Khalifa University Science and Tech Review

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COP28 EDITION

THE CARBON COPY

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Consumer habits, government policies push adoption rates for electric vehicles — **P32**

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Khalifa University Science and Tech Review

KUST Review is dedicated to publishing authoritative, reliable and accessible information about science, innovation and technology news and trends. Although we report on news from around the world, we highlight advances, innovators and topics of interest from the Middle East and North Africa region. Our mission is to spread knowledge of and enthusiasm for science and technology in the Arab world and beyond through responsible and trustworthy journalism.

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LETTER FROM
THE EDITOR

The science is clear:
Climate change is happening.

Global temperatures are at the highest recorded levels. This in turn is affecting weather patterns, bringing not only droughts and heatwaves, but producing storms that last longer and are more intense, driving not only immediate loss of human life and property damage but disease, forced displacements, famine and the extinction of other species.

As a result, many nations have drafted initiatives to lower the carbon production that is driving climate change. And the world is meeting now in Dubai for COP28 to take stock of its progress on the Paris Agreement, the international treaty on climate change.

The UAE was the first nation in the MENA region to draft a net-zero target, adopting a long-term strategy to reduce greenhouse gases and help limit the rise in global temperatures by 2050.

A key element of this strategy is deploying clean-energy solutions to replace carbon-producing fossil fuels. The UAE has invested more than U.S.$40 billion in the sector, with hundreds of millions more in aid and soft loans for clean energy projects.

In this issue of the KUST Review we look at this energy transition as the world seeks to move away from the fossil fuels that drive carbon emissions.

We investigate some of the details of this transition, as well as how to live more sustainably.

KUST Review Deputy Editor Steve Griffiths talks about making smart cities cyber-secure and -resilient.

Senior science writer Jade Sterling looks at the logistics of the energy transition as well as improvements in aviation fuel.

Editor Suzanne Condie Lambert writes about the hydrogen economy and an innovative way to make cement with a significantly reduced carbon footprint. And Maggie Kinsella dives into what to do with the carbon we capture.

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So page, click, subscribe and follow to get the best of our coverage of science in the Middle East and around the world in English and in Arabic.

As always, be informed and stay curious.

Dr. Arif Sultan Al Hammadi
KUST Review Editor-in-Chief

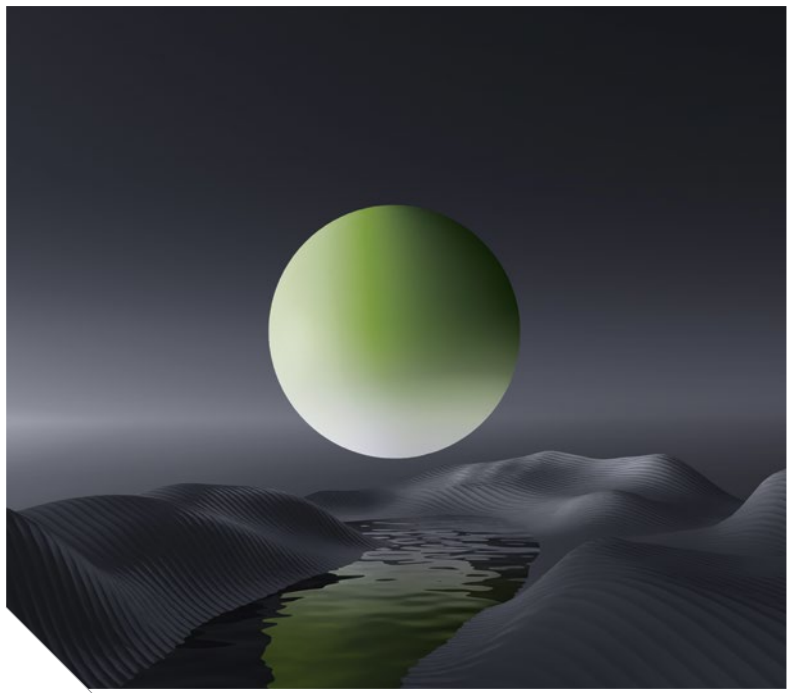
IN THIS ISSUE

COP28 EDITION

Moving from fossil fuels to renewable energy sources is a large part of ambitious global goals to reduce CO2 output and fight climate change.

In this issue of KUST Review we examine some of those renewable energy sources as well as technology likely to improve energy efficiency in such areas as logistics and transportation.

We also look at mitigating the plastic waste that pollutes the planet as well as what to do with the CO2 that's already in the environment. Read on to find these stories and more.



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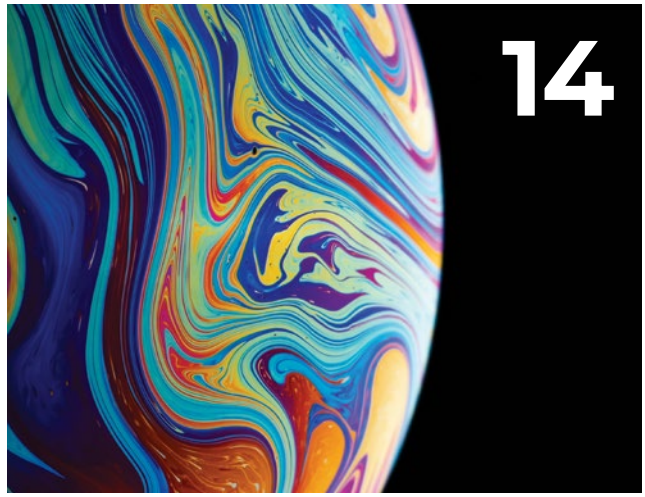
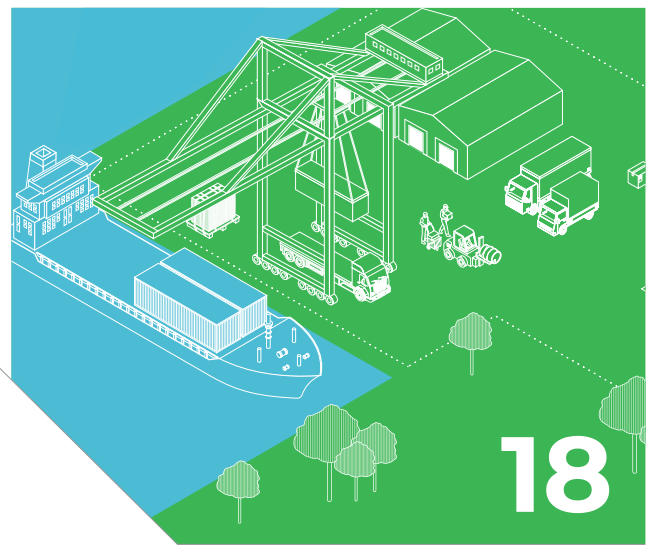
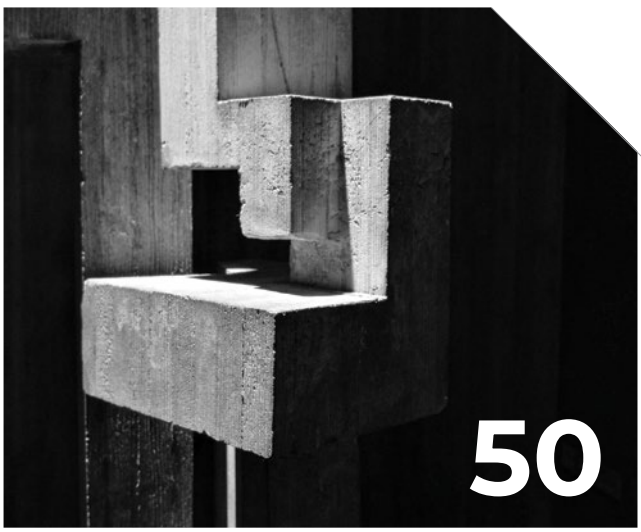
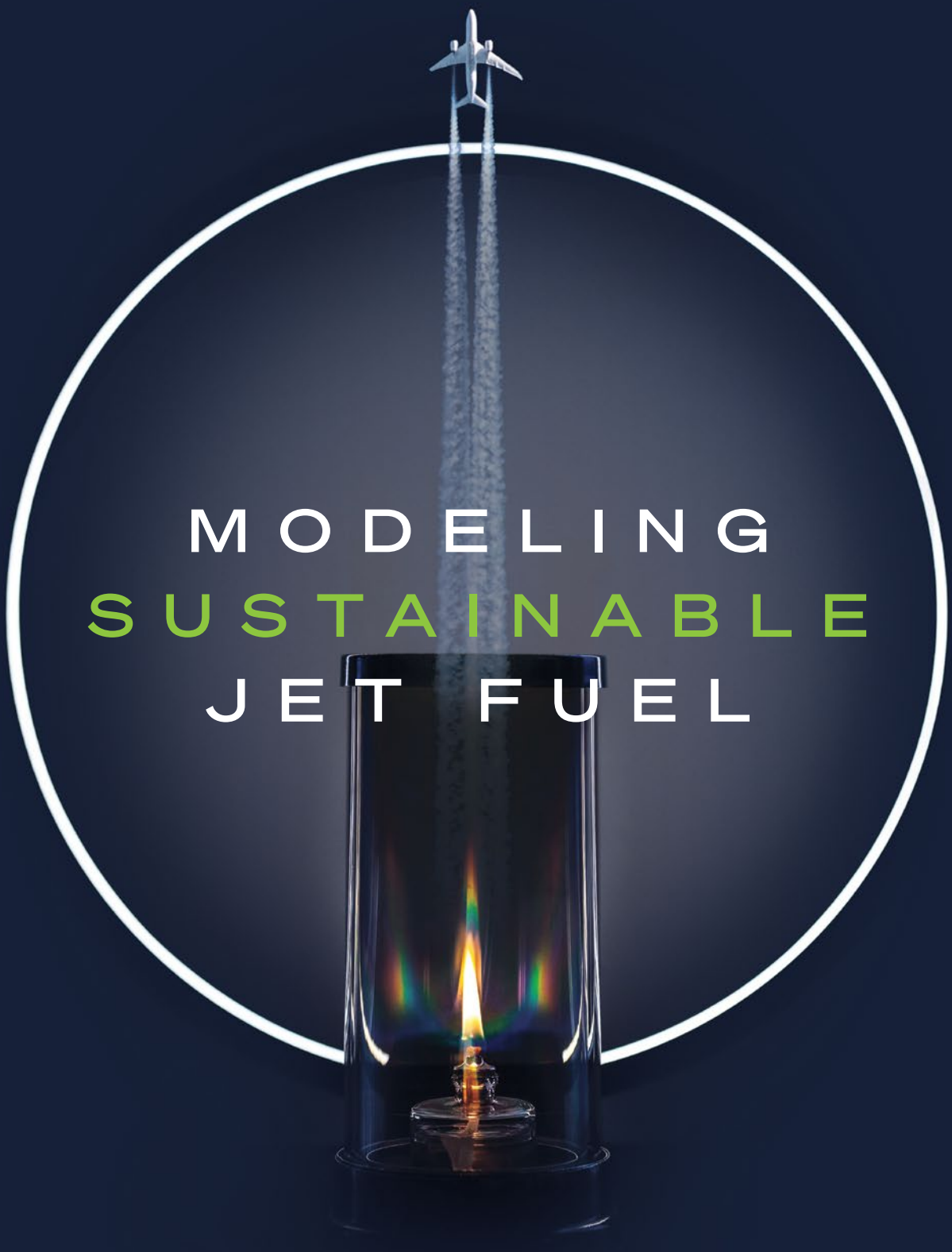








MODELING SUSTAINABLE JET FUEL

Researchers create tool to improve operating conditions and catalyst design

By: **Jade Sterling**

IN 2019, approximately 3 percent of global CO2 emissions were attributed to the aviation industry, excluding contributions from airport construction and operations. Improved aircraft designs and operational measures can help reduce those emissions, but sustainable aviation fuel is a must to meet net-zero targets.

