largely discussed in the context of mitigation, but it may prove equally well or even better suited to adaptation.

One important venue of climate adaptation that is overlooked is energy efficiency. A 2022

IMF paper8 states that improving energy efficiency brings a significant reduction in CO2 emissions and at the same time strengthens energy security, with considerable energy savings on the consumption side.

A Spectrum of Tools to Reduce GHG Emissions

The energy sector in MENA is undergoing structural changes with sustainability at its core to deliver on the region's climate pledges. These changes are accompanied by a comprehensive set of economic and regulatory reforms to maintain a certain level of socioeconomic development to attain climate targets while considering each country's energy security context.

On the policy front, MENA countries are prioritizing capacity building and empowering institutions to be able to plan, prepare and react to climate change. Climate policy coherence and integration are the building blocks of any effective regulatory reform.

On the financing front, net-energy importers in MENA are suffering from fiscal distress and debt burdens as a fallout from the COVID pandemic, increasing commodity costs, high-interest rates, and a looming global economic recession. These countries are pursuing strategic partnerships with MDBs and international financial institutions to help finance mitigation and adaptation actions to remain on track to realizing their climate pledges. With the climate action price tag estimated at USD 275 Tn over the next 30 years (USD 9 Tn/yr.) for a 2°C scenario, MENA net-energy importers will only be able to reduce their GHG emissions conditional to international financial support as reflected in their submitted Nationally Determined Contribution (NDC).

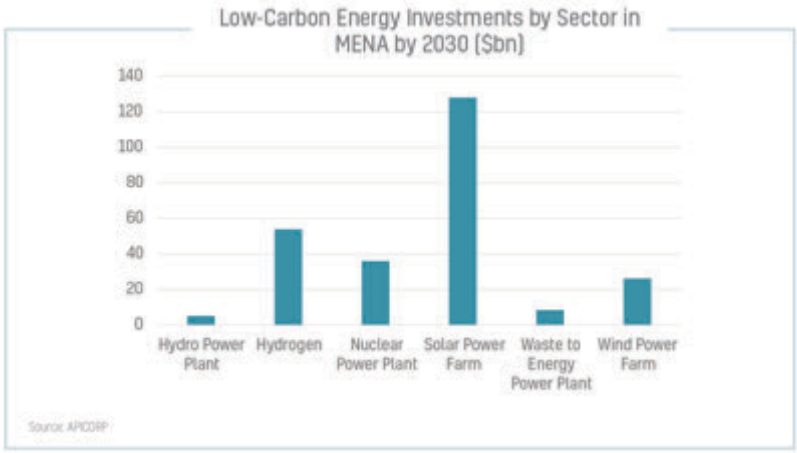
On the technological front, there is a plethora of elements shared among MENA countries that serve as implementation mechanisms to achieve the targeted GHG emissions reduction. For countries aiming at decarbonizing their energy sector; energy efficiency, CCUS (carbon capture utilization and/or storage), blue & green hydrogen, methane management, renewables & energy storage lie at the heart of their strategic plans to reduce GHG emissions.

Energy Efficiency: Several initiatives are being implemented to reduce energy consumption in targeted sectors, such as upgrading home appliances and air conditioning units, optimizing feedstock utilization in petrochemicals, enhancing the transportation fleet fuel economy, phasing out inefficient and used light-duty vehicles, and improving the thermal efficiency of power generation assets. Reducing energy consumption before scaling up energy supply is a strategic tool that will help MENA countries achieve their NDCs. Energy subsidy reform and amending regulatory frameworks will be essential to integrate energy efficiency measures in various segments of the economy.

> **"On the financing front, net-energy importers in MENA are suffering from fiscal distress and debt burdens as a fallout from the COVID pandemic, increasing commodity costs, high-interest rates, and a looming global economic recession."**

Carbon Capture Utilization & Storage (CCUS): Capturing CO2 emissions at the point source for conversion into value-added products or storage in geological reservoirs is a critical technology for climate pledges. Net-energy exporting countries are building upon their experience in enhanced oil recovery (EOR) programs to advance the uptake of CCUS technologies and scale up their deployment. CCUS hubs will leverage the concentration of the manufacturing industry, proximity to sinks, and transport infrastructures in a circular economy.

Currently, less than 30 large CCUS facilities are in operation globally that capture around 40-50 MtCO2 per annum. Investments over the last ten years amounted to around USD 10 Bn, less than 0.5% of the USD 2.9 Tn investments in renewable technologies over the same period. Greater international engagement is required to overcome obstacles that keep CCUS from reaching the required



scale. These range from large upfront costs, energy losses, poor market signals and regulatory hurdles, to public acceptance issues and safety concerns.

Blue & Green Hydrogen: In light of the gradual energy transition towards a low-carbon future in the region, blue and green hydrogen molecules will play a central role due to their versatility as clean energy vectors for domestic use and exports. According to IRENA's 1.5°C scenario, hydrogen could meet up to 12% of final energy consumption by 2050. Global hydrogen demand is expected to increase from the current 90 MTPA in 2020 to almost 300 MTPA in 2050, according to IRENA. By leveraging its strong potential, the MENA region is well-positioned to supply around 10% to 20% of the global hydrogen markets by 2050.

In addition to its prospective role as a large-scale energy storage medium, hydrogen can be optimally utilized to decarbonize the hard-to-abate energy-intensive industries where electrification proves to be challenging. Pilots, research, and demonstration projects will be prioritized to improve technology maturity and lower costs in the aviation, maritime shipping, refining & petrochemicals, and hard-to-abate industries. For the MENA region, the most adequate near-term applications are the petrochemicals & refining industries (which currently depend on grey hydrogen and can shift to cleaner hydrogen vectors), steel and aluminum smelters, ammonia, and methanol. In the medium to long term, large-scale seasonal energy storage, long-haul transportation, and maritime shipping are prospective applications.

In the medium term, blue hydrogen proves to be a more attractive option to the MENA region. Blue hydrogen can be produced at a relatively low cost, and it will slightly disrupt the IOC/NOC's existing business models. This is a central metric in the energy transition journey since hydrocarbon producers will play a key role in decarbonizing the upstream oil and gas sector and help reach net-zero targets by mid-century. Blue hydrogen can yield very low greenhouse gas emissions, only if methane leakage emissions do not exceed 0.2% with close to 100% carbon capture.

For green hydrogen, the two main elements that need to be assessed are the cost of electricity from renewable energy sources and electrolysis. The MENA region has a highly competitive advantage in generating low-cost renewable electricity with high-capacity factors reaching 20%. The levelized cost of renewable electricity in the region has reached world-record levels nearing USC 1.04/kWh (in the 600 MW Al Shuaiba PV IP project in KSA). However, due to the supply chain disruptions resulting from the pandemic over the past two years, the downward trend of renewable electricity costs is expected to invert temporarily before returning to its low levels by 2023-2024. As for electrolyzers, the technology risk resides in scaling up to a multi-GW scale that can be operated with intermittent renewable energy sources at high efficiencies. It is expected that the cost curve of green hydrogen will decline with time, and it will be cost-competitive with blue and grey hydrogen by 2030.

