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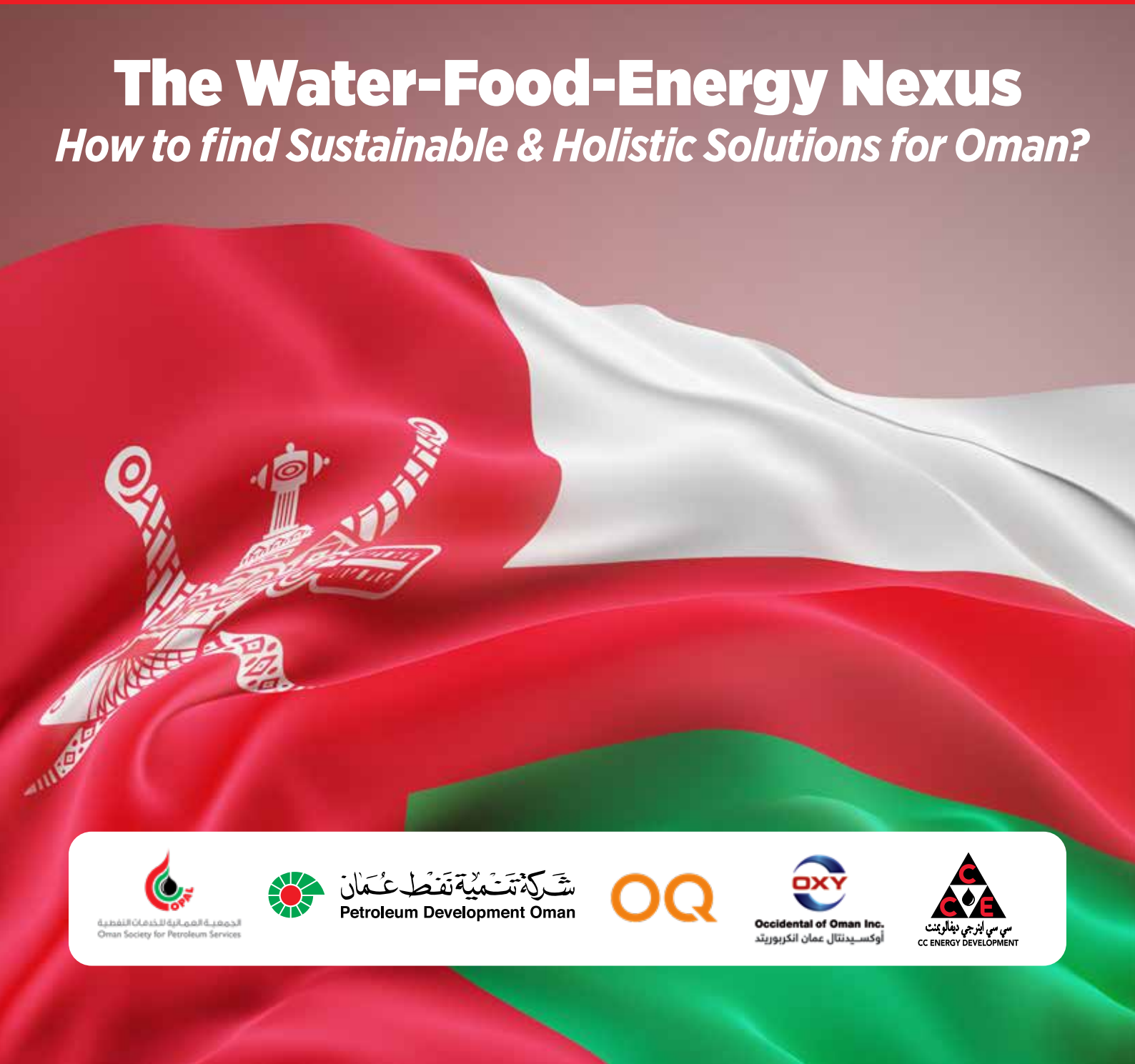
OMAN ENERGY MASTER PLAN 2040
Special Report Part V

Whitepaper

Q1, 2022

The Water-Food-Energy Nexus

How to find Sustainable & Holistic Solutions for Oman?



OPAL
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Oman Society for Petroleum Services

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Petroleum Development Oman

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GI Special Report: Action Plan

WHITEPAPER – Executive Summary

Oman's crunch point is very real. The Sultanate must strengthen its water-food-energy nexus if it wants to resolve its share of what is an intensifying global challenge – and quickly.

By 2050, global demand for energy will nearly double, while demand for water and food will rise by more than 50%.[1] Now consider that Oman must balance these factors with its swelling population (+46% by 2050[2]), rising energy consumption (+55% across the Middle East by 2040[3]), and a thickening environmental rulebook as per the Paris Agreement. The enormity of this challenge cannot diminish its urgency – the climate clock is ticking louder than ever before and every corner of Oman's government, industry, academia, and society must respond. To overcome the increasing constraints that the Sultanate faces, it must fundamentally rethink how it uses the cornerstones of civilization: water, food, and energy.

Time for holism

The decision-making process for water, food, and energy sectors tends to occur in isolation, without sufficient coordination and consideration of how changes in one sector can impact another. This challenge is certainly not exclusive to Oman; nearly every country worldwide must improve this balancing act. This singular approach to managing such valuable resources can lead to unsustainable policies and rising costs. At worst, it further jeopardizes water availability, increases food imports, and weakens the fundamentals of the Sultanate's energy market. Also consider that the latter is one of the main engines of Oman's economy (nearly 70% of Oman's GDP is derived from oil and gas[5]). Clearly, a holistic approach that reinforces all three areas is essential; one cannot thrive without the other two, and vice versa.

Like all nations, Oman has one very limited resource when it comes to improving this vital nexus: time. Speed is paramount, so the Sultanate should strive to post significant progress in 2022.

Young minds, future growth

The Sultanate's plans to rework its water-food-energy nexus must be built on a strong foundation of knowledge and support within the Omani community. This is especially true for younger generations (those aged 18-29 consisted of 24% of the total Omani working population in 2020[6]). In this vein, improving and deepening young Omanis' education and awareness of the country's changing water-food-energy outlook will help spur much-needed solutions and public buy-in. These benefits will also feed into supporting the private sector as it focuses on filling job vacancies, enhancing research and development (R&D), and generating long-term wealth, as per the National Vision.