Sustainable aviation-fuel production amounted to less than 0.1 percent of the roughly 300 million tons of jet fuel used by commercial airlines in 2019, however, leaving plenty of room to scale up. But developing sustainable aviation fuel can introduce side reactions that can significantly influence the final product's efficacy and quality. Modeling tools, therefore, are crucial to improved operating conditions and catalyst design.

A team including researchers from Khalifa University has developed a modeling approach to examine the conversion of carbon dioxide and hydrogen to methanol using a copper catalyst. They say their model offers a reliable tool for revealing the role of active sites that may control the performance of a CO2 hydrogenation catalyst.

Kaiser Ahmad, Maguy Abi Jaoude, Kyriaki Polychronopoulou, director of the Khalifa University Center for Catalysis and Separation, and Florent Ravaux of Abu Dhabi's Technology Innovation Institute developed the model and published their results in Fuel.

"Renewable methanol can play an important role as a feedstock in the production of lower-emission fuels with suitable power and gas-to-liquid targets for sustainable aviation," Abi Jaoude says. Producing green methanol from human-created CO2 and renewable hydrogen is an effective alternative to biomass conversion, she says, adding that "it can meet global decarbonization objectives without endangering food security."

The alcohol-to-jet pathway can convert ethanol, isobutanol or methanol into aviation fuel. In many cases, biomass from forestry residues and agriculture is used as feedstock, but processing biomass into jet fuel requires a lot of biomass. The hydrogenation of carbon dioxide would be a more sustainable process, but the mechanism behind the conversion remains a subject of debate.

Researchers have proposed two pathways for methanol production from carbon dioxide and hydrogen, and understanding how this process works will allow more effective and efficient catalysts to be developed.

"In chemical kinetics, key pathways that govern the reaction mechanism at a catalyst's surface are predicted based on its physicochemical properties," Abi Jaoude says. "Understanding the kinetics on a particular surface of a catalyst for a specific reaction can assist in designing a new and improved catalyst."

Determining the pathways and kinetic activities in the lab is time-consuming. Experimental evaluation is also expensive and tedious. Modeling approaches, however, can generate results much more quickly and easily.

The KU research team wanted to find the minimum energy pathway for methanol synthesis and derive its kinetic expression. They investigated a catalyst made from copper, zinc oxide and chromium oxide. Copper is a more effective catalyst in the presence of metal oxides, and the zinc and chromium oxides aid in increasing catalyst activity, enhancing its performance in the hydrogenation process.

300 Million Tons

OF JET FUEL USED BY COMMERCIAL AIRLINES IN 2019

Their model predicted the minimum energy pathway, and their simulations with experimental data confirmed the model's accuracy. Their outcomes were consistent with documented reports, confirming the validity of the proposed modeling method.

Developing a kinetic model for the most favorable pathway based on the activation energy and interactions of molecules on the catalyst surface can help researchers gain an in-depth understanding of the surface science and kinetic-parameter dependence on the catalyst, Abi Jaoude says.

"Our model can be used to study the kinetics of catalytic reactions targeting sustainable aviation fuels or their precursors at reduced cost and time."

PHOTOS: Unsplash

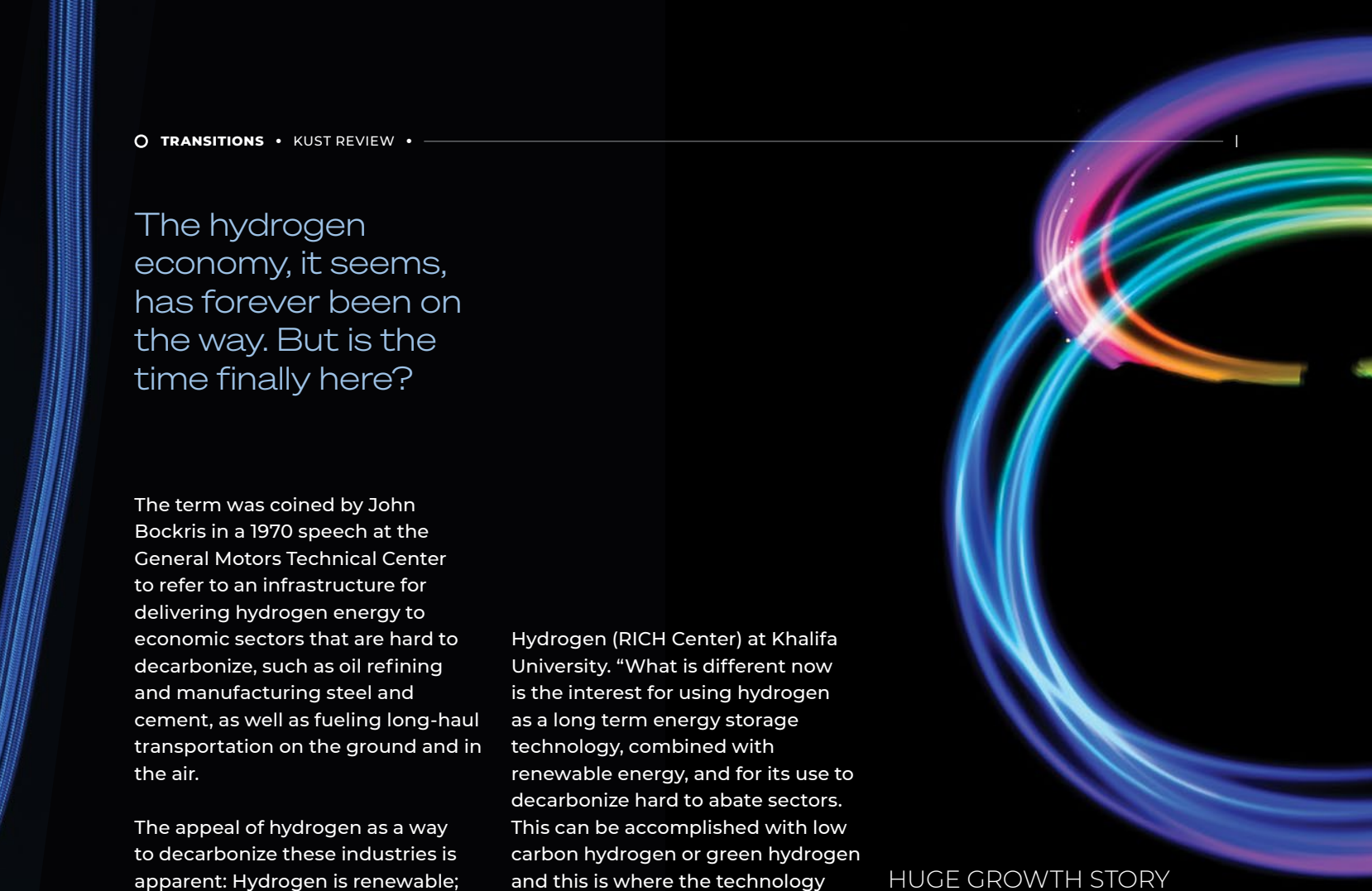
PHOTOS Unsplash, Freepik

GROWING A

HYDROGEN ECONOMY

By: **Suzanne Condie Lambert**

Renewable energy source looks great on paper, but when will we see it in action?



The hydrogen economy, it seems, has forever been on the way. But is the time finally here?

The term was coined by John Bockris in a 1970 speech at the General Motors Technical Center to refer to an infrastructure for delivering hydrogen energy to economic sectors that are hard to decarbonize, such as oil refining and manufacturing steel and cement, as well as fueling long-haul transportation on the ground and in the air.

The appeal of hydrogen as a way to decarbonize these industries is apparent: Hydrogen is renewable; it's easy on the power grid, produced and stored during times of excess of renewable energy and readily available during peak demand; it can reduce pollution (it only generates heat and water when burned); it can be produced locally from a range of materials; and by 2050 it could provide jobs for up to 30 million people with revenues of U.S.$2.5 trillion a year, according to a report from global management consultant McKinsey.

But not much has happened to move the technology toward its long-imagined place as a major player in the world's energy-transition process. That is, until the past five years or so.

"Hydrogen has been produced for a long time for its use in refineries and fertilizers, and technology has evolved to improve the efficiency of them," explains Lourdes Vega, director of the Research and Innovation Center on CO2 and Hydrogen (RICH Center) at Khalifa University. "What is different now is the interest for using hydrogen as a long term energy storage technology, combined with renewable energy, and for its use to decarbonize hard to abate sectors. This can be accomplished with low carbon hydrogen or green hydrogen and this is where the technology needs to be improved to reduce its cost."

As countries, businesses and organizations seek to reach the Paris Agreement target of 1.5 C global warming, attention has turned again to the hydrogen-economy model to solve the problems that so far keep the hydrogen economy at bay: finding a reliable way to balance affordability with low greenhouse-gas emissions into the atmosphere.

Hydrogen is an important factor in most strategies devised by at least 75 countries that are seeking to achieve net-zero carbon emissions by 2050, according to a paper from academics at the Polish Academy of Sciences.

Additionally, hydrogen has been identified by the International Renewable Energy Agency as one of six technological avenues to achieve net-zero by 2050.

HUGE GROWTH STORY

Among countries expressing an interest in hydrogen: A U.K. House of Commons committee issued a report in December 2022 on the future of hydrogen in the country. The report concluded that although hydrogen couldn't be considered a panacea to the U.K.'s energy issues, it would certainly play a major role in sectors of the economy, becoming a "huge growth story" over the next 30 years.

Areas identified as best suited for hydrogen include those that are hard to electrify, such as parts of the rail network or heavy transportation and uses that don't require extensive refueling networks, such as local bus services. The benefit to bus services, Vega says, is that vehicles can operate longer than those powered by electric batteries.

The sectors most likely to benefit from hydrogen (aside from such traditional areas as refineries,

chemicals and fertilizers) are metallurgy, cement and heavy transportation, Vega says. “In addition, hydrogen can be used in the heat and power sector, replacing natural gas, with a huge potential market.” Furthermore, green hydrogen can be used, combined with CO2, to produce synthetic fuels such as methane or methanol, usually called e-methane or e-methanol.

And the United States in 2021 announced that the first program in its Energy Earthshots Initiative, aiming to accelerate advances in clean-energy technology, would focus on hydrogen. The Hydrogen Shot’s goal is to reduce the price of hydrogen by 80 percent to U.S.$1 per kilogram in a decade.

That price, as with everything, is critical.

The cost in money — and carbon produced — depends on how that hydrogen is made. (See: “Colors of Hydrogen,” Page 14.) Greener forms are more expensive and therefore represent a small percentage of total hydrogen currently produced. In fact, most hydrogen produced today is made using fossil fuels (methane) and with no CO2 emissions controls; this “gray hydrogen” accounts for 2 percent of the world’s CO2 emissions. And the International Energy Agency predicts fossil fuels will remain the primary source of hydrogen for the United States, Europe and Japan through 2050.

Vega, however, has a more optimistic view, seeing sectors transition from gray to more blue and blue and green as technologies advance and costs come down.

UAE HAS PLANS

Fossil fuels are key to the UAE’s plans, announced in January 2022, to control 25 percent of the world’s hydrogen market using natural gas with CO2 capture (blue hydrogen) and green hydrogen. The nation’s Hydrogen Leadership Initiative pursues a research-and-development collaboration across industries, according to the Emirates News Agency, the UAE’s official news service.

Targeted markets include Japan, South Korea, Germany and India. Emirates Global Aluminium, one of the largest companies in the UAE, joined the initiative in September 2022.

“The UAE sees hydrogen as a promising fuel for the future to achieve carbon neutrality and the UAE Net Zero by 2050 Strategic Initiative. Such partnerships will help accelerate the transition to clean and renewable energy," UAE Minister of Energy and Infrastructure HE Suhail bin Mohammed Al Mazrouei says. By 2031, according to the Ministry of Energy & Infrastructure’s UAE Energy Strategy 2050, updated in July 2023, the country plans to:

Develop a resilient hydrogen supply chain to support the growth of the local industry;

Consolidate the UAE’s role as a leading global producer and supplier of low-carbon hydrogen;

Promote innovation in industrial zones in the UAE and;

Establish a robust hydrogen economy that can support the country’s nationwide decarbonization efforts.