Methane Management: Considering its global warming potential, methane emission management is central to climate pledges. Measures include reduced flaring in the oil and gas industry, recovery, and subsequent utilization for power generation and production of petrochemicals. Currently, KSA, UAE, Bahrain, Qatar, Kuwait, Oman, Iraq, Jordan, Egypt, Tunisia, and Morocco, are all members of the Global Methane Pledge, a coalition established in COP26 with currently 100 countries representing nearly 50% of total global methane emissions. The coalition pledges to voluntarily work to reduce global methane emissions at least 30% by 2030, which could eliminate over 0.2˚C warming by 2050.

Renewables: Renewable energy systems have been gaining momentum across MENA driven by ambitious national targets, technology cost declines, and increasing investments toward low-cost and low-carbon technologies. The national renewable energy targets set for 2030 –ranging between 15% and 52% of electricity generation by 2030 portray the governments' will to double down efforts and increase the share of renewables in the energy mix. As of 2020, the total installed capacity of renewable energy in MENA crossed 10.6 GW, almost double the capacity of 5.4GW in 2010.

Renewable Energy Targets in Selected MENA Countries

MENA countries with abundant renewable energy sources are accelerating their renewable energy plans to achieve their renewable energy policy ambitions while reducing domestic consumption of fossil fuels. Integrating renewables in their generation mix is part of a shared policy objective to diversify the power mix with low-cost, low-carbon energy vectors while maintaining the security of the power supply. Countries with robust renewables potential aim to reduce dependence on fossil fuel imports and integrate low-cost renewables into domestic grids.

Morocco and Jordan are currently at the forefront of renewable energy deployment in MENA, achieving their short-term policy targets. Morocco has reached almost 40% of its installed capacity from renewable energy in 2021, meanwhile, Jordan has achieved nearly 20% of its generation capacity. Other countries such as Saudi Arabia, UAE, Egypt, and Oman have relatively low renewable energy generation, but the share is expected to witness a significant hike with large capacities planned and committed in the project pipeline.

The increase in renewables in MENA is mainly driven by utility and distributed solar PV, onshore wind power, and other energy sources such as CSP, geothermal and hydropower. The MENA region is expected to add around 33 GW of renewables by 2026 (by installed capacity), with around 26 GW as utility and distributed solar PV.

Energy Storage: Meeting the national renewable energy targets requires scaling up and systematic integration of variable renewable energy (VRE) systems into the power grid which in turn necessitates deployment of energy storage solutions (ESS) for firming the power capacity, building flexibility, and ensuring power systems stability. ESS also plays a critical role in managing intermittencies of VREs and in mitigating potential power supply disruptions while providing ancillary services.

The pace of integration of energy storage systems (ESS) in MENA is driven by three main factors: 1) the technical need associated with the accelerated deployment of renewables, 2) the technological advancements driving cost competitiveness of ESS, and 3) the policy support and power markets evolution that incentivizes investments.

Although the energy storage market in MENA is bound to grow, several barriers exist that hinder the integration of ESS and ramping up of investments. Financial, regulatory and market barriers need to be addressed via policy tools that shall lay the foundations for an evolved power market to integrate the deployed ESS.

Strong Pipeline of Low-Carbon Energy in MENA by 2030

The MENA region has a pipeline of USD 257 Bn in low-carbon energy projects by 2030. These include projects are different stages of development, where the planned low-carbon energy projects (at the pre-FEED stage) make up around 71% of total projects by net value.

The low-carbon energy sectors are witnessing accelerated project activity that will contribute to achieving climate pledges in MENA. The sectors include renewables (solar PV, wind, hydro), hydrogen, nuclear and waste-to-energy.

For project investments at both planned and committed stages of development, solar PV leads with a 50% share by project value, followed by hydrogen (21%), nuclear (14%), and wind (10%). Hydropower and waste-to-energy projects both constitute 5% of total projects by value.

On a MENA regional level, low-carbon energy projects are mostly concentrated in North Africa (59%), followed by the GCC (38%), and the Levant (4%) by project value. ■

[Courtesy: APICORP]

For green hydrogen, use of experience will be key to its success

In this article, the author promotes the development of Imodco's jetty-less solutions for open sea transfer of energy carrier cargo, leveraging on his experience gained over 28 years working for SBM Offshore.

By **Philippe Lavagna**
Terminals for New Energies Product Account Manager
Imodco, part of SBM Offshore Group

The need for energy will not reduce simply because we strive to make better use of it – starting by reducing the many wastages in our present-day lifestyle and bad habits – will not compensate the larger number of persons in need of energy. Consequently, as we must reduce our GHG emissions, we will ineluctably need more renewable energies. Ideally these should be produced locally, but the storage of renewable energy remains the problem to crack. Green Hydrogen and its various vectors (called Hydrogen Carriers) are an attractive solution to store and transport Green Energy for the largest capacities over the longest durations.

Many Hydrogen Carriers (Ammonia, Methanol, most LOHC) are rather compatible with existing storage and transport infrastructure such as tankers and loading/offloading terminals. A significant step in enabling the Hydrogen economy to happen successfully is to leverage on experience wherever possible. This is particularly valid for the Green Hydrogen mega projects, for fluid cargo transfer from shore to vessels.

As a promising Green Hydrogen Hub, the Sultanate of Oman has a key role to play in the decarbonated world to come. This will require facilities to transfer Green Hydrogen cargoes from the coastline area like South of Duqm, and Ras Markaz. There are various technologies available for fluid cargo transfer from onshore storages to gas carriers in the open sea, in other words, without the need for new harbor nor expensive jetty – so these systems are called 'jetty-less'. The experience of the fluid cargo shipping industry can be adapted to the Hydrogen economy's new needs.

Jetty-less offloading systems have been invented over 60 years ago mainly for large oil tankers which would not fit in the existing harbors or which would need to load or offload oil or oil derivatives from a refinery away from existing infrastructures. A bit of history: for some large development projects, heavy and long-term investments were made into large jetty systems to receive these large vessels. Over the years, the experience of these large projects indicates that jetty systems typically are not only expensive but also have long delivery schedules. This is mainly due to the nature of jetty systems, especially those with breakwater, requiring many studies of the impact on the environment and the time consuming, associated permitting process. Jetty-less systems have a more straight forward permitting process and shorter overall schedule, as the simplicity of the overall system enables a virtuous spiral of simplification and cost efficiency: Jetty-less systems are conceived from day one with a view of minimum impact on the environment, including possible site reinstatement. This eases the permitting

process and reduces the number of required impact studies. Finally, a shorter schedule and simpler system have combined and significant positive effect on the overall CAPEX.

