ENABLING BUSINESS FOR THE ENERGY SECTOR

Energy OMAN

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TRANSITIONING TOWARDS NET-ZERO

The risks and challenges for fossil-fuel dependent countries

GREEN HYDROGEN SUMMIT OMAN 2022

Platforming Oman's green energy quest

PATHWAY TO A LOW-CARBON FUTURE

Exclusive interview with PDO Managing Director Steve Phimister on the company's strategy to sustain energy production in a low-carbon world

GREEN HYDROGEN SUMMIT OMAN

DEC 5-7, 2022

MUSCAT, SULTANATE OF OMAN

GLOBAL SUMMIT & EXHIBITION

AT **OMAN CONVENTION & EXHIBITION CENTRE**

LEADING THE ENERGY TRANSITION STRATEGY

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Chairman's Message

Dear Readers,

There is always palpable excitement whenever any discussion on energy veers towards clean energy – and green hydrogen in particular. And justifiably so! After all, the Sultanate of Oman finds itself on the cusp of transformational change as it seeks to pivot away from hydrocarbons towards sustainable green hydrogen. In the space of two short years, the country has made important strides towards a clean energy future that will supplant Oil & Gas as the mainstay of economic growth. Green hydrogen projects potentially worth billions of dollars have been pledged, massive swathes of land allocated, and partnerships drawn up with investors, technology vendors and offtakers. Already, Oman is tipped to be among the frontrunners in the global race to make green hydrogen a commercial reality.

Energy Oman, represented by Birba Energy, is proud to have played a modest, yet notable, part in positioning green hydrogen front and centre of the nation's energy transition. This was the overarching goal of the Green Hydrogen Summit Oman (GHSO) that Birba Energy hosted, with the amazing support of the Ministry of Energy and Minerals and a large roster of local and international stakeholders, last November-December. The second edition of this signature platform on green hydrogen will be held later this year on a far bigger and impactful scale. Snapshots of the last event, as well as the upcoming Summit, are featured in this edition. Partner with us in delivering yet another stellar summit on green hydrogen.

Abdullah Al Harthy

Oman's hydrogen-centric green energy future gets Royal assent

His Majesty the Sultan's Royal directives have been broadly welcomed, not least because they reinforce the Omani government's firm ambition – no longer just an aspiration – to embrace green hydrogen as the 'new oil'.

With His Majesty Sultan Haitham bin Tarik, Sultan of Oman, giving his Royal imprimatur to the nation's momentous transition from greenhouse-gas emitting hydrocarbons to climate-friendly hydrogen, any lingering skepticism about Oman's future being shaped by green energy has been effectively and comprehensively addressed.

That historic affirmation came on March 3, 2022 when His Majesty the Sultan chaired a meeting of his Council of Ministers. He began by referencing the immense benefits associated with the pursuit of green hydrogen, not only in the production of clean energy to generate electricity, and to power local industries and public transportation, but crucially, as a much-sought-after commodity for large-scale export as well. His Majesty also alluded to green hydrogen's pivotal importance in decarbonisation and climate change mitigation.

The Sultan of Oman then went on to issue a series of Royal directives to underpin the development of an end-to-end green hydrogen industry for the country. These directives are paraphrased as follows:

- Keep abreast of global trends and advancements in green hydrogen technologies
- Formulate supportive legal frameworks and accelerate the rollout of regulation of this emerging sector
- Draft policies to support the growth of green hydrogen
- Identify and allocate suitable sites for the production of green hydrogen with the aim of enhancing FDI inflows and localizing related technologies
- Carry out studies necessary to support the growth of a robust clean energy sector
- Establish a new Directorate General for Clean Energy and Hydrogen at the Ministry of Energy and Minerals
- Establish a government-owned company to invest in this lucrative sector.

In the wake of these instructions, the relevant stakeholder entities within the government have been galvanized into action. While many of His Majesty the Sultan's directives on green energy have been part of the Energy Ministry's broad vision for transitioning away from hydrocarbons, they now become powerful mandates for implementation.

> **"The Royal directives have been broadly welcomed, not least because they reinforce the Omani government's firm ambition – no longer just an aspiration – to embrace green hydrogen as the 'new oil'."**

Local and international developers of green energy projects can also take heart from His Majesty's directives, notably with regard to Royal calls for regulation to be rolled out expeditiously. Issues related to land allocation as well – presently a key sticking point, given the massive land parcels required for each project – will likely be resolved speedily as well.

The Royal directives have been broadly welcomed, not least because they reinforce the Omani government's firm ambition – no longer just an aspiration – to embrace green hydrogen as the 'new oil'. A large and prestigious roster of international companies, and several local players as well, have pledged to explore opportunities for green energy-based investment in the Sultanate. The list includes Shell, BP, TotalEnergies, OQ Group, Petroleum Development Oman, Energy Development Oman, DEME Group, SOHAR, ACME Group (India), InterContinental Energy, Uniper, EnerTech (Kuwait), Hydrogen Rise and SCATEC (Norway), among others. This strength of interest, combined with the Royal directives, promise to further cement Oman's potential to evolve into a major regional hub for green hydrogen production and export. ■

SOUNDING BOARD

Members of the Editorial Advisory Board of Energy Oman share their thoughts on what promises to be an exciting energy future for the Sultanate of Oman, shaped by green hydrogen.

Royal impetus to low-carbon future

Perhaps the single most heartening development of recent weeks in the realm of green energy is His Majesty Sultan Haitham bin Tarik's recent pronouncements affirming a hydrogen-based energy future for the Sultanate of Oman. In affixing his Royal stamp of approval to this transition to green hydrogen and low-carbon fuels in general, His Majesty the Sultan has cleared the decks for a comprehensive decarbonisation of the all-important energy sector and the wider economy as well.

The Ministry of Energy and Minerals, which has the mandate to steer this transition, has already been at work crafting legislation to underpin the growth of a promising green hydrogen sector. That process will be accelerated in accordance with His Majesty's directives. All of the other government agencies with a stake in the success of a future green energy sector will also be pulling together to put green hydrogen at the front and centre of the country's decarbonized economy. This goal also aligns perfectly with Oman's commitment to the Paris Accords on climate change mitigation. Of course, hydrocarbons will bridge this hopefully seamless transition to our low-carbon future.

Eng Saif Al Salmani, Technical Director – CC Energy Development (CCED)

Oman – testbed for clean energy projects

There seems to be no lack of investment appetite – local and international – in the Sultanate of Oman as a destination for green energy projects. This is abundantly clear from the many large-scale schemes that are making headway in their early development less than a year since they were first unveiled.

Although there are still some misgivings about the commercial efficacy of some technologies associated with green hydrogen production and transportation, developers are putting their faith in the unparalleled appeal of hydrogen as the panacea for Planet Earth's warming woes. The initial handful of green hydrogen projects envisioned in Oman will, no doubt, be pilots that will pave the way for larger-scale ventures to be rolled out – an outcome that will be eagerly watched by the rest of the world.

Dr Anwar Al Kharusi, Vice President – Upstream Business Development, OQ Upstream Business Unit

Oman on global hydrogen map: Steps in the right direction

In the global race to meeting Paris Agreement goal of keeping global warming below 1.5 C, hydrogen has increasingly become part of energy systems transformation pathways especially given its role to decarbonize hard-to-abate sectors. While a net oil exporter, Oman has joined global forces to addressing climate change and recognizes the importance of hydrogen to unlocking many economic, environmental and social co-benefits. These include the hydrogen role to diversify its economy, develop new export industry and boost country's economic competitiveness in a carbon-constraint world. Oman's geographical location on the sunbelt and with a coast on the Arabian Sea, positions the country to both be a prospective producer and exporter of hydrogen, especially green hydrogen or green ammonia due to country's endowment with vast solar and wind resources.

Dr Aisha Al-Sarihi, Research Fellow, Middle East Institute, National University of Singapore; non-resident Fellow, The Arab Gulf States Institute in Washington

Oman has already taken incredible steps to unlock its hydrogen development and deployment potential. These include signing memorandum of understandings to support hydrogen research and development, project agreements with international companies to develop hydrogen projects in Oman, and bilateral deals and agreements to enhance exchange of knowledge and hydrogen trade including with Belgium and Netherlands. The establishment of the national alliance for hydrogen to include thirteen national entities from public, private, oil and gas industry and research is an impactful step in the right direction. Moving forward, a development of a national hydrogen strategy will be an essential roadmap to foster and maintain the momentum of Oman's hydrogen development and pave the way for the country to be a leader in an emerging global hydrogen map.

Sustainable future

I often look back on the Green Hydrogen Summit Oman (GHSO), which was held in Muscat late last year, with great satisfaction primarily for two fundamental reasons. Firstly, thanks to the Summit, no discussion on energy is complete without a reference to green energy, in general, and green hydrogen in particular. It was, until recently, the preserve of experts, academics and energy professionals, but today, awareness of green hydrogen as an energy source of the future is more widespread.

Secondly, and perhaps more importantly, there is growing recognition that green hydrogen offers the Sultanate of Oman a safer, greener and sustainable alternative to hydrocarbons as the country acts to decarbonize its economy in accordance with its commitments under the Paris Accords. As hydrocarbons, the transition to a greener future will also unlock investment, jobs and socioeconomic development – with the added assurance of sustainability.

Dr Zakiya Al Azri, Corporate Research and Development Adviser, Petroleum Development Oman (PDO)

ACKNOWLEDGEMENTS

Outgoing Members

Heartfelt thanks to Eng Fahmy Al Musharafi and Dr Omar Al Jaaidi who have stepped down as members of the Editorial Advisory Board. During their roughly year-long membership of the Advisory Board, they made a valuable contribution to our periodic deliberations on the editorial focus on each edition, offering perspectives and inputs that helped the production team organize incisive and enriching content for the magazine. We thank them immensely for their unstinting support and encouragement for our magazine enterprise.

Incoming Members

Their departure paves the way for a fresh set of faces to be part of the advisory team: Dr Zakiya Al Azri, Corporate Research and Development Adviser at PDO; and Dr Aisha Al-Sarihi, Research Fellow, Middle East Institute, National University of Singapore; non-resident Fellow, The Arab Gulf States Institute in Washington. We welcome them on board and look forward to their valuable input and guidance in enhancing the overall appeal of Energy Oman.

Our founding Advisory Board members Dr Anwar Al Kharusi, Vice President – Upstream Business Development, OQ Upstream Business Unit; and Eng. Saif Al Salmani, Technical Director – CC Energy Development (CCED), continue to provide strong and consistent support for Energy Oman, for which we are ever so thankful.

Abdullah Al Harthy, Chairman

الجمعية العمانية للخدمات النفطية
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THEME of 2022

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A Sustainable Strategy to thrive in a Low-Carbon Future

With strong growth in sustainable hydrocarbon production and a clear decarbonisation roadmap, PDO aims to half its carbon emissions by 2030 and to accelerate the development of low-cost, low-carbon and renewable projects in solar, wind, CCUS and hydrogen, says Managing Director Steve Phimister.

Petroleum Development Oman (PDO), a pivotal player in the nation's Oil & Gas industry which contributes a dominant share of national revenues, is moving energetically to reduce its carbon footprint in line with global emissions reduction targets whilst staying the course on its strategic mission to find, develop and produce oil and gas safely, responsibly and profitably, in order to contribute to the sustainable development of Oman.

It also envisions a significant role for itself in Oman's burgeoning new energies space, currently focused on solar and wind resource development, but eventually aligning with the country's strategic goal to entrench a hydrogen-based industry as an alternative to hydrocarbons.

In an exclusive interview to Energy Oman, PDO Managing Director Steve Phimister provided insights into the majority state-owned energy company's decarbonization drive, encompassing energy efficiency enhancement, methane emission reduction, an end to all routine gas flaring by 2030 and the replacement of thermal power generation with renewable power. At the same time, PDO is accelerating the development of low-cost, low-carbon and renewable projects centring around solar, wind, hydrogen and carbon capture, utilization and storage (CCUS), he said.

Mr. Phimister shares his thoughts on PDO's ambitious energy transition objectives, as well as its ongoing critical contribution to the growth of Oman's hydrocarbon sector, and its pioneering efforts to advance localization and ICV development in the following Q&A:

EO: *With oil prices having returned to relatively healthy levels, how will this trend improve the outlook for investments in, for example, new projects that may have been put on ice due to the constrained fiscal environment, as well new exploration programmes, and ramped up activity levels in 2022 and beyond?*

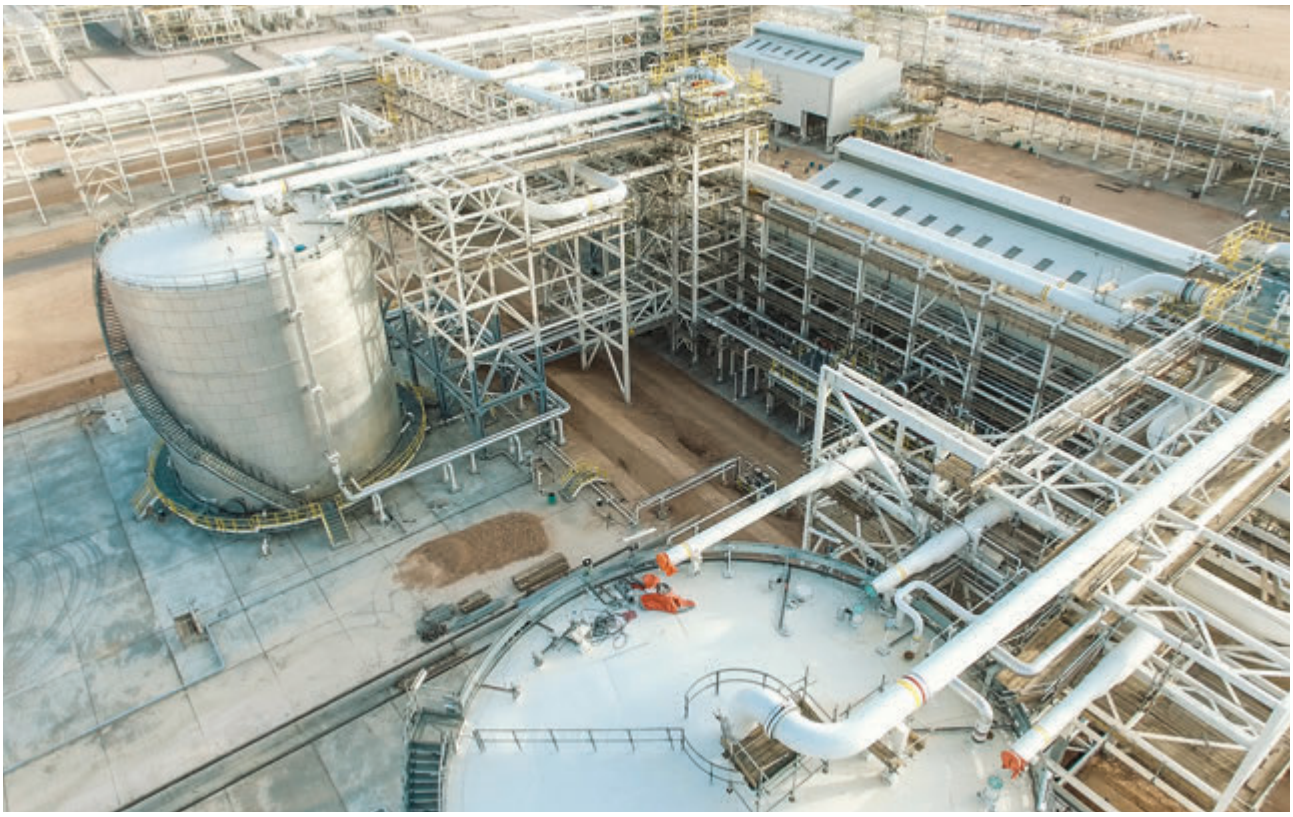
We are pleased to see something of an economic rebound both at home and globally which should support new investments. Global investment in Oil and Gas has been severely reduced over the last two years and

the risk of a supply 'crunch' is now a very real possibility. In such an uncertain and volatile environment, it is imperative that we continue with robust and sustainable new projects whilst producing existing fields more efficiently and cost-effectively. This is a major focus for us in PDO currently. We are also focusing a greater portion of our investment in projects that abate our Carbon emissions and new low-Carbon energy investments, to address mounting climate change realities and in line with the Oman 2040 Vision.

EO: *How have PDO's mega projects contributed to the nation?*

All our projects, and in particular our mega-projects are key to maintaining production and revenue growth, in line with our ambition to reach a sustainable 700,000 barrels per day production within the next five years.

We recently officially inaugurated the Yibal Khuff project (YKP), our second largest and most technically complex project ever. This will produce five million cubic metres of gas per day, about 20,000 bpd of oil, with 235 tonnes of sulphur extracted daily.



What also distinguishes the scheme is the way PDO supported skilled Omanis in critical roles in its development whether in design, construction and operation, all as part of our In-Country Value (ICV) programme.

YKP was the first project to allocate a scope for Omani SMEs to provide services and procurement, with around 1,200 employed on-site in the building of the facilities and a further 200 nationals deployed as fully qualified welders.

This venture is a world-class addition to our portfolio and was delivered with a remarkable safety record. It will be essential in powering the country, generating revenue for the nation, and funding research and development for renewables and investment in greener energy installations and infrastructure.

YKP followed the Rabab Harweel integrated project (RHIP), the largest oil & gas investment project in our history, adding more than 500 million barrels of oil equivalent reserves and providing a major income stream for the nation.