Meanwhile, UAE Undersecretary for Energy and Petroleum Affairs H.E. Sharif Al Olama tells Reuters that the country plans to produce 1.4 million tons of hydrogen annually by 2031.

Of that number, UAE clean energy company Masdar is expected to produce 1 million tons of green hydrogen by 2031. The remaining 0.4 million tons will be blue hydrogen, produced using natural gas accompanied by CO2 capture and storage. »»

Al Olama tells the news agency that the 2031 goals include two "hydrogen oases" or production hubs, located in Ruwais and the Khalifa Industrial Zone Abu Dhabi (KIZAD). There will be five hubs by 2050, he says. This follows the Paris Mission Innovation on Clean Hydrogen's suggestions to promote hydrogen valleys.

The UAE's plans for at least a partial fossil-fuels-based hydrogen future seem to align with the low-carbon hydrogen developments that Daryl Wilson, executive director of Belgium-based advisory board the Hydrogen Council, says he expects to see across the globe.

"By low-carbon (hydrogen), we mean fossil-fuel-derived hydrogen with carbon capture and storage. Low-carbon hydrogen will be faster, cheaper and quicker to scale than renewable sources in regions such as North Africa," says Wilson, whose group is made up of 132 energy, transport, industry and investment companies with an interest in building the hydrogen economy.

BUILDING AN INFRASTRUCTURE

Infrastructure for the hydrogen economy, however, is still in its early stages, Wilson says, adding that disruptions in energy markets brought by Russia's invasion of Ukraine have accelerated regional connection from North Africa to Europe.

"Already pipeline corridors have been proposed with an EU backbone, and routes through the Iberian Peninsula and north through Italy.

"Port terminal infrastructure is under development as we contemplate moving large quantities of hydrogen and its derivatives from sources in Australia to Japan and Korea," he tells *KUST Review.*

Vega, however, sees the changes coming more as a result of accelerating consciousness about the need for independent energy sources that can be produced using local resources in a sustainable manner.

But while materials may be new, the infrastructure will be similar to what the energy industry has used in the past. And that's good news, says the Hydrogen Council's Wilson.

"Ammonia, e-kerosene and methanol will make a contribution as carriers with seaborne trade. From a technical point of view, there are many points of commonality with natural-gas-pipeline development, (liquefied natural gas) cryogenic transport and bulk carrier development for the sea," Wilson says. "The scale in hydrogen is new ground, but the underlying engineering is not new to industry."

Well, yes and no, says KU's Vega.

"Hydrogen and natural gas are both known to industry, but they are not exactly the same, neither the technologies and infrastructure to produce, transportation and storage," she says.

Governments, however, play a critical role in developing the hydrogen future, Wilson says, "funding the green premium during the transition, providing a clear stable policy regime to support long-term investment decisions, and developing the tradable standards platforms."

Development goes even beyond individual countries, Vega adds. "The policies should apply on a more global level to truly develop and implement the hydrogen economy. Clear policies will help investors and hence, industry to move."

And when that hydrogen future finally arrives, it might not be visible to members of the public, who may ride on hydrogen-fueled buses oblivious to the infrastructure that supports them.

But "they will experience the benefit of long-term stable cost and security of supply from local renewable energy sources – a very different feeling than the vulnerable uncertainty of our current sources of fossil-fuel energy," Wilson says.

HYDROGEN PRODUCTION HUBS ARE KEY

Establishing hydrogen oases, also called hubs, clusters or valleys, is perhaps the most essential aspect of the UAE hydrogen strategy, says Steve Griffiths, senior vice president of Research and Development at Khalifa University.

But balancing supply and demand through production clusters is the most significant challenge in scaling hydrogen, Griffiths says.

"Clusters allow for clean hydrogen production to be matched with industrial hydrogen off-takers with minimal need for hydrogen storage and transport, both of which can substantially increase the cost of hydrogen for final use," he says. "Technologies that are proven, or nearly proven, can be deployed into clusters immediately while research and development efforts continue to improve technologies across the hydrogen value chain."

Griffiths says he expects the top industries using clean hydrogen through 2030 will be refining, chemicals, iron and steel and, in the UAE, aluminum.

"Beyond 2030, continued research and development will enable hydrogen to be commercially viable for extended applications, particularly sustainable aviation fuels and maritime shipping fuels," Griffiths says.

Research and development activities at Khalifa University may also support the overseas export of hydrogen by ammonia and other, more novel, vectors, he says.

"We established the Research and Innovation Center on CO2 and Hydrogen at Khalifa University to make such future innovations possible. That is, we pursue the cutting edge of hydrogen research while supporting development and implementation projects with partners like ADNOC and Emirates Steel Arkan," Griffiths says.

PHOTO Unsplash

UNITED COLORS OF HYDROGEN

Hydrogen is an invisible gas, yes. But different forms are given color codenames to help distinguish among them, essentially based on the molecule used to produce hydrogen and the source of energy.

There is no universal agreement on what the colors mean, so definitions may change over time or between countries. Here's our guide to the generally understood hydrogen rainbow:

By: **Suzanne Condie Lambert**

GRAY

The most common form of hydrogen production – roughly 95 percent – is produced today from the main component of natural gas (methane) through a steam reforming process. In this case, natural gas reacts with steam at high temperatures and pressures producing hydrogen gas and carbon dioxide (CO2). CO2 is released into the air, accounting for 2 percent of the world's CO2 emissions.

BLUE

Blue hydrogen is produced by the same steam reforming process as the gray hydrogen. In this case, carbon capture and storage (CSS) is added in its production to avoid the CO2 emissions.

WHITE

This form of hydrogen, not very common, occurs naturally in geological deposits, generated by the interaction of water with some metals of the rocks at high temperatures and pressures. It can be released by a process named fracking. The same name is given to the hydrogen produced as a byproduct in industrial processes.

YELLOW

Yellow hydrogen is a new term to define hydrogen produced from the electrolysis of water using solely solar power as the energy source. It is a particular case of green hydrogen.

GREEN

Made with surplus energy from renewable energy sources such as solar and wind power to split water, green hydrogen produces no harmful greenhouse-gas emissions, just hydrogen and oxygen.

PINK, PURPLE OR RED

These colors denote hydrogen that is produced using nuclear power as the energy source to break the water molecule into hydrogen and oxygen.

TURQUOISE

The newest color is produced by a process called methane pyrolysis, which creates hydrogen and solid carbon. It is still experimental. If the process is powered by renewable energy and the carbon is used or permanently stored, turquoise is potentially a valuable low- or zero-emission hydrogen.

BLACK & BROWN

These are the most environmentally damaging forms of hydrogen because they're created using bituminous coal ("black") or lignite ("brown"). Gasification byproducts CO2 and carbon monoxide are released into the atmosphere.

PHOTOS: Unsplash

NUCLEAR ENERGY IS DEAD!

exaggerated

By: **Suzanne Condie Lambert**

As nations battle rising energy costs and world temperatures, nuclear looks to remain an important part of the clean-energy mix, even in countries that had previously stopped investing in the technology.

Japan, for example, turned against nuclear after the 2011 Fukushima disaster, when a tsunami and earthquake struck, leading to power loss and the failure of cooling systems in three reactors. But the country in 2022 announced that it would restart old plants. extend the life of plants past the 60-year limit and build next-generation reactors. Other countries are also reinvesting. Many U.S. states with the most vigorous climate goals are putting millions of dollars into nuclear power.

“We are moving expeditiously toward a clean energy mix, but that is going to take a while,” Joe Fiordaliso, president of the New Jersey Board of Public Utilities, says in an article for Pewtrusts.org. “We can't build renewables fast enough, and people still need energy. Nukes are an important interim part of the mix.”

The U.S.’ first new reactor in 40 years came on line in Georgia in 2023. Sweden’s parliament in June green-lit plans to build new nuclear reactors. The country plans to build 10 in the next 20 years as part of a target to reach net-zero emissions by 2045. The country 40 years ago voted to phase out nuclear power.

"This creates the conditions for nuclear power," Finance Minister Elisabeth Svantesson said in parliament per Reuters. "We need more electricity production, we need clean electricity and we need a stable energy system."

As of May 2022, there were 439 nuclear plants operating in about 30 countries. The United States had the most, with 92. One of the newest of the world’s plants, however, is the UAE’s Barakah facility, which opened in 2020 and began operating commercially in 2021. Three reactors at the plant are in operation with the fourth expected to go online in 2024.

“Nuclear is really important in the energy portfolio. For the UAE to embark on the nuclear program is important for the country’s energy security mix as well as to reduce carbon emissions,” says Saeed Al Ameri, a professor in Khalifa University’s Department of Mechanical and Nuclear Engineering.

Mohamed Ibrahim Al Hammadi, chair elect of the World Nuclear Association board of directors, was also keen on the technology’s future in the UAE when he spoke in 2022 at

> Reactors online today can expect to operate for 60-80 years
>
> – Henry Preston

the opening of the Barakah plant's third reactor. "The Barakah plant is spearheading the decarbonisation of the power sector, sustainably generating abundant electricity to meet growing demand and power growth," he said.

Other countries in the MENA region, including Saudi Arabia and Egypt, are also investing in nuclear, KU's Al Ameri adds. Egypt began construction on its El Dabaa site on the Mediterranean coast in 2022.

Meanwhile in France, President Emmanuel Macron in 2022 announced six new reactors to come online by 2050.

That year is important, says Henry Preston of the World Nuclear Association.

"Demand for electricity is set to increase at least 50 percent by 2050, with the global population, electrification and access to electricity all projected to increase," he tells KUST Review. "It is therefore crucial to use cost-effective and proven solutions to provide secure access to 24/7 low-carbon electricity to support socioeconomic development for everyone."

Low-carbon backbone

The International Energy Agency, an intergovernmental organization based in Paris, in a 2019 report called nuclear, along with hydropower, "the backbone of low-carbon energy generation," providing 75 percent of global low-carbon energy generation.

This has reduced CO_2 emissions by more than 70 gigatons over 50 years, Preston says. To put that into perspective, a single gigaton is equivalent to about twice the mass of all humans on Earth. Seventy gigatons also equals nearly two years of global energy-related emissions, Preston says.

And as the U.S. Office of Nuclear Energy points out, reactors have small physical footprints, needing little more than a square mile to operate. The Nuclear Energy Institute says a wind farm producing about the same amount of electricity needs 360 times more land area. Solar farms are more compact, but still need about 75 times more space to produce the same amount of electricity.

Land use is one of the issues addressed in Simon Friederich and Maarten Boudry's 2022 paper in Philosophy & Technology on the ethics of nuclear energy in times of climate change. They conclude that even considering such issues as waste disposal and diminishing uranium reserves, "From the point of view of climate-change mitigation, investments in nuclear energy as part of a broader energy portfolio will be ethically required to minimize the risks of decarbonization failure."

Looking ahead

The 2019 International Energy Agency report foresaw risks of steep declines in nuclear's use in advanced economies. And there are drawbacks to the technology, to be sure: It's expensive to build and slow to roll out. The power it produces is also expensive, rising 40 percent per kilowatt since 2011 while solar's price is falling. And what to do with the waste remains an issue. But the World Nuclear Association's Preston remains enthusiastic.