Many years of operations of jetty-less systems confirm, for properly designed jetty-less systems, the overall high commercial attractiveness of the solution. The important decision for the economics is the selection of the right type of jetty-less systems:

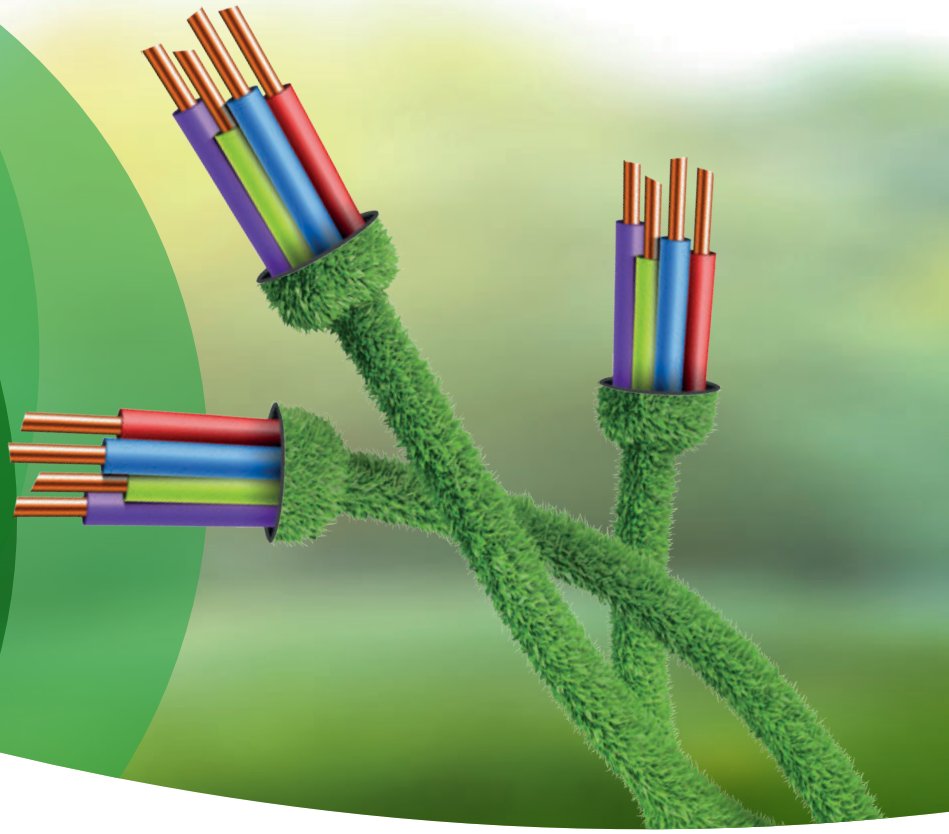
- Conventional Buoy Mooring (CBM) are for "fixed heading" concepts where the operations are made while the vessel heading is kept in the same direction. Despite lower CAPEX, these fixed heading systems are potentially economically viable only in locations where the environment is either benign and/or directional enough to enable the required uptime. History has shown poor uptime of fixed heading concepts hence the invention of a weather-vaning concept.
- Single Point Mooring (SPM), often called CALM – see Figure 1, terminals allow the weather-vaning of the carrier during the loading/offloading operations. In other words, the operations can continue, thanks to a swivel system allowing the flow of fluid transfer even if the weather direction changes and naturally rotates the vessel heading. The relatively small delta CAPEX is quickly paid back by the higher uptime, especially in more exposed locations. This SPM concept results from cracking the problem of poor operational uptime of fixed heading solutions, since then it has become the standard with over 1,000 CALM Terminals in use worldwide.

The safety records with SPM jetty-less systems are excellent and guaranteed by the well documented regulations and guideline/recommendations (e.g. OCIMF). For most products that are in liquid form at ambient temperatures, the captains of carrier vessels are generally used to berth, load/offload, unberth from SPM jetty-less systems. This is a testament to the fact that SPM jetty-less systems are widely used for simple reasons: it works and it is cost effective (best Net Present Value for all-scale projects).

During the Green Hydrogen Summit Oman on December 7th 2022, a review of the technologies for Green Hydrogen cargo transfer in open sea will be presented and this work indicates that SPM jetty-less will provide similar results for Hydrogen Cargo Transfer in remote locations. ■

Figure 1: Typical architecture of CALM terminal (Single Point Mooring – SPM)

Building Sustainable Growth



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OQ is wholly owned by the Government through Oman Investment Authority (OIA) and is a leading Omani integrated energy group with businesses operating across the energy value chain. OQ was established in 1996 to pursue investment opportunities in the energy sector both inside and outside Oman. In June 2020, the Group announced the formation of its new Alternative Energy (AE) business unit. This new business unit is intended to leverage the Group's broad asset base, its integration capabilities and seek organic growth to reduce the Group's exposure to oil and gas volatility and reduce its future carbon footprint. The AE operating model is organised around three pillars: energy excellence, clean energy and low carbon molecules.


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PEM Electrolyzers Key to Decarbonizing Oman

Experts agree green hydrogen is the key to safely powering at least 20% of our world.

As pressure mounts to decarbonize the Oman economy, leaders have been looking to green hydrogen solutions to help the nation reach net-zero by 2050. The solution for reaching that sustainability goal is PEM electrolyzers, a technology that has proven to become increasingly popular around the world.

Experts agree that green hydrogen is the key to safely powering at least 20% of the world, including the economy in Oman. Green hydrogen is produced from renewable resources like wind, water or solar. Other forms of hydrogen are produced from non-sustainable sources that release carbon emissions, whereas green hydrogen only releases oxygen.

Not only is green hydrogen environmentally friendly, it doesn't have the problems that many other forms of energy have. For example, industries that transitioned to batteries quickly learned that they aren't practical for long-term use in the delivery fleet industry in particular because of the added weight to the vehicle and decrease in available package space during the transportation of goods. Hydrogen fuel cells do not have these issues.

To ensure adoption of green hydrogen is as easy as possible, Plug created the green hydrogen ecosystem where every step of operations is addressed, including liquifying, producing, storing, and transporting the fuel.

Oman is uniquely positioned to become a world leader in the hydrogen economy, specifically in green hydrogen production with several factors driving that desire, such as the availability of year-round solar and wind energy, vast available space, a highly stable socio-political system, a strategic location on the world shipping map and well-developed ports.

Electrolyzers 101

The process of electrolysis has been known for more than two centuries with PEM electrolyzer production beginning in 1950. Interest in electrolyzers is quickly growing with experts estimating the global electrolyzer capacity to grow at a compound annual growth rate of 78% over the next decade, rising from 0.5 gigawatts (GW) of installed capacity in 2022 to 84.7 gigawatts in 2031, according to a March 2022 report from Guidehouse Insights, a marketplace advisory firm that covers the energy industry.

The International Renewable Energy Agency noted in 2020 that the post-2020 generation of electrolyzer projects is expected to move from niche to mainstream and escalate from megawatt to gigawatt in scale. Industry's goals are to reach lower cost, higher durability, and higher efficiency for electrolyzers over time, which will require scaled production, more manufacturing power, and research-driven technological advancements.