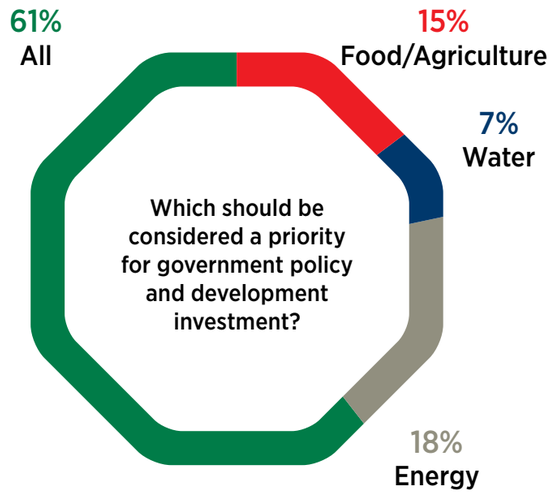
Government's guiding hand

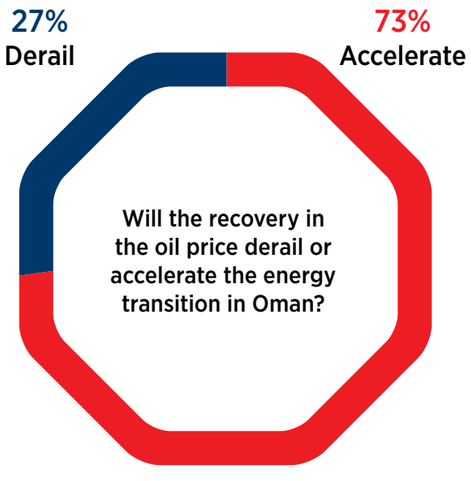
A robust nexus is not possible without governmental support – it is that simple. Therein lies the critical importance of weaving in the support of an official body into the day-to-day operational changes that must be made. From regulatory clarity to bolstering accountability to inspiring Omanis to embrace these changes – a government-led voice plays a central role throughout. For example, having a body that can issue government-approved mandates would significantly boost the tempo of progress across Oman. Such a body could also help monitor project timeframes, reduce bureaucratic hurdles, and foster communication between the Sultanate and international institutions. Amid the many question marks, one point remains clear: a major collaborative effort that engages all stakeholders is non-negotiable. Like all nations, Oman has one very limited resource when it comes to improving this vital nexus: time. Speed is paramount, so the Sultanate should strive to post significant progress in 2022.

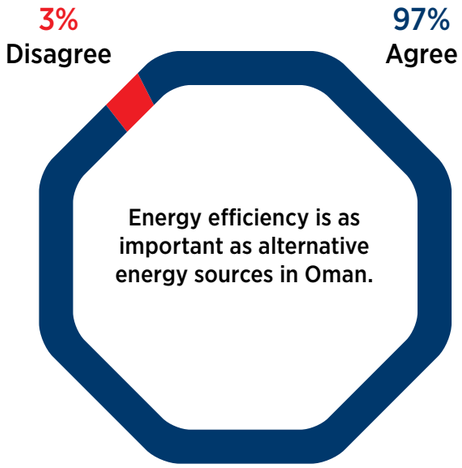
[1] IRENA; [2] United Nations (UN); [3] BP Outlook; [4] UNFCCC; [5] United States' Department of Commerce; [6] Muscat Daily

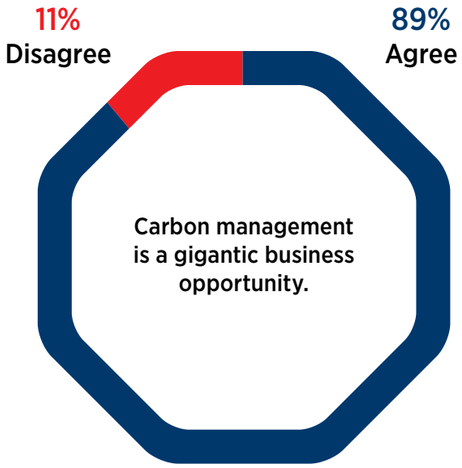
WHITEPAPER REPORT - OMAN NATIONAL SURVEY

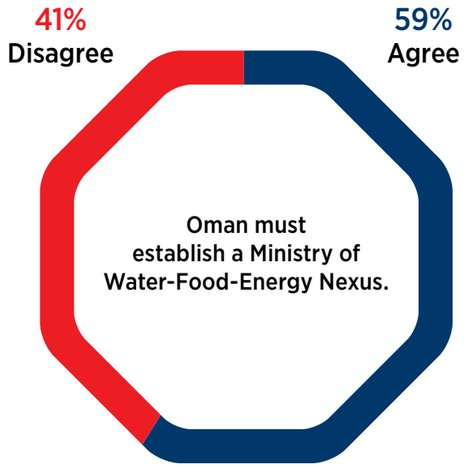
What is the Status of Oman's Nexus?

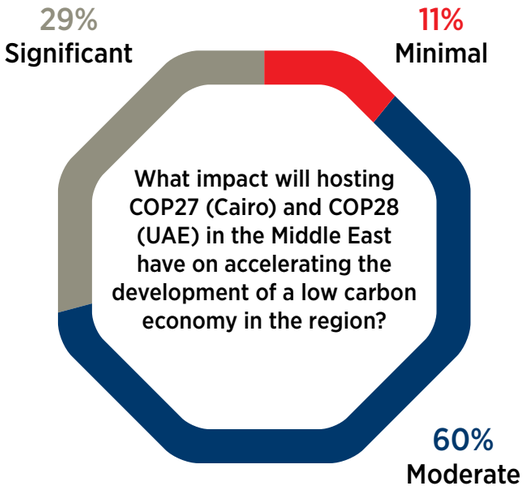


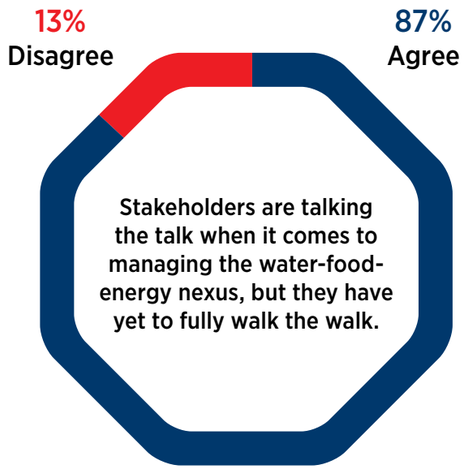


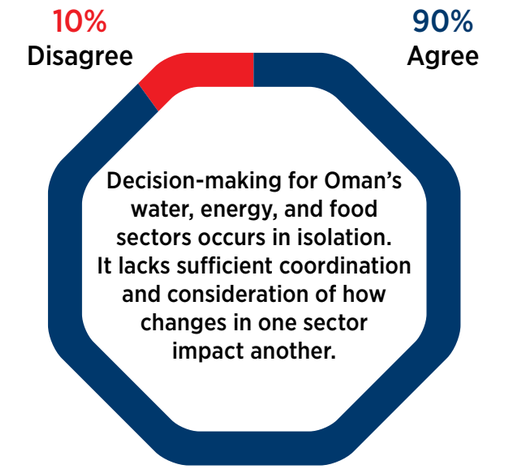


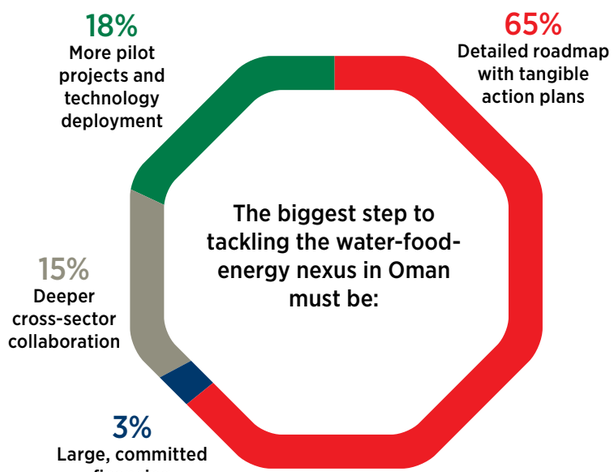


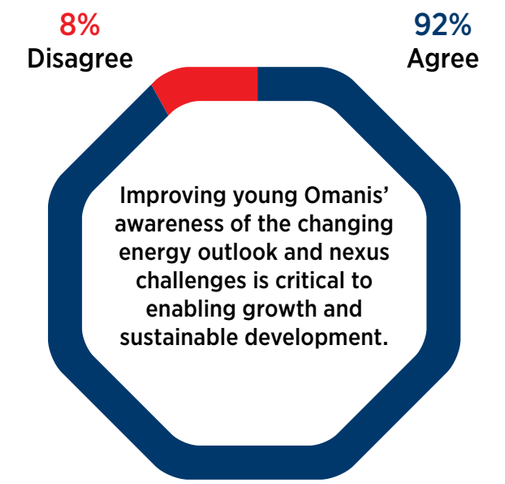












FEATURE INTERVIEW

Great Challenges, Great Opportunities...?