Again, ICV was a major consideration for the RHIP with 50% of the procurement cost spent within the Sultanate using local supply chains. The project has created a huge number of jobs and development opportunities for PDO, local suppliers and contractors. For example, pressure vessels, process columns, pre-assembly pipe rack modules, and power and instrument cables were all supplied by Omani companies.

Both these "mega" projects have added to the Company's sour gas expertise, which we plan to also leverage regionally and globally.

EO: *Please share key details of PDO's strategy to progressively decarbonize its operations with the ultimate objective to become a Net Zero emissions company.*

PDO has a primary objective to generate and grow value and cashflow for the Nation through hydrocarbon development. We will go on doing that and, in the process, we will address the sustainability of our business to ensure its longevity in a low-carbon world. Indeed, through capitalising on the existing setup and resources and in collaboration

with key players, PDO can play a leading role in Oman's energy transition and sectoral decarbonization. To fund this transition and sustain its contribution to the Nation's revenue, we will continue to grow our core hydrocarbon business in a sustainable manner.

PDO's refreshed strategy will enable longevity in the energy transition and generate significant value upside and employment for Oman over the coming decades.

The deliberations of COP 26 summit in Glasgow to keep "1.5 alive", halve greenhouse gas emissions by 2030 and eliminate them by 2050 or 2060 have highlighted the special role we in the fossil fuel industry have to protect the planet. We are part of the solution to the global challenge of climate change.

This journey is well underway, and in PDO we have set ourselves ambitious targets – starting with a 50% reduction in our own emissions by 2030 – and a Decarbonization Roadmap to get us there. We are making excellent progress with a range of measures and investments including energy efficiency enhancement, methane emission reduction, an end to all routine gas flaring before the World Bank 2030 deadline and the replacement of thermal power generation with renewable power.

> **"PDO's refreshed strategy will enable longevity in the energy transition and generate significant value upside and employment for Oman over the coming decades."**

We are also accelerating the development of low-cost, low-carbon and renewable projects for example in solar, wind, CCUS and Hydrogen. These are intended not only to address PDO emissions but also to support the broader decarbonisation of Oman's industrial and power sectors, and we will leverage partnerships both inside and

outside our sector as a matter of priority.

We have developed a long-term Strategy for PDO to guide us on this pathway. This will ensure we stay the course on our key priorities while at the same time enable PDO to effectively and efficiently tackle the challenges and opportunities arising from the energy transition.

EO: *What will be the contribution of renewables, clean fuels and energy efficiency initiatives in this decarbonisation journey?*

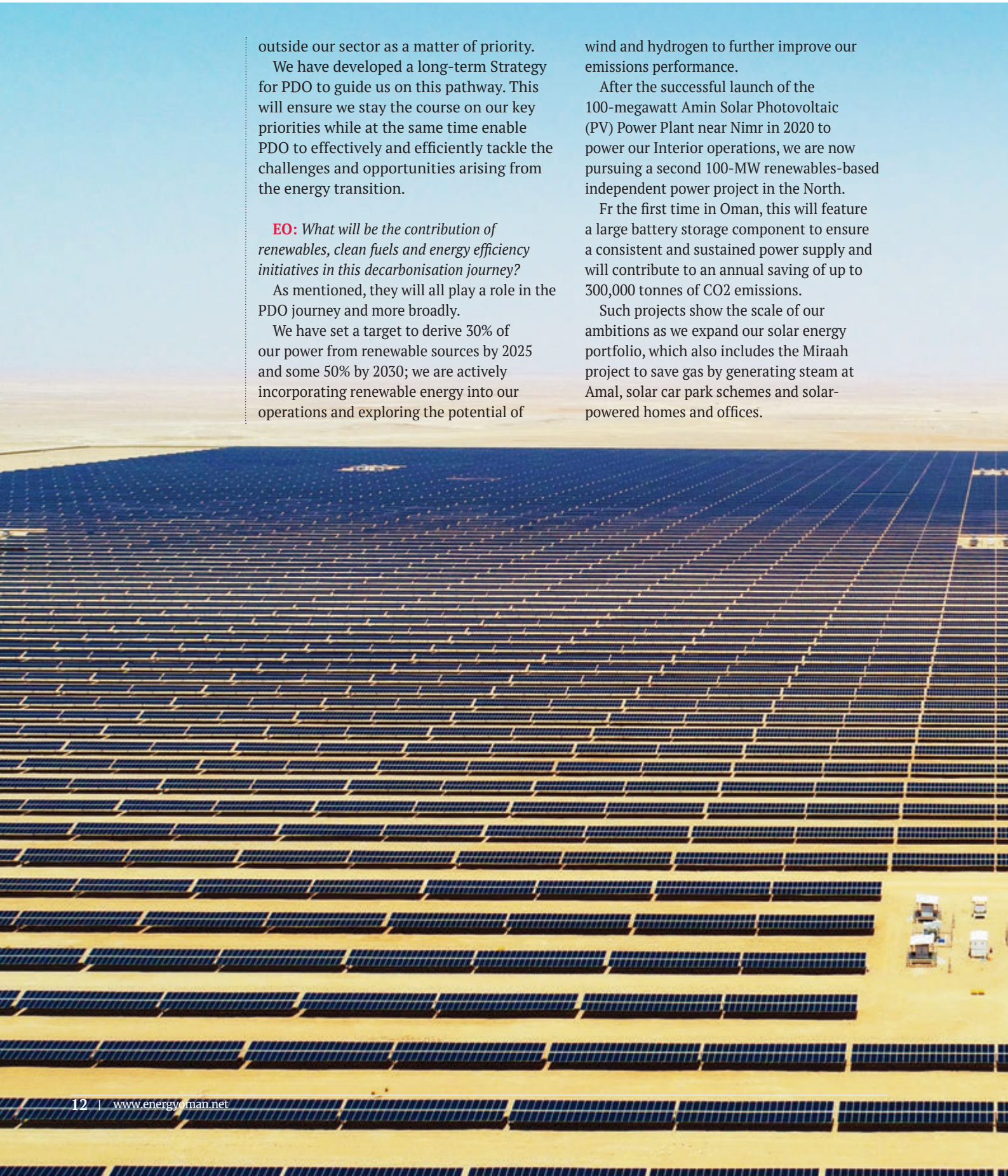
As mentioned, they will all play a role in the PDO journey and more broadly.

We have set a target to derive 30% of our power from renewable sources by 2025 and some 50% by 2030; we are actively incorporating renewable energy into our operations and exploring the potential of wind and hydrogen to further improve our emissions performance.

After the successful launch of the 100-megawatt Amin Solar Photovoltaic (PV) Power Plant near Nimr in 2020 to power our Interior operations, we are now pursuing a second 100-MW renewables-based independent power project in the North.

Fr the first time in Oman, this will feature a large battery storage component to ensure a consistent and sustained power supply and will contribute to an annual saving of up to 300,000 tonnes of CO2 emissions.

Such projects show the scale of our ambitions as we expand our solar energy portfolio, which also includes the Miraah project to save gas by generating steam at Amal, solar car park schemes and solar-powered homes and offices.



We are also aiming to develop a commercial-scale wind power scheme in the South, testing numerous sites currently for commercial viability.

Energy efficiency is a key focus of our gas conservation strategy. Efforts to enhance this have been made via co-generation and waste heat recovery in our steam

generation activities, resulting in a significant improvement of power generation efficiency.

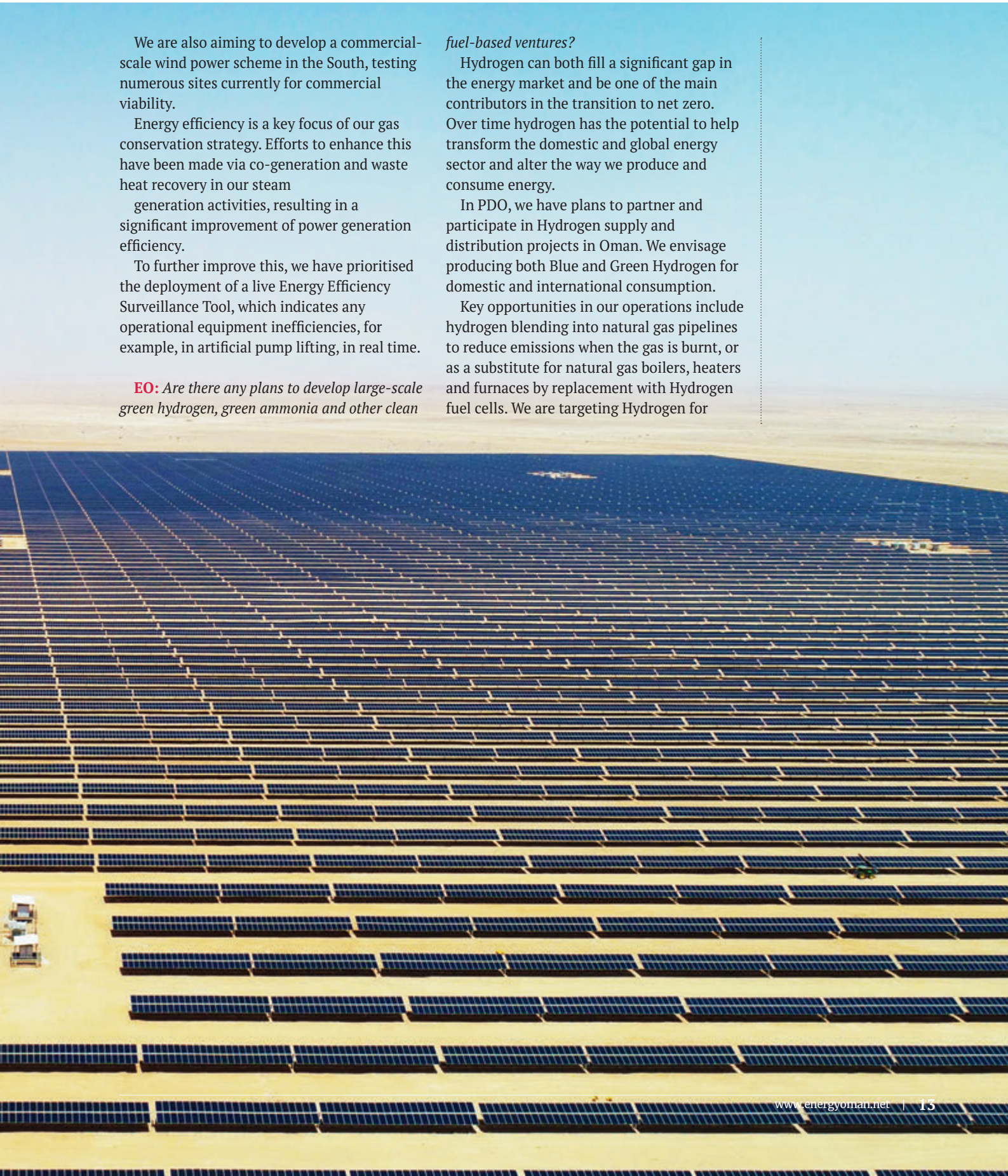
To further improve this, we have prioritised the deployment of a live Energy Efficiency Surveillance Tool, which indicates any operational equipment inefficiencies, for example, in artificial pump lifting, in real time.

EO: *Are there any plans to develop large-scale green hydrogen, green ammonia and other clean fuel-based ventures?*

Hydrogen can both fill a significant gap in the energy market and be one of the main contributors in the transition to net zero. Over time hydrogen has the potential to help transform the domestic and global energy sector and alter the way we produce and consume energy.

In PDO, we have plans to partner and participate in Hydrogen supply and distribution projects in Oman. We envisage producing both Blue and Green Hydrogen for domestic and international consumption.

Key opportunities in our operations include hydrogen blending into natural gas pipelines to reduce emissions when the gas is burnt, or as a substitute for natural gas boilers, heaters and furnaces by replacement with Hydrogen fuel cells. We are targeting Hydrogen for



Steve Phimister
Managing Director
Petroleum Development Oman (PDO)

> **"Key opportunities in our operations include hydrogen blending into natural gas pipelines to reduce emissions when the gas is burnt, or as a substitute for natural gas boilers, heaters and furnaces by replacement with Hydrogen fuel cells."**

Mobility using it to fuel trucks and other heavy vehicles in our transportation fleet across Oman.

We have conducted a study with the Belgian sustainability consultancy firm Hinicio for a pilot-scale 'green hydrogen' production at two locations within the PDO concession. The trial will help us evaluate the efficacy and viability of green hydrogen technologies before they can be rolled out as commercial-scale projects. The process involves the use of electricity generated by the solar PV panels to power the electrolyser that produces Hydrogen for petrochemical, industrial and refining applications. We are also examining using produced water from our oil fields in the feedstock of electrolysers to create hydrogen.

EO: *As one of the founding members of the National Hydrogen Alliance (Hy-Fly), what would be PDO's role in (i) supporting the training and development of human capital necessary for a future industry around hydrogen (ii) exploring the potential for investment in the manufacture of hardware, equipment or accessories related to the industry and (iii) support the creation of a centre of excellence to drive Oman's positioning as a hub for green hydrogen.*

The National Hydrogen Feasibility Study is expected to be published soon which will detail more about what is expected from all Hy-Fly members.

However, we expect to have a very significant role in all those areas. We already have a proven track record in pioneering and deploying new technology and energy, we have strong contractor and service company relationships, extensive infrastructure across the country and we are regarded as an ICV role model.

PDO and the wider energy industry in Oman has had more than 60 years of developing local and, in some cases, international supply chain capabilities. This expertise includes the development of SLCCs, LCCs, SMEs, and collaboration with academia to serve PDO, Oman, and in some cases the region. So, we come from a place of strength. We can leverage this strength to develop hydrogen and low-carbon supply chains and we see great opportunities to develop/strengthen upstream and midstream manufacturing and services including solar panels, inverters, transformers, axis trackers, electrolysers and wind turbines.

There are also multiple avenues for R&D and innovation, through platforms such as Ejaad, which enables academia to devise solutions for our technical challenges, and to build new or enable existing infrastructure, including pipelines and central production facilities.

We intend to develop the value chain within our Block 6 concession and there have already been fruitful discussions with representatives of the Italian, Belgian and other governments to explore mutual opportunities on hydrogen and associated supply chains.

Hy-Fly marks a step change as collaboration between all the relevant

sectors is key to ensuring the strength and integration of the green hydrogen supply chain, especially since this is a relatively new field. We cannot work in silos if we are planning to accelerate the pathway to achieving our targets.

EO: *With job creation and skills development an ongoing priority for the Omani government, do you see PDO playing a bigger role than before in supporting this initiative?*

We always say that In-Country Value is a marathon not a sprint, and PDO is in it for the long haul.

The Company has been a champion of ICV since its inception, and we have helped transform the lives of many thousands of Omanis with our job and training opportunity programmes, both in the oil and gas sector and beyond.

Our role in supporting His Majesty's Government and working with other stakeholders in this noble endeavour is one we cherish and we will continue to actively champion and invest in ICV.

We've invested many billions in local businesses – more than 150 SMEs and community contractors are involved in our operations – and realised 73 opportunities to generate Omani jobs and build competitive and robust supply chains since the launch of the ICV Blueprint for our industry in 2013. And last year alone, we signed 13 Memorandums of Collaboration related to capability building and employment.

"We've invested many billions in local businesses – more than 150 SMEs and community contractors are involved in our operations – and realised 73 opportunities to generate Omani jobs and build competitive and robust supply chains since the launch of the ICV Blueprint for our industry in 2013."

At the end of 2021, 38% of the total value created by PDO was being retained locally on goods, services, investments and Omanisation – and that will climb even higher in the years to come.

PDO is now considered as the Sultanate's de facto ICV centre of excellence and our ICV model and experience are being increasingly recognised globally.

We must now build on the remarkable achievements so far and focus all our ICV efforts on the Energy Transition, digitalisation and the Fourth Industrial Revolution, job creation, and capability building. ■

Credit: Vox Media

TRANSITION PATHWAY TOWARDS NET-ZERO:

The risks and challenges for fossil-fuel dependent countries

By Nora Al-Hinai

What is Net-Zero?

Most of us have heard about net-zero and its importance in mitigating climate change, but what exactly is Net-Zero?

Net-Zero is about balancing the amount of greenhouse gases released and removed from the atmosphere. The Paris Agreement stresses the urgency for Net-Zero, requiring states to "achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century".

As global average temperatures have increased by 1.2oC compared to the pre-industrial era, if recent trends continue without mitigation, global temperatures are predicted to increase 3-5oC by 2100. It is now clear that an aggressive cut in emissions is not enough to cap global warming to 1.5oC by 2050, scaling up removals is also necessary in achieving net-zero.

So how will Net-Zero help in mitigating and tackling climate change?

According to The U.N. climate science panel, man-made CO2 emissions need to decrease by 45% by 2030 from 2010 levels, and reach net-zero by 2050 to limit global warming to 1.5oC thereby avoiding the worst impacts of climate change.

Climate change refers to long-term shifts in global average temperatures causing changes in weather patterns. Since the 1800s, human activities such as burning of fossil fuels (coal, oil and gas) have been proven to be the main facilitator of climate change. The burning of fossil fuels, deforestation, agriculture and other activities causes the release of greenhouse gas emissions (such as CO2 and methane) into the atmosphere that behave like a blanket draped around the earth, thereby trapping the sun's heat and raising temperatures.

Net-Zero is required to curb these emissions through strategies such as decarbonization, carbon sequestration, afforestation, and replacing fossil fuels with renewable energy.