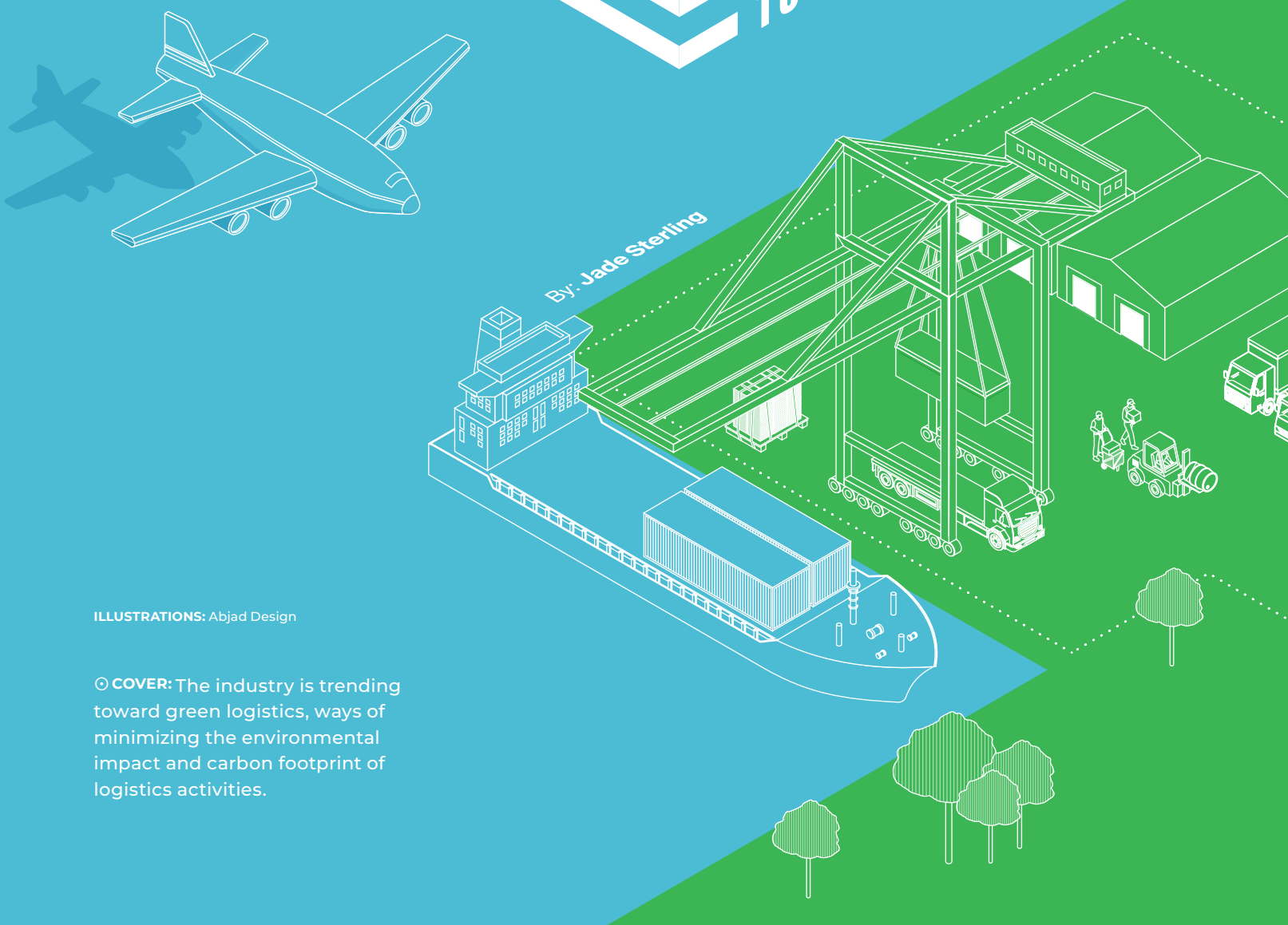
"Reactors online today can expect to operate for 60-80 years, so I think there is also a growing appreciation that nuclear power plant construction and operation generates thousands of long-term, high-quality jobs, along with substantial socioeconomic benefits into the local, regional and national economies," Preston says.

KU's Al Ameri is similarly enthusiastic. "In terms of the technology itself, we know that nuclear is clean. Operation cost is not expensive. And it continuously supplies energy to the grid." ●

PHOTOS: Unsplash

DELIVERING A GREENER FUTURE

CLIMATE GOALS DRIVE THE LOGISTICS INDUSTRY TO FIND MORE RESPONSIBLE WAYS TO GET PRODUCTS FROM POINT A TO POINT B



By: Jade Sterling

ILLUSTRATIONS: Abjad Design

COVER: The industry is trending toward green logistics, ways of minimizing the environmental impact and carbon footprint of logistics activities.

The buzzword for the logistics industry? Green. The industry is trending toward green logistics, ways of minimizing the environmental impact and carbon footprint of logistics activities. With 37 percent of global greenhouse gas emissions coming from the transport and logistics industry, transport is the easiest place to start.

"With respect to the environment, transportation is the most visible aspect of supply chains," says Jacqueline Bloemhof, professor of operations research and logistics at Wageningen University, the Netherlands. "One of the main choices in transport is the mode of transportation — plane, ship, truck, rail, barge or pipelines — and each mode has different characteristics in terms of costs, transit time, accessibility and environmental performance."

Niklas Simm, Ph.D. candidate at Linköping University, Sweden, says for years, logistics professionals have not prioritized environmental concerns, despite academia's steady increase in research interest: "The basic premise of logistics has been to manage and organize flows of goods in a resource-efficient manner. However, with the development of the U.N.'s global goals for sustainable development and emerging environmental interest, logistics operators have acknowledged an increased public interest in environmental questions, changing the perception of logistics and adding a new dimension. Supply chain organizations have begun to take responsibility for their logistics practices and have seen the need to consider the environmental effects of their practices."

While there's more to greenifying the industry than just the physical transportation of goods — think green packaging materials, space-saving packing, reducing returns and failed deliveries, improving warehouse layouts — transport is a major concern to companies looking to reduce their carbon footprint. Logistics giant DHL, for example, developed a "Green Logistics Toolkit."

"In today's globalized and interconnected society, modern consumers demand goods that are both affordable and readily available at a moment's notice," Mohamed bin Thamer Al Kaabi, Bahrain's minister of transportation and telecommunications, told the World Economic Forum. "This depends on reliable and resilient supply chains. But supply chains are only as good as their weakest link — and, as the past few years have shown, that weak link often ends up being transportation." »»

KEEP ON TRUCKING

According to CITEPA, a France-based organization that collects, analyzes and disseminates information about climate change, light duty trucks account for 20 percent of greenhouse gas emissions from transport, and heavy duty trucks account for 22 percent.

In a product's journey from warehouse to consumer, the final step is known as the "last mile of delivery." Last-mile delivery is the most expensive and time-consuming part of the process and covers the product's actual delivery to the recipient. This is a hotbed of inefficiency because a shipment's final leg typically involves multiple stops with low drop sizes.

Emrah Demir, professor of operational research at Cardiff University, says the last mile is an increasingly powerful force reshaping supply networks around the world: "Customers wish to have on-time delivery of the products, which might be a very difficult task for the logistic service providers because of various operational challenges and uncertainties."

Because warehouses have moved farther from city centers, the distance traveled to deliver goods has significantly increased. Additionally, most deliveries are home deliveries, increasing the number of stops for a delivery service. Changing to a pick-up point service encourages customers to use clean mobility solutions, such as walking, public transport or cycling, especially in urban areas. But most importantly, perhaps, is the increase in order frequency. Online shopping has intensified, particularly thanks to the global COVID-19 pandemic changing consumer behaviors.

"In 2022, retail e-commerce sales were estimated to exceed 5.7 trillion U.S. dollars worldwide," Demir tells *KUST Review*. "This figure is expected to reach new heights in the coming years."

DHL's Green Logistics Toolkit recommends route optimization to reduce time and distance to destinations, lowering fuel consumption and reducing both emissions and costs. It also suggests training delivery drivers in eco-driving – driving behaviors that reduce emissions and fuel consumption – and using green fuels or electric vehicles.

The path to decarbonizing road freight transport seems straightforward: electrify. Dependence on fossil fuels remains one of the greatest challenges facing logistics, especially because effective, economically viable solutions have yet to be found.

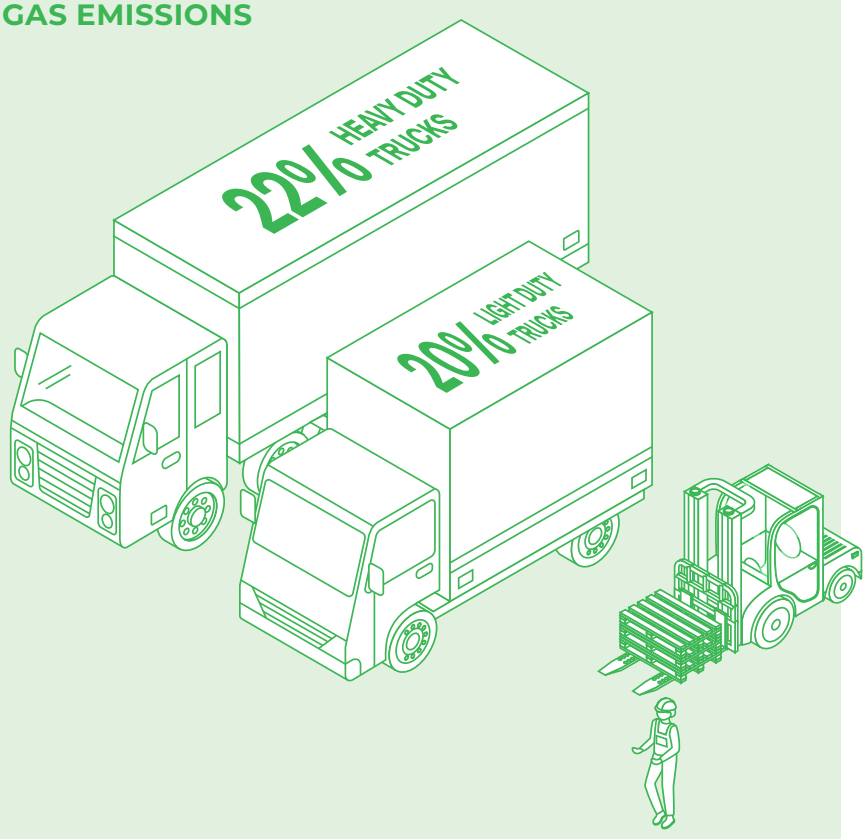
Many businesses, however, are shifting to EV fleets, which offer lower operating costs and less downtime. EVs offer another advantage too: They can be easily integrated into a greater cloud-connected supply chain network allowing AI-powered technologies to streamline operations.

Demir thinks EVs are the only option for delivery vehicles.

"For last-mile urban transportation, the future is EVs, but the technology is not there yet for heavy goods vehicles," Demir tells *KUST Review*. "Phasing out fossil fuel road freight vehicles is an essential step to reducing emissions and combatting climate change."

He points to the U.K.'s plans to ban sales of new diesel and petrol vans by 2030; require all new vans to be fully zero emission at the tailpipe from 2035; and ban the sale of

CONTRIBUTORS TO TRANSPORT GREENHOUSE GAS EMISSIONS



all non-zero emission heavy duty vehicles by 2040 and lighter HDVs from 2035.

“Phasing out fossil fuel road freight vehicles will not only reduce emissions but also improve air quality and create new jobs in the green energy sector,” Demir says.

Limited electric recharging and hydrogen refilling stations in urban areas are an important drawback, however. Currently, light duty electric vans can travel around 250 kilometers before they need to be recharged. As technology develops and more electric vehicles are used, charging speeds will be reduced and more recharging hubs will become available in the network, but in the early days of the transition, recharging stations are a hard find.

“(EVs) are environmentally friendly since their engines have almost no emissions and emissions in electric power stations can be controlled,” Bloemhof says. “With their limited range, they are better suited to city transport, and to compensate for the short range, a dense power re-supply network could be set up, possibly in conjunction with a swap of batteries.”

Intelligent fleet management can also be put to better use here. Algorithms can prioritize dispatch of an eco-friendly fleet, encouraging consumers to choose eco-friendly delivery methods to get their items sooner.

Alix Vargas spent 2020 working with Connected Places Catapult, an innovation accelerator in the U.K. There, she focused on sustainable collaborative logistics using planning algorithms to better manage freight logistics between companies: “Optimized truck journeys through collaboration will lead to a reduced total distance traveled and reduced number of trucks on the road with a consequent reduction in environmental and social costs.”