Steve Phimister, Managing Director, Petroleum Development Oman (PDO)

How are international oil companies (IOC) and national oil companies (NOCs) approaching the energy transition differently?

It's not that dissimilar as we're trying to respond to a common external stimulus – the like of which we've never seen before. I've worked in the business for 30 years, with the energy system being quite stable and static, putting price volatility and business cycles aside. Now that is far from true: the pace of change is dramatically accelerating. Moving from a global perspective into a country-specific role in a company that is focused first and foremost on Oman – i.e., from an IOC to a NOC – actually has an identical context. The portfolio looks different, but the pathway to achieving industrial and hydrocarbon decarbonization is the same. There are differences in how companies partner and collaborate within the sector, outside the sector, and varying government regulations. But we are all still playing in the same pond.

How can the energy sector support the Paris Agreement and COP26 commitments while sustaining energy security?

Oman's Nationally Determined Contributions (NDCs) are rooted in its Vision 2040 and National Energy Strategy. While gradual, these will support the transition into a low carbon economy. That can be achieved through the deployment of renewable energy or deepening energy efficiency, for example. Both are carbon control pillars, which will enable the Sultanate to slow down its CO_2 emissions growth. As a sector, we also have a mandate around energy security and economic prosperity. We need to produce cleaner energy, adopt new technologies, electrify our business, and employ digital solutions to tackle our own emissions. We can also move into lower carbon fuels, such as clean hydrogen and ammonia and other facilitators, like carbon capture and storage (CCS). We can develop new supply chains by leveraging existing infrastructure and skills that we have in our oil and gas industry. We can also explore cross-sector investment: this is not a single sector discussion. Up to 85% of CO_2 emissions generated worldwide come from the consumption of energy systems – just 15% come from production.

"I've worked in the energy business for 30 years and the system has been quite stable. Now that is far from true: the pace of change is dramatically accelerating. Communication and innovation lie at the core of our ability to create a better water-food-energy nexus – and soon."

How can we best synergize a sustainable transformation of the water-food-energy nexus?

This remains a big challenge. Sustainable development, particularly around the nexus, is not a new concept. In Oman, water scarcity in agriculture and general access to water and electricity are real issues. These sectors are currently largely working on their own agendas. We probably need an overarching umbrella framework to help drive sustainable transformation, and one that's competitive because we are playing in international markets. This will require considerable investment in the near-term to make it a reality. There are some straightforward crossovers. For example, emitted CO_2 can be used sensibly in smart farming and is already being used worldwide in intensive seaweed farming. We can use produced water from the energy sector rather than re-injection or disposal, so that we don't consume new water sources. PDO produces substantial amounts of water. We can manage its use and the energy consumed in that process as well as conduct research around the crossovers – something we have already started. Water usage and efficient allocation to food and energy is critical, but the balance in that ecosystem is challenging.

85%
of CO_2 emissions generated worldwide come from the consumption of energy systems – just 15% come from production. Therein lies the importance of a holistic approach, one that encompasses all aspects of business, government, academia, and society.

30%
increase in global water demand could be seen by 2050 – particularly concerning for nations that are already facing water stress.[1]

34%
increase in Oman's population by 2050 is anticipated from today's 5mn people.[2] Addressing the strained nexus now is imperative for the security of future generations.

[1] UNESCO; [2] United Nations (UN)

NATIONAL NEXUS:

FOOD - ENERGY - WATER

- **Eng. Saleh Al Shanfari, Group CEO, Oman Food Investment Holding Company (OFIC)**
- **Abdulrahman Al Yahyaei, CEO, Oman Society for Petroleum Services (OPAL)**
- **Eng. Zaher Al Sulaimani, President, Oman Water Society**

What is your top recommendation to align the nexus in Oman?

Eng. Saleh Al Shanfari
We must redesign food and energy systems – so circularity is a major driver. Currently, most of the food in Oman is produced through linear methods. We want to be a responsible investor, one who cares for society and the environment, producing food more efficiently. An example of where we have made progress in the dairy business is by converting the slurry into biogas, which is then converted into energy. We also capture carbon, store, and inject it into greenhouses to accelerate the production of fruits and vegetables. We must develop more green technologies and implement more food production powered by renewable energy and better utilize saline water, which is plentiful. Through our mandate at Oman Investment and Finance Co. (OFIC), we can demonstrate to the Omani people and the world what can be done.

Eng. Zaher Al Sulaimani
We must use technology to reengineer and modernize our agriculture system. The groundwater in Oman is depleting and our food and water systems are also affected by urban expansion and climate change. Today, 90% of our domestic water comes from desalination.

Abdulrahman Al Yahyaei
The water-oil ratio is very high. We are investing in R&D to find the technology required to clean the water produced from oil wells. We are also building dams to protect the land from cyclones.
The nexus plays a crucial role in Oman and the wider Middle East and we have a strong foundation already. OPAL has more than 450 member companies from the oil and gas sector and members from the electricity sector have also recently joined. But we need to speed up decision-making and set clear policies – we must move faster. OPAL can play a vital role in bringing nexus stakeholders – agriculture, power generation, and water desalination companies, for example – together. We have done this on many occasions, including during the Covid-19 crisis.

How can better efficiencies be produced for water in the energy space?

Eng. Zaher Al Sulaimani
Technologies to treat water are still very expensive. We are working on nanotechnology research with stakeholders and to minimize risk and remove poisonous material from produced water.

Are government policies sufficiently aligned for the nexus to succeed?

Abdulrahman Al Yahyaei
The Oman Investment Authority oversees most of the agriculture and fisheries and when it comes to oil and gas, we have the Ministry of Energy and Minerals, which also oversees power generation and desalination plants. These bodies can work together and develop joint policies and strategies to connect the full value chain. Energy efficiency is also very important. For example, Oman's electricity capacity is 40% higher than our consumption, so the different stakeholders can put the right strategies in place to support redistribution. Such collaboration is already underway.

How strong is Omani's awareness of food and water security?

Eng. Saleh Al Shanfari
Being inclusive is a major driver in this regard. Most of our projects are in rural areas, which have very fragile communities that need attention. As partners, we are fully engaged in what we do and we want to disseminate financial, technical, and environmental benefits, including employment and training. I've been in the sector for more than 33 years and this is how we design most projects – working closely with communities. They are the ultimate customer.

Eng. Zaher Al Sulaimani
We need to work harder at public awareness. We should publish the figures relating to the environmental cost and the CO_2 footprint of the energy we use for desalinating water, for example. Domestic water bills are still subsidized. Our group is bringing all stakeholders together to try to disseminate this information.

90%
of Oman's water is currently generated by desalination plants.

2nd
is Oman's ranking for food security in the Arab world.

2025
is when Oman intends to have a fully self-sufficient dairy sector.