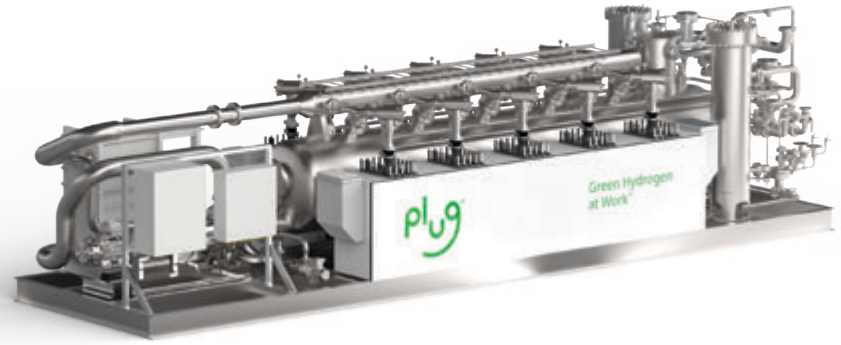
With a team that has nearly five decades of experience, Plug has developed electrolyzers that have very high current densities, high pressure output and seamless load following capabilities. The Plug team is currently providing electrolyzers for projects ranging from 1 megawatt to 1 gigawatt, deployed across five continents to help decarbonize a multitude of applications, including refineries, chemical and fertilizer production, manufacturing and

heavy industry, heating homes and buildings, and powering fuel-cell electric vehicles.

In fact, Fertiglobe — the strategic partnership between OCI N.V. and Abu Dhabi National Oil Company — recently selected Plug to provide 100 megwatts of electrolyzer to produce green hydrogen as a feedstock for up to 90,000 tons of green ammonia production at EBIC in Ain Sokhna, Egypt.

Green ammonia, produced from renewable energy such as solar and wind instead of natural gas, is a versatile product that is an ideal carrier fuel to store and transport hydrogen, and can help decarbonize numerous sectors which represent around 80% of current global greenhouse gas emissions, including as an important alternative fuel in the power sector in Japan and other countries.

Plug electrolyzer solutions range from turnkey containerized modules to custom-engineered plants for large-scale production. Containerized solutions work best for 0.5 to 10 tons of hydrogen per day demand, whereas plant-level solutions are ideal beyond 10 tons per day.



PEM vs Alkaline

When it comes to the complexity and cost of balance of plant (BOP) as the system size increases, PEM has a lower cost compared to alkaline, according to the Fraunhofer Institute for Solar Energy Systems ISE. In fact, the total cost of ownership of a PEM electrolyzer is lower than alkaline with forecasters estimating that PEM service costs are one-third of alkaline.

When scaling an electrolyzer, PEM has significant cost advantages in balance of plant economics. On a per-kilowatt basis, the capital expenditure associated with an alkaline

A Glance at Plug Customers

- **OCI in Egypt:** Plug recently shipped its first 5-megawatt module to Fertiglobe, a strategic partnership between OCI and the Abu Dhabi National Oil Company, in Egypt. It's the first of many units that will be a part of a 100-megawatt project, which will be the largest independently owned facility globally when it comes online. Plug is proud to support Fertiglobe as it produces green hydrogen as feedstock for up to 90,000 tons of green ammonia production at EBIC in Ain Sokhna, Egypt.
- **H2 Energy in Denmark:** Plug will deliver a 1-gigawatt electrolyzer to hydrogen company H2 Energy Europe. Planned for a green hydrogen production complex in Denmark, this is the largest capacity electrolyzer installation in the world to date. Harnessing offshore wind power, Plug's electrolyzer technology will enable the production of up to 100,000 metric tons per year of green hydrogen for use in the energy and transportation sector in northern Europe, supplying the fuel needed for the equivalent of approximately 15,000 heavy duty vehicles per day.
- **New Fortress Energy, USA:** Plug and New Fortress Energy Inc. entered into an agreement for a 120-megawatt industrial-scale green hydrogen plant in Texas. Expected to be one of the largest of its kind in North America, the facility will leverage Plug's industry-leading proton exchange membrane (PEM) electrolysis technology and enable the production of more than 50 tons per day (TPD) of green hydrogen. With the development of additional supporting infrastructure, the facility will be scalable to nearly 500 megawatts.
- **MOL in Hungary:** MOL Group and Plug have partnered to build one of Europe's largest-capacity green hydrogen production facilities at MOL's Danube Refinery in Százhalombatta, Hungary. Green hydrogen will reduce the carbon footprint of the Danube Refinery operation and enable emission-free mobility in the longer term. Utilizing a 10-megawatt (MW) electrolysis unit from Plug Power, MOL's €22 million facility will be able to produce approximately 1,600 tons of clean, carbon-neutral, green hydrogen annually, removing up to 25,000 tons of carbon dioxide by displacing the currently used natural gas-based production process.
- **NTPC in India** – Plug has partnered with France's Technip Energies to supply, construct and commission a 5-megawatt electrolyzer to NTPC. NTPC intends to produce hydrogen through PEM water electrolysis and capture carbon emissions from waste flue gas to convert into methanol.
- **Hiringa in New Zealand:** Plug will provide eight 1-megawatt electrolyzer systems to create hydrogen for Class 8 FCEV truck refueling along the island nation's primary ring road delivery route.
- **Lhyfe in France:** Plug will provide 10 5-megawatt PEM electrolyzer systems to Lhyfe, which aims to produce a renewable green hydrogen using primarily wind and solar-power for various mobility applications in Europe, including forklifts and light commercial vehicles, such as the Master Van from Hyvia, Plug's joint venture with Renault with hydrogen deliveries as early as 2023. Plug and Lhyfe also recently announced the first marinized electrolyzer to produce hydrogen at sea.

electrolyzer increases significantly as the system scales. With PEM, there are options for streamlining BOP to minimize upfront cost in larger systems above 10 megawatts.

When considering output pressure, standard alkaline electrolyzers deliver output at a low pressure of 1 to 10 bar, which is a nearly ambient pressure. For most applications, hydrogen must be further compressed for transport, storage, or consumption. On the flip side, Plug's PEM electrolyzers have an output of 40 bar — that's 4 to 40 times of a typical alkaline system.

Finally, the cost of safety is another measurement businesses should consider. Increased safety concerns with alkaline electrolyzers lead to more required safety equipment, labor, permitting, and compliance costs for businesses, and worst of all, putting worker well–being at risk. Alkaline electrolyzers also use potassium hydroxide, which is a highly corrosive chemical that can severely harm any individual who encounters it. Health experts say it can cause headaches, nausea, eye damage or irritation to the lungs, among other symptoms.

With PEM electrolyzers, technicians and operators only deal with one "chemical" while working on PEM systems – water.

Electrolyzer Technology for Oman

Oman is an ideal country for renewable energy due to the high-solar radiance and wind, and PEM is the optimal technology to pair with intermittent renewable energy due to its ability to ramp up and down quickly.

Promoting In-country value (ICV) is an important element in Plug's overall strategy for Oman. Plug, which has an office in Muscat, is well-aligned with Oman's drivers for ICV and its significance. Depending on specific project requirements and expectations, Plug is committed to sourcing from the local supply chain and to training local talent in order to bring additional value in Oman for years to come.