Climate change is here: and is heading for a catastrophe without aggressive intervention

Climate Change does not only mean warmer temperatures, as the earth's ecosystem is connected, a change in one area can impact changes in other areas. The consequences of rising temperatures have created a domino effect of intense drought, desertification, water scarcity, scorching wildfires, rising sea-levels, flooding and loss of biodiversity. Geographical regions will be impacted in different ways, and weather systems will become more frequent and severe.

Diseases are expected to spread more such as malaria, as tropical zones expand with a warming planet. Under business-as-usual scenario, UN scientists predict that five billion people across the world will not have access to adequate fresh water by the year 2050. The World Bank's Groundswell report warns that by 2050, climate change can displace up to 216 million people across the world.

Milestones and strategies for achieving net-zero

So, what is the best way to reach Net-Zero by 2050?

The International Energy Agency (IEA) has mapped out a detailed pathway for limiting global warming to 1.5oC. in order to meet this target, developed economies such as the EU, US and UK will be required to support in transforming the global economy over the next three decades. Under the scenario of the IEA, total global energy consumption from fossil fuels will be replaced by renewables by 50% by 2050. Electricity grid flexibility will be necessary to accommodate renewable energy, supported by smarter and digitalized electricity networks.

Further development of technologies is required such as hydrogen, direct air capture, storage and batteries. Increase in electric vehicle sales will increase from 5% to 60% by 2030, and decarbonizing the transportation industry is prioritized which is a heavy emitter of carbon dioxide. The necessary changes will impact every aspect of our lives including retrofit to buildings, decarbonization if cement, plastics, aviation, shipping and expanding public transport networks.

The Reality: Barriers to achieving Net-Zero within fossil fuel dependent countries

Developing countries and fossil-fuel dependant regions are more exposed to the transition, with higher concerns for growth and inequality.

Countries that are the least resilient to a net-zero future are the ones whose GDP is largely made up of hydrocarbon exports. For decades the rise and fall of oil prices has underscored economic weaknesses and highlighted the urge to develop new business and industrial sectors to reduce fossil fuel reliance. Usually in these countries, the revenues from hydrocarbons have not been adequately managed, further exposing the failure to diversify and promote other domestic industries or create secure long-term revenues through a sovereign wealth fund. How

these fossil-fuel dependent economies adjust to the future of energy transition is crucial as they represent a third of the world's population and emit a fifth of global greenhouse gas emissions. Whether they succeed or fail in a low-carbon global economy, the repercussions will have a widespread impact on geopolitics, inequality, energy security and migration patterns.

The shift towards cleaner fuels will likely shock supply chains and industries tied to the fossil-fuel industry. This disturbance to the revenue stream and labour market means there is not enough motivation for these national producers to cut back on emissions and pledge global commitment to net-zero.

Adapting to the low-carbon transition will require fossil fuel exporters to identify and implement solid strategies for sustainable economic diversification in line with low-carbon growth. Fiscal discipline will be critical, i.e. mobilizing private capital by strengthening legal and regulatory framework for investment and establishing strategic investment funds. The speed of this transition will be dictated by technological advances, political forces, regulation and how big energy consumers decide to meet their needs.

Policy prospects for fossil-fuel dependent countries

Diversification of the economy in nonfuel sectors is more critical than ever, as developing countries governments depend on fossil fuel revenues. Divestment in alternative export sectors such as manufacturing, agriculture and information technology services will be

required to replace fossil fuel income. Local suppliers and labour working in the energy field will need to adapt to a low-carbon supply chain without the protection of government subsidies. Human capital and skills need to be transferrable to other industries through training and education.

As going 'net-zero' will require capital, oil and gas production and export will still be required to allocate funds towards the transition. Governments should consider development and extraction of fossil fuels for reserves that are less expensive to extract while factoring in a possible carbon tax by reducing the costs for foreign investors. However, also avoiding subsidizing the fossil fuel sector as subsidies spent on exploration and extraction for local companies may keep the countries reliance on fossil-fuels.

Costly Transition

The transition will require a total annual energy investment of USD 5 trillion by 2030 based on the IEA's joint analysis with the International Monetary Fund. The scale of the task is daunting, cutting emissions by 45% from 2010 levels, and reaching net-zero by 2050 is by no means an easy feat. Doing so will require a swift transition in energy, land, urban, industrial systems and infrastructure (transport and buildings). Shifts in behaviour, international co-operation and massive policy interventions are required to ease social and political barriers.

Countries that depend largely on hydrocarbons will suffer a fall in revenues and are vulnerable to a low-carbon future, as there is a growing likelihood that fossil-fuel consumption and demand will decline. This has not only been indicated by the outcome of the Paris Agreement, but growing evidence shows that global economic activity is spending less carbon per dollar of GDP. Technological advances in alternative energy resources such as storage of renewable energy also indicate less reliance on fossil fuels. This could create the possibility of "stranded nations", where most of the fossil fuel reserves might not be worth extracting.

> **"Climate Change does not only mean warmer temperatures, as the earth's ecosystem is connected, a change in one area can impact changes in other areas. The consequences of rising temperatures have created a domino effect of intense drought, desertification, water scarcity, scorching wildfires, rising sea-levels, flooding and loss of biodiversity."**

For policymakers in these developing countries, dealing with the declining demand for their commodities will be the most important task to undertake in the near and distant future. Developing countries would need subsidies from developed countries as they lack the long-term finance and incentives to adopt these targets. Unless immediate action is taken, an existential catastrophe that is man-made will only worsen. ■

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Scaling up solar energy in Oman

Although Oman has a comprehensive regulatory framework in place, the Sector Law does not make specific provisions for solar-based electricity generation. In a new report, SolarPower Europe – a prominent EU-centric trade body – has called for renewables to be given a separate status in energy legislation, with the regulator suitably empowered to propose specific programmes to target the growth of this key sector.

Oman is among four key countries in the Middle East and North African (MENA) region covered in the latest report of SolarPower Europe, a prominent EU-centric trade grouping of than 200 organisations operating across the renewable energy value change.

Titled 'Middle East: Solar Investment Opportunities', the report focuses on the specific national energy context, key stakeholders, and regulatory frameworks for investments in the solar sector in each of the four countries, including the Sultanate.

The following article, excerpted from the report, discusses the national energy landscape in Oman, its regulatory framework for investment in broader electricity and the renewable energy sector. It concludes with a list of recommendations designed to enable the Sultanate to harness its enormous photovoltaic potential and encourage international investment in the renewable energy sector:

Energy and electricity

Oman's highest solar PV potential is concentrated on its south coast, near the city of Salalah, at over 2,045 kWp/year (Solargis, 2018). However, the country is yet to make use of this as its electricity mix is almost exclusively dominated by gas, with less than a 0.01% share of solar (Ritchie and Roser, 2020). Nearly one quarter of Oman's domestic natural gas production (32.3 billion m3) is used to power electricity generation and water desalination plants. Electricity production comes mostly from gas power plants, which represent more than 99% of Omani electricity production. Total electricity production increased to 33,796 GWh in 2019 from 33,547 GWh in 2018.

Peak demand historically grew at an average of 7% per year, while average demand grew by 9% annually in the period 2005-2018 (OPWP, 2019). In terms of projections, the base case considered by national utility Oman Power and Water

Procurement Company (OPWP) is an average demand growth by 5% from 2019-2025 (OPWP, 2019).

Electricity infrastructure

In the efforts to privatise the electricity sector, the private sector now owns 100% of generation capacity in Oman's Main Interconnected System (MIS), and efforts have started to privatise other network companies involved in transmission and distribution activities. If implemented, Oman will be the first country in the Middle East region to have privatised its electricity transmission and distribution sectors.

Oman has a forecast peak demand increase of more than 50%, reaching 9.96 GW by 2023. In terms of network connectivity, the Dhofar region is not yet fully integrated with the MIS grid in the north. OPWP expects a new 400 kV transmission line to be completed by 2023, linking the MIS to the Petroleum Development of Oman's (PDO) power system and to the developing industrial hub at Ad Duqm, which will be ultimately extended to Dhofar. This will enable full integration of capacity planning and operations, achieving significant operational efficiencies and financial benefits.

The existing regional interconnection with UAE has limited transfer capacity and provides access to other GCC countries' power systems through UAE's national grid. A direct transmission line between Oman and Saudi Arabia will eventually reduce the reliance on UAE's grid for future electricity exchanges with GCC countries.

In Oman power generation has largely been privatized and there are currently 15 generating companies operating in the sector. The oldest of these companies is the United Power Company SAOG, which began operations in 1996. The company is 40% publicly owned and operates a 270 MW gas-fired combined cycle power plant. The company's PPA with the Oman Power and Water Procurement (OPWP) company has since come to an end.

The OPWP is currently a monopolistic bulk buyer and seller of Oman's electricity and associated desalinated water (OPWP, 2019). It is a wholly owned subsidiary of Nama Holding and is mandated with managing production capacity to meet electricity demand, forward planning, and procuring ancillary services in coordination with the Oman Electricity Commission Company (OETC). The OPWP buys power from the electricity generators through power purchase agreements (PPAs). The contractual arrangements for power delivery under these PPAs can be differentiated as firm capacity, reserve sharing, non-firm capacity, and energy-only.

Transmission is handled by the Oman

Electricity Transmission Company (OETC), which owns and operates the 220 and 132 kV transmission system that serves the Main Interconnected System. The OETC connects eight main power plants in the country and transmits power over 220 kV and 132 kV, stepping down to 33 kV for distribution (OPWP, 2016).

The distribution sector is made up of three closed joint stock companies that operate in different areas of the country. The Muscat Electricity Distribution Company (MEDC) operates in the Muscat region of the country and is responsible for the distribution of electricity in this area. Its other responsibilities include the building and maintaining of distribution infrastructure. The Mazoon Electricity Company (MZEC) operates in Dakiliya, Sharqiya and the South Al-Batinah regions. The Majan Electricity Company (MJEC) operates in the North Al-Batinah and Al-Dahirah regions and the Buraimi Governorate. It is worth noting that the MIS does not yet cover the entire country. For those areas that fall outside the MIS and the Salalah system, the Rural Electricity Company (RAECO) distributes power from diesel generators to them. It is also responsible for progressively electrifying rural areas (OPWP, 2016).

Spot Market

In July 2018, OPWP began working towards a pilot spot market for electricity, ahead of commercial operation. The new spot market would reportedly operate alongside the existing system of long-term PPAs and power- and water-purchase agreements. The pilot would be implemented only on the MIS. OPWP stated that the new market would increase competition among power generating companies and create a market for fresh capacity that might not otherwise be absorbed by existing PPA channels. All existing electricity producers will have the option to join the spot market when their current contracts expire (OPWP, 2018).

The proposed electricity spot market will only apply to power generation and will not cover the purchase of electricity by customers or distribution companies who will continue to purchase power from OPWP at the Bulk Supply Tariff.

Electricity prices in Oman are set centrally and are uniform across the country. Despite making significant progress in unbundling and reforming the electricity sector, retail tariffs are still subsidised. Government subsidy in the electricity market is estimated to stand at an average of 30%. The prices have also been low because of the low cost of fuel used for electricity generation as natural gas is sold domestically for lower than the price of natural gas on the international market.

Oman has developed a strategy to introduce tariffs for industrial users that fully reflects generation and other costs. In October 2016, the regulatory authority announced that it was hiking power prices for 10,000 industrial and commercial users, to reflect Cost Reflective Tariffs. The hikes for corporate users took effect in January 2017.

More recently, in January 2021, a new hike (minimum rise 40% for commercial users) was introduced in an effort to remove subsidies gradually (100% removal by 2025).

The slabs are as described below:

1. Cost-reflective tariff (CRT) is applicable to all large consumers (except residential) with a consumption in excess of 100 MWh/year. It contains 4 components: Total Cost = Bulk Supply Charge + Transmission Charge +

Distribution System Charge + Supply Charges.
2. Remaining non-residential category, will all be grouped into one category including industrial, commercial, government, and tourism.
3. The agricultural and fishery sectors will continue to have a special tariff.
4. Residential sector.

Despite the changes in 2017, only 57% of the overall economic cost of supply of electricity was recovered from customers through retail tariffs in the MIS. The remaining 43% of the revenue requirement came in the form of direct government subsidy. In 2017, electricity demand from large industrial customers and government users decreased by 2.6% and 1.3% respectively compared to the previous year, due to the implementation of cost-reflective tariffs in these two customer categories.

The main law applicable for development of renewable energy projects is the Regulation and Privatisation of the Electricity and Related Water Sector as promulgated by Royal Decree No. 78/2004 (the "Sector Law"). It does not specifically address renewable energy power generation but all types of privately developed power plants. However as per reports, the APSR is working on a dedicated renewable energy regulatory framework.

Update on solar market demand

In 2020 Oman had a cumulative installed solar capacity of 225 MW and its annual market has seen relatively modest growth to date, with its biggest annual installation totalling 115 MW in 2020. Whilst the market is set to grow, it will not reach GW-scale until 2025 according to SolarPower Europe's medium and high scenarios (SolarPower Europe, 2021). The original target of 10% of electricity to be produced from renewable sources was set for 2020. However, they were subsequently revised (as of January 2020) to 2025, increasing to 30% by 2030 (MESIA, 2021).

This target is planned via several OPWP tenders. The largest of the awarded tenders is the IBRI II solar PV plant project, which will add 500 MW of solar capacity, and was won by a consortium led by ACWA Power. The project acheived financial close in 2020. The 105 MW Amin Solar project was awarded to Marubeni and was commissioned in 2020. There are currently two largescale open tenders, Manah I and Manah II, which together represent over 1 GW of additional solar PV capacity. Bids for these are due

shortly and the OPWP has planned a further 600 MW tender through its Power 2022 programme and a further 700 MW one through the Power 2024 programme (OPWP, 2019).

While the OPWP projects have moved on with relative success, the hybrid project tender issued by Tanweer for 11 rural sites with solar-hybrid systems has been under development for over two years. Of the 14 prequalified bidders, only one, EDF, submitted a proposal (Informa Markets, 2020). Feedback indicated that the main obstacle was the logisitcal difficulties of managing large portfolios.

With the country also being a focus of Green Hydrogen efforts, large scale execution of solar projects is envisaged. As per recent announcements, the state-owned oil and gas company OQ, the Hong Kong-based renewable hydrogen developer InterContinental Energy and the Kuwait-based energy investor Enertech are planning to build a green hydrogen plant powered by 25 GW of solar and wind capacity (Paddison, 2021).

Subsidised tariffs have meant that the C&I segment has grown slowly as the savings are modest. However, the Sahim II programme, which targets rooftop projects in Muscat, aims to cover up to 30% of buildings with rooftop PV. This translates into roughly 250,000 rooftop installations or around 1 GW of solar capacity by 2025-2030. The pilot batch of Sahim will target 3000-5000 houses in Muscat and aim to reach 100,000 houses covered by 2023 (Sarac and Podgore, 2021).

RECOMMENDATIONS

As the country recovers from the economic shock of the COVID-19 pandemic, there are several recommendations that would help speed up the development of projects.

- Although Oman has a comprehensive regulatory framework in place, there are several areas that pose challenges for the nascent renewables sector in the country, such as the lack of statutory definition of renewables or clean energy; Similarly, the Sector Law does not make specific provisions for solar and defines generation very broadly as the production of electricity by any means. We recommend giving

renewables a separate status and empowering the regulator to propose specific programmes to target the growth of renewables. The regulator should also be able to propose amendments to the existing laws and introduce strategies such as wheeling or bilateral trading of electricity. Creating specific legal provisions for renewables could also include the granting of more regional power licences. This would lead to increased competition and decreasing costs of energy production.

- A further limit on the development of renewables is the ability of the national grid to absorb new capacity. To further develop its renewables market, we recommend that funds and programmes for national development be directed towards strengthening and upgrading the national grid infrastructure.
- Currently Oman faces issues around access to project financing. This is due to several unfavourable downgrades by credit rating agencies on one hand, and a lack of experience in operating in the country on the part of commercial banks, on the other. Risk of default remains low, barriers to investment are limited, and the growth potential of the country is very high, as highlighted by this report. We recommend that DFIs, impact funds, and other finance providers use this report as a basis for developing a proper understanding of the Omani context and the opportunities it offers in long-term visibility in the renewables space.
- Subsidies for fossil fuels are particularly high in Oman. Despite solar PV's unrivalled levelised cost of electricity, the market distortion from subsidies, and the lack of a legal framework for bilateral electricity trading (as in C&I or distributed generation sectors) make the country less attractive to potential investors. Currently the target date for removing subsidies entirely is 2025. We recommend that this date should be considered as the latest possible moment for ending subsidies. This would help developers and key stakeholders in the renewable energy market to immediately start planning a development strategy in Oman. ■

SolarPower Europe

Fossil fuels are clean hydrogen's ally

Perhaps it sounds like an unlikely match: fossil fuel experts helping drive the growth of clean hydrogen, a market some call the "new oil of the 21st century." But alliances actually make sense.

By **Hatem Al Mosa**
CEO, Sharjah National Oil Corporation (SNOC)

The Middle East's crown as the world's historical epicenter of fossil fuels – notably gas and oil – was hard won through decades of building expertise in infrastructure, trade, and talent. Now, in the global push for a greener future, all this knowledge is transferable to the very infant market of clean hydrogen.

Fossil fuel stakeholders are keenly aware that their market's dominance has an end date. There is no doubt that gas, considered the cleanest fossil fuel, is a critical "bridge" between fossil fuels and renewables, a glue within the modern energy basket. But that does not mean that gas players do not need to keep up with the rapidly evolving energy landscape. And for many, this means aiding the world in the supply of blue and green hydrogen – commonly referred collectively to as clean hydrogen. In many ways, it is a safe bet.