1mn
tons of fish a year will be produced in Oman within the next five years. The Sultanate is already one of the world's biggest producers and exporters of fish, with the market value reaching OMR364mn ($950mn) in 2020.[1]

[1] Times of Oman

Snapshot: Oman's Food Security?

Oman is ranked second in terms of strong food security in the Arab world and 32nd globally, so we have a resilient food reserve system. We are currently developing projects that are financially sustainable and that bring investors and buyers together. For one, Oman's dairy sector will be fully self-sufficient by 2025. The Sultanate is also one of the world's largest producers of fish. Our consumption is around 150,000 tons, but we produce half a million tons – and we are aiming for 1mn tons by 2026. However, Oman does have a shortage of rice, wheat, and some pulses, so we are looking at investment opportunities beyond the Middle East. We work closely with Australian and Argentinian producers to secure some of our needs and that of the broader region, for example.

Source: Eng. Saleh Al Shanfari

Energy Industry's Evolution or Revolution?

- **Steve Phimister, Managing Director, Petroleum Development Oman (PDO)**
- **Steve Kelly, President & General Manager, Occidental of Oman**
- **Walter Simpson, Managing Director, CC Energy Development (CCED)**

Are energy companies in Oman firmly committed to the transition?

Steve Kelly
Many have made decisive turns to get us to the point we are today in terms of the transition to renewable energy sources and a commitment to carbon monitoring. As a sector, we've got a huge role to play, particularly in getting the message across. Not all the areas we are pushing for are accepted as being part of the solution. We must demonstrate what we are doing to drive the world in the right direction.

How can energy companies work better with food and water stakeholders to drive efficiencies across the nexus?

Walter Simpson
There has been a realization of how central energy and food and water are to each other and how we can work as teams. The industry has a lot of experience in these areas, but I sense we are generally not trusted. However, without our involvement, an effective transition can't be done. We've done a lot of work on the stewardship of resources. Now, we need to work on gaining trust by reducing our emissions and being transparent about the fact that we're working hard to do it. For example, we manage water sources effectively by making sure saline water doesn't contaminate areas and by working with communities and industries in our operational areas to create solutions.

Do NOCs have a bigger role to lead in the nexus than the food or water sectors?

Steve Phimister
Major oil companies like PDO have a role to manage water resources and lead by example, at least. We already have a clear policy and strategy to reduce, reuse, and relocate water. For example, if we're producing up to ten barrels of water for every barrel of oil, we need to do something responsible with that and take any excess water to where there's a shortage. On a local scale, we have applied a methodology that has a value-based approach for the last five years. We've employed 32 new technologies across what we call our ten corporate challenges, which include core hydrocarbon production issues, energy efficiency, and water management. Another country initiative is the Oman Water Hub. This collaborative effort was established by professionals from across the three sectors in 2020, along with other companies, academia, and government, to innovate and solve problems in water.

What are the obstacles to such cooperation across the nexus?

Steve Kelly
We have the advantage in Oman that we are respected and trusted – much more than oil companies in the UK or the US. We can build on that and demonstrate our progress towards a lower carbon economy and zero emissions. We already have buy-in from the government and the population. We are supporting the food and water sectors, for example, in date palm plantations and livestock farming.

What lessons have we gained in regards to energy efficiency during Covid-19?

Walter Simpson
One of the real "benefits" of Covid-19 was how the workforce got used to using digital solutions to execute tasks. That's now going to lead to a better uptake overall. The first thing we need to do is be as efficient as possible with our current energy use before we start looking for alternatives. Digitization and using data to get efficiencies is one of the biggest tools available to us – and its full potential is still not being explored.

Is the energy sector maximizing the opportunity to better manage carbon?

Steve Kelly
Our ultimate objective is to be regarded as a carbon management company – to build on the base of many decades of CO_2 use management. We want to use those skills and align ourselves and relationships with other technology providers in the field in direct capture, zero emissions hydrocarbon power generation, and reusing CO_2 in enhanced oil recovery (EOR) projects. In some cases, the technology around this is in its infancy, while others are underway. What's going to be really critical going forward is our relationship with the logistics people in the supply chain and ensuring that we all understand how that integration drives the efficiencies we seek.

Has the industry moved fast enough on carbon abatement?

Walter Simpson
We've been creative and solved some very difficult problems, but CCS remains a challenge. It's an integral part of the industry surviving, particularly when we see that there's place for the smaller independents. We've got to be the low-cost producer and that means focusing on the supply chain and working with partners to drive maximum efficiencies. Part of this also means capturing carbon, storing it, and managing our water and waste effectively.

32
new technologies have been employed by PDO on a local level across what the company calls its ten corporate challenges, including hydrocarbon production, energy efficiency, and water management.

2020
saw the establishment of the Oman Water Hub.

32%
increase in the global storage capacity of CCS in the last year. While CCS remains a challenge in Oman – and many other nations – the market's growth means more action is needed to keep pace with global developments. There are now 135 commercial CCS facilities in the project pipeline from a diverse range of sectors including cement, steel, and hydrogen.[1]

[1] Global Status of CCS

INSIGHTS

People, Planet, Profit

How can the energy industry swiftly adopt a sustainable strategy to cater to this triple bottom line?

- **Eng. Saleh Al Shanfari, Group CEO, OFIC**
- **Dr. Hammou Laamrani, Senior Expert, Water, Energy, Food Security and Climate Change Nexus, League of Arab States**
- **Dr. John Kilani, Director of Sustainable Development, Al-Attiyah Foundation**

Host: **Dr. Badar Al Kharusi, North Director, PDO**

People, planet and profit: the new bottom line of the 21st century. Achieving this new balance will take time and effort from all quarters in Oman, but it is certainly achievable. Necessity is the mother of innovation – a premise often proven true in the Sultanate's fossil fuel industry and one that must again come into play. A penchant for innovation has enabled Oman to leverage its particularly challenging and mature oil fields, including ground-breaking solar-powered EOR projects. That same spirit must be applied to hitting this new bottom line in the 2020s in order to achieve social, climate, and economic security by 2040 and beyond. We must acknowledge how vastly complex and interconnected this nexus is; it touches upon every area of society, environment, and businesses. Absolute application will take time and novel thinking. Equally, all actors must remember that time is short, as encapsulated by one roundtable participant: "We are now one minute from the clock striking midnight."

"We must recognize that responding to the "people and planet" part of this nexus may mean compromising the profit part. Equally, remember that alternative markets – hydrogen, solar, circularity, and more – bring their own long-term economic opportunities and very importantly, job creation."

65%
carbon pricing initiatives exist worldwide,[1] representing a "very big piece of the glue that holds the people-planet-profit nexus together," one roundtable participant said. Oman is exploring a tradeable energy credit plan.[2]

$50trn
of global assets will be for environmental, social, and governance (ESG) purposes by 2025, reshaping the world's $140.5trn assets under management.[3] Accordingly, Omani stakeholders must embrace ESG quickly, for such credentials will start to directly impact their ability to lock in competitively priced financing.