Interested in exploring how Plug can help your company improve operations with our best-in-class green hydrogen electrolyzer products? Contact us today at plugpower.com/contact-us. ■

Geothermal Energy: A Little-Known Weapon in the Fight Against Global Warming

Tevfik Kaya
SLB business development manager for geothermal, and carbon capture, utilization, and sequestration (CCUS) solutions

As the tangible impacts of climate change become impossible to ignore, more people are realizing the need to switch to clean sources of energy to power their daily lives. While much of the focus is on wind and solar, there are other forms of renewable energy that have the potential to make a significant contribution in achieving a more sustainable future. One of the most promising is geothermal energy. Not only is it a proven solution, it has some inherent advantages that may surprise people unfamiliar with this sector.

It's always about the economics

Geothermal energy is green and plentiful, and it can be used for generating electricity or heating and cooling buildings. However, in several parts of the world its available potential is far greater than current utilization, and while it has an important role to play in the energy systems of many countries, it has yet to become a mainstream solution. About a decade ago, an increase in US federal funding for renewable energy projects enabled it to start gaining some traction. But by the time technology for geothermal resource development was ready, the funding had been exhausted.

Renewed interest in clean energy from the public, markets, and energy industry shareholders over the last couple of years has revived investment viability. The growing shift in people's priorities and innovative clean energy generation technologies suggest that geothermal energy's moment has finally arrived. The International Energy Agency's (IEA's) World Energy Outlook 2022 indicates that pledges announced for geothermal power generation show an increase from 16 GW in 2021 to 102 GW by 2050.

An inherently renewable resource

Geothermal energy taps into the heat that exists deep below the Earth's surface. Superheated water extracted from these depths is converted into steam to generate electricity. The steam cools and condenses, and the water is returned to the subsurface to restart the cycle. Massive amounts of power can be generated with minimal CO2 emissions. The Earth has been generating heat for about 4.5 billion years and will continue to do so for billions more because of ongoing radioactive decay in its core. Steam powered the start of the industrial revolution and now, it is at the center of a new one.

A massive but little-known advantage

Investors focused on maximizing short-term profits were put off by the large upfront costs. However, that is starting to change, thanks to help from an unlikely source. While not always considered part of the solution for a clean energy future, the oil and gas industry already possesses much of the expertise needed to make geothermal energy viable.

Decades of studying the complexities of the subsurface, understanding and harnessing the Earth's resources, efficiently managing large assets, developing advanced technologies, and optimizing subsurface and surface integration with efficient infrastructure design have uniquely qualified the hydrocarbon industry to meet the geothermal challenge. These skills

can now be applied to geothermal projects, where the only resource extracted from the Earth is renewable subsurface heat.

Repurposing highly developed know-how, technologies, and infrastructure to address the planet's changing energy needs gives the geothermal industry a significant edge in the clean energy revolution. With experts transferring their knowledge from one resource to another, applying skillsets and technologies similar to those they have already mastered, both the investment and time to bring geothermal energy to market greatly reduce.

No hidden costs

While harnessing wind and solar energy has gained popularity because of lower startup costs, it should be noted that these solutions engender significant back-end costs, such as batteries for energy storage to ensure an uninterrupted supply of electricity. When these aspects and maintenance costs are factored in, an investment in geothermal projects is approximately the same as one in wind or solar energy. Moreover, because of its inherent 24/7 availability irrespective of weather, geothermal energy avoids the supply chain and sustainability issues associated with battery production. Another advantage of geothermal energy is that it is a domestic resource. It enables electric power supply diversification and reduces the risk of price increases due to rising fuel costs.

Time to act

The time for sitting on the fence is over. We need to invest in sustainable, safe, cost-effective, and reliable solutions to the changing energy demands of our world. The benefits and possibilities of geothermal energy make that task considerably easier.

Oman has joined the group of nations committed to reaching net-zero emissions by 2050, in line with the objective of the Paris Agreement to limit global warming to 1.5 degC above preindustrial levels. Exploring the country's geothermal potential by leveraging its extensive oil and gas expertise, subsurface datasets, and technology access can be one of the paths to success. ■

How Sustainable Hydrogen and Ammonia Transform the World

Erika Niino-Esser
thyssenkrupp Uhde

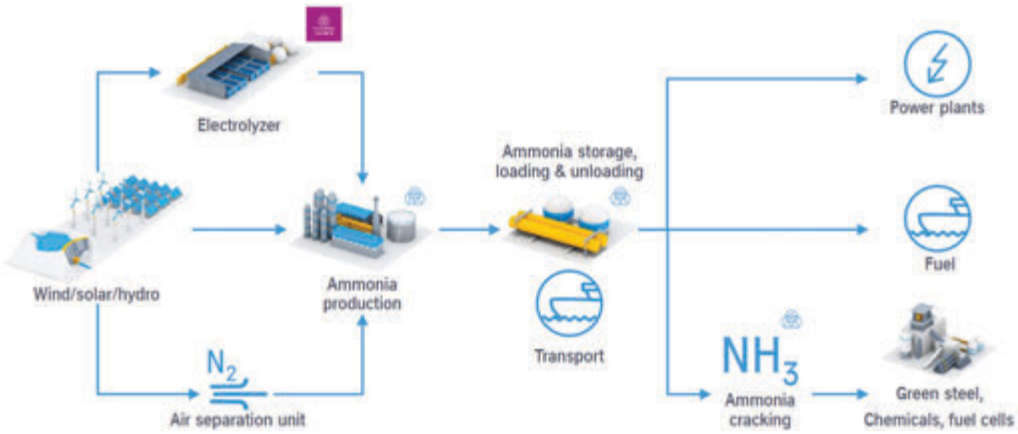
At the beginning of 2018, I started working as a development engineer for water electrolysis at thyssenkrupp nucera. At that time my vision was very clear: I wanted to contribute to a climate-friendly world by mastering the technology for green hydrogen production through utilization of renewable energies and help improve it. But did I have any idea of the importance this technology would have just a few years later? Certainly not.

Three years later I relocated to the United Arab Emirates, knowing that the Middle East is especially suitable for green hydrogen production. One has to see and experience the Middle East with your own eyes to realize the enormous potential of the region compared to the rest of the world. Oman in particular offers abundant renewable energy in both solar and wind power. Picturing a GW-scale green hydrogen project being realized in a few years increases my motivation and purpose significantly.

At the same time, I also believe that green hydrogen production alone will not be enough to reach the climate goals on time. A subsequent green ammonia production to establish a reliable hydrogen carrier will also be of immense importance. I hope to cause no misunderstanding: I am convinced that all kinds of hydrogen carriers are essential for exporting the "new oil" from the Middle East to off-takers in Europe or Asia. Several studies have been published by renowned organizations, in which pros and cons of different hydrogen carriers have been thoroughly analyzed already. In this brief article, I would like to take the opportunity to shed some light on the aspects of using ammonia as an energy carrier.