The Hydrogen Council's research shows that hydrogen can provide the lowest cost decarbonization solution for more than 20% of final energy demand by 2050, contributing a cumulated reduction of 80Gt of CO2. What do these numbers boil down to? Simply put, building clean hydrogen economies is integral to reaching the 1.5°C climate scenario by 2050 – certainly no small feat.

So far, the industry is building a solid foundation. More than 520 large-scale projects and 90GW of electrolyzer production capacity have been announced worldwide – equivalent to $160bn of direct investments, the Hydrogen Council highlights. But there is still a very large mountain to climb: a fourfold increase is required by 2030 to put the world on the trajectory to net zero. And therein lies the pivotal support role of gas and other fossil fuel experts in the 2020s, acting as a guiding hand in what is still relatively uncharted territory.

Strong springboard

Announced projects in Saudi Arabia, the UAE, and Oman alone are set to produce 3mn t/yr of hydrogen in the 2030s, with Oman's 14GW Al Wusta and Saudi's 4GW NEOM projects among the world's most ambitious to date, details S&P Global Platts. And there will be plenty more to come if the raft of partnerships being signed by the region's leading fossil fuel companies comes to fruition.

Even when we just look at the UAE, a huge amount of work is underway. For one, the launch of the Abu Dhabi Powerhouse in December speaks volumes about the green intentions of a global gas producer. TAQA, Mubadala, and ADNOC will be shareholders of Masdar, creating a global champion in renewables and green hydrogen. ADNOC is also exploring Abu Dhabi's hydrogen potential with Korea's GS Energy,

developing a decarbonization roadmap for power generation in its downstream and industry operations with GE to include the potential use of hydrogen, and has signed an agreement with three Japanese companies to explore hydrogen and blue ammonia.

These efforts – and many others by world-leading fossil fuel experts in the Middle East – not only share valuable knowledge for the hydrogen market, but it also highlights the industry's progressive approach to supporting the ever-diversified energy basket to ensure three key goals are met: energy security, environmental security, and economic security. For one, gas companies are not just managing their own market – one of the world's most influential energy commodities – but they are becoming guardians of a greener future as well.

Governments' playbook

The clean hydrogen story will fall apart without any supportive regulations and policies. With even more supportive frameworks, it can thrive – a correlation we witnessed in the development of solar power. In this vein, governments worldwide, especially wealthier ones, must help with early temporary subsidies – a vital tool to achieving a competitive market by the early 2030s. The fossil fuel market can share its errors and lessons learned in this process, ensuring subsidies in clean hydrogen do not become an overly costly crutch in the long-term. Governments must also work alongside industry to introduce a carbon pricing mechanism – be it carbon taxes, permits, or a cap-and-trade scheme – to dramatically spur momentum in green energy, including clean hydrogen.

It is also wise to tread carefully, for the industry and media's talk of clean hydrogen often gives the impression it is already a fully-fledged, tradeable market. And it most certainly is not. There are many building blocks needed to get this market of immense potential off the ground. One of the first steps is education, i.e., understanding that blue hydrogen carries great merit as a steppingstone until green hydrogen achieves greater scale and cost-competitiveness. All those in the value chain – from the media to the off-takers – must have fundamental knowledge in order to craft robust roadmaps and hasten overall action. Again, gas experts can support this effort.

Holism matters – a lot

Adopting an entire view of the supply chain lies at the heart of crafting a globally competitive clean hydrogen economy in the Middle East by the 2030s. This will help stakeholders pin down supply-demand balances far faster and more accurately, which in turn will bolster investors' appetite to support the market. Mismatched dynamics where we have supply and no off-takers acts as a red flag to even the keenest of financiers. Again, this is an area where gas operators can share intel from their decades of experience.

We are facing a global problem. It is not one country's problem, nor one government's or one industry's challenge. It is very simple: without a cultural commitment to collaboration, we will not hit our clean hydrogen targets, and in turn, we will fail to reach our global climate goals. As an optimist, I believe we can do it – but only if we do it right and we do it now. ■

F2V: Innovative Solution to Flare Gas Utilisation

F2V's vision is to create a F2V Centre of Excellence of flare gas utilisation in the Sultanate of Oman and unlock business and employment generation opportunities across the value chain.

Dr Frigyes Lestak,
CEO – F2V LLC

Amid intensifying efforts by the Omani government, as well as Oil & Gas players, to rein in carbon emissions in support of the nation's COP 26 climate mitigation commitments, a British-Omani company has been garnering accolades for its own distinctive business solution to a longstanding environmental and resource waste challenge: gas flaring.

F2V (Flare2Value) LLC, a subsidiary of UK-registered F2V International Ltd, has set up operations in Oman to provide energy companies across the region with end-to-end solutions designed to help them not only address their emission reduction targets, but at the same time, to unlock new value and revenue-generating opportunities from what is essentially regarded as a waste stream.

"We provide complete flare gas utilisation solutions without investment from energy companies or governments," said Dr Frigyes Lestak, CEO – F2V LLC. "Additionally, we focus on standardised solutions which can lead to reduced delivery time. Third, we bring a strong team specialised in flare gas monetisation, with expertise in business development, technology, project management and finance. In summary, we are a one stop shop for flare out," he stated.

Gas flaring, according to the expert, contributes to about $30 billion of resource waste and up to 700 million tons of CO2 emissions every year. The amount of gases flared is equivalent to the gas demand of Japan and South Korea combined, he warns.

But with flare abatement, significant value is created by reducing resource waste and curbing harmful environmental emissions. Importantly, flare abatement projects also create jobs across a broad spectrum, stresses Dr Lestak.

"Flare gases are resources that can be utilised to generate energy or useful products. If the flare gas is burned in a flare, instead, it is wasted. In some countries the potential for saving is significant. In Oman, the value of gas burned is equivalent to 0.4% of the country's GDP, which is significant."

Flaring is also associated with harmful emissions that, on the one hand, can reflect poorly on a company's, and indeed the country's, commitment to meeting climate action goals.

The CEO explained: "Flares burn gases, produce CO_2 and other molecules as well

as are the sources of methane emissions. We all know that governments, investors and communities increasingly demand energy with less CO2 emission. Through flare reduction we do not only reduce waste, but also reduce the CO2 intensity of the produced crude oil or gas."

Part of F2V's mission to enable companies and countries deliver on their commitments under the 'Zero Routine Flaring by 2030' initiative launched by the World Bank in in 2016. Oman is a signatory to this global pledge, which is also supported by energy companies and countries currently accounting for over 60% of crude production worldwide.

Notably, flare abatement can spawn significant numbers of jobs, according to the expert. "The world needs thousands of projects to eliminate flaring and it needs them quickly. This means jobs for operators, maintenance people, drivers, engineers, construction professionals and more," he says.

In a major breakthrough for the company and its innovative flare abatement solutions, F2V LLC recently signed an agreement with Occidental Oman, the largest independent oil producer of the Sultanate of Oman, for the construction and operation of a flare gas recovery facility at Oxy's Mukhaiza heavy oilfield in Block 53. The landmark pact, which will showcase F2V's superior, cost-effective and environment-friendly solution, will help reduce emissions and create economic value from captured associated gas.

"We have developed the Mukhaizna opportunity at our own cost," said Dr Lestak. "We will construct our gas capture facility and will operate it. As the result, Oxy will be able to reduce flaring, CO_2 emissions and operating cost."

Underscoring the significance of the agreement for the hydrocarbon industry was the presence of His Excellency Salim bin Nasser Al Aufi, Undersecretary – Ministry of Energy and Minerals, at the event.

Extolling the benefits of the project not only for the two partners, but for the industry and the economy as well, HE Al Aufi said: "We are very pleased that Oman can provide a platform for innovation in the area of collecting and utilizing flared gas. What is even more pleasing is the alignment of this project and F2V business with our national aspirations, to reduce flaring of low pressure gases, reduce emission of greenhouse gases, build value in country, facilitate technology and know-how transfer and build a platform for further FDI into Oman. We are looking forward to rapid scale up: delivery of the follow up projects, first in Oman, and the expansion of flare out delivery capabilities."

For F2V LLC, the maiden Mukhaizna project will serve to showcase the company's novel business model and its capabilities. It will also help accelerate the delivery of future projects in the company's development funnel.

F2V's longer term vision for the Sultanate of Oman is to evolve into a specialist hub centring around gas flaring abatement that unlocks business and employment generation opportunities across the value chain.

"We are committed to creating a F2V Centre of Excellence in Oman, providing support to our projects in construction, operation and later in project development, engineering and finance in country and in the region. Additionally, our projects will create opportunities for construction companies, manufacturing, maintenance, transport and support services. Local communities may benefit from providing resources to our projects and operations and perhaps in the future, using the energy we generate from waste," he added. ■

[For further information, please contact Dr. Frigyes Lestak (f.lestak@f2vi.com)]

How the GCC is managing the transition risks from a global low-carbon future

To manage the transition risks, GCC countries have embarked on structural and fiscal reforms to lay the foundation for a low carbon economy by increasing the share of other productive sectors and diversifying exports and fiscal revenues, says a new report titled, 'Economic Prospects and Policy Challenges for the GCC Countries', published recently by the staff of the International Monetary Fund (IMF).

Climate change is impacting the GCC region. Climate stressors have significant impact on water, environment, and health. The region has begun to take actions to mitigate and adapt to climate change. Structural and fiscal reforms have been accelerated in response to the transition risks from a global low-carbon future.

Stressors: The region exhibits significant vulnerabilities to climate change. Current climatic conditions range from semi- to hyper-aridity, with extremely low rainfall, lack of perennial rivers or permanent water sources, and high evapotranspiration. The annual average temperature has seen an increase of 1.3°C—more so than MENAP global averages—since the turn of the millennium. Low rainfall, where precipitation averaged 6.7mm annually compared to 16 mm for MENAP and 94 mm for the world over the period 1991–2020, have resulted in limited renewable resources of surface water. Agriculture (about 85 percent of total water consumption in Oman, Saudi Arabia, and UAE) and urbanization (approximately 50-60 percent of total water consumption in Bahrain and Qatar) have increased the pressure on non-renewable natural water sources. As a result, water stress is severe, with freshwater usage exceeding their available freshwater resources, placing GCC (except Oman) among the 10 most-water stressed countries. Desertification has increased the severity of sandstorms. Coastal zones are highly vulnerable to the impacts of sea level rise. Coral reefs are at risk of disappearance due to climate change (ocean acidification and seawater warming) and human activities (fishing, dredging and marine pollution).

Responses: GCC countries communicated a mix of mitigation and adaptation actions, which have co-benefits in the form of reduction of greenhouse gas (GHG) emission, through their nationally determined contribution (NDC) as part of the 2015 Paris Agreement.1 Also, to identify adaptation needs and implement programs to address those needs, Kuwait, Oman, and UAE published a National Adaptation Plan (NAP).

Some countries have also formulated climate strategies outside of the NDC and NAP process: Oman developed the National strategy for Adaptation and Mitigation 2020-2040; Saudi Arabia established the Circular Carbon Economy National Program to consolidate and accelerate the current momentum toward climate sustainability;2 and UAE adopted the National Climate Change Plan 2017-2050. A range of actions have been undertaken to address the region's vulnerability to climate change impacts and foster resilience, including but not limited to:

Energy sector: with the sector being the largest GHG emitter, countries have set targets to increase the share of cleaner energy sources: 20 percent in 2030 (Oman), 50 percent in 2030 (Saudi Arabia), 40 percent in 2040 (UAE). Also, the sector has implemented measures to reduce gas glaring, improve the energy efficiency in the upstream and downstream facilities, and reduce methane leaks.

Water management: Integrated water management actions have aimed at harnessing new sources of freshwater (e.g., building additional dams in Oman and Saudi Arabia) and prudent use of water. Wastewater management actions have also promoted the reduction, recycle, and reuse of water, while reducing water desalination and thereby energy consumption.

Agriculture: responding to the water-food-energy nexus, the region has adopted sustainable agriculture practices to ensure water and food security such as vertical and hydroponics agriculture. Oman prioritizes domestic production through investment in mega-projects in agriculture and fisheries.

Land degradation: A range of actions have been implemented to reduce desertification and stabilize sand movements through using green belts as barriers. The Saudi Green Initiative and Middle East Green Initiative aim to plant 50 billion trees in the upcoming decades.

Marine protection: Costal management measures have been undertaken to protect biodiversity of seas, reduce coastal erosion, and increase the sinks for blue carbon. GCC's actions have included planting of mangrove

seedlings, restoring coral reefs, and landing artificial reefs (Bahrain and UAE).

Health and early warning systems (EWS): The development of EWS within the region aims at: reducing vulnerability to extreme weather events such as floods and dust storms; increasing resilience of infrastructure; and raising environmental quality and thereby improving public health. A mid-day break is mandatory for outdoor workers during summer.

Urban planning: Ongoing measures have included expansion of metro systems to promote the use of public mass transport systems (Saudi Arabia and UAE) and within urban areas (Dubai and Riyadh). Also, green building councils have promoted the construction of energy efficient, resource efficient, and environmentally responsible buildings.

Efficiency: District cooling systems have been built to conserve energy and water (Qatar and UAE). Fuel and water tariff reforms have been implemented over the last few years to reduce subsidies and improve energy efficiency and use of water. Ongoing education and awareness programs aim to reduce energy consumption amongst both residential and commercial consumers, including through energy efficiency products (e.g., appliances and air conditioners).

Carbon capture, utilization, and storage: It has been used by BAPCO (Bahrain), Aramco and SABIC (Saudi Arabia), and ADNOC (UAE) to either store carbon emissions deep underground or turn them into marketable industrial and commercial products.

Waste management: Circular economy actions have been implemented. Qatar recycles and reuses construction waste. Saudi Arabia has established the National Center for Waste Management in 2019 to promote waste reduction, recycle, and convert the waste into energy. Abu Dhabi adopted the Single Use Plastic Policy in 2020.

Sustainable finance: Governments and state-owned entities have stepped up green financing to boost green investment and accelerate the transition to a low-carbon economy. UAE adopted Guiding Principles in Sustainable Finance to encourage financial firms to incorporate ESG considerations in their business. Oman and UAE are developing sustainable finance frameworks to mobilize private capital for sustainable investments. Saudi Arabia is developing an ESG agenda for its financial market and plans to issue its first green bond in 2022.

[Credit - GCC: ECONOMIC PROSPECTS AND POLICY CHALLENGES FOR THE GCC COUNTRIES]

International collaboration: NDCs emphasized the need for technology transfer and technical assistance from advanced economies to achieve adaptation and mitigation targets.

Transition: Oil and gas are the region's main sources of export and fiscal revenue. Global mitigation efforts will pose a particularly serious challenge for the demand of oil over the medium to long-term, stemming from moving to net-neutrality and thereby shifting away from fossil fuels. This would have a profound macroeconomic impact, especially on fiscal and external sustainability. To manage the transition risks, GCC countries have embarked on structural and fiscal reforms to lay the foundation for a low carbon economy by increasing the share of other productive sectors and diversifying exports and fiscal revenues. ■

Is hydrogen the antidote for climate change?

Khalid Bin Hadi
Managing Director
Siemens Energy Oman

Let's be honest, 2021 was a not a great year for climate change and it showed us all that it's time to act. After all, we did start off the year with widespread wildfires, followed by bleak reports from the Intergovernmental Panel on Climate Change (IPCC) indicating that we are off-track to achieving the Paris Agreement targets. Then came COP26 to affirm what we already knew to be true and serve as a stark reminder of our shortcomings as nations of the world to deliver on pledges made years back.

To the untrained eye, these developments might be, if not entirely, shocking. After all, 2020 saw CO2 levels drop for the first time since 2010 – albeit for a short-lived time – during lockdowns. But keen observers and decision makers in vital industries saw it coming and have been making efforts to fight global warming. Many of these efforts have lately revolved around one unique element touted to be our savior – hydrogen. If climate change is slowly killing our planet, could hydrogen be the antidote? Yes and no.

Yes, because...

1. It's the right element.

One thing is for sure, we need hydrogen. Without it, hitting the 2050 net zero targets is virtually impossible. A big part of the shift away from fossil fuel involves electrifying some of the everyday machines we use that are powered by oil and gas - cars and local transport, and heating for homes in some countries, for example. For those already electrified, like computers and home appliances, electricity from nuclear and renewables like wind and solar are replacing coal. But there are some industries that require so much energy that traditional renewables can't meet their demand. That's a problem, because those industries are among the top emitters of greenhouse gas. This is where green hydrogen has huge potential.

Producing hydrogen without emissions is quite expensive right now, but it will inevitably be the cheapest source of renewable energy for many applications that electric batteries can't solve. The scaling up of electrolyzer production is driving down costs. Within the next decade, we can expect H2 to reach break-even points with fossil fuels across different applications, after which hydrogen uptake will bring cost savings.

H2 uptake can serve other objectives beyond decarbonization. For example, hydrogen's ability to substitute natural gas in many applications allows for a degree of energy independence and reduced reliance on liquefied natural gas or pipeline imports. And while renewables like solar and wind are limited by the extent of electrical grids, hydrogen can be transported by pipeline or potentially by ship. That means it could become an exportable renewable energy source, eventually replacing petroleum as the main global energy commodity.

As a crucial element in achieving 2050 net-zero targets, hydrogen production, storage, and transport represents a multi-trillion-dollar opportunity, not only for energy incumbents but also for investors. IRENA estimates by 2050 that 12% of global energy demand will be covered by hydrogen and that more than 30% of it could be traded across borders, a higher share than natural gas today. Scaling up hydrogen technologies and building the H2 economy could translate to millions of new job opportunities in the coming decades. Facilities to produce this cleaner form of the gas have popped up across the globe - in the United States, western Europe, China, Australia, Chile and South Africa, among other countries. The burgeoning global green hydrogen market could be worth $11 trillion by 2050, by Goldman Sachs' estimates.