8.6%
of the world's operations are currently circular. Clearly all nations, including Oman, have a long way to go – but the reward is worth it. Having a circular economy can yield up to $4.5trn in economic benefits by 2030.[4]

[1] World Bank; [2] PwC; [3] Bloomberg Intelligence; [4] World Economic Forum

GI Special Report: Action Plan

TOP TAKEAWAYS

Circularity works

The colossal importance of designing a circular economy cannot be overlooked: it plays a central role in achieving the people-planet-profit equilibrium. For one, the current level of waste in the global system can grind progress on this nexus to a halt all on its own, regardless of other pressures. The good news is that Oman is making meaningful inroads, with its journey so far including the opening of six investment opportunities linked to waste-to-energy (WTE) and waste reprocessing – with investments totalling OMR580mn ($1.5bn).[1] Plus, PDO has installed thousands of solar photovoltaic (PV) panels at its car parks at Mina Al Fahal to supplement the power used in its headquarters at Muscat. The 5.92 MWp (megawatt peak) solar car park project will generate around 9,500,000 KWh/yr of solar electricity and save 42,000 m3/d of gas that would otherwise be burned to generate the same electricity. The solar electricity generated from the rooftops of the car parks will be connected to three of the main office buildings and feed into the domestic grid at off-peak time.[2] Other efforts in Oman include rethinking waste when drilling with oil-based mud (OBM). These wet cuttings are transported by BDHL subcontractors to PDO's waste management yards, where they are stored and dried before being treated in a traditional process that is both expensive and energy intensive. In 2016, BDHL said it wanted to transport semidried OBM drill cuttings to the coast near Muscat to be turned into cement for use in Oman.[3]

Build food-water alliances

Plans must put a far stronger spotlight on water and food security – both fundamental building blocks to a circular economy and in turn, the people-planet-profit nexus. According to one ranking, Oman ranks 40th out of 113 nations in terms of strong food security,[4] and it is one of the world's most water-stressed nations. Water and food security are sometimes seen as a hindrance to the broader goal of decreasing CO_2 footprints, roundtable participants said. This attitude must change. Gas was long seen as a waste product. Now it is one of the world's biggest commodity markets and a critical "bridge" between fossil fuels and renewables in the global energy transition. There is no reason why the water-food nexus cannot follow a similarly positive track, thereby supporting the broader people-planet-profit nexus. Some progress is already underway. For one, PDO agreed with the Agriculture Production and Marketing Company (APMC) in September to plant crops and 500,000 trees over the next decade, focusing on a 35km² tract of land at Rahab in the south of PDO's concession area.[5]

"Combined, industries' knowledge stretches into thousands of years' worth: it should be leading the development of this people-planet-profit nexus, not following it."

Leverage industry's know-how

Rethinking the role of industry is essential: they are allies, not culprits. Oman's industries hold vast knowledge when it comes to energy management, environmental initiatives, talent management, nationalization efforts, safety management, and a plethora of other areas. Combined, industries' knowledge stretches into thousands of years' worth: it should be leading the development of this people-planet-profit nexus, not following it. Those who move quickly can hugely benefit, diversifying their energy baskets to lock in more revenue streams over the long-term. Those who do not risk being alienated. One roundtable participant said a major aluminum smelter in the UAE has already had their product excluded from certain markets due to its large carbon footprint.

Everyone, together

Part of achieving this nexus means "looking beyond the government's role" in the Paris Agreement (ratified by Oman on April 22, 2016[6]). Instead, holistic efforts are pivotal to driving progress, notably a stronger public-private-society nexus. Looking ahead, far greater political support is needed to reinforce this regulatory framework and in turn, boost investors' visibility and appetite. This feeds into bolstering the talent pool and more effective R&D to scale-up existing technologies and explore new innovations.

[1] Oman Observer, Zawya; [2] DHL; [3] DHL [4] Global Food Security Index; [5] Petroleum Development Oman (PDO); [6] United Nations Framework Convention on Climate Change (UNFCCC)

INSIGHTS

Water Technologies

What technologies have the potential to change the face of renewable desalination and water reuse?

- **Eng. Zaher Al Sulaimani, President, Oman Water Society**
- **Richard Connor, Water Resources Specialist - World Water Assessment Programme (WWAP), UNESCO**
- **Dr. Edoardo Borgomeo, Water Specialist, World Bank**
- **David Reavley, CEO, Solar Water Plc**

Oman faces an increasingly worrying water shortage – and it is not alone. Up to 70% of the Middle East and North Africa (MENA) is exposed to high or very high water stress and water scarcity. This could affect up to 14% of the region's GDP by 2050.[1]

As a nation partly formed by a desert landscape, Oman must balance high water consumption and a growing population and prospering industry with a natural water shortage, unsustainable groundwater use, and historical subsidies. It is a challenging blend. Therein lies the ally of technology: helping balance these intensifying pressure points to safeguard both water and economic security.

But it is equally important to remember that investing in technologies to create greater water supplies can "give a false sense of abundance and, paradoxically, this can encourage unnecessary water use," a roundtable participant warned. Therefore, instilling new technologies alone will not work. Deep-rooted change must run in parallel with technological deployments. This includes reshaping society and industries' view of water consumption. Amid the current unknowns, one point is undeniably clear: the complexity of upgrading renewable desalination and water reuse is matched by its urgency.

> *"We survived millennia without electricity, but we can only survive seven days or so without water. We must take its protection more seriously."*

16,000

desalination plants operate in 177 countries, producing a volume of freshwater equivalent to almost half the average flow over the Niagara Falls.[1] Improving the environmental credentials of these – i.e., via renewably powered desalination – will be increasingly key in the 2020s.

2021

is the first time the Omani government started reducing water subsidies, supporting a much-needed rise in awareness. In the country's 2020 budget, subsidies for water and electricity totalled $1.95bn.[2]

72%

of all water withdrawals worldwide are used by agriculture, 16% by municipalities for households and services, and 12% by industries.[3] Therein lies the importance of holistic efforts to address the challenge.

2.3bn

people live in water-stressed countries, of which 733mn live in high and critically water-stressed nations.[4] Lessons learned in Oman can be exported to others in need, thus supporting the Sultanate's National Vision to become a knowledge-based economy and exporter.

3

liters a day of water can be saved by simply fixing a leaky tap.[5] Consider that all the taps in the Sultanate – an average of three per person – amount to 15mn taps saving 3 liters of water every day, which means up to 45mn liters of water could be saved every day in Oman alone. To put that into context, that is the equivalent to the water used to fill 18 Olympic-sized swimming pools[6] every day – and 6,570 pools over the year.[7]

225

liters of water can be saved in just 15 minutes when you use a watering can to water your garden instead of a hosepipe.[8]

90%

less water can be used by leveraging aquaponics versus traditional farming.[9]

95%

less water is used in vertical farming than in traditional farming practices.[10]

[1] United Nations (UN); [2] Bloomberg Intelligence; [3] UN-Water 2021; [4] UN-Water 2021; [5] Anglian Water; [6] Phinizy Center for Water Services; [7] Gulf Intelligence; [8] Anglian Water; [9] Farming Aquaponics; [10] EIT Food

TOP TAKEAWAYS

Knowledge is power

Oman must use technology to better account for its water: to understand where it is, how much there is, how it can best be used, who is using it, and so on. Only then can the Sultanate create measures to reuse wastewater and invest the right resources – finances, time, talent – into more renewable desalination technologies. Part of building transparency means leveraging the digital toolbox of the 4th Industrial Revolution (4IR), such as sensors, predictive analytics, big data, Internet of Things (IoT), and digital twins. Such aids can also be applied to modernizing agricultural navigation and better mapping groundwater reserves, for example.