> **(EVs) are environmentally friendly since their engines have almost no emissions and emissions in electric power stations can be controlled.**
> - Jacqueline Bloemhof

These algorithms and their associated platform can help potential collaborators trust each other, share data and build a new business model based on collaborative networks.

"Collaboration would reduce the number of heavy goods vehicles on the motorways, decrease emissions, reduce empty running, and identify routes and journeys where operators can consolidate their loads into single-vehicle trips,” Vargas explains.

Kardinal is a delivery-optimization platform for the logisticians. It recommends decreasing the number of vehicles used and the number of kilometers traveled. This can be achieved by optimizing routes and loading trucks to full capacity.

Kardinal also highlights the role companies need to play in raising awareness of a delivery’s environmental cost. A survey by the French Senate in May 2021 found that 93 percent of respondents felt insufficiently informed about the environmental impact of the delivery of their online purchases, and more than 85 percent thought it would have an impact on their choice of delivery method.

Cardiff University’s Demir thinks there’s more to it than simply optimizing the route:

“The traditional approach in route optimization was to reduce traveling distance, but all research in green logistics shows there are many other factors affecting fuel consumption,” Demir tells *KUST Review.* “Vehicle speed, congestion, road gradient, payload and driver behavior are all factors affecting fuel consumption alongside traveling distance. My own Ph.D. in 2012 looked at these factors, and only now have more and more software packages started looking at these factors together.”

According to an IBM Research Insights report, 57 percent of consumers are willing to change their ecommerce purchasing habits to reduce their environmental impact. Another study by UNiDAYS, a discount website for students in the United Kingdom, found 80 percent of Gen Z students would consider paying more for sustainably delivered products. »»

SHIPPING INDUSTRY EMISSIONS

With the rise of the gig economy, crowdsourcing platforms are stepping up to ease last mile delivery difficulties in cities. Local, non-professional couriers who use their own transportation can make deliveries. And with the ongoing integration and enhancement of automation across industries, delivery robots and drones are quickly becoming a reality.

“Using drones and delivery robots as assistants in parcel delivery is a new service option, as seen in Amazon, UPS, Walmart, Alibaba, etc.,” Demir says.

“With their joint work as assistants, the delivery services can be carried out more efficiently and environment friendly. When an adequate number of assistants is deployed, the cooperated delivery system would reduce the required energy consumption and the amount of CO_2 emissions generated.”

> **Now, biofuels based on corn or on organic waste can easily be mixed with standard gasoline.**
> - Jacqueline Bloemhof

Until then, Bloemhof says, an important aspect in green transportation is the choice of fuel. “Modern gasoline is cleaner compared to old gasoline as we focused on removing lead additives. Now, biofuels based on corn or on organic waste can easily be mixed with standard gasoline, but more extensive use requires adapting engines, which is quite expensive.”

Demir is happy to see autonomous vehicles introduced in the transport sector. It’s a major step forward, he says:

“Autonomous vehicles reduce emissions and air pollutants, protecting the environment and improving people’s lives For example, truck platooning technology can be used to control

the position of all vehicles in the platoon, permitting the group to operate extremely closely, reducing wind resistance and decreasing fuel consumption. The future of transportation will be seamless mobility where all modes and (semi-) autonomous vehicles are fully connected and integrated into a single network of information exchange.

"In an ongoing research study, the Giro Zero project assessed the viability of adopting alternative technologies, such as low carbon vehicle technologies like electric vehicles, and hydrogen, and dynamic planning tools that enhance the planning and execution of trips run by trucking companies in Colombia. Similar country-specific studies can shed a light on the transition to cleaner technologies by using real-life transport data and considering the requirements of the country."

ADVANCES AT SEA

Today's globalized and interconnected supply chains mean that some 80-90 percent of the world's goods are transported by sea. Each year, container ships ferrying these goods emit upward of 1 billion metric tons of carbon dioxide, accounting for 3 percent of all greenhouse gas emissions.

The European Commission projects these emissions to increase if measures aren't taken. The commission has made several legislative proposals as part of its Fit for 55 package, which aims to reduce net greenhouse gas emissions by at least 55 percent by 2030. One such proposal is to support demand for marine renewable and low-carbon fuels and boost alternative fuel infrastructures.

Danish shipping company Maersk has started to pivot toward carbon-neutral methanol-powered ships to offset the 33 million tons of carbon dioxide it emitted in 2020. Fully electric tanker ships and even the world's first autonomous electric cargo carrier are also helping to wean the industry off fossil fuels. Norwegian chemical company Yara launched the fully electric, fully autonomous cargo ship in 2021 to demo the journey between two cities on the Norwegian coast.

The International Council on Clean Transportation says hydrogen could fuel 43 percent of voyages between the United States and China without any changes to fuel capacity or operations and 99 percent of voyages with minor changes.

For the shipping industry, it's not just what fuel it uses, but what fuel it delivers too. »»

Changes to the oil and gas industry as the world shifts from fossil fuels will directly impact the shipping sector too: Thirty-six percent of current trade is transporting energy goods, primarily oil, coal and gas. The shipping freight industry's biggest problem right now? Declines in shipments of oil and gas outweigh growth of transport of new fuels. Different forms of energy would not be difficult for freight companies to deliver, given existing infrastructure and familiarity with the cargo. While no shipping vessels have been tested with hydrogen, retrofitting existing ships with hydrogen fuel cells should be relatively easy.

And, if we can figure out hydrogen transportation, bioenergy and hydrogen shipments have the potential to be as high as coal and gas shipments, but such increases still do not offset an overall decline in energy products transported by sea.

UP IN THE AIR

According to the Air Transport Action Group, air transport as a whole represents 2.1 percent of global carbon emissions. Air freight produces around 10 times more CO2 than transportation by ship. Jet fuels created from waste products and other sustainable feedstocks have the potential to reduce these emissions by 80 percent. These are known as sustainable aviation fuels (SAF), and their development could be the key to sustainable air travel.

The International Air Transport Association says more than 450,000 flights have taken to the skies using SAF and more than 50 airlines have experience with the product.

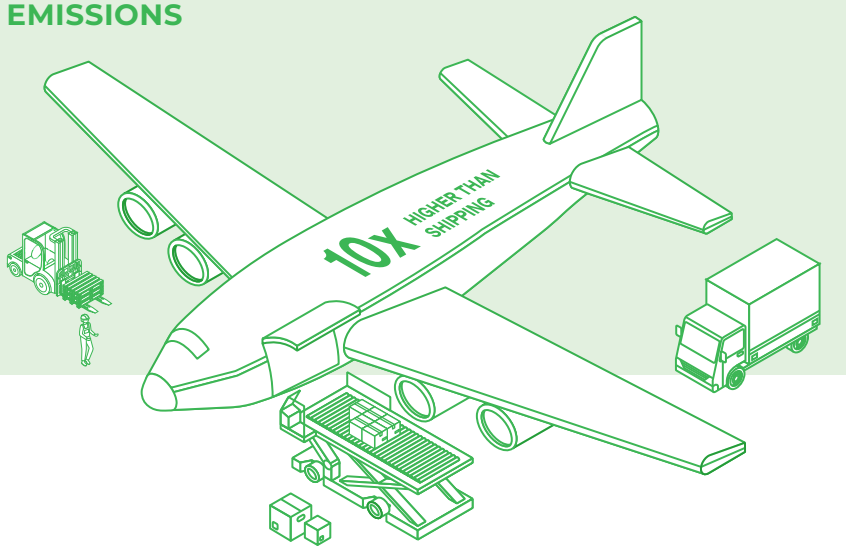
SAFs can be mixed with traditional liquid aviation fuel but they're also known as drop-in fuels — they can replace traditional fuels without any changes to the engines or systems of modern aircraft. However, SAFs are more expensive, which limits their uptake. Lufthansa Cargo and Air France KLM Martinair have adopted SAF programs for their air cargo activities but scaling up their use to a global market requires substantial investment.

Battery-powered aircraft are also an option. Working toward electrifying air freight is an important step since electrified commercial flights remain out of reach. Larger-capacity electric planes require major advancements in battery technology but smaller flight distances could benefit.

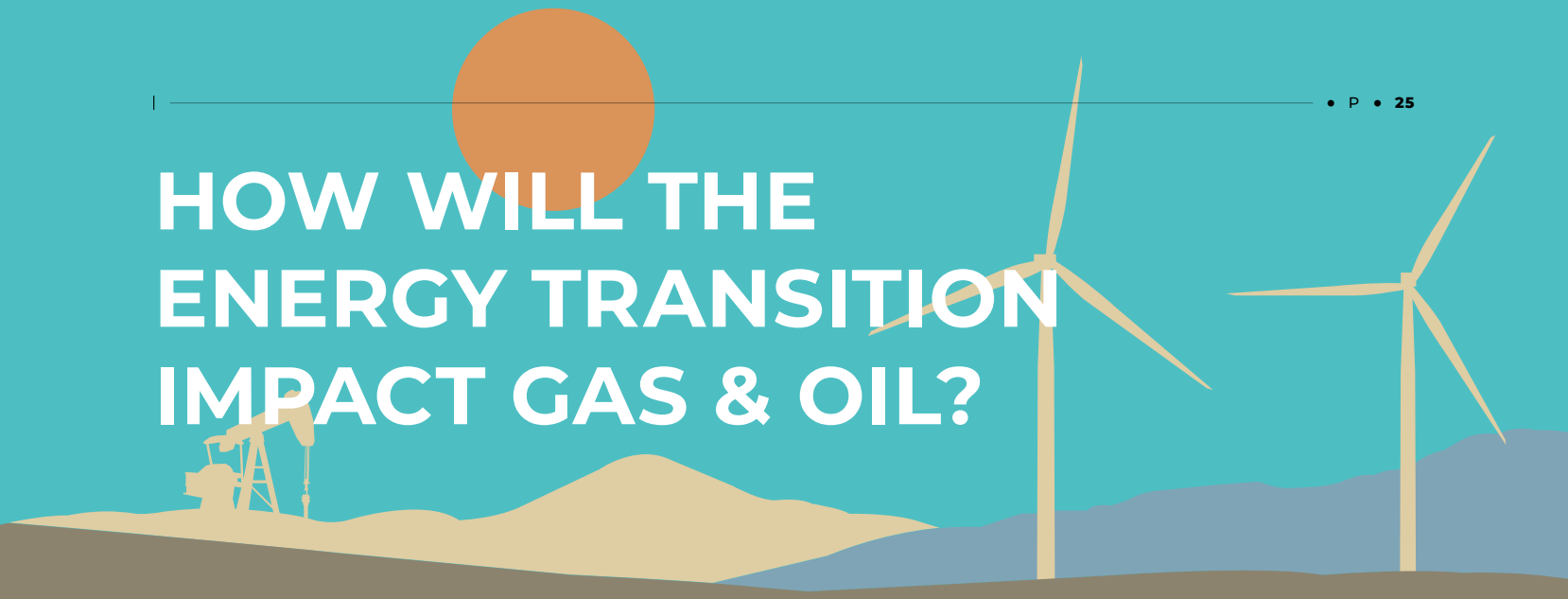
Eviation, an electric aircraft manufacturer, offers a freighter version of its planes that could be used to cover shorter, primarily domestic routes.

Beyond the fuels used, advances in AI and digitalization can support and accelerate sustainable air freight logistics. Blockchain technology, for example, could help provide companies with "fully traceable environmental attributes of SAF to help decarbonize air travel" — so says Avelia, a blockchain solution backed by Shell, Accenture and Amex GBT.

AIR FREIGHT CO2 EMISSIONS



> **(Blockchain could help) decarbonize air travel.**
> - Avelia



HOW WILL THE ENERGY TRANSITION IMPACT GAS & OIL?

The oil and gas industry plays a major role in driving economic and social growth. According to BP's energy outlook 2030, the world's primary energy consumption will grow 39 percent over the next 20 years. Concerns over environmental impact and future availability have prompted a transition to low carbon industry, but there has been little research into the impact of this transition on the oil and gas supply chain.