Ammonia is not only an intermediate product for fertilizer production but serves as a promising energy and hydrogen carrier when it comes to global trading. To highlight the facts here, around 180 million metric tons of ammonia are produced across the world, out of which 20 million metric tons are traded, annually. Of course, a substance like ammonia is never meant for end consumers and will only see professional use. But did you know that ammonia transportation is state of the art, and existing infrastructure can be utilized for distribution? The numbers are astonishing: an incredible number of 120 ports are already able to handle ammonia and up to 170 ships are suitable for carrying this base chemical. More importantly, 40 ships already conduct ammonia shipment all the time. You can see: Global standards, measures and procedures for safe storage and handling are already established worldwide.

Clean ammonia especially makes sense if the end-users are interested in ammonia as a base chemical or other direct uses. The majority of ammonia, namely 80 % is utilized for fertilizer production, hence implicitly, food production. The remaining 20 % are needed for other purposes, such as refrigerants, pharmaceuticals, or chemical products. Now, new applications for ammonia are becoming more and more attractive. In gas turbines, clean ammonia can be used for co-firing to reduce emissions in electricity generation. And turbines for 100% ammonia are being developed, effectively enabling zero emission energy generation as water and nitrogen are the only emissions in this process. The same is true for using ammonia to power transport ships, which is gaining more and more interest from shipping companies. So, ammonia all by itself is incredibly versatile, and while direct use is the most cost-effective solution,



it is also possible to reconvert ammonia into hydrogen and nitrogen. The process is called ammonia cracking and represents a reverse reaction of ammonia production. Colleagues at thyssenkrupp Uhde are currently working on this technology, and I am very excited about the development of this future-oriented technology.

As thyssenkrupp, we used to be technology providers for the chemical industry. Our new strength is to connect chemistry and energy, so we can meet our decarbonization targets and achieve net-zero as soon as possible. Thank you, Green Hydrogen Summit Oman for creating an open space to exchange about the vision for a sustainable hydrogen economy! ■

Hydrogen pipelines: The use of fracture mechanics for lifetime assessment

Exposure to hydrogen can make metals brittle and cause defects. Given this, the fatigue life of new and existing pipelines transporting H2 must be determined and monitored. TÜV SÜD uses the method of fracture mechanics to provide a reliable lifetime prediction and integrity management.

Dr Albert Großmann, Expert High-Pressure Gas Pipelines, TÜV SÜD Industrie Service
Jan Sachse, Team Lead Pipelines, TÜV SÜD Industrie Service
Dr Johanna Steinbock, Expert Fracture Mechanics Analysis, TÜV SÜD Industrie Service

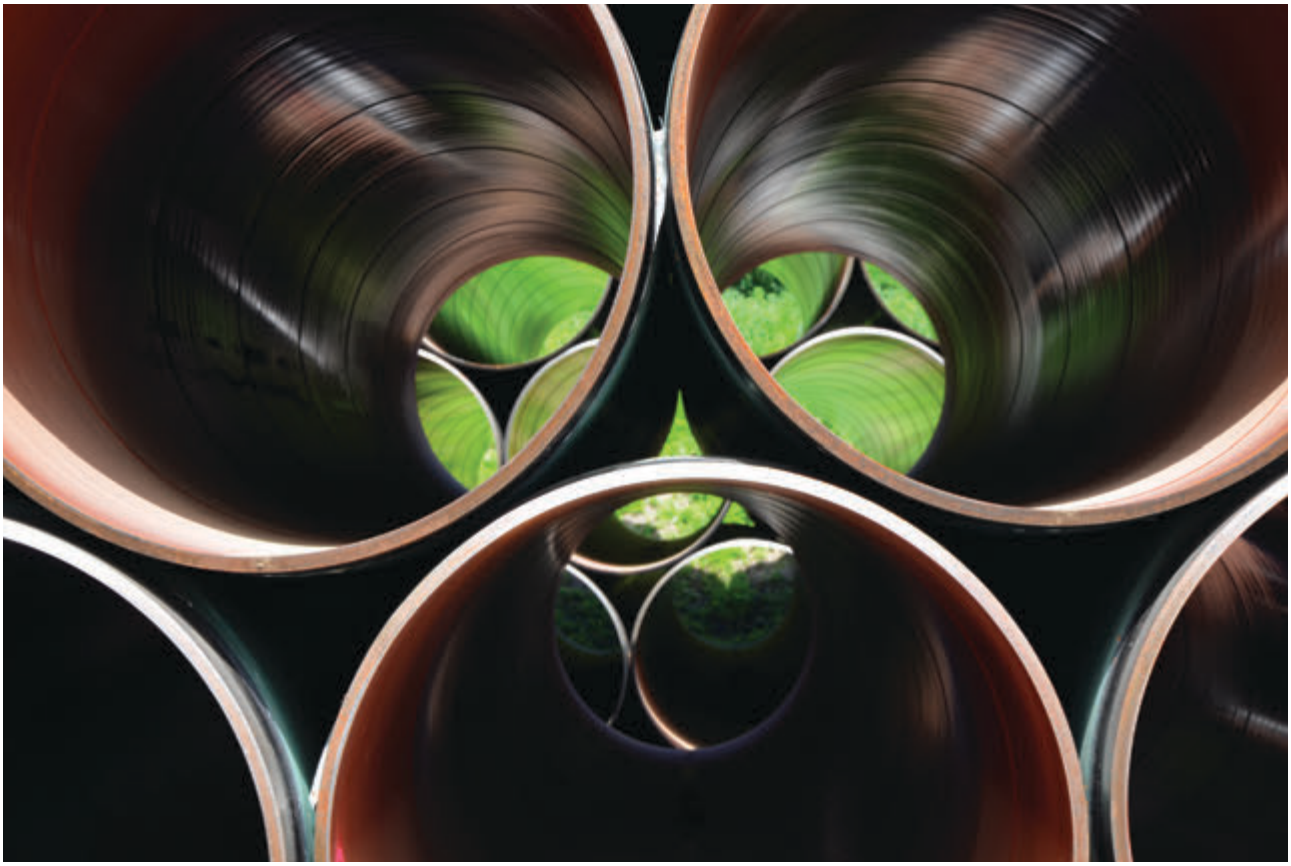
For the world's future hydrogen-centric economy, a suitable infrastructure is needed for transporting hydrogen throughout countries, as well as for its regional distribution and local storage. Pipelines represent the most ecological and cost-effective transport solution. For cross-regional gas transport, they have diameters of up to 1,400 mm and are operated at pressures of up to 100 bar. Proof of integrity is a prerequisite for their safe use.

For new hydrogen pipelines, a fracture-mechanics analysis is a must. Within the scope of design, its purpose is to define the detection limits for non-destructive testing of the parent material as well as for the welds. Existing natural gas pipelines that are converted into hydrogen pipelines particularly require a special safety concept. Here, the fracture-mechanics analysis helps not only to calculate the lifetime of a pipeline but also to decide whether an existing pipeline can be converted to operate with hydrogen.

History of changing fluid

History in other countries has proven that natural gas pipelines do tolerate changes in the transported fluids. In Germany, for example, the first pipeline networks distributed what is known as "town gas" produced from coal. Town gas already contained a high percentage of hydrogen as well as methane, nitrogen, and carbon monoxide. In the second half of the 20th century, town gas was replaced by natural gas. Natural gas is categorised as "low calorific gas" or "high calorific gas". As less of the former gas is extracted, the amount of the latter, that is fed into German gas networks, is increasing. It is characterised by a higher methane content, which is the reason for its higher calorific value.