Utilize the sun

Solar-powered desalination systems have the potential to sustainably create freshwater from seawater on an industrial scale with a carbon neutral offering[2] – arguably making it well-suited to Oman's 1,700km coastline.[3] For one, Oman has launched a pilot project at a farm in the Suwaiq wilayat in the North Al Batinah Governorate to desalinate seawater with the use of solar power in a project sponsored by the Korean Ministry of Environment, within the framework of the Korean-Omani cooperation.[4] Usually the reverse osmosis process utilizes a large amount of electricity, but this device can reduce the cost of electricity to be cost effective, producing 32 tons of fresh water per day (8 hours) using just 56 KWts of electricity. The system has the capacity to produce PV energy of 350KW in 8 hours, so the excess electricity can be used for other purposes – which also supports Oman's circularity principles.[5] Many more efforts of this like are needed across the Sultanate – home to strong sun and winds – as many desalination processes carry an environmental toll. In most desalination processes across the globe, every liter of potable water creates about 1.5 liters of liquid polluted with chlorine and copper. This wastewater is twice as saline as ocean water and if not properly diluted and dispersed, it may form a dense plume of toxic brine which can degrade coastal and marine ecosystems.[6] Consequently, Oman must not only make its desalination production processes more renewable, but its entire value chain.

"Public awareness is extremely important. Even just turning the tap off when brushing your teeth saves more than two full buckets of water per person every day.[12] That amounts to at least 10mn buckets of water saved every day in Oman, 70mn a week – and an astonishing 3.6bn buckets of water saved every year, just from a tiny change."

Spotlight on groundwater

Up to 75% of water use in Oman is from groundwater; water that is stored in and moves slowly through geologic formations of soil, sand, and rocks called aquifers.[7] With Oman's water shortage, attention is fast focusing on how best to understand and manage groundwater. This is easier said than done, for groundwater is largely "invisible"; tracking it is far harder than other water sources. One solution is working more closely with the oil and mining industry in Oman. Years of geological study and exploration means Oman's oil industry – which underpins the largest non-OPEC producer in the Middle East – has a strong understanding of the Sultanate's hydrogeology. Using this intel alongside other agencies, academia, and government can enable the right technologies to be used at the right points in the value chain. In turn, this will proactively reduce misalignment and cut waste.

Focus on growing sectors

Rethinking normal water use practices in all sectors is crucial, but especially those experiencing significant growth. For example, Oman reported 9.85% growth in its agricultural industry in 2020.[8] While positive news, it equally requires careful examination of water resources and waste. Agriculture is the largest consumer of the world's freshwater resources.[9] Consider that it typically takes between 3,000 and 5,000 liters of water to produce 1kg of rice and 2,000 liters for 1kg of soya, plus 500 liters for 1kg of potatoes.[10] Over the long-term, Oman's efforts to readdress this water-food balance "at home" can

support its goal to become a knowledge-exporter internationally. For one, irrigated areas in sub-Saharan Africa are expected to more than double by 2050. This will benefit millions of small-scale farmers, but 41% of current global irrigation water use occurs at the expense of environmental flow requirements.[12] Oman can help these nations and others find the right balance, which would also reaffirm its environmental know-how on the global map.

Start small, achieve big

Each member of Omani society must play a proactive role – from households, to farmers, to businesses, academia, government, and everyone in between. Even just turning the tap off when brushing your teeth saves more than two full buckets of water per person every day.[12] That amounts to at least 10mn buckets of water saved every day in Oman, 70mn a week, and an astonishing 3.6bn buckets of water saved every year – just from a tiny change. Having every aspect of society involved in the conversation will help the government pin down the areas of greatest need, be it in rural areas not wholly supported by desalinization or in more urban areas that are reporting the greatest population growth.

Areas to watch

Harvesting water directly from the air is an area roundtable participants described as "promising", as are more nature-based water management techniques. For example, the green technology of Constructed Wetlands often means few mechanical parts, limited maintenance, limited need for specialized staff, reduced GHG emissions, minimum energy consumption, and no harmful by-products, for example.[13] Oman must also further explore how technologies can help with the green principles of ecological engineering, technologies for urban and rural water management, sustainable urban drainage systems, and natural flood management. The same applies to investigating better ways to manage ecosystem restoration and environmental connectivity and wildlife corridors.[14] This all also encompasses the importance of broader environmental protection – as per the 21st century mantra of people, planet, and profit.

[1] World Bank; [2] Solar Water; [3] Canvas; [4] Utilities Middle East; [5] Zawya, Oman Observer; [6] United Nations; [7] Groundwater Foundation; [8] Oman Observer; [9] United Nations; [10] WWF; [11] Food and Agriculture Organization of the United Nations (FOA); [12] Anglian; [13] Research Gate, Closed Cycles and the Circular Society' Symposium 2020, Technical University of Crete; [14] Cranfield University

INSIGHTS

Circular Economy

Best approach for Oman to create a sustainable nexus?

- **Karl W Feilder, CEO, Founder & Chairman, Neutral Fuels**
- **Aditya Shah, Head of Circular Economy Investments, Creek Capital**
- **Peter Godfrey, Managing Director, Energy Institute**
- **Jessica Obeid, Non-Resident Scholar, Middle East Institute, and Senior Global Advisor, Azure Strategy**

"**We are still in Chapter One of this story," described one roundtable participant. Achieving this nexus is a complex, nuanced, and ambitious road – but it is also a non-negotiable one.** Oman currently faces significant challenges in its adaptation to and mitigation of climate change. It lies in a region that is among the most vulnerable to climate change and it faces water scarcity, rising food and energy demand – all important inputs into society that need careful and progressive management. For now, this mix is exerting increasing pressure on Oman's resources, ecosystems, and talent pool. Identifying approaches to reduce cross-sectoral strain of this water–food–energy nexus is a decades-long overhaul: Oman must pick up the pace now.

> *"We must rethink the way we have done things over the last hundred years. It's a big ask – but there's no choice."*

1992
saw the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal come into play, with the support of Oman from 1995.

9mn+
per year deaths occur worldwide due to air, water, and soil pollution – equivalent to nearly double the size of Oman's population.

100bn+
tons of resources enter the economy every year – everything from metals, minerals, and fossil fuels to organic materials, like plants and animals. Yet just 8.6% is recycled and used again.

54mn
tons of electronic waste (e-waste) are generated worldwide every year, with just 17.4% collected and recycled. Oman's high digital penetration rate (95%) means the Sultanate has the expertise to help be part of the solution.

1.5
Earths are needed in terms of resources by 2050 if we do not change how we live.

300mn
tons of plastic waste are generated worldwide every year, equivalent to the weight of the entire human population of 7.8bn people. Even taking a very relatively small step – such as reusing the thousands of plastic water bottles discarded in Oman every day – will improve the Sultanate's contribution to this figure.

45%
of global GHG emissions come from product use and manufacturing, as well as food production. Circular economy strategies can cut these by 39%, helping avert the dangerous impacts of climate change.

Sources: UN Basel Convention; World Resources Institute (WRI); Datareportal

TOP TAKEAWAYS

Localization works

"It doesn't make sense to move raw materials halfway around the world and then ship the finished product halfway around the world again," one roundtable participant stressed. Accordingly, Oman must focus more on localized solutions: local production, local talent, local off-takers. In part, this means moving away from the dominant centralized system, where there is one supplier of power, one supplier of fuel, one supplier of water, and so on. Deregulation of these key components will foster a more competitive environment – critical to instilling circularity principles. This model also empowers communities to take a proactive stance, as is seen in Singapore, roundtable participants pointed out. The state rezoned its urban areas to create a community-centric management system, with circularity at its core.