2. It's the right time.

We are emerging from a year that made the accelerating pace of climate change painfully clear. But it's still not too late to act. And while we can't turn back the clock and reverse the effect of any of the sobering climate milestones occurring – we are in ample time to change the course of history.

On the bright side, this dire need for clean energy sources has seen positive trends in favor of renewable energy with hydrogen in particular gaining serious traction around the world and in the Middle East. Governments are committing to national strategies and partnerships are being forged with key stakeholders, especially in the private sector. These are all encouraging signs that show us we are on the right track and that this might just be hydrogen's moment to shine.

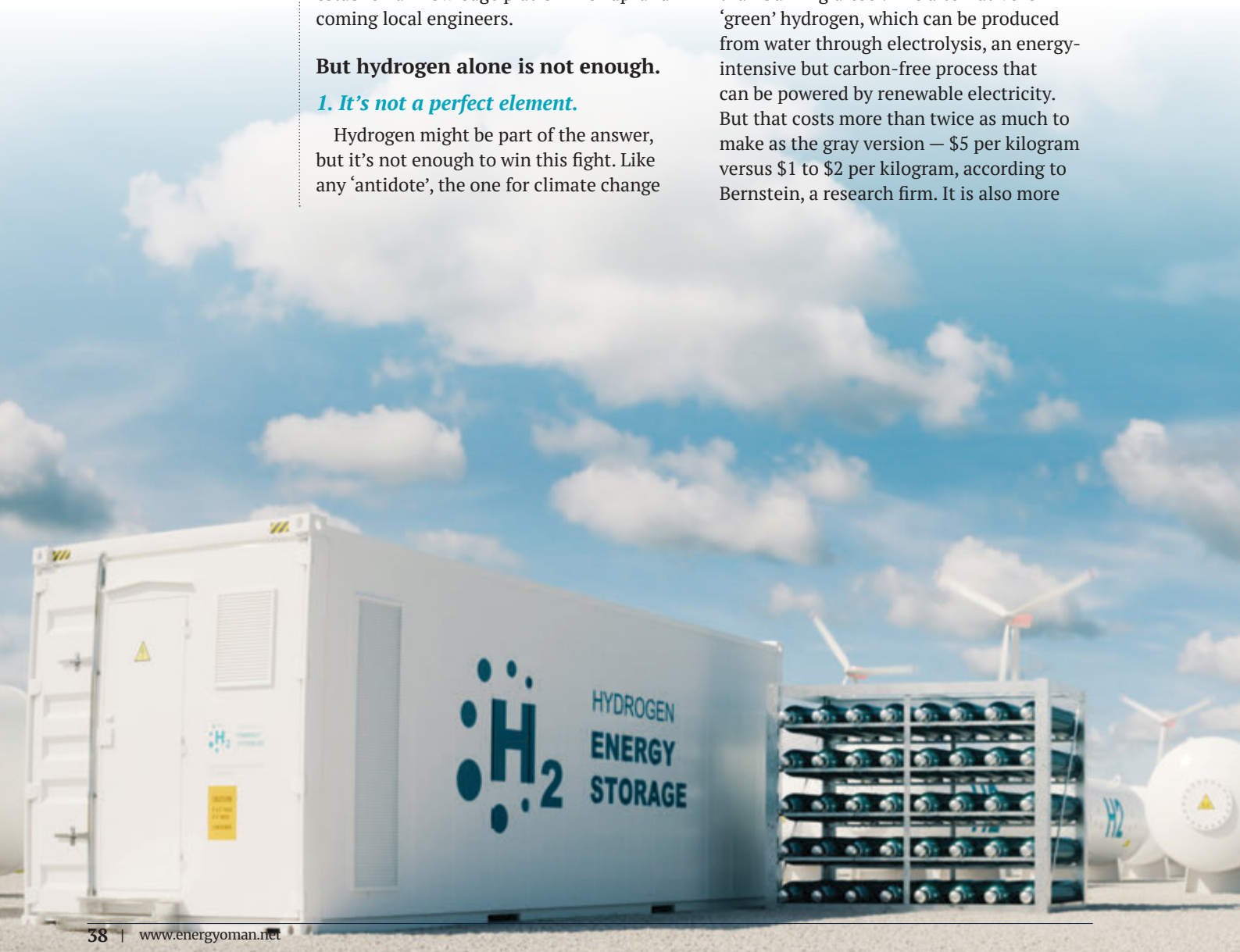
At Siemens Energy, we are also keen on building on this momentum and elated to witness increased interest in the use of H2 as an energy carrier in the region. After milestones in the UAE and Egypt, we have most recently signed an MoU with the Oman Hydrogen Centre to collaborate on identifying potential green hydrogen markets in local industries to jointly develop technical solutions and local competence. Green hydrogen has the potential to become a core part of the future clean economy in Oman. These partnerships are so important as they don't only support the commercial production of hydrogen but will also work to establish a knowledge platform for up-and-coming local engineers.

But hydrogen alone is not enough.

1. It's not a perfect element.

Hydrogen might be part of the answer, but it's not enough to win this fight. Like any 'antidote', the one for climate change has to be made up of different components. The reality is that we still have many challenges to overcome when it comes to the production, transportation, and storage of an element like hydrogen.

While it might be the most plentiful element in the world, H2 does not exist alone. It must be separated from other substances, like water or fossil fuels. And the process to do that is the real game-changer. At the moment, industries like oil refining use large quantities of so-called gray hydrogen that is mostly made by separating hydrogen from natural gas. That process generates more greenhouse gas emissions than burning diesel. The alternative is 'green' hydrogen, which can be produced from water through electrolysis, an energy-intensive but carbon-free process that can be powered by renewable electricity. But that costs more than twice as much to make as the gray version — $5 per kilogram versus $1 to $2 per kilogram, according to Bernstein, a research firm. It is also more



expensive than conventional fuels, like diesel. The fact is that only less than 5% of the hydrogen produced today is emission-free.

2. We don't live in a perfect world.

In a perfect world, green hydrogen would work. To be fair, in a perfect world climate change would not be an issue to begin with but that's a discussion for another day.

We do however live in a world that has been shaken up by a global pandemic. COVID-19 was a wake-up call for us all. It put things in perspective and reminded us once again what's really at stake and how fragile our systems can be in the face of nature forces. As it stands, and with the challenges we are well-aware of accompanying hydrogen use, we need massive changes in behaviors and mindsets to make it work. For green hydrogen to become a major energy source, it will require first and foremost backing from governments, including subsidies and regulations that encourage its' use in industry and heating. It will also need better infrastructure and consumers willing to adopt new habits. But more than anything, it will require compromises, at times even sacrifices, from all parties. Every stakeholder from public to private to academia to individuals have a role to play in this fight. Is it a big ask? Absolutely. But as the saying goes, 'desperate times call for desperate measures,' and we are approaching desperate times in this battle.

The more we delay our actions, the bigger the cost will be. We might not be able to create perfect conditions for energy transition, but if we come together, we can make the right investments today for a better tomorrow. With the right collaborations and incentives, we can still tip the scale in our favor before it's too late. It's all up to us. ■

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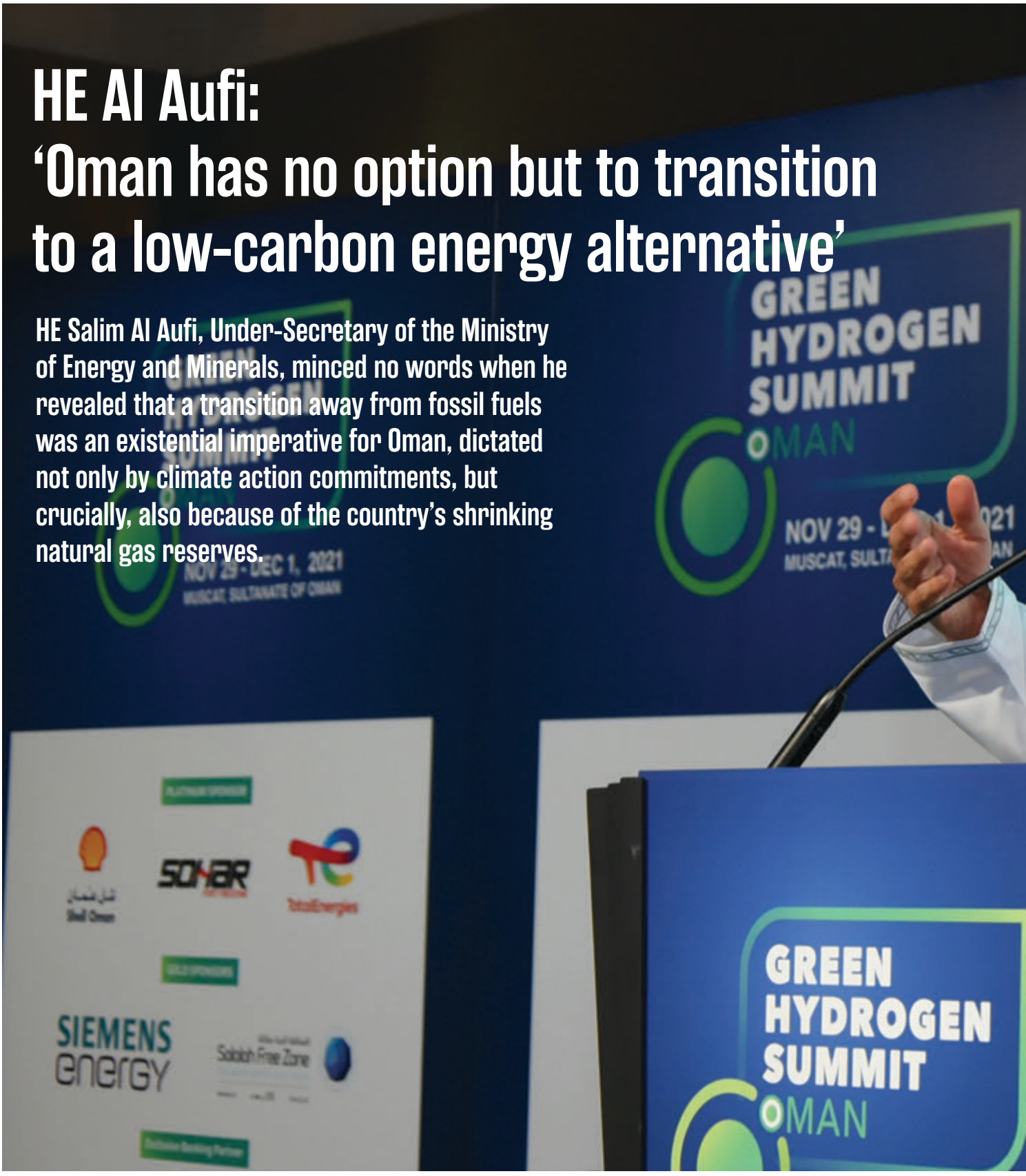
HE Al Aufi: 'Oman has no option but to transition to a low-carbon energy alternative'

HE Salim Al Aufi, Under-Secretary of the Ministry of Energy and Minerals, minced no words when he revealed that a transition away from fossil fuels was an existential imperative for Oman, dictated not only by climate action commitments, but crucially, also because of the country's shrinking natural gas reserves.



It was a stark warning delivered at the opening of the Green Hydrogen Summit Oman (GHSO): Natural gas supplies – the lifeblood of the electricity, industrial, petrochemical and other key sectors of the Omani economy – is anticipated to run out in 15 – 20 years. That leaves Oman facing a relatively short window to complete its transition from fossil fuels to a greener alternative, such as hydrogen.

That sombre revelation, coming from a person no less than the Under-Secretary of the Ministry of Energy and Minerals, set the tone for two days of earnest discussions around the need for collaboration encompassing industry stakeholders and global economies in overcoming the formidable technological and cost-related challenges in unlocking the power of green hydrogen.

Delivering the keynote address, HE Salim Al Aufi stressed that the Sultanate of Oman has no option but to press ahead with the pursuit of Green Hydrogen.

> **"I have a lot of passion for Green Hydrogen, but I believe Blue Hydrogen could be a transition to get us to Green Hydrogen. Still, Green Hydrogen is the future of energy as we know it."**

"I don't think traditional hydrocarbons are going to last for too long," he warned. "We may not be running out of hydrocarbons, but we will be running out of the appetite to continue consuming these beautiful molecules that got us to where we are today. And I strongly believe this is going to be the case, whether in 10, 15 or 20 years – it's anybody guess -- but what is important is that we are on a transition journey. The genie is out of the bottle and he is not going back!"

Affirming his strong personal, as well as the Omani government's, commitment to embracing green hydrogen as the sustainable energy alternative to fossil fuels, the Under-Secretary said: "I am a very strong believer of hydrogen; those who know me know how much passion I have for the subject. Some may see me to be overly optimistic and too passionate. I have a lot of passion for Green Hydrogen, but I believe Blue Hydrogen could be a transition to get us to Green Hydrogen. Still, Green Hydrogen is the future of energy as we know it."

Any shortfall in gas supplies, HE Al Aufi pointed out, would be a double whammy for the Omani economy. For one, it would impact existing industries dependent on natural gas as feedstock or fuel. Secondly, investments in new industries would shrink in the absence of assured energy supplies. "So we have no option but to start thinking of what the next best energy alternative is, which is hydrogen," he stressed.

In support of this national objective, the Ministry is working very hard with partners from different parts of the world – governments, public and private sector organisations and other stakeholders – to explore collaboration in a number of key areas. This includes certification of hydrogen fuels, technology transfer, capability building and In-Country Value (ICV) development, he said.

Additionally, the Ministry is focused on its own set of deliverables. Besides formulating rules and regulations to support a future green hydrogen industry,

the Ministry is also working with fellow government departments in ensuring that potential investors get suitable land and other incentives to help them get started with their green ventures.

Importantly, the transition to a low-carbon energy resource is also warranted by Oman's commitment to decarbonisation in line with its Paris Accord obligations, said the Undersecretary.

"We all have an obligation to contribute to make the environment better, safer and healthier for future generations. I want my grandkids to grow in an environment that is liveable and not one that is toxic that we created because of our hunger for unclean energy. It got us to where we are today, and we should be thankful for that, and what we need to start doing seriously is to transition out of it to something more clean and sustainable," he added.

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Nevertheless, the transition to green hydrogen will not mean a complete end to the fossil fuel industry in Oman, given that there will still be lingering demand for oil and gas in some parts of the world. "As long as there is a buyer and we can produce it in a cost-effective manner, we will continue to produce oil and gas, but we will do it in a more responsible way, by hopefully capturing CO2, managing methane emissions, and so on, to make sure that our operations is as green and clean as possible."

Auguring well for Oman's green hydrogen aspirations, HE Al Aufi said, is the keen enthusiasm shown by a number of countries around the world in partnering with the Sultanate in the development of large-scale projects that take advantage of the country's abundant solar and wind resources. Interest from several prestigious energy companies has been equally heartening as well.

Earlier, responding to apprehensions about green hydrogen voiced by some key attendees taking part in an executive roundtable discussion the previous night, the Undersecretary said the Sultanate "absolutely" determined to progress the hydrogen agenda forward. "We have a serious demand to transition for our own industries to grow, And also to contribute to the global challenges of decarbonisation," he added.

by Conrad Prabhu

Green industries, green jobs, green economy

In addition to creating tens of thousands of new 'green' jobs, a future national hydrogen economy also has the potential to position Oman among the region's Top-3 producers of clean hydrogen, says Dr Abdullah Al Abri, Head of Energy Renewal – Petroleum Development Oman (PDO).

A future hydrogen-centric economy can be potentially transformational for Oman: an estimated $34 billion in green investments by 2040; massive employment generation of between 36,000 and 147,000 new green jobs; growth of new low-carbon industries; significant non-market benefits; creation of new supply chains; annual savings of an estimated 40 million tons of CO2 emissions; and a coveted ranking for Oman among the region's top-3 hydrogen producers.

This compelling and upbeat picture of a decarbonised economy – far removed from its current reliance on hydrocarbons for its sustenance – was outlined by Dr Abdullah Al Abri, Head of Energy Renewal at Petroleum Development Oman (PDO), at the opening session of the Green Hydrogen Summit Oman (GHSO).

As one of only a handful of Omani energy professionals who have been associated with the country's green hydrogen journey from its outset, Dr Al Abri is indeed uniquely qualified to provide a deep dive into Oman's national hydrogen strategy, presently under finalisation.

Oman, he began by saying, has come a long way since green hydrogen was first bandied about as a potential energy resource of the future. "Today, the focus of our discussion is where we see Oman - given the competiveness of renewables, given the expertise we have in Oil & Gas and energy infrastructure, and given the interlinks with the global trade hubs -- in 2030 and 2040," he stated.

As Project Manager of the National Hydrogen Economy Strategy (until its formal handover to the National Hydrogen Alliance – Hy-Fly – last year), Dr Al Abri's mandate was to chart a pathway for the development of a green hydrogen industry in the Sultanate.

"The journey towards green hydrogen development was orchestrated as a three-step staircase starting with building the momentum in the energy transition. The journey was inclusive, well-governed and data-backed to ensure sustained development towards a green economy," he said.

Phase 1 of the journey (up to 2019) focused on gaining a fundamental understanding of what opportunities could be harnessed from solar and wind in comparison with Oil & Gas. Insights gained during this exercise were discussed during the National Energy Lab – a key forum held at the time to explore quick-win project opportunities in the energy sector.