Not only was the conversion successful, but it also benefited from professional planning and implementation of the associated technical measures. In Germany, many owners and operators of gas grids can look back on over a hundred years of experience – that is how long some of their networks have



been in use. Now, state-of-the-art measures must be determined to ensure safe operation of the pipelines that will transport 100 percent hydrogen in Germany and in Oman in the future. Therefore, material-related investigations are key.

Steel under examination

The harder the steel and the rougher its surface, the more susceptible it is to hydrogen embrittlement. This process occurs when hydrogen atoms form on the metal surface. When this atomic hydrogen starts to diffuse into the metal lattice, instead of forming H2 molecules on the surface of the material, the hydrogen atoms will recombine into molecules inside the material, resulting in gas bubbles or material separation (cracking) and ultimately embrittlement.

Locations with high mechanical stresses are particularly vulnerable to hydrogen embrittlement and hydrogen-induced cracking. Carbon steels show particularly reduced fracture resistance and accelerated crack propagation even at low partial pressure.

Suitable for conversion?

All factors that affect the life expectancy or integrity of pipelines must be analysed: Are there any flaws, such as cracks or corrosion? What is the general technical state of repair of the gas pipelines? The preferred method for identifying the condition of the pipeline is an assessment using pipeline inspection gauges known as "PIGS". The data collected by PIGS and other sources (if any) are then used for further analyses and evaluations. The PIGS provide the initial fault size, which is used as basis for a fracture mechanics analysis of integrity and service life expectancy.

In the first step, TÜV SÜD experts review the existing documents on design, construction, operation, servicing, and maintenance.

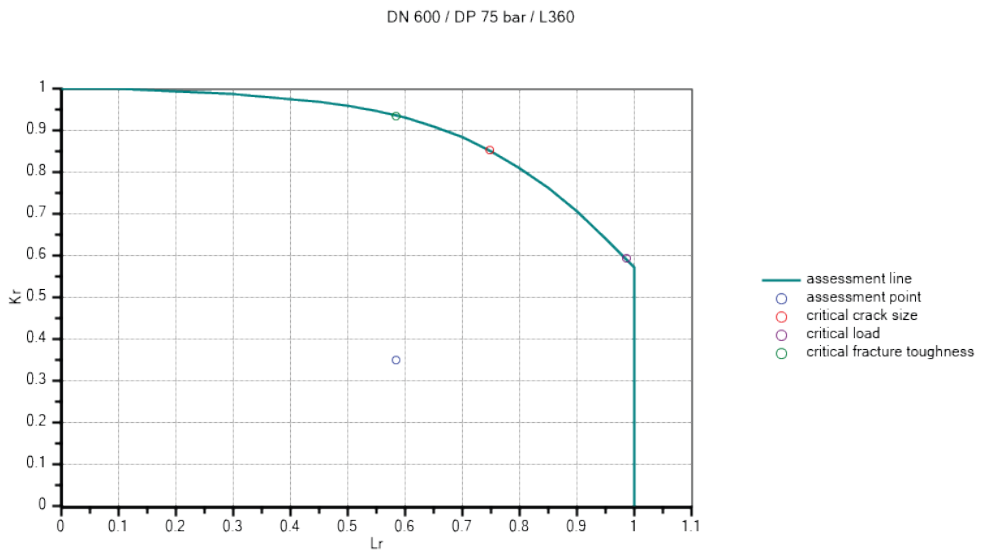


Figure 1: Load intensity and stress intensity in the failure assessment diagram (FAD)

> **“TÜV SÜD uses existing methods of pipeline integrity assessment in combination with method of fracture mechanics to deliver reliable lifetime prediction.”**

Further aspects, such as the extent and frequency of changes in operating pressure and the stress on the pipeline due to additional loads are also included in the review. Depending on the steel grades and materials used for pipelines and fittings respectively, the experts clarify whether additional destructive laboratory tests will be necessary. This is the case, for example, if the strength of the material under exposure to hydrogen has not yet been tested and is unknown. The final determination of service life by means of fracture mechanics considers the actual dimensions of the component, the loads to be expected and the material properties in a hydrogen atmosphere.

Crack behaviour and failure assessment

As a certain percentage of inhomogeneities is present in all existing and also new steel pipes, their behaviour under load must be examined. Fracture mechanics analyses cracks in components exposed to loads, considering material-specific resistance. The common variables such as stresses and distortions are not sufficient to adequately describe the pipe behaviour.

The analysis is based on the interaction of component geometry and material properties. The results are visualised in a failure assessment diagram (FAD). The two variables analysed are load intensity Lr and stress intensity Kr (Figure 1). They are computed from the actual component and fault geometries and the defined load and material parameters. The ratio of these two variables supplies an evaluation point, which is plotted in the diagram. A limit curve divides the FAD into two zones.

If the evaluation point is above the curve, the result is inadmissible; if it is below the curve, it is safe to assume that no component failure will occur. The diagram also enables statements to be made on critical crack depth, load carrying capacity (critical load) and the required (critical) fracture toughness. Following this analysis, the permissible crack depth is calculated by considering appropriate safety factors. It serves as a criterion for crack-growth analysis and the remaining service life.

Analysing load cycles

To determine the remaining lifetime as precisely as possible, future load cycles and their amplitudes should be known. On the one hand, recorded load cycles are analysed

and simulated for the following years. This leads to a realistic lifetime evaluation considering the physical and mathematical fact that every load cycle leads to a certain crack propagation, which means that the so-called stress intensity (force causing the crack) changes with every load cycle. On the other hand, for a quick rough lifetime estimation (e.g., during the design study to differentiate between possible pipeline designs), crack growth analyses can be performed using only full-load cycles.

The maximum number of cycles (lifetime without safety factor) is determined based on the cyclic growth analysis from the depth at start (prior to conversion) to the critical crack depth (end of lifetime). Halving the load-cycle amplitude of full load cycles may increase the lifetime as much as eightfold. Repeating the crack growth analysis with load cycles that reach from 80 to 100 percent of the design pressure results in the 125-fold increase in lifetime compared to full-load cycles. Thus, for a realistic lifetime evaluation, it is worth considering a realistic load profile for the intended operation in the future. The conversion into years depends on the number of load cycles expected per year of service. With this approach, professionals can define maintenance, servicing and inspection intervals depending on the number of load cycles and taking into account the appropriate safety or adjust these intervals in the course of time or on the basis of new findings.