"We tend to look at the energy sector, the food sector, and the water sector as individual areas. This traditional approach will no longer work. Why? Because we must think holistically to achieve a circular economy."

Boost visibility

We can only track and mitigate what we know. Therefore, Oman must invest more resources – time, money, talent – into identifying the prime areas of circular potential across its society and businesses. Effectively pinning down and then tracking these points enables the Sultanate to craft roadmaps to instil tangible change in the next few years. Such efforts are paying off in Abu Dhabi, roundtable participants shared. Any restaurant and hotel in the Emirate that does not participate in efforts to recycle their cooking oil into biofuels is subject to fines or a suspension of their trade license. This system is driving positive change, but it has only been possible because Abu Dhabi invested in technological resources to track the waste.

"Waste" doesn't exist

What is commonly referred to as "waste" should be recategorized as "raw material" and it should certainly stop being exported overseas, as this means the Sultanate loses the in-country value (ICV) of redeveloping this product and creating much-needed jobs. Turning these waste items into resources requires an enabling regulatory framework. Some efforts are already underway, such as higher taxes on the export of cooking oil waste. The pressure to change is truly on, as described by Waste Dive:

"When trash is packed into a pile, the oxygen-free environment supports bacteria that thrive in those conditions. As the microbes degrade the waste, they release CO_2 and methane. The latter is 84 times more potent of a global warming agent than carbon dioxide in the first 20 years of its release."[1]

The right push-pull

Pinning down a balance of incentives and disincentives is key. For the former, this includes making it easy for investors to support recycling and reuse policies. For the latter, there should be costs associated to the disposal of non-necessary waste. For example, textile production (including cotton farming) uses almost 100bn cubic meters of water per year – approximately 4% of global freshwater withdrawal. At the same time, people worldwide throw away still-wearable clothes worth an estimated $460bn each year.[2] Being charged every time a textile item is unnecessarily discarded is one route to encourage society to rethink their consumption choices. The same mentality applies to kitchen cupboards and fridges. Nearly one-third of all food produced is wasted and that food waste continues to be the top product found in landfills.[3] Circularity principles offer a here-and-now solution to address this inefficiency, but implementing it requires a fair yet effective blend of incentives and disincentives.

Embrace hearts and minds

Inspiring Oman's large population of youth to learn, act, and innovate to support the water-food-energy nexus is an invaluable step in the 2020s. Crafting stronger ecosystems for training and job opportunities to help unleash more entrepreneurship is very important. It also helps youngsters in classrooms and the workplace to "see" a career in this field, which feeds ICV back into the Omani community. Already more than 78,000 youth in the 18-29 age group work in private sector companies, constituting 49.4% of the work force in Oman.[4]

[1] World Economic Forum (WEF), Waste Dive; [2] World Resources Institute (WRI); [3] United Nations (UN); [4] National Centre for Statistics and Information (NCSI), Muscat Daily

What is a circular economy?

We must transform every element of our take-make-waste system: how we manage resources, how we make and use products, and what we do with the materials afterwards. This is what will create a thriving circular economy, which can benefit everyone in Oman and beyond. A circular economy provides tools to tackle climate change and biodiversity loss together, while addressing important social needs. It also generates prosperity, jobs, and resilience while cutting GHG emissions, waste, and pollution. Other definitions incorporate carbon. For example, Saudi Aramco describes a circular carbon economy as a closed loop system for managing and reducing emissions, involving 4Rs: reduce, reuse, recycle, and remove.

Sources: Ellen MacArthur Foundation, Saudi Aramco

INSIGHTS

Collaboration

How to foster deeper collaboration between Oman's food-water-energy sectors to streamline nexus targets and spur innovation?

- **H.E. Dr. Saif Al-Haddabi, Undersecretary of the Ministry of Higher Education, Research and Innovation, Sultanate of Oman**
- **Prof. Saif Nasser Al-Bahry, Director, Oil and Gas Research Center, Sultan Qaboos University (SQU)**
- **Prof. Paul Stevens, Distinguished Fellow, Energy, Environment and Resources Programme, Chatham House**
- **David Rosenberg, CEO, Aerofarms**
- **Dr. Syham Bentouati, Managing Director, NAFAS International**

Two heads are better than one, as the adage goes. This point is amplified when merging companies' intellectual resources to strengthen this critical water-food-energy nexus. The multifaceted and nuanced nature of this challenge means "all hands are needed at the pump," as one roundtable participant described. But the effort will reap countless rewards for society, the planet, and businesses. While Oman's journey is still in its infancy, significant progress is being recorded.

Innovation Park Muscat, Oman's newest and most ambitious science and technology development, is one such example, with a focus on energy, water and environment, food and biotechnology, plus health.[1] Collecting cross-sector intel "under one roof" is invaluable to fluidly sharing knowledge and identifying solutions that support all sectors – i.e., holistic problem-solving. Ejaad is another valuable example of collaborative efforts that have made tangible progress in Oman. This membership-based virtual platform enables industry, academia, and government to interact and engage in energy-related research and innovation activities.[2] It works as an enabling marketplace to connect academic research and know-how to industry needs, and vice versa on focus areas: Energy, Oil & Gas, Renewable Energy, and Water. The Ministry of Higher Education, Research, and Innovation is also getting ready to set up a unified digital platform.[3] These are just some of the actions underway. Many others are being rolled out across the Sultanate, including research into using nanotechnology for desalination and building state-of-the-art housing to test renewable water methods and energy efficiency.[4]

> *"One of the great challenges in Oman is balancing government intervention against effective market operations."*

GI Special Report: Action Plan

$1.2bn
will be invested by the OFIC in strategically significant food-related projects up to 2027.[1]

164.3
points out of a maximum 300 on the Water-Energy-Food (WEF) Nexus Index in Oman are divided by: 42.7 points for Water, 63.2 points for Energy, and 58.4 points for Food.[2]

$700,000
cash reward was offered to the winner of the Oman Humanitarian Desalination Challenge, a global water prize seeking the delivery of a low-cost, stand-alone, hand-held desalination device. The device must be suitable for short-term use and rapid deployment during humanitarian crises.[3] Such calls for collaborative innovation will increase as the Sultanate works to inspire its population to "think out of the box" to support this critical nexus.

33%
of the food for global human consumption every year – approximately 1.3bn tons – is lost or wasted.[4] Far greater efforts are needed in Oman and beyond to dramatically reduce this percentage.

$12trn
bill every year in global health, economic, and environmental costs from the global food system. This equates to 20% more than the market value of the world's actual food systems.[5] Especially amid the economic strain caused by Covid-19, Oman must reduce its share of losses within this equation.

50%
of all carbon emissions released by human activity by 2050 will be generated by our food industry, unless more steps are taken to reduce its environmental impact.[6] As more companies set climate mitigation targets, uniting efforts to address this nexus will feed directly into CO_2 management as well.

[1] Oman Observer; [2] WEF Nexus Index; [3] Oman Humanitarian Desalination Challenge; [4] UNEP; [5] World Economic Forum (WEF); [6] Eat Forum

TOP TAKEAWAYS

Commit to deploy

A win-win factor must lie at the core of every collaborative effort, especially as companies face increasing environmental, economic, and social pressure. Robust commercial viability must be evident from the outset. Part of this is ensuring a commitment to deploy, for poor tangibility means a collaboration risks "being a nice project that doesn't make a difference," a roundtable participant warned. The same importance applies to scalability, as collaborative efforts cannot be limited to small or medium-sized scales. The gravity of the climate challenge means the vast majority of solutions must inevitably be ramped up without weakening the economic equation.