"We started to see some renewable energy projects taking shape for power generation, and there was also momentum building towards human capital development and certification of professionals. Things were beginning to take shape and fast," he said.

Phase 2, spanning the 2020-2021 timeframe, focused on 'Shaping the National Economy', with hydrogen serving as a major vector in the country's energy profile by 2040, said Dr Ali. A key highlight of this phase was the constitution of a Steering Committee overseen by the Ministry of Energy and Minerals that worked closely with least 10 leading energy stakeholders – from Oman and abroad – in shaping the hydrogen strategy for Oman. Its brief included a feasibility study for a National Hydrogen Economy, techno-economic building blocks necessary to achieve this goal, incentives and strategic enablers, potential projects, and a national roadmap for realising the hydrogen economy by 2040.

Value proposition

The National Hydrogen Economy Feasibility Study covered the following objectives and value drivers, said the official:

Objectives:

- Develop necessary understanding and value proposition for this emerging economy
- Establish strategic business and

Dr Abdullah Al Abri, Head of Energy Renewal – Petroleum Development Oman (PDO)

collaboration opportunities for hydrogen as an energy carrier and as feedstock through the identified and marketable products (H2, liquid H2, NH3, methanol, DME, MCH etc). These opportunities shall include local, regional and international markets where possible
- Develop partnership and investment strategies to carry out the business and collaboration opportunities
- Develop understanding of the required enablers, such as policies, regulations, incentives and others
- Map out associated technical and innovation challenges/opportunities that are part of this emerging economy

Value Drivers:

- Diversify energy supply ad increase network resilience
- Reduce emissions
- Foster economic growth
- Development hydrogen for export
- Develop supply chain and strategic partnerships
- Support national innovation and competence development
- Stimulate FDI
- Create opportunities for green jobs (direct and indirect)

As for Phase 3, which kicked off in 2022, the focus has shifted to the concrete development of projects, some of which have their Final Investment Decisions (FID) slated over the next two years, he said.

This stage will also assess, among other things, the local demand for feedstocks, industrial process substitution, mobility, green chemicals, and so on; It will seek to strengthen local integration and support cross sector opportunities; export energy carriers; place Oman in the EU Green Deal; establish partnerships with Japan and South Korea; develop partnerships with key global maritime companies; and support tech and supply chain development.

Further, with the aim of building a strong platform for Oman, the National Hydrogen Alliance (Hy-Fly) was conceived. It was formally launched in August 2021 as a grouping of 13 key public and private organisations encompassing government bodies, oil and gas operators, educational and research institutes as well as ports that will work together to support and facilitate the production, transport and utilisation of clean hydrogen for domestic use and export. In October that year, the Steering Committee formally handed over the reins of the National Hydrogen Strategy to the newly established alliance.

Essential trappings

Auguring well for the growth of a promising hydrogen economy, according to Dr Ali, is the presence within Oman of many of the industry's essential trappings – natural resources, geographical settings, support infrastructure, human capital and other wherewithal.

He explained: "Oman sits on a very competitive landscape for clean hydrogen, whether blue or green. We have expertise in oil and gas, an established profile for renewables for electricity, but also for power for steam. Green hydrogen requires a lot of water – we have desalination plants, but also produced water that we can utilise. Our wind resources integrate very well with solar to sustain the load for green hydrogen, and our infrastructure is well developed – all of which will drive low-cost hydrogen production."

Additionally, Oman's roughly 4,000 kilometres of gas networks are relatively new

compared to some other countries, said Al Abri. He noted in this regard the promising potential for blending of hydrogen into the gas networks.

Driving the National Hydrogen Strategy, he said, are several factors: a commitment by the Omani government to achieve zero-carbon emissions likely by 2050, the global shift to low-carbon fuels and green hydrogen; competitive combination of low-cost renewables, technology and infrastructure; growing international interests in strategic and business partnerships with Oman; and perhaps most importantly, a much-anticipated shortfall in natural gas supply.

On the demand side, various stakeholders are projected to use hydrogen as feedstock for industry, and as a fuel resource for heat applications and power generation. Hydrogen will also have major application in transportation (buses, heavy goods vehicles, shipping, maritime services and aviation). Additionally, it will serve as a base ingredient in the production of new and enhanced chemicals (such as synthetic fuels). Export demand is a key factor as well.

Based on this demand outlook, the hydrogen economy targets 1 gigawatt (GW) of renewable energy capacity by 2025, rising to 10 GW by 2030 with a ramp-up to 30 GW anticipated by 2040, he said.

Unlocking opportunities

In the upshot, the positive knock-on effects from a hydrogen industry for the wider national economy are hugely promising. On the environmental side, hydrogen projects will offset up to 40.5 million tons of CO2 per annum. It will stimulate green investment inflows to the tune of about $34 billion by 2040, as well as unlock growth of between 53 – 96 per cent in non-market benefits. Furthermore, the growth of green industries will help create between 36K to 147K new green jobs. Most importantly, green hydrogen has the potential to position Oman among the Top 3 exporters of this zero-carbon fuel, Dr Al Abri stressed.

A phased roadmap to achieve the country's green hydrogen economic vision advocates a holistic approach, according to the official. Spanning a 20-year timeframe through to 2040, the roadmap is made of three clearly defined phases. In the Near-term (2021 – 2025) phase, the focus is on market activation for local industries, as well as activation of partnerships with global players. In the Mid-term phase (2026 – 2030), the emphasis will be on large-scale electrolyte production, as well as Carbon Capture Utilisation & Storage (CCUS) enabled hydrogen production. Finally, the Long-term phase (2031 – 2040) envisions the consolidation of the hydrogen economy.

"It starts with small to midscale blue and green hydrogen production for Oman, before we move to the networks and transportation issues. We can either truck it or invest in small-scale pipelines with small-scale storage capacity."

Already, a project funnel – which was bare a few years ago – is "filling up and maturing nicely as well", said Dr Al Abri. Opportunities identified so far include natural gas blending in Nimr, Qarn Alam, South Oman Gas Line (SOGL) and elsewhere. Likewise, there are prospects for the use of hydrogen in the production of dimethyl ether (DME) – a chemical that commands significant value in a $9.5 billion global industry. Hydrogen as feedstock in refinery processes is prospective as well.

Mega green hydrogen and green ammonia ventures are being realised as well. OQ Group's green hydrogen/ammonia project in partnership with DEME Group has a Final Investment Decision (FID) pencilled in for 2023.

The proposed projects are diverse in nature – they target the production of hydrogen products as energy carriers, but also as chemicals that can remove heavy minerals from produced water, which can then be used in electrolysers for hydrogen production, he noted.

Concluding his presentation on a strongly upbeat note, Dr Al Abri added: "We are moving forward with confidence. The leadership is keen on getting the agenda for hydrogen drawn up and finalised in the short term phase (2021 – 2025), upon which we then roll forward." ■

by Conrad Prabhu

Dr Khalil Al Hanashi, Energy Tech Lead – Energy Renewal, Petroleum Development Oman (PDO)

Clean Hydrogen Hubs:

A promising proposition for Oman

Oman has great potential to develop hydrogen hubs to serve local demand and export, says Dr Khalil Al Hanashi, Energy Tech Lead – Energy Renewal, Petroleum Development Oman (PDO).

A checklist of tasks before the Steering Committee, mandated by the Ministry of Energy and Minerals to formulate a National Hydrogen Strategy for Oman, began with a fairly straight-forward question: Why Green Hydrogen?

Those conclusions reached by the panel, at the outset of Oman's hydrogen journey nearly three years ago, enshrine the compelling value proposition associated with a green energy future powered by green hydrogen. They powerfully validate the Omani government's decision to pivot away from hydrocarbons as part of a broader commitment to decarbonisation fueled primarily by green hydrogen.

According to Dr Khalil Al Hanashi, former member of the Steering Committee who is presently the Energy Tech Lead at PDO's Energy Renewal Unit, the panel identified eight value drivers associated with the pursuit of a zero-carbon fuel resource like green hydrogen.

For one, green hydrogen would contribute

to a diversified energy mix essential to the goal of decarbonizing the energy industry. Secondly, it would contribute to the growth of a green economy. Perhaps, most importantly, large-scale production of green hydrogen has the potential to positon Oman as a major exporter of this commodity. Besides, in addition to driving FDI inflows into the country, the new fuel resource will help stimulate the growth of new supply chains through strategic partnerships that leverage the reach of the National Hydrogen Alliance (Hy-Fly) and also through bilaterals and trilaterals with different countries. Other value drivers identified by the panel pertain to green hydrogen's potential to support innovation, R&D and capacity building, and eventually elevate Oman into a competency hub for this carbon-neutral fuel. More tangible benefits in the form of significant job creation are envisaged as well.

Complementing these value drivers is a series of natural, environmental and geological factors that bode well for the development of a thriving hydrogen industry in Oman, says Dr Al Hanashi. The Sultanate, he argues, can capitalize on its abundant diverse natural resources to build and sustain a green economy around hydrogen. The potential to harness the country's unique geological features in support of a green hydrogen industry should be explored as well, the renewable energy expert adds.

Salt domes, for example, discovered in some parts of the country, can be explored to study their potential for the geological storage of large quantities of clean hydrogen in subsurface rock salt caverns, said Dr Al Hanashi. Likewise, ophiolite rocks found in abundant quantities in the Sultanate are known as a source of natural hydrogen production. A number of research organisations are currently studying the phenomenon of surface separate of high concentrations of natural hydrogen, he said.

Peridotite rocks, long believed to hold the secret of CO_2 mineralisation – albeit on a

Oman's Green Hydrogen Projects and Milestones

Feb2020	National Hydrogen Workshop
Dec2020	HyPort Duqm: 1.3 GW Solar and Wind Project-Green Ammonia
Feb2021	Green hydrogen blending with natural gas was discussed as a demonstrator in PDO as a mobility option
May2021	Green fuel mega project 25 GW solar and wind -one of the largest in the world
July 2021	Discussion of how to ship this H around the world. Duqm Port joins Global Ports Hydrogen coalition-first port in the region to do so
July 2021 together	Detailed study of blending hydrogen into Oman's natural gas pipeline with OQ and Energy Renewal Unit and National Hydrogen team
Aug2021	National Hydrogen Alliance (Hy-Fly) established
Aug2021	ACME Green Ammonia, 3.SGW green ammonia project
Oct 2021	Salalah H2 lGW wind and solar project to produce green hydrogen and ammonia
Nov2021	Green Hydrogen Summit

slow natural process - must be investigated to assess their potential for commercial-scale capture of carbon-dioxide from the atmosphere, further helping offset the CO_2 footprint, Dr Al Hanashi noted.

These fledgling geology-related opportunities, coupled with the immensely promising potential offered by Oman's renewables-based capacities – centring on solar and wind resources – leave little doubt about the exciting future that awaits the Sultanate in its transition to a greener economy, he stressed.

"If you look at the solar map of Oman, the high solar density found in the south makes its viable for the development of green hydrogen projects for export. Indeed, we have one of the world's most competitive levelised costs of electricity generation from solar. Likewise, Oman has proven high wind resources, as demonstrated by the fact that the first wind farm in the GCC was set up in Oman's Dhofar Governorate. In July 2021, the 50 MW wind farm operated at 100 per cent of its design capacity, which gives confidence about the potential of wind energy," the expert stated.

He further added: "All three potentials – geological, solar and wind – when taken jointly into consideration, provide the fundamentals for clean hydrogen production, and are a key differentiator for any green hydrogen project in Oman. Together, they will help us achieve one of the lowest hydrogen production costs. Also, due to the abundant availability of solar energy, the cost of hydrogen projects will be reduced by 10 – 15 per cent, as they will keep operating at night when the wind blows."

Adding to the strong value proposition offered by Oman's solar and wind resources are the country's potentially attractive geological characteristics and structures that can be used, on the one hand, for large-scale storage of hydrogen, and on the other, as carbon sinks to offset the remaining CO_2 life cycle, Dr Al Hanashi noted.

Dr Zakiya al Azri, Corporate Research and Development Adviser at PDO

Fit-for-purpose decarbonisation strategy for PDO

In its quest to become a net-zero energy company by 2050, Petroleum Development Oman (PDO) aims to harness hydrogen in the decarbonization of its power and steam generation activities, and as a greener alternative to fuel gas - particularly in heavy goods transportation.

For well over 50 years, Petroleum Development Oman (PDO) contributed the lion's share of Oman's oil and gas output – volumes that burgeoned over the decades in line with the country's economic growth. But as the imperatives of decarbonisation loom, the majority state-owned energy company says it has no plans to take its foot off the production pedal. On the contrary, it is committed to sustaining output in trend with the country's escalating energy requirements, while at the same time, reining in carbon emissions from its activities.

Ensuring this balance between, on the one hand, meeting energy demand growth and, on the other, the abatement of climate-change inducing emissions is a 'fit-for-purpose' decarbonisation strategy, according to Dr Zakiya al Azri, Corporate Research and Development Adviser at PDO.

It envisions the production of oil and gas sustainably, supported by the adoption of energy efficiency practices across the company's operations. And as PDO positions itself for the future, it also aims to create sustainable value beyond its current focus on hydrocarbons, and potentially even beyond its Block 6 concession area.

To its credit, the management of greenhouse gas (GHG) emissions from its operations began almost 10 years ago, says Dr Al Azri. Leveraging new technologies, the company has managed to cut emissions by around 20 per cent over the past three years alone, notably through flaring reduction, Power to Gas initiatives, deployment of micro-turbines, implementation of energy efficiency programmes, installation of energy efficient artificial lifts in ESPs, and its forays into the renewable energy space. Noteworthy is the Amin Renewable Energy Project – a 100 MW scheme that was launched two years ago. A similar-sized solar PV project is also currently under tender preparation, she said.

Zero-carbon energy

Significantly, PDO is now banking on hydrogen to further accelerate GHG emission abatement, according to Dr Al Azri. Hydrogen's efficacy in driving decarbonisation, she explained, has been validated by studies, as well as by experts representing developers, technology providers and others across the hydrogen supply chain.

"We have identified opportunities for hydrogen to abate around 21 per cent of PDO emissions by 2050. This will accelerate momentum towards Net Zero emissions by 2050, and we have aspirations to go faster by up to 50 per cent reductions by 2030," the official stated.

Hydrogen has the potential to play an important role in four key areas of PDO's operations: (i) As an alternative to fuel gas in power and steam generation (ii) as an alternative to fuel gas in oil and gas field operations (iii) as a low-carbon fuel resource in heavy vehicle transportation, and (iv) in hydrocarbon recovery. Additionally, surplus hydrogen output can be offered for local industrial consumption or exported as well, she points out.

In PDO's sights currently is Blue Hydrogen, says the executive. "We see Blue Hydrogen as a transition enabler towards green hydrogen. It can have tremendous potential, particularly when using the waste gas stream in our operations or combining it with carbon capture, among other utilisations."

Listing potential applications involving hydrogen, Dr Al Azri says Blue Hydrogen can be used in place of fuel gas to run gas turbines found across Block 6. Hydrogen can be used to maintain steam production, thereby contributing to the partial decarbonisation of activities, particularly in the Amal and Qarn Alam thermal clusters.

Another option is to retire some gas turbines and replace them with hydrogen, subject to the availability of hydrogen storage media. To explore the viability of this option, PDO is preparing to kick off a feasibility study to compare how hydrogen storage can be integrated with the company's renewable energy systems and future renewable energy projects. Additionally, hydrogen can substitute fuel gas, which is currently being used in off-grid locations particularly for gas driven compressors and boilers. These applications have the potential to pare CO2 emissions by 26%. A further 14% contribution in GHG abatement can be achieved if hydrogen is used for furnaces and heaters scattered across Block 6.

Importantly, a significant contribution to decarbonisation can be achieved with the use of hydrogen in transportation, given that PDO currently operates a massive fleet of heavy duty vehicles. To this end, PDO plans to shortly kick off a pilot project to study the benefits of hydrogen use for mobility applications. If viable, hydrogen use in mobility can cut 85% of CO_2 emissions associated with heavy transportation.

Nevertheless, PDO will continue to explore the long-term benefits of green hydrogen to help decarbonize its operations, said Dr Al Azri. "We are going for a green hydrogen demonstrator to learn to build our capability; We see it as a minimum risk strategy, which will give us more time to take advantage of cost reductions and technology advancements until we realise this goal – sometime beyond 2030," he added. ■

Hamed Al Naamany, Oman LNG CEO

Oman LNG eyes a role for hydrogen in its future decarbonisation strategy

In addition to exploring energy transition and decarbonisation opportunities within Sur Industrial City, the study will also look at the potential for establishing hydrogen clusters across the Sultanate of Oman.

A recent agreement signed by Oman LNG with the Sustainable Energy Research Centre (SERC) at Sultan Qaboos University (SQU) will support a pre-feasibility study to assess the potential for clean hydrogen development, as well the establishment of an Energy Transition Cluster at Sur Industrial City, where its $2 billion gas liquefaction complex is located.

Billed as landmark in its visionary intent, the agreement could enable the majority state-owned gas liquefaction company to transition away from natural gas in the

future as part of a global shift away from fossil fuels responsible for planet-warming CO_2 emissions, towards low-carbon fuels.

Announcing the signing of the pact in a twitter post, Oman LNG said the agreement will support the objectives of the National Hydrogen Alliance (Hy-Fly), a high-profile grouping of public and private organisations that have joined forces to advance the country's ambitions with regard to national energy security, decarbonisation, and a transition to a green economy.