"Even though the evolution process from high carbon to low carbon energy is currently very slow, we should be identifying how the shift will affect the supply chain of oil and gas," Marisa P. de Brito said at the Asian Conference on Sustainability, Energy and the Environment in 2013. De Brito, lecturer in sustainable supply chain management and circular economies at Breda University of Applied Sciences in the Netherlands, investigated the impact of energy transition on sustainable supply chain management of oil and gas.

Her review of sustainability reports of companies in the oil and gas industry noted that the energy transition is an issue attracting considerable attention. However, as the players in this space move toward becoming energy companies, not just oil and gas producers, focus shifts to the infrastructure supporting alternative energy sources too.

"We are seeing increased efforts concentrated on improving efficiency of operations and products, which could help in addressing sustainability issues, especially in terms of carbon emission reduction,"

De Brito said. "Around 73 percent of the companies we looked at discussed issues related to supply chain management in their reports. Of these, 18 companies disclosed that they are in planning and/or research and development phase of alternative energy sources and significant investment must be made in their supply chains to develop production and logistics infrastructure that can deliver this energy."

De Brito emphasized that logistics infrastructure such as storage and transport systems must be efficient so as to reduce cost and time to deliver supplies to users because many production sites are located in remote areas. The sustainability concerns plaguing the oil and gas supply chain – such as sustainable sourcing; clean production; water and waste management; and the carbon footprint of the production process and logistics activities – are the same facing the development of alternative energy.

"As one of the major players in the energy sector, the oil and gas industry will be affected by the energy transition. They can either continue doing what they do best — exploring and producing oil and gas —but risk running out of business in the long run, or get involved in the so-called clean energy race to remain resilient against the changes in their business environment."

De Brito's points remain salient almost a decade on. The oil and gas industry continues to face increasing demands to reduce greenhouse gas emissions and the strategic challenge of balancing short-term returns with its long-term operations. Reimagining existing supply chains can build a sustainable and efficient network for the movement of energy products.

PHOTO: Unsplash

PROMISING APPROACHES TO TREATING WASTEWATER

Wastewater treatment protects both human and environmental health. Plus it conserves water. Abu Dhabi researchers offer promising approaches using innovative membranes.

By: **Jade Sterling**

FILTERING OUT NUTRIENTS

High levels of nutrients sounds like a benefit to an ecosystem, but when an environment sees too many, otherwise known as eutrophication, algal blooms and waters with too little oxygen can kill fish and seagrass, setting off a chain reaction in the ecosystem.

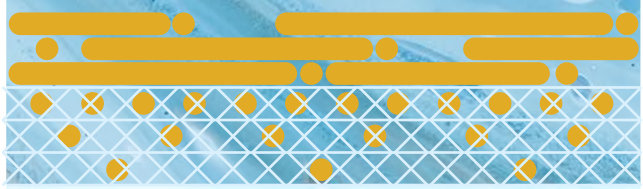
Large amounts of carbon dioxide from the decomposing matter acidify the water, slowing the growth of fish and shellfish. Eutrophication is an economic threat as well — smaller harvests mean more expensive seafood.

“We need to control the levels of nutrients and develop innovative technologies to treat water and remove excess nutrients,” says Shadi Hasan, director of the Khalifa University Center for Membranes and Advanced Water Technology (CMAT), whose team published its research in *npj Clean Water*.

The KU team developed a composite polylactic acid (PLA) and nanomaterial membrane to remove nutrients from wastewater.

The membrane works via adsorption, the process by which a solid holds molecules, in this case liquid, as a thin film. The team used a functionalized positively charged multi-walled carbon nanotube/graphene oxide hybrid nanomaterial to remove nitrogen (as ammonia) and phosphorus from wastewater while enhancing water permeability. The nutrients are collected in the pores of the nanotubes at the surface of the membrane.

REMOVING OIL FROM WATER



Wastewater can be difficult to treat, especially when trying to remove fine oil droplets.

“The large volume of industrial oily wastewater is difficult to treat due to its emulsified fine oil droplet content,” says Linda Zou, a Khalifa University professor. “Conventional membranes experience low separation efficiency and oil fouling issues, which we wanted to overcome.”

Zou and other researchers incorporated molybdenum disulfide (MOS2) nanospheres into a cellulose acetate matrix. MOS2 nanospheres repel water but attract oil — that is, they are oleophilic — whereas the cellulose acetate polymer has high water affinity and is hydrophilic. The membrane is designed to be amphiphilic, meaning it can target and capture oil droplets in a large volume of water. This is important for separation because the membrane has components that attract the oil droplets but can also facilitate the passage of water.

The membrane’s amphiphilic nature also eliminates fouling caused by oil droplets.

The team found the membrane had a high separation efficiency in tests, with greater than 90 percent removal of oil from the diluted oil-in-water mixture. The membrane also had good stability and durability, meaning it could be used repeatedly without losing performance, which makes it a promising material for industrial application.

WE'VE CAPTURED

By: **Maggie Kinsella**

Before the industrial revolution the world removed carbon from the air all by itself. With global carbon emissions breaking records in 2022 and potential risks of storing carbon underground, however, companies are getting creative and repurposing captured carbon in unexpected ways.

The Paris Agreement in 2015 had countries all over the world commit to take part in the race to net-zero emissions.

Those countries are working toward the agreement's renewable-energy goals, but more can be done to control greenhouse gases. One solution is carbon capture.

Natural or human-made

Carbon capture is the process of retrieving carbon emissions from the air and storing them. The process can be natural or manmade.

Natural carbon capture and storage is achieved by elements of the planet's ecosystems. Trees, for example, are an effective carbon-capture and storage mechanism: Their leaves absorb carbon dioxide from the air through photosynthesis. But if trees are cut

NOW WHAT?

Emissions removed from the air might fuel jets, clean your laundry or put bubbles in your drink

and burned for firewood — or even if the tree dies naturally — stored carbon is released back into the atmosphere.

The largest source of natural carbon capture is the world's oceans. The United Nations estimates that the oceans soak up about 25 percent of all greenhouse-gas emissions and 90 percent of the surplus heat those emissions cause.

This natural carbon-capture process is called the carbon cycle. The problem is the world's ecosystems can't keep up with the greenhouse gasses that are being produced by humans.

Enter man-made carbon capture.

Carbon-capture processes are designed to remove carbon from industrial waste or from the air outside. Carbon-capture plants typically have walls of giant fans, sucking in air. They remove the carbon from the air, convert it to liquid, store it underground or use it to inject into oil fields to simplify oil extraction. But there are challenges with carbon capture.

These large plants require a lot of energy in the form of materials to build the facilities and the energy to run them. Additionally, once the carbon dioxide is stored, there are risks. The carbon dioxide could leak out of the stored areas, polluting water sources and eventually reaching the surface — once again polluting the air.

Reasons for concern

There is also concern that pressure from injecting the carbon underground could cause seismic activity and controversy over whether carbon capture and storage might embolden fossil-fuel use. The 2022 report from the Institute for Energy Economics and Financial Analysis says, "Captured carbon has mostly been used for enhanced oil recovery" and "enhancing oil production is not a climate solution."

While easing oil removal is the most common use of captured carbon, some companies are getting creative and managing carbon in other unusual ways.

Many large companies purchase carbon offsets to reduce their footprints. But individuals can purchase them as well.

One company selling to individuals is Climeworks, a Swiss-based carbon-removal company that captures 900 tons of carbon annually. Buyers can even offer this as a "green gift" in the name of someone else. Climeworks also produces the bubbles for carbonated beverages for such clients as Coca-Cola.

Also getting off the ground is E-Jet fuel from carbon-capture company Twelve. The company says this fuel lowers greenhouse-gas emission of traditional fuels by 80 percent. Twelve entered into a memorandum of understanding with Alaska Air Group and Microsoft to work toward testing the fuel on a commercial flight.

Taking off

In an announcement of the partnership, Nicholas Flanders, co-founder and CEO of Twelve said, "By producing our drop-in E-Jet fuel from captured CO2, we can rapidly and efficiently close the carbon cycle and allow businesses to sustainably use emissions to power their own business travel." No date for the testing of the commercial flight has been announced.

Air Transport Action Group reports that aviation makes up 12 percent of emissions from all transport sources.

After returning home from a green commercial flight, weary travelers might do some green laundry with laundry capsules made from captured carbon.

In 2010, Unilever, which produces over 400 household brands such as Omo, Ben and Jerry's and Dove, began a decades-long commitment to halve its environmental impact by 2030.

One of the ingredients used to make foam in Omo (Persil) laundry capsules is fossil fuels. But on World Earth Day in 2021, Unilever launched a limited-edition capsule that used captured carbon instead of fossil fuels in a new process that makes the capsule 82 percent less carbon intensive.

Unilever aims to achieve net zero emissions from its product line by 2039. Even with the volume of removal, storage and creative ways carbon is being repurposed, carbon neutrality remains out of reach.

The 2021 Global Status of Carbon Capture and Storage Report estimates that in order to reach mid-century goals, the number of carbon-capture facilities would have to increase by 100 times. There are currently 27.

⊙ **PHOTO:** Unsplash

TURNING CARBON TO ROCK

Iceland company looks to nature for sequestration solution

By: **Maggie Kinsella**

Companies around the world are using recycled materials to create new products for consumer use but a company in Iceland is looking to recycle carbon captured from the air into a part of the natural landscape.

Carbfix, an Iceland-based company, is using captured carbon and converting it to rock.

Once the carbon is captured, it is dissolved in water and injected below ground. The injection site is selected based on the presence of basalt in the subsurface.

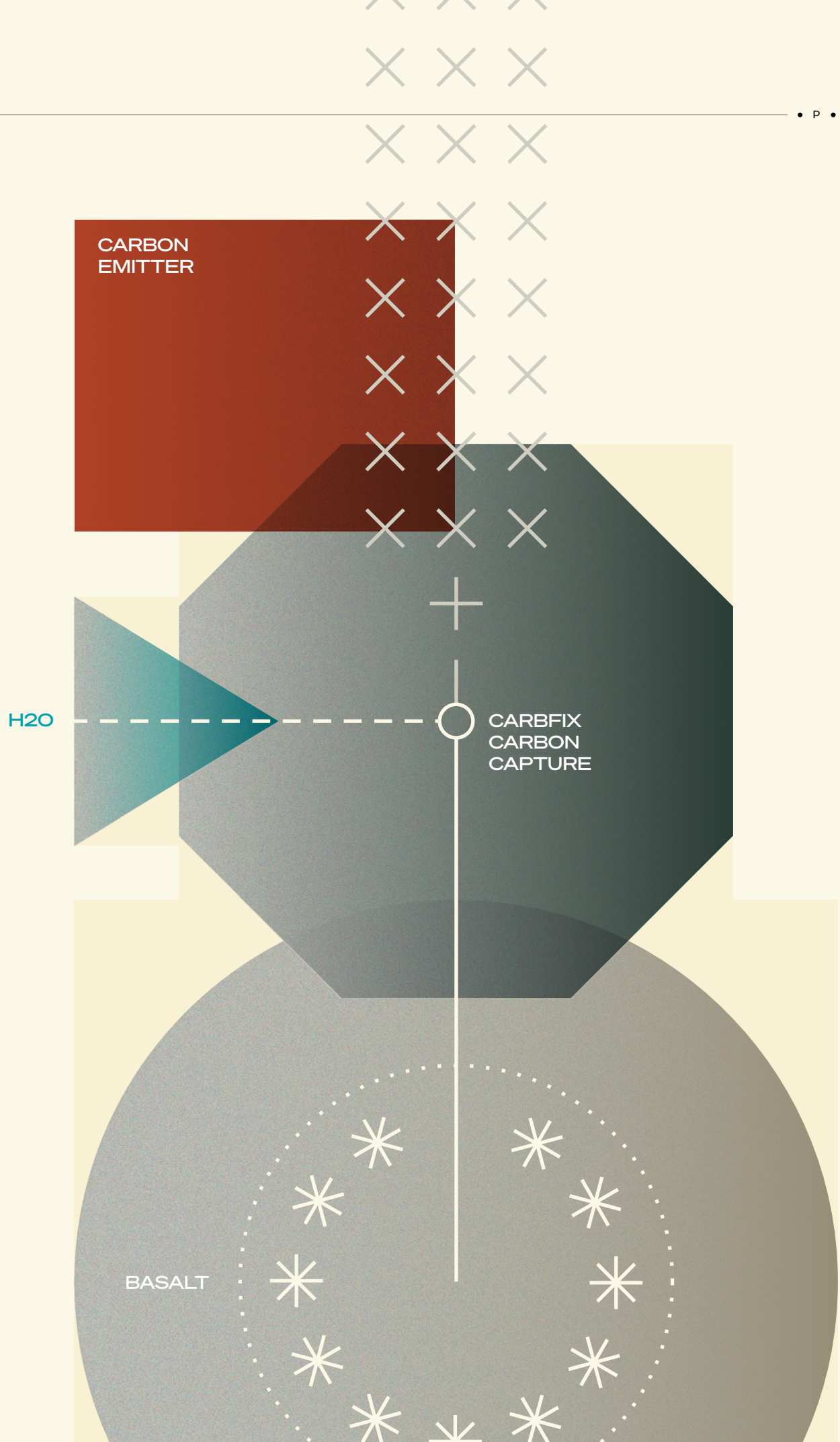
Basalt is a type of rock formed from cooled lava and is one of the world's most abundant volcanic rocks. Once the carbonated water interacts with the basalt, it begins a natural transformation.