Impartial Expertise from design to market launch

TÜV SÜD experts point out essential measures within the safety concepts of hydrogen pipelines to contribute to a safe, carbon-neutral energy supply. A key element is the fracture mechanics analysis for lifetime assessment of new and existing infrastructures. In feasibility studies, the international provider of testing, inspection, and certification services investigates in which existing natural-gas pipelines the fluid can be changed to hydrogen. The specialists are represented on all relevant committees and provide impartial third-party expertise along the value chain. ■

From Ambition to Reality 2: Measuring change in the race to deliver net zero Laying the foundation in the critical decade for action

Laying the foundation in the critical decade for action

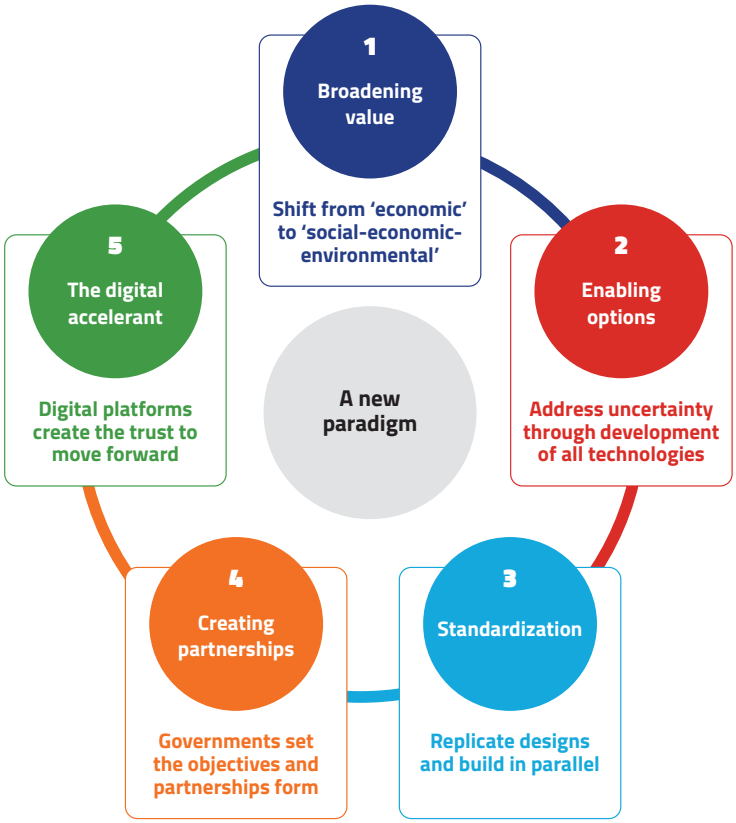


Figure 1 – the five shifts of the net-zero delivery paradigm

Worley and Princeton University's Andlinger Center for Energy and the Environment are exploring what it will take to move the world to net zero by mid-century. We have studied the required infrastructure and found the speed and scale of development unprecedented. Continuing to develop and build infrastructure the way we currently do will not be sufficient. What is required is a complete reimagining of infrastructure delivery.

As a global community, we must make systemic changes to the way we share value, develop technologies, standardize designs, create partnerships, collaborate, and embrace digital tools and thinking. In short, we must establish a radical but durable new paradigm for infrastructure delivery that will provide the foundation to move confidently towards net zero by mid-century.

In this, our second From Ambition to Reality paper, we dive deeper into the five key shifts described in our first paper. We explore examples from a range of sectors where new implementation approaches have had a transformational impact. From reducing vaccine development time from ten

years to one through parallel development and partnerships, to being able to assemble a bridge in a week by leveraging modular design.

We propose fifteen leading indicators of change, three per shift, that will allow us to measure, adjust, and correct our infrastructure delivery practices to meet the challenge of scale and speed. We outline how performance against these indicators needs to progress over time, starting from an assessment of where we are now, where we need to be by 2026, and ultimately by 2030 which is a pivotal target year if we're to have any chance of reaching net zero by 2050.

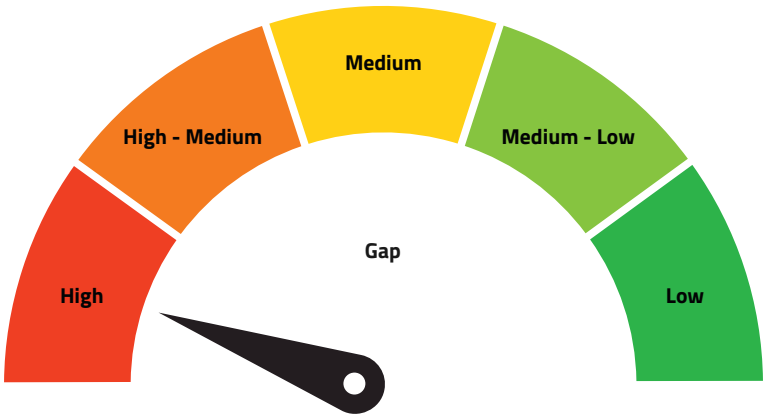


Figure 2 - The net-zero gap in 2022

Success by 2030 looks like:

- Broadening value. Projects deliver more than financial value with communities at the heart of the transition.
- Enabling options. Existing low-carbon technologies are being deployed and there is investment in the future technologies we need. Intellectual property is shared openly.
- Standardization. Engineers are working to agreed global standards, with designs based on equipment and modules already available in the supply chain.

- Creating partnerships. Partnerships broaden and collaboration becomes the norm. The public has full visibility of projects, operating assets, and performance.
- The digital accelerant. Secure digital platforms connect all stakeholders and assets. Project data is openly shared, with teams learning from each other.

Today, we assess the overall gap between our current project delivery practices and where we need to be by 2030 as high. There is a lot to do in the next four years to close the gap on all five shifts by 2030.

To help close this gap, our ambition into reality work will be informed by an independent annual global survey that we outline in the paper. Undertaken by Princeton University, the survey will track these indicators of change, year on year from 2023 to 2030, across ten core stakeholder groups (including asset owners, project developers, regulators, communities, service providers, educators, and policy makers) influential in the delivery of infrastructure. The Ambition to Reality Survey is aiming to establish a panel of more than 3,000 individuals across multiple regions. The results will be used to determine if and where the global infrastructure build is on track. And where it is not, how we might course correct.

Finally, reinforcing the extent of the challenge, we provide a new set of net-zero numbers. This time for a very different economy to the US (examined in our first paper), using data from Net Zero Australia. A much smaller energy economy, but with greater energy exports, the Australian numbers are just as daunting. Requiring up to 3,000 GW of new renewables by 2050, essentially replicating the total world renewable current fleet, and up to 1 GT of CO2 sequestration. Despite the differences between the nations, the scale of the challenge is similar.

To achieve such numbers the message is clear: we must dramatically rethink the way we deliver infrastructure. Authentic ESG-charged partnerships, standardized design, confident supply chains, fully immersed communities, a digital overhaul, honesty, transparency, and a collective imperative: that's how we'll get to net zero by mid-century. ■

Figure 3 – The changes we need to see by 2026 and 2030 to plug the gaps across the five shifts we see today.

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At Air Products, we are delighted and honored to work with OQ, Oman's leading integrated energy group, and ACWA Power to develop a multibillion-dollar project in Oman's Salalah Free Zone, which would be similar to the world-scale green hydrogen project we are implementing with our partners in NEOM in the Kingdom of Saudi Arabia. We look forward to applying our know-how, technology and more than 60 years of experience in hydrogen to help move this project forward and take another significant step in decarbonizing Oman and the world.

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