In addition to exploring energy transition and decarbonisation opportunities within Sur Industrial City, the study will also look at the potential for establishing hydrogen clusters across the Sultanate of Oman – a move that aligns with the efforts of Hy-Fly's Project Management Office, presently overseen by the Renewal Energy Unit of Petroleum Development Oman (PDO).

The goal of the study, said Oman LNG, is to create a "roadmap" for the development of a clean hydrogen and energy transition cluster to unlock "sustainable economic growth and decarbonisation opportunities for Oman LNG and beyond".

Importantly, the move will further strengthen Oman LNG's bid to secure an extension in its mandate from the Omani government to operate beyond 2025, when its current 25-year concession expires. The Qalhat plant, set up at a cost of $2 billion, is currently the subject of a multi-million dollar, multi-year capacity restoration, debottlenecking and rejuvenation programme aimed at boosting efficiency and ensuring long-term sustainability.

The proposed study builds on a future vision for Oman LNG articulated by CEO Dr Hamad al Naamany at the Green Hydrogen Summit Oman (GHSO) held in Muscat last December.

As major LNG consumers pledge to ditch fossil fuels in favour of low-carbon and even carbon-neutral fuels such as green hydrogen, Oman LNG is gearing up to bolster its value proposition in alignment with this global transition, the CEO said.

"The party that should feel the most challenged by this transition is perhaps the LNG industry, but at Oman LNG, we don't see it that way – we actually see opportunity," he stated.

That opportunity, he explained, can be harnessed if key stakeholders operating in the neighbourhood come together to establish an energy hub that exploits synergies among themselves to, on the one hand, add value to their operations, and on the other, advance the nation's decarbonisation goals.

In the close vicinity of Oman LNG's complex at Qalhat (Sur) are three other entities which, while currently operating in standalone mode, can potentially complement each other in the realisation of a low-carbon, hydrogen-based, energy hub, Dr Al Naamany pointed out.

"Located in a five sq km radius around Oman LNG in Sur are a large water plant, a massive power plant, a petrochemical project (Omifco) and the LNG plant. This is what we want to bring to the table in terms of how local coalitions can unlock opportunities," he said.

"In effect, what we have a meta grid at Sur," the CEO noted. "If we bring all of them into the discussion of leveraging the different sources of energy, creating the right margins, putting an arbitrage on the table, (thus instead of dealing one-to-one, but as a coalition), each one of us should be able to play in the energy market."

For a coalition like this to work out, we need to bring about a hub that is cost-competitive and creates larger economies of scale, he added. ■

GHSO 2022:

OMAN TO TAKE CENTRE-STAGE at international green hydrogen summit

Building on the outstanding success of the inaugural edition of the Green Hydrogen Summit Oman (GSHO) last December – an event that has firmly entrenched the preeminent role of hydrogen in Oman's decarbonisation strategy – a follow-up edition is being held later this year to accelerate the realisation of this green future for Oman and its international partners.

This time around, the 2nd Green Hydrogen Summit & Exhibition (greenhydrogensummitoman.com), scheduled to be held at Oman Convention and Exhibition Center (OCEC) Muscat from December 5 to 7, 2022, will focus not just on the Sultanate, but key global markets as well. The enlarged forum, featuring prominent experts, energy companies, utilities, R&D institutions and governments, will seek the harness growing international interest in adopting green hydrogen as the world's zero-carbon fuel of choice.

As with last year's inaugural event, this year's three-day forum and exhibition will be held under the auspices of the Ministry of Energy and Minerals, with the support of a number of Omani government ministries, key energy companies and public sector

organisations. It is being organised by Muscat-based Birba Energy in cooperation with Oman Society of Petroleum Services (OPAL), along with the Energy Renewal Unit of Petroleum Development Oman as Strategic Partners.

The overarching theme is: 'Leading the Energy Transition Strategy'. But dedicated sessions over the three-day event will seek to do a deep dive a broad array of themes vital to the success of a future green hydrogen industry. Key areas for discussion include Green Hydrogen Potentials, Opportunities & Challenges; Regulations anPolicies, Certification; Emerging Technologies; Storage and Transportation Challenges; Green Hydrogen Financing and Projects/Investments Partnership; Renewable Energies at the Heart of Green Hydrogen Production; Water Resources for Green Hydrogen; and the Transition to a Green Hydrogen Society.

To help fine-tune the programme agenda, the organisers have constituted high-level Executive and Technical Committees to ensure that event is both illuminating for attendees and impactful for the participating countries.

The Executive Committee comprises Dr Abdullah al Abri, Head – Energy Renewal Unit of PDO (Conference Chairman); Abdulrahman al Yahyaei, CEO – OPAL; Mohammed al Mukhainy, Oman LNG; Dr Salim al Huthaili, CEO – Solar Wadi; Nasser al Rizeiqi - Hydrogen/New Energies Specialist, Ministry of Energy and Minerals; and Dr Faiza al Harthi, Energy Sector Head, Oman Vision 2040 Implementation and Follow up unit.

Also assisting in the delivery of a high quality forum is a Technical Committee including: Prof Dr-Ing Michael Modigell of Oman Hydrogen Centre (Technical Committee Chairman); Dr Khalil al Hanashi – PDO Energy Renewal Unit; Dr Zakiya al Azri, Corporate Research & Development Adviser – PDO; Dr Juman al Saqlawi, Alternative Energy – OQ; Mohammed al Taie, Project Engineering Manager, Oman LNG; Khalid Bin Hadi, Managing Director – Siemens Energy; Olav Carlsen, Founder – Hydrogen Rise; Dr Amer al Hinai - SQU Deputy Vice-Chancellor of Postgraduate Studies & Research; Dr Talal al Wahaibi - Associate Professor at Engineering Department A'Sharqiyah University; Prof Bruno G Pollet - President of Green Hydrogen Division at International Association for Hydrogen Energy - Director of Green Hydrogen Lab - University of Quebec at Trois Rivieres, Canada; Monica Trench - Hydrogen Origination and Business Development at BP-UK; Simone Corbò - Hydrogen Platform Leader Baker Hughes; Cédric Roux - Green Hydrogen Technical Manager - Total Energies; and Stephen B Harrison - CEO, SPH4 GmbH, Germany.

Underscoring the broad international appeal of the Green Hydrogen Summit, a number of leading global organisations have extended their backing to the event. The list includes the International Energy Agency (IEA), Green Hydrogen Lab, Arab- German Chamber of Commerce and Industry, AKH German Industry and Commerce, and World Hydrogen Leaders.


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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.

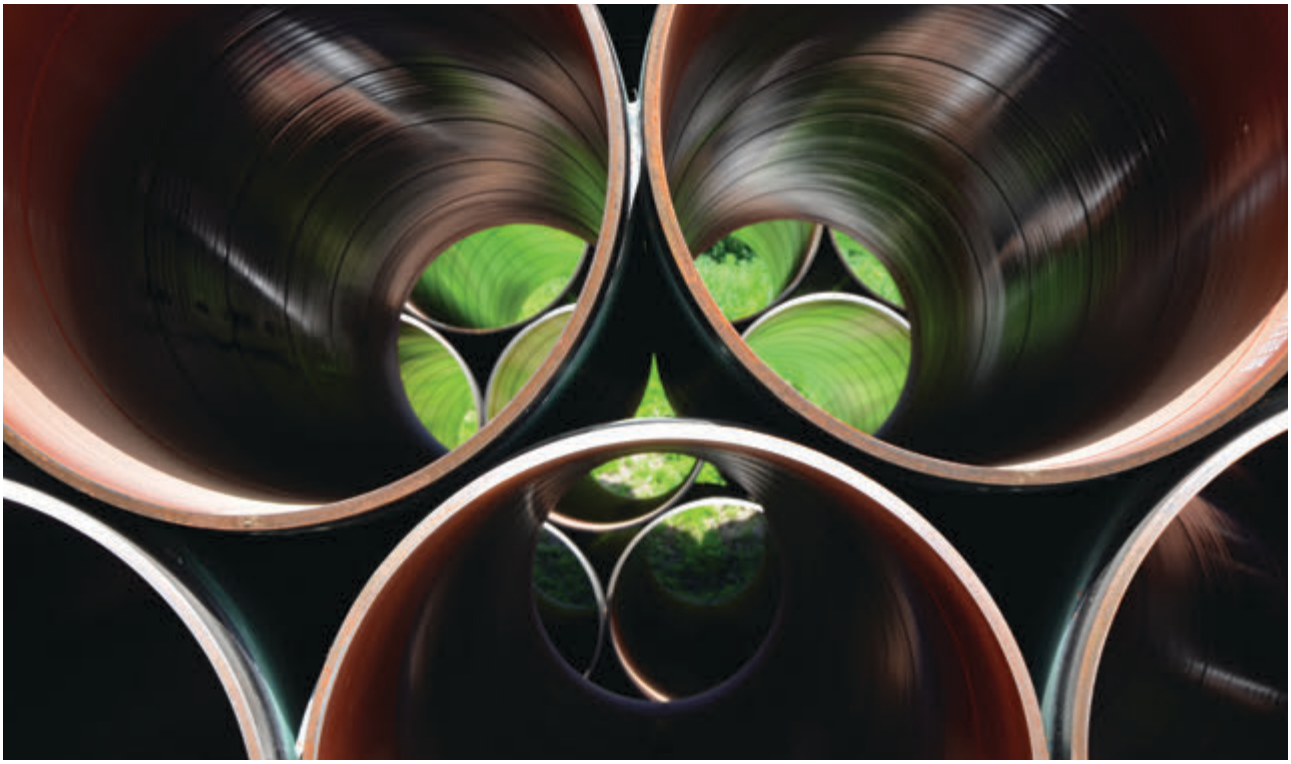
For the world's future hydrogen-centric economy, a suitable infrastructure is needed for transporting hydrogen throughout countries, as well as for its regional distribution and local storage. Pipelines represent the most ecological and cost-effective transport solution. For cross-regional gas transport, 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. Further aspects, such as the extent and frequency of changes

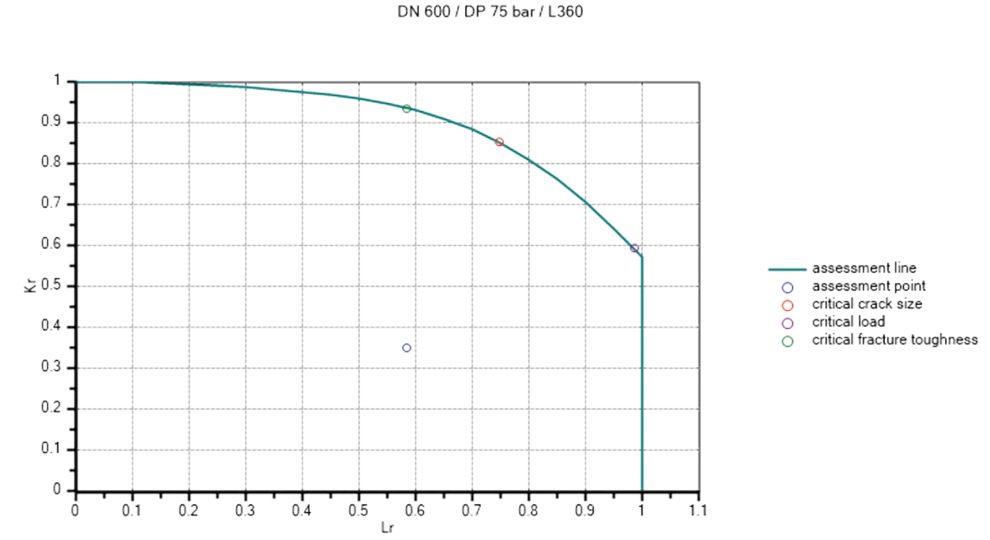
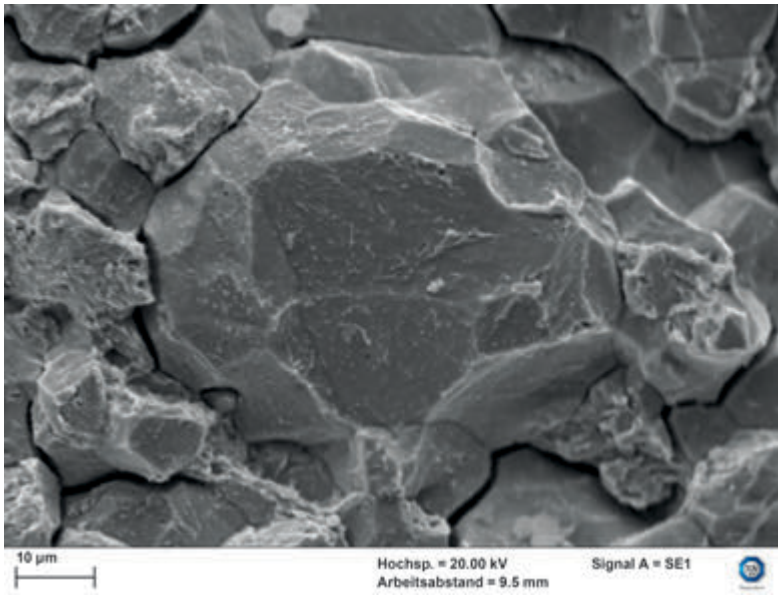


Figure 1: Load intensity and stress intensity in the failure assessment diagram (FAD)

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. ■

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

The essence and benefits of fracture mechanics

Fracture mechanics offer a mathematical proof that a pipeline is safe and functioning even in the presence of existing inhomogeneities like embrittlement caused by hydrogen. They are an important element for the management of pipeline integrity. TÜV SÜD-Experts determine the service life of a pipeline depending on the number of load cycles and define the inspection intervals of its non-destructive testing.

Fracture mechanics distinguishes between two theories: linear-elastic fracture mechanics (LEFM), also referred to as brittle fracture mechanics, and non-linear fracture mechanics (NLFM). LEFM describes fracture processes by applying the theory of linear elasticity and mainly records brittle fracture processes. NLFM describes inelastic material behaviour characterised by elastic-plastic or viscous effects.

Delivering a more sustainable world

By designing its own supply to the world markets, following the right approach, Oman can become a world class provider of green hydrogen products.

Dr. Hans Dieter Hermes
Vice President Clean Hydrogen, Worley

Oman Vision 2040 is the Sultanate's gateway to overcome challenges and guide it through the global competitive landscape. Vision 2040 emphasizes the need to build a diverse sustainable economy, charting course away from hydrocarbons for economic growth. The climate emergency and focus on the energy transition makes the green hydrogen economy a natural choice for Oman.

Hydrogen markets are emerging rapidly in all parts of the world. To meet the climate mitigation measures, being reflected in the Paris Agreement and in the current COP26 climate pledges, the world economies have agreed to enter net-zero emissions strategies and substantial energy transition.

This is triggering massive future needs for green hydrogen products, such as green ammonia and synfuels.

At Worley we are committed to delivering a more sustainable world and we believe that low-carbon hydrogen is a part of a low emissions future with enormous potential to support the global energy transition. Today, less than one percent of current hydrogen production is low carbon. This means most of the hydrogen we make comes from fossil fuel plants that release carbon into the atmosphere. However, pathways already exist for a hydrogen economy that can quickly and reliably slash emissions. Hydrogen shares similarities with the way we transport and process previous energy carriers like oil and gas, opening opportunities to utilize existing infrastructure, rather than build it all from scratch.

> **"The global energy transition is not a scenario – it's our reality.**
>
> **One we need to embrace, plan for and deliver."**
>
> **Chris Ashton,**
> Chief Executive Officer, Worley

Oman is blessed with abundant solar and wind resources, which can be used to create an inexhaustible supply of green hydrogen. This has the potential to reduce transport emissions, revolutionize steel making, assist oil refineries to generate green fuel and provide feedstock for fertilizers. Hydrogen can be the savior for industries that must decarbonize, but don't know how. This market situation favours projects in an environment with low-cost renewable energy supply from solar and wind, and an environment that enables fast and agile development.

By designing its own supply to the world markets, following the right approach, Oman can become a world class provider of green hydrogen products.

Worley has been involved in commercial applications of hydrogen for decades. Low-carbon hydrogen might only have emerged recently, but we have extensive experience having been there from the start. We have established the expertise to engineer it, produce it, transport it, store it, process it and use it. We work across industries and geographies engaging with every step of the low-carbon hydrogen journey to play a leading role in pioneering projects including:

- concept studies and engineering for solar PV, wind and green energy transmission system
- studies on the feasibility of crude oil to hydrogen pathways in the Middle East
- a study on building a green hydrogen industry for South Australia
- designing 36 GW of electrolyser capacity for an artificial island off the coast of The Netherlands
- working on one of largest commercial green hydrogen production facilities in the world
- engineering for solar project in Latin America capable of generating 2,400 GWh by year
- engineering for a 43 million gallon/year renewable jet fuel and renewable diesel plant
- engineering and detailed design for a 52,000 bbl/day renewable diesel refinery (world's largest)
- a detailed analysis of hydrogen in Australia, from ammonia synthesis to fuel cell mobility
- technical counsel for an offshore wind farm and hydrogen electrolyser facility for a refinery in the Netherlands
- using hydrogen in high pressure natural gas lines in Canada
- the engineering, procurement and construction phase of a green hydrogen refueling station in New Zealand
- concept studies and FEED for solar and battery storage for one of Australia's largest LNG compression and export facilities
- engineering for 50,000 tpa synthetic methanol facility using biogenic CO2 from a biomass -fired powerplant and green hydrogen. ■

EXECUTIVE SUMMARY

From ambition to reality

Weaving the threads of net-zero delivery

Translating pathways to reality

In this groundbreaking paper, Worley and Princeton University's Andlinger Center for Energy and the Environment explore the practical shifts required to successfully develop and deliver the energy infrastructure needed to achieve mid-century net-zero targets.