The high concentrations of magnesium ions and calcium react with carbon dioxide, creating the minerals magnesite, dolomite and calcite. The process takes approximately two years.

The project began in 2012 at a test site in Iceland, and the team published its results in *Science* in 2016. The subsequent years were spent certifying the process for international standards. New project plans on the global stage are also underway.

In an interview with Bloomberg, Carbfix Chief Executive Officer Edda Sif Pind Aradottir said, "Basically we are just doing what nature has been doing for millions of years, so we are helping nature help itself."

Carbfix is building a large-scale storage plant to hold captured carbon until suitable locations are found underground.

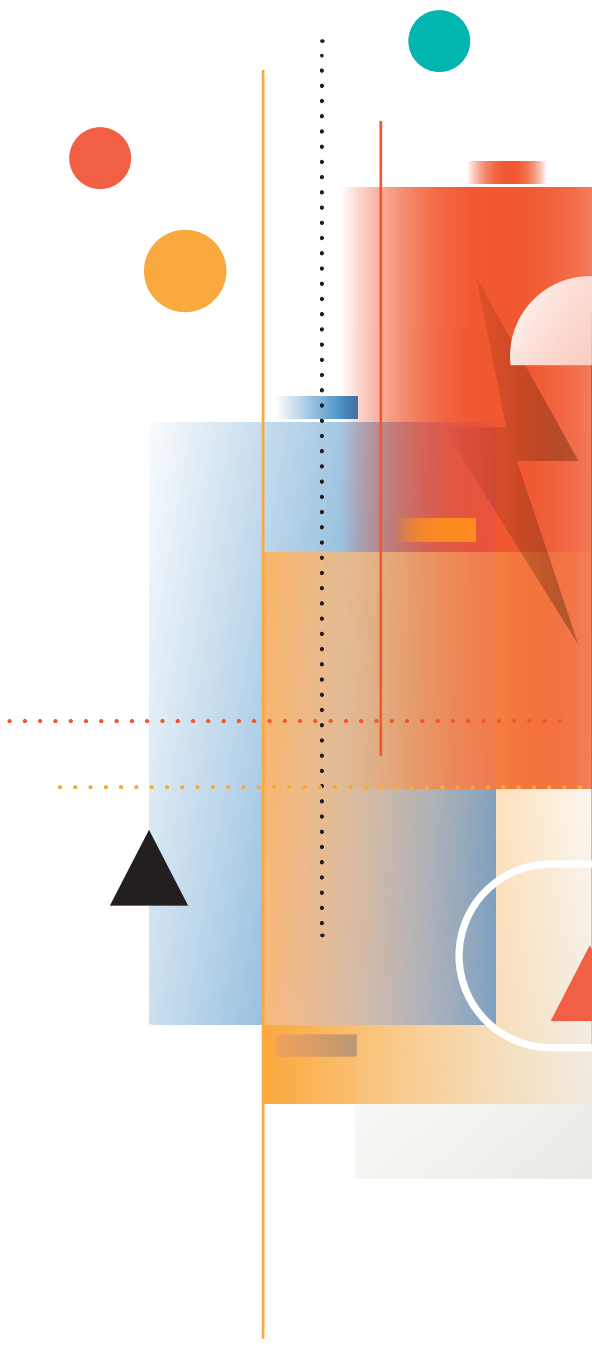


GRAPHICS BY Abjad Design

WHAT'S THE ETA ON EVs?

Consumer habits, government policies push adoption rates for electric vehicles

By: **Jade Sterling**



In July 2022, Bloomberg analysts reported that the U.S. has now reached the "tipping point" for mass adoption of electric vehicles. According to the report, the nation has reached the magic number that signals a period when "technological preferences rapidly flip." That magic number is just 5 percent — and 5 percent of new car sales in 2022 were electric vehicles.

Sales for electric vehicles, commonly called EVs, are on track to double every couple of years, says Loren McDonald of EVAdoption. The industry analysis group predicts 40 million EVs on U.S. roads by 2030. In 2020, some 276 million vehicles were registered.

The industry certainly seems to believe in the proliferation of electric vehicles: Vojay Chandler, investment strategist at Morgan Stanley, says EV's share of global auto sales is likely to grow from about 7 percent today to nearly 90 percent by 2050.

There are plenty of reasons for this. Climate change and its consequences are forcing people to consider their environmental impact. Governments across the globe are developing policies to significantly reduce greenhouse gas emissions and increasing energy efficiency wherever possible. Fuel prices are at the mercy of political instability, particularly in Europe, and governments are hesitant to introduce e-fuels.

As Nasir Salari, marketing expert at Bath Spa University, points out, despite the sluggish growth rate »»

ILLUSTRATIONS: Abjad Design

of electric cars, the latest report by the International Energy Agency in 2020 illustrates promising figures in major markets. The global electric car stock hit the 10 million mark, a 43 percent increase over 2019. And while China has the largest fleet with 4.5 million, Europe had the largest annual increase to reach 3.2 million. In the United Kingdom, 67,100 passenger electric cars were registered in 2020. This is promising, Salari says, but the adoption curve is still at the early stage.

Salari conducted research in the U.K. looking at the factors contributing to the "sluggish growth rate." He interviewed 336 individuals in the U.K. to assess their willingness to buy an EV. Like most analysts, he predicts a boom in the coming years, particularly with the U.K. government reaffirming its commitment to ban new petrol and diesel cars in 2030. With pressures like these, new cars will be electric, but people currently seem reluctant to dive into the electric future.

"There are various reasons for this," Salari tells *KUST Review*. "This has always been the case for new revolutionary products: the first color TV, smartphone, cameras, for example. There have always been early adopters and then majority adopters and the people open to embracing technology in general will also be more willing to adopt an electric car. The TRI is a good indicator of this."

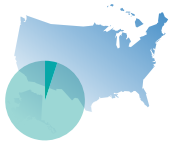
Developed in 2000, the TRI (Technology Readiness Index) is a »»

> **Electric vehicles are advertised as environmentally friendly and they are! And people know this, but this isn't necessarily encouraging people to purchase them.**
> - Nasir Salari

RIGHT: Shutterstock, Unsplash

KEY FIGURES

5%
of new car sales in the U.S. in 2022 were electric. vehicles



40m
EVs are predicted to be on the U.S. roads by 2030.

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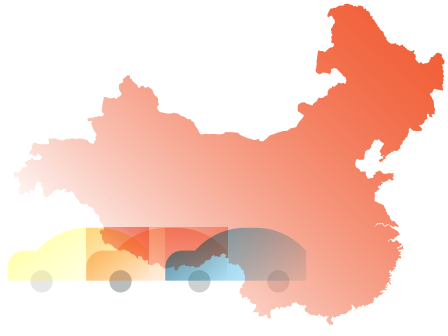
4.5m
CHINA has the largest electric car fleet. Europe has the largest annual increase to reach 3.2 million.



43%
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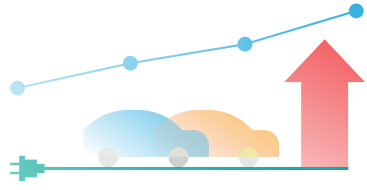
EV sales are on track to double every couple of years.



THE MIDDLE EAST BRINGS ITS OWN CHALLENGES TO EV ADOPTION

Although consumer interest is high in the region — local company M Glory Holding Group in the UAE opened its electric vehicle manufacturing plant in 2022 with plans to produce 55,000 electric cars annually to meet a rising demand for green mobility — there are still numerous obstacles hindering the widespread adoption of EVs.

The limited availability of EV charging stations is one concern, but more pressing is the new demand placed on power grids by at-home charging stations. Traditional power-distribution grids are not designed to handle a significant number of EVs charging in the evenings when their owners return home from work. Utilities providers will need to predict and account for this surge in demand.

EV manufacturers also face the challenge of keeping up with demand, not just for EVs themselves but for their constituent parts. Replacement parts are expensive relative to components needed for internal combustion vehicles, especially when supply chains are not fully developed and hampered by the aftermath of the COVID-19 pandemic on logistics around the world. Localized procurement is the answer for the future, but companies and suppliers need time and investment to set up and serve the local market. In a relatively nascent industry, this is not a short-term solution.

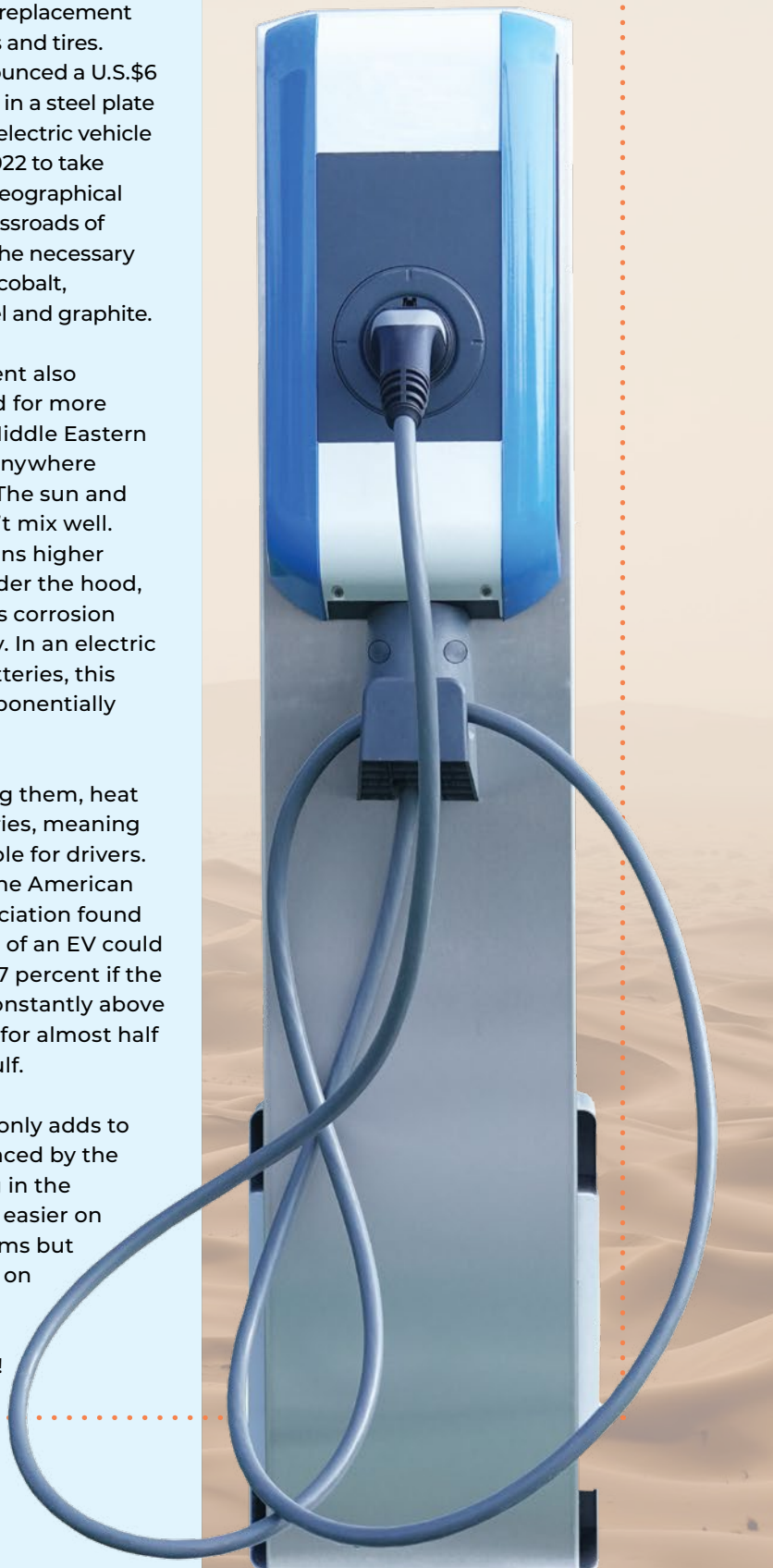
Included in those replacement parts are batteries and tires. Saudi Arabia announced a U.S.$6 billion investment in a steel plate mill complex and electric vehicle battery plant in 2022 to take advantage of its geographical location at the crossroads of the producers of the necessary minerals: lithium, cobalt, manganese, nickel and graphite.