Clearer government goals

All three sectors – water, food, and energy – tend to have large external costs and influences and it is the "function of government to internalize those," a roundtable participant said. European governments' ability to do this is a large reason the continent has one of the world's fastest transitions towards a strong water-food-energy nexus and low carbon growth. Accordingly, the government in Oman needs clearer objectives. Equally, the complexity of this balancing act means such clarity cannot be achieved overnight. Some stakeholders in the food sector may want cheaper water so they can affordably grow more produce, yet getting more water at an affordable price also carries longer-term environment risk, i.e., the risk of contaminated water, unsustainable subsidies, and excessive use. By supporting one sector (food), another is jeopardized (water), which is why great care is needed. One route is to create a performance-based system that encourages sustainable methods, while providing an economic safety net – not necessarily subsidies, but competitively priced loans and grants – for those more vulnerable.

"Companies with huge operations – like Amazon – have nailed the efficiency factor. We must look at how other sectors operate and pin down commonalities. Then we can apply it to our nexus in Oman."

Learn from others

The US has adopted a "use it or lose it" water policy in parts of its agricultural sector, with any unused water removed from farmer's allocation the following year. Another water management tactic is using land size to determine the volume of water allocation,

"It's not just about solving problems – it's also about being a problem-solver. Technology is moving at warp speed and it's an excellent enabler that we must use far better."

roundtable participants said. Both strategies have improved water management processes so far, as did an endeavor in San Joaquin County in California, an established farmland community. Local operators there identified dead zones due to contaminated water and decided to tax those using certain fertilizers and pesticides, or excessively using them, another roundtable participated detailed. Again, the tax worked as the farming community became better stewards of fertilizers and pesticides, leading to cleaner water supplies.

Explore vertical farming

The value of the global vertical farming market is expected to reach $17.59bn by 2028 – a vast increase on the $3bn this year.[5] The anticipated growth is easily explained by the potential benefits. Every square meter of floor space of vertical farming produces approximately the same amount of vegetable crops as 50 square meters of conventionally worked farmland, which in some places also reduces deforestation and supports soil restoration. A vertical farm is able to use 95% less water (because it is recycled) and the indoor production means virtually no herbicides and pesticides are used. It also supports the continuity of food security because vertical farming enables year-round cultivation.[6] Oman's first foray into vertical farming is being considered by the OFIC, the government's food sector investment and development arm. A portfolio of new projects up to 2026 are expected to include the first ever commercial-scale project. In its pre-feasibility phrase, the initial project cost is estimated at OMR10mn ($26mn).[7] This is a good start, but the multitude of benefits of vertical farming means Oman must significantly scale up its efforts.

[1] Innovation Park Muscat; [2] Ejaad; [3] Muscat Daily; [4] Roundtable participant; [5] Fortune Business Insights; [6] Vertical Farming Institute; [7] Oman Observer

ACTION PLAN

How to find Sustainable & Holistic Solutions for Oman to Achieve Water-Food-Energy Security?

Top 10 Recommendations to Execute

These top recommendations have been extracted from the open discussions and opinions shared by all the high-level stakeholders involved in the event. They aim to give a holistic and cross-complementary overview of the next best steps to strengthen the water-food-energy nexus in Oman in 2022 and beyond.

	Champion	Support
1. Establish a unifying body Efforts to improve the water-food-energy nexus are mostly siloed. An overarching framework that is created, monitored, and updated by the collaborative spirit of representatives of all three sectors would bolster knowledge-sharing, strengthen risk mitigation, and boost innovation. As the adage goes: "Many heads are better than one." A unifying body would also make Oman's international offering more competitive and it would help the Sultanate attract more international business. Governmental participation is paramount.		
2. Identify clear objectives The complexity of the nexus' balancing act cannot be underestimated. For example, some stakeholders in the food sector want cheaper water to grow more produce at a more competitive rate. But greater, cheaper volumes of water can incur longer-term environmental risk, i.e., the risk of contaminated water, poor pipeline maintenance, unsustainable subsidies, and excessive use. In this scenario, supporting one sector (food) jeopardizes another (water). Clear objectives that do not clash between the sectors is essential – all must thrive in parallel.		
3. Establish joint strategies The Oman Investment Authority oversees most of the nation's agriculture and fishery products and the Ministry of Energy and Minerals oversees the oil and gas sector. Going forward, these bodies can work more closely together, perhaps under a unifying body (*see Recommendation One*) to develop joint policies that create a circular value chain.		
4. Invest in local circularity Water, food, and energy systems must be redesigned towards a circular system. This must also promote local solutions: local production, local talent, and local off-takers. In part, this means gradually transitioning away from the dominant centralized system, where there is one supplier of power, one supplier of fuel, one supplier of water, and so on. Deregulation will foster more competitive environments that can drive innovation and circularity – ultimately creating a healthier nexus.		
5. Elevate industries' role The combined experience of industry in Oman equates to thousands of years' worth of knowledge that can be pivotal in helping the Sultanate create a robust nexus. Among the many benefits, the energy industry can significantly aid hydrogeologists as they try to map groundwater. Plus, industries have digital expertise, as per the 4th Industrial Revolution, which can save each sector time and money over the long-term – both individually and collectively.		

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	Champion	Support
6. Track and map groundwater A greater understanding about the nation's groundwater reserves will help Oman accurately track, map, and plan its water management processes. With 90% of the Sultanate's water generated by desalination technologies, more resources must be allocated to preserving natural supplies.		
7. "Waste" is no more What is commonly referred to as waste should be recategorized as raw materials, as per circularity principles. It should not be exported and instead redeveloped within Oman to enhance the Sultanate's in-country value (ICV). This creates much-needed jobs, spurs innovation, and dramatically improves the country's environmental and social credentials.		
8. Build public buy-in Greater public awareness is key to gaining Omanis' support for strategies that will strengthen the nexus, such as removing subsidies. This is especially crucial for Oman's large youth population. Crafting stronger ecosystems for training and job opportunities will help unleash more entrepreneurship and enable youngsters in classrooms and the workplace to "see" a career in supporting the nexus, which also feeds ICV back into the community.		
9. Increase alliances' accountability Commercial viability must be evident from the outset of every collaborative effort – the win-win matters. Part of this means ensuring a commitment to deploy, for poor tangibility means a collaboration risks "being a nice project that doesn't make a difference to the nexus," as encapsulated by one energy stakeholder. The same importance applies to scalability, as collaborative efforts cannot be limited to small or medium-sized scales. The urgency of improving Oman's nexus means the vast majority of solutions will inevitably be ramped up – and must do so without weakening the people-planet-profit equation.		
10. Leverage sector crossovers Oman can explore more accessible yet highly effective methods to reinforce the nexus in the short-term. For example, lessons can be learned from the Sultanate's dairy business, which converts slurry into biogas to create energy. Stakeholders can also support the use of carbon capture and storage (CCS) in greenhouses to accelerate food growth or invest in vertical farming to dramatically increase food production while cutting water use by up to 90%.		

[1] United Nations

Consultancy
Intelligence
Publishing