The collaboration was formalized through Princeton E-ffiliates Partnership, a corporate membership program administered by Princeton University's Andlinger Center for Energy and the Environment. The program enables corporations to pursue transformational innovations in energy and the environment in close collaboration with academic experts.

Drawing on research and analysis in Princeton's Net-Zero America study, it is apparent that achieving net zero is technically feasible and affordable.

However, to do so is an immense infrastructure delivery challenge – unprecedented in global terms – which will require businesses and governments to transform how they engage communities and develop and deliver projects.

The focus of the paper is on supply-side energy infrastructure, to explore five key shifts in thinking needed to deliver a net-zero transition.

The paper will help you understand the scale of the task, and then take you through each of these shifts. The combination of all five shifts is how we can go about making net zero a reality.

This paper is a must read for decision-makers in government, industry and the broader community. It illuminates the significant delivery challenges that we face and outlines key shifts needed to transform project delivery to enable the necessary changes.

Shift 1: Broaden how value is defined

We need to consider whether our projects deliver social and environmental value, in addition to financial value. We also need to share a project's value – money, jobs, clean environments – amongst all stakeholders. To broaden what value means, we need to:

- **Strengthen human capacity.** Make the energy sector a more attractive employer.
- **Invest with foresight.** Invest in technological options and earmark land we'll need over coming years in the transition.
- **Increase system redundancy.** Strengthen resiliency in electrical infrastructure, assure grid reliability and protect against cyber-attacks.
- **Nurture people's trust.** Involve people who'll be impacted by the energy infrastructure or transition in the planning and development process.
- **Accelerate approval and regulatory processes.** Be transparent, so that people trust in the governance processes.

Shift 2: Keep our technology options open

Net zero requires a tapestry of different technology approaches, working within resource, geographic, market, and enviro-socio-political constraints. All technologies will have their own advantages as well as constraints, making them more or less suitable in different situations.

We need to develop all possible decarbonization technologies, spreading our effort and investment broadly. This gives the best chance of enabling future solutions.

We must start the transition now, with the low-carbon technologies we already have – such as wind and solar – while investing in those still emerging, like hydrogen and direct air capture.

Shift 3: Design one, build many

We must standardize as many aspects of a project's design as possible, and then replicate that design many times. We must also develop projects in parallel. The execution of large programs of projects will streamline all steps in the development sequence.

This approach will:

- **Save time.** Cut down engineering effort and time taken for regulatory approvals. Multiple projects being built at once will dramatically compress schedules.
- **Optimize resources.** Use the transition to distribute job opportunities more evenly and equitably, across regions.
- **Speed up the supply chain.** By introducing common equipment standards across countries, equipment will be quicker to make, transport and install. This will enable establishment of local supply chains.

Shift 4: Communicate and collaborate

Countries, policy makers, industry and communities will need to communicate and collaborate like never before. To enable this mutual respect, trust, clarity, and well-defined roles and expectations will be required.

We will need to share information more openly. Government master plans must keep communities at the center of their development plans. Industry must work with all and share risks, ideas, patents, processes and designs, using innovative contracts with transparent, auditable margins.

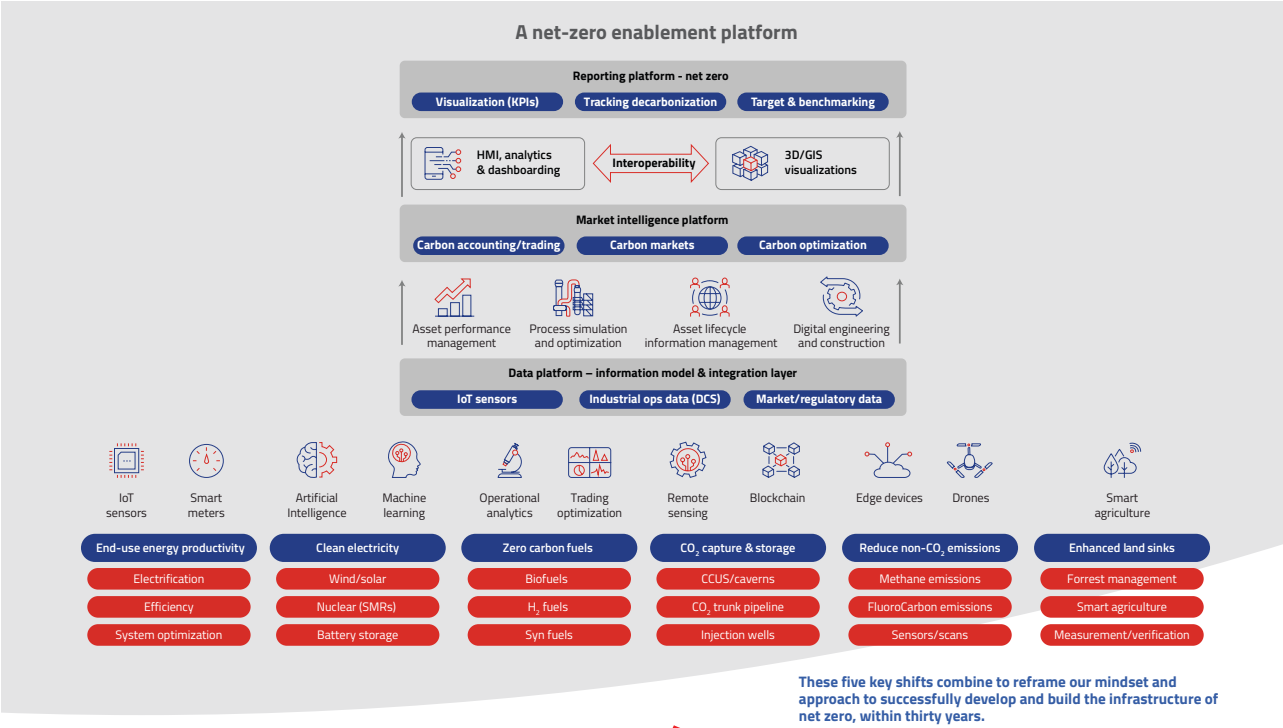
We need to form coalitions, empowered to hit net-zero targets and deliver value. Value in financial terms. In job creation. And in clean environments.

Shift 5: Enable and monitor digitally

Digital is key to accelerating the net-zero transition in a way that ensures transparency, trust and shared value.

Using digital technology, we can visualize the impact of a project, and track its performance once it's up and running. We'll encourage public scrutiny and, consequently, public trust.

We envisage a Net-Zero Enablement Platform, which builds on Princeton's six decarbonization pillars and has three distinct levels, shown in the figure on the next page.



These five key shifts combine to reframe our mindset and approach to successfully develop and build the infrastructure of net zero, within thirty years.

Humanity has risen to monumental challenges before. We can do it again. This paper shows us how we might begin to turn our net-zero ambitions into reality.

Worley energy | chemicals | resources

Princeton E-Filiates Partnership EFFILIATES

andlinger center for energy+the environment


GROVE

2021 was a good year to be an oil company: TETHYS OIL

Swedish energy firm Tethys Oil's contribution to the Omani economy from its investments in Oil & Gas assets in the country stands at over $1 billion since 2015, says Managing Director Magnus Nordin.

2021 was a good year to be an oil company. As Covid-19 released its grip on society and the economy during the course of the year demand for our product returned, resulting in steadily increasing oil prices. For the full year, Tethys Oil's achieved selling price increased by more than 30 percent to average 62.80 USD per barrel compared to the year before. Fueled by the oil price increase our key financials have skyrocketed! Our net result is up by more than 400 percent, our operating result increased by close to 180 percent and our year-end cash position is up 22 percent compared to last year, leaving us with USD 68.6 million of cash as we enter 2022. This record cash balance was reached whilst both investing in our assets but also returning more than USD 16 million to our shareholders by way of dividends, redemptions, and share buybacks in the year.

In fact, since 2015 Tethys has distributed more than USD 135 million dollars to its shareholders while contributing over one billion dollars to the Sultanate of Oman's economy. The Board of Director's dividend and distribution proposal for 2022 will add a further USD 25 million to that already impressive shareholder return tally.

The source of this cash distribution and the force behind our strong results in 2021 is our stake in our 'star' asset onshore Oman – Blocks 3&4. Over the last three years our share of production from the Blocks has amounted to close to 13 million barrels of oil whilst maintaining 2P reserves of more than 26 million barrels. In other words, we have consistently replaced our production with new reserves. 2021 is the first year in which we have replaced less than 100 percent of our production and we also saw a small drop in production compared to the year before (-1.7 percent).

At first look these numbers could be seen as a sign of weakness. But put in perspective they are actually numbers of great strength! Investments in Blocks 3&4 almost halved during 2020 and 2021 compared to previous years. Precipitously dropping oil prices and production limitations in 2020 led to massive cost savings and shutting in of producing wells. The 2021 outlook was cautions and the work programme limited. As conditions started to normalise by mid-2021, bottlenecks appeared, and back logs

By **Magnus Nordin**
Managing Director,
Tethys Oil Oman

increased. In short it was not easy to get back to where we had been before.

As we enter 2022, we clearly see signs of under-investment. This will be remedied by a major increase in capital spending during 2022. Don't forget, these investments are subject to cost recovery. The majority of these investments on Blocks 3&4 will be repaid to us almost immediately in the form of increased Net Entitlement with only a small "haircut". Considered the drop in investments our production and reserves development in 2021 is indeed a sign of the tremendous resilience and robustness inherent in Blocks 3&4. And just to make this point even stronger. The overall asset base of 2P reserves and 2C contingent resources increased during 2021.

So, we have every reason to remain confident that Blocks 3&4 will continue to be the backbone of our financial strength for several years to come.

But Tethys Oil is more than Blocks 3&4. Since a few years back we have used our experience, and a portion of our cash flow from Blocks 3&4 to add other onshore Blocks to our portfolio in Oman. One of them, in particular, is looking very promising.

As we started to understand the potential of Blocks 3&4, now more than a decade ago, we described the Blocks as 'a smorgasbord of opportunities. Block 56 today offers a similar smorgasbord of opportunities of various shapes, sizes and value potential.

At the time of writing, we have started to evaluate the first of these opportunities on Block 56, the Al Jumd trend of leads and prospects in the North-western part of the Block. The initial work programme calls for establishing commercial viability through the drilling of a horizontal well Al Jumd-2 and putting this on a long-term production test while drilling two more wells to establish the reserve base in the area.

In the central part of the Block, we are halfway through a 2,000 km2 seismic survey which should give us state-of-the-art 3D seismic data over three different petroleum plays and more than a dozen potential leads. We believe the central part of the Block holds the tastiest dishes of the Smorgasbord, but we must, alas, await the results later in 2022 before we can set our teeth in them.

A likely desert table, to push the metaphor, is Block 58 where we are working to mature some very interesting leads.

> **Since 2015 Tethys has distributed more than USD 135 million dollars to its shareholders while contributing over one billion dollars to the Sultanate of Oman's economy. The Board of Director's dividend and distribution proposal for 2022 will add a further USD 25 million to that already impressive shareholder return tally.**

Depending on the results here, including the result of a recently completed seismic study, Block 58 could come to complement Block 56 maybe also as a main dish.

To conclude our exploration portfolio, we expect to finalise a reservoir study of the sandstones in the Thameen well where we encountered an almost 40-metre gross hydrocarbon column last year that refused to flow to surface, however. The study will address several ways of stimulating the tight reservoir to release the hydrocarbons trapped within it. The results of the study will form the basis for our continued work in Block 49. The current license extension expires in June of this year so by that time we must have made up our mind as how to proceed.

As our partners EOG have advised that they wish to leave the Block, we are formalising the paperwork to go back to 100% ownership. We thank EOG for excellent partnering during 2021 and hope to have the opportunity to work with them again in the future.

We will have an active year and I expect to have many opportunities to write about all our Omani activities in upcoming letters throughout the year.

We will also have opportunity to address the more global questions of great importance for us and our industry and, for that matter our planet, such as Energy Transition, oil's place in the future world, as well as other ESG matters, more fully later in the year. First out will be our Sustainability Report and our Annual Report to be published in April.

Key energy transition trends to watch in 2022

CO_2 emissions to hit record high in 2022 despite greater focus on climate; emissions policy is on the ballot in key markets.

By S&P Global Platts Analytics

Despite the focus on emissions reductions and a lengthening list of countries that have made net zero targets, we expect that CO2 emissions from energy combustion will increase by 2.5% in 2022 to new record levels as some economies recover more fully while others push for growth. While leaders at COP26 pledged to strengthen 2030 emissions targets by the end of 2022 rather than waiting for the formal "stock taking" process, there are significant risks to domestic environmental policy agendas from elections in 2022.

During COP26, 100 countries committed to 30% reduction in methane emissions by 2030 (with some notable exception) which should further bolster interest in having fossil fuel market differentiated by their associated upstream carbon intensities. Record high carbon prices in the UK and Europe are at levels that are triggering market intervention reviews, though we expect that they will step back from recent highs.

Midterm elections in the US could derail the Biden Administration's environmental agenda, while Australia's opposition party is looking to oust the more conservative government by prioritizing more vital environmental targets. These elections are reminders that "all politics are local" and the fates of global agreements are often determined by domestic elections, public sentiment, and policy shifts.

Strong power prices boost incentives for renewables installations, but can they deliver? Input costs and policy risks still loom

Strong power prices have pushed renewable power margins to historically high levels across major markets and boosted prospects for faster installation growth in 2022. This is slightly ironic since the underperformance of renewables was a key factor behind the surge in global gas and power prices in the first place.

Despite an ~10% increase in commissioning costs due to historically high raw materials prices and labor issues, Platts Analytics expects solar PV capacity additions will increase by 4% in 2022, while onshore wind installations increase by 1%. However, capacity growth is predicted to decline for offshore wind, which will contract by 25% in 2022 after a strong 2021 due to China's phase out of subsidies.

More broadly, the world will need to learn to develop policies that balance the need to add zero carbon electricity supply with the cost of the dispatchability/availability of oftentimes intermittent renewable power. These are risks that that renewables uptake will be increasingly associated with energy shortfalls and resulting high prices – and we will be looking to see if policymakers start trading off energy transition for reliable supply.

Carmakers' shifting preference for EVs to become even more apparent; Light Duty EV sales to a new record high of over 9 million in 202

The automotive sector struggled with supply chain issues in 2021, primarily a shortage of semiconductor chips, a key element in electric vehicles. However, it appears that OEMs did not constrain the manufacturing of electric vehicles as much as internal combustion engine vehicles, which supported a 108% year-over-year growth in EV sales. In addition to government-backed regulations, high fuel costs and financial incentives supported strong growth in electric vehicle sales in 2021, especially in China and the European Union.

While the prevailing factors that drove growth in 2021 will continue to be at work in 2022, an acceleration in EV sales growth will occur in 2022, driven by actions taken by automakers themselves. Automakers continue to increase investments in battery technology and electric vehicle manufacturing and will be offering a larger and broader range of EV models, and are adding to the build out of charging stations, which will help reduce range anxiety. The drivers of EV adoption will increasingly shift from policy/subsidies to producer and consumer choice. S&P Platts Analytics forecasts EV sales will grow over 40% YOY in 2022.

Gap between hydrogen production ambition and reality will be tested

Ambition surrounding hydrogen development was certainly on display in 2021, with announced projects of low carbon hydrogen production capacity in Platts Analytics' Hydrogen Production Assets Database swelling to 29 million tons by the end of 2021. These project announcements have been supported by a growing number of countries announcing hydrogen strategies, which provide ambitious targets and incentive structures for new production capacity.

While the achievability of even near-term hydrogen production targets (such as the EU's target of 6 GW of green hydrogen production capacity by 2024) will not be fully determined in 2022 alone, developers will need to start to show that projects can be completed on time and on budget this year. There is production capacity across several different hydrogen production pathways that is slated to become operational in 2022, ranging from a larger-scale project using biogas and landfill gas, to small scale electrolyzers paired with renewables.

While Platts Analytics does not expect any large-scale blue hydrogen (natural gas + carbon capture) projects to become operational in 2022, we will be closely monitoring the development and policy support of carbon capture projects that are not associated with hydrogen production this year as a key signpost of the viability of blue hydrogen projects.

> **"The world will need to learn to develop policies that balance the need to add zero carbon electricity supply with the cost of the dispatchability/ availability of oftentimes intermittent renewable power. These are risks that that renewables uptake will be increasingly associated with energy shortfalls and resulting high prices."**

Technology milestones in 2022 to point the way forward in the energy transition

Perhaps the greatest challenge of the energy transition is going beyond increasing wind and solar generation and electric vehicles, to reducing emissions in sectors that are more difficult to decarbonize, such as aviation and marine transport. While technologies that could move the needle in these sectors are still essentially in the demonstration phase, several milestones look to be achieved over the next 12 months, including a pair of hydrogen-fueled maritime vessels hitting the water, and eight ships that will be "ammonia ready" as an alternative fuel if/when the supply and infrastructure is available. While not powered by hydrogen itself, the first large liquefied hydrogen (LH2) carrier will load its first cargo of hydrogen in Australia in early 2022, an early indication that international hydrogen trade can be viable.

On the aviation front, Platts Analytics looks for greater use of sustainable aviation fuels (SAF) in the sector, driven by government mandates (e.g., France mandating 1% SAF usage beginning in 2022) and commercial airlines looking to test higher SAF blend rates (following the lead of United Airlines which achieved the feat on a commercial flight in December 2021). The change to the size of the orderbooks of ships and planes designed to use alternative fuels will be a key factor to watch in 2022. ■

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