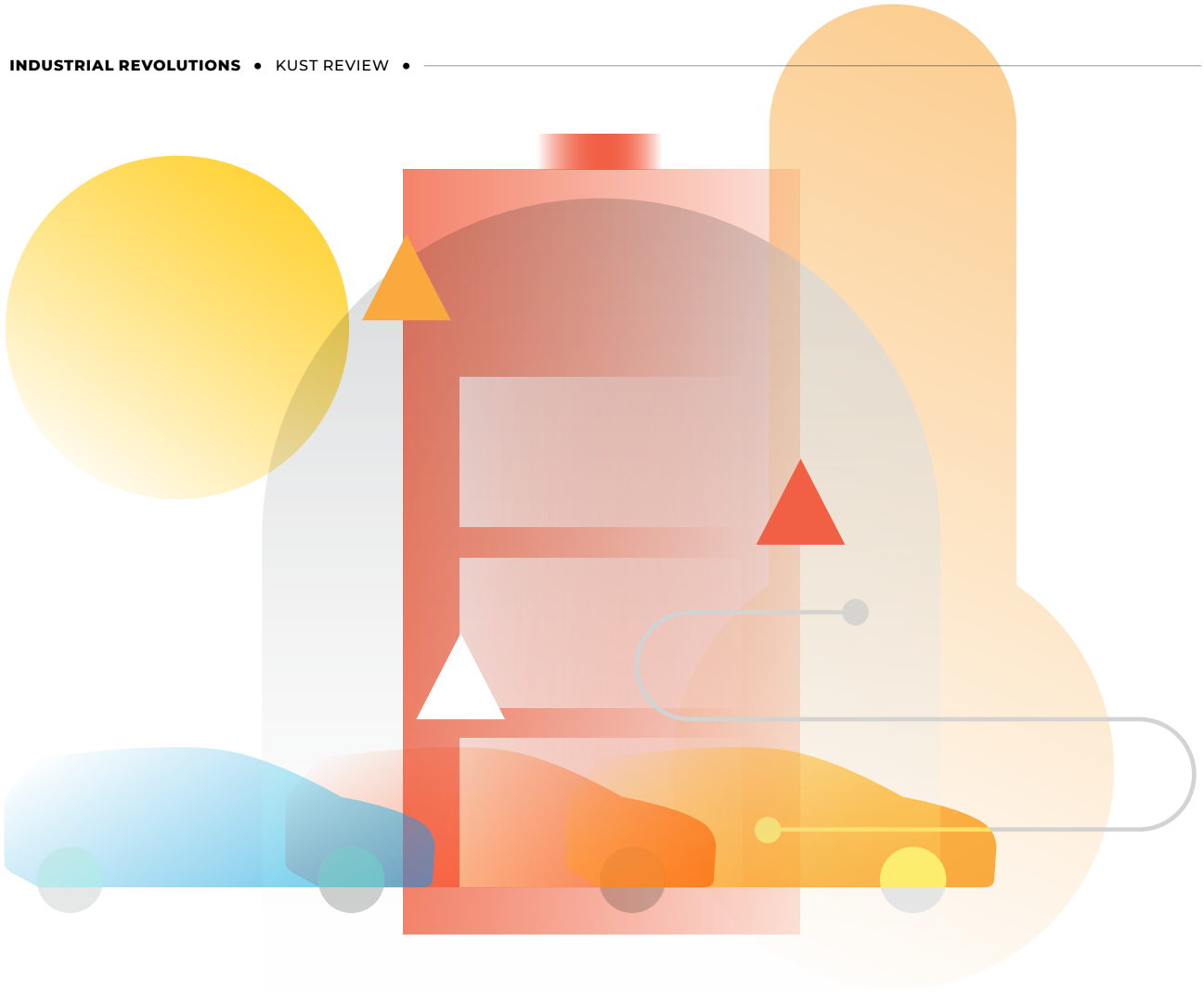
But this investment also foresees the need for more batteries in the Middle Eastern EV market than anywhere else. Put simply: The sun and car batteries don't mix well. Hot weather means higher temperatures under the hood, which accelerates corrosion inside the battery. In an electric vehicle, full of batteries, this is naturally an exponentially larger concern.

Beyond damaging them, heat also drains batteries, meaning less range available for drivers. A 2019 study by the American Automobile Association found the driving range of an EV could reduce by up to 17 percent if the temperature is constantly above 35C — which it is for almost half the year in the Gulf.

Charging the EV only adds to the heat experienced by the battery. Charging in the evening makes it easier on the cooling systems but that puts a strain on the power grids.

It's all connected!





> **Environmentalism does not have an impact on purchasing an electric car; its functionality is more important.**
> - Nasir Salari

RIGHT: Unsplash

widely used scale in understanding technology adoption behavior and a powerful tool to predict the adoption of incremental and revolutionary technologies.

"Our data shows no difference between men and women in their willingness to purchase an EV or pay a higher price for the product," Salari says. "However, the overall TRI is higher amongst men than women, and this difference is statistically significant. This shows that overall, men are more willing to embrace new technology and possess new and unique items in general. There was also no significance between age groups for their willingness to purchase, but I was surprised to see a significant difference in how much environmentalism played a part: The 50-plus age group expressed higher levels of green values than the 20-29 group."

Interestingly, Salari found that most consumers were more concerned by the economic impact of their purchase, rather than the environmentalism aspect: They cared more about their investment than how green they were being.

"Electric vehicles are advertised as environmentally friendly and they are! And people know this, but this isn't necessarily encouraging people to purchase them," Salari says. "Environmentalism does not have an impact on purchasing an electric car; its functionality is more important."

Like Salari, experts believe that demand for electric vehicles will increase as they become more affordable. Morgan Stanley predicts that continued performance improvements and reductions in the cost of batteries (which account for about 35 percent of an EV's

total cost) could lower the average EV price to $18,000 by 2025.

Salari says it also depends on consumer incentives: “People aren’t running out to buy electric vehicles because they’re good for the environment. They’re hesitating because they’re expensive but they’re in favor because their running costs are much cheaper. Regular drivers are more open to adopting EVs because of fuel costs, so it all depends on how you market your product. Enviro isn’t doing it: Shift your marketing to the economic benefits.

“Prices will be lower in the future — that’s how innovation works. The first time a product launches, it’s not a cheap product, but as it becomes a mainstream offering, it will become more affordable. The market is still in its infancy. To grow it, we need more early adopters and government incentives are one way to drive adoption.”

Tax credits and improved infrastructure are the way forward then. The U.K. is certainly investing in its electric vehicle readiness: Lampposts across London are being fitted with sensors and EV charging points to reduce emissions and cut congestion, and parking is even free in the capital for EV drivers. New-build houses come with electric vehicle charging stations as standard and many are fitted with solar panels to power this.

As charging infrastructure gets more support, subsidies and incentives become more robust, and governments enforce more petrol-banning policies, electric car sales will continue to rise.

“It’s happening,” Salari tells *KUST Review*. “It may not be where we expected it to be by now, but it’s happening.” ●

Bringing down charging times

One of the issues with electric vehicles is the charging time. But a team at Khalifa University is working on cutting that time down.

On-board EV charging is generally done through two stages, says Vinod Khadkikar, who leads the project funded by Abu Dhabi’s ASPIRE. In the first stage, AC voltage is converted into DC voltage. But this DC voltage is generally higher than the EV battery voltage, so an additional DC-DC converter is needed to charge the battery.

Most current commercial on-board chargers use a full-power processing converter at the DC-DC stage, which requires higher voltage and current rating of switches and diodes. This restricts the charging speed. The size, cost and efficiency of any EV charger also largely depends on the device rating and number of power processing stages. The KU team proposes partial power processing-based topographies at the DC-DC stage that use a fraction of the power.

“Therefore, the DC-DC converter size is reduced and the charger efficiency is high (97-99 percent with hard switching). The semiconductor device rating is reduced significantly, which helps to achieve higher power density (smaller footprint/compact size). This lets the user use the same footprint size to design the charger for higher power,” Khadkikar says.

6 INNOVATIVE WAYS TO STORE ENERGY

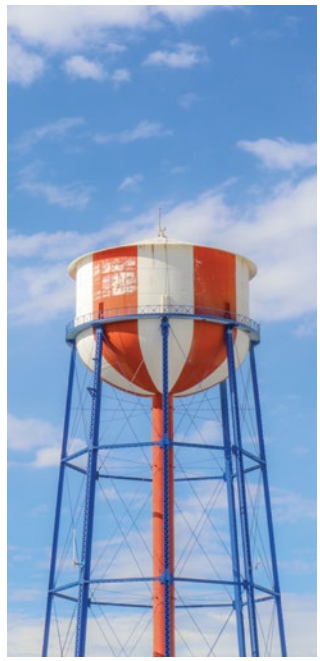
By: **Suzanne Condie Lambert**

As the world looks to a renewable-energy future, storage becomes a concern because with renewables, supply and demand aren't always in balance

Renewable energy sources such as wind and the sun aren't always "on" when consumers need energy, and excess power that can't be used immediately is wasted unless it's stored. Storing energy can be expensive, however, so some utilities use plants that burn fossil fuels to make up the difference during times of peak demand. Those plants operate most efficiently when at full power, however, and using these plants to redistribute power can lead to more pollution.

Chemical batteries are useful for electric vehicles but they may not be the best option for utility companies. Chemical batteries' life cycles can also be short. Lithium ion batteries, for example, last about five to 10 years. They're expensive. And the metals used to make them raise issues of geopolitics and human rights.

Looking at other materials seems to be a good idea. **Here are six innovative materials and methods we might use instead:**



PUMP STORAGE WITH WATER

This isn't a new idea: People have been using pump storage since the early 20th century.

Early pump storage used fossil fuels to move water from a lower reservoir to a higher one during off-peak hours, when that energy was cheapest.

Then when the energy was needed, gravity returned the water to the lower reservoir, turning turbines as it flowed.

Such systems today can substitute renewable energy for power from fossil fuels. This is the most popular method of storing electricity today and accounts for 93 percent of utility-scale energy storage in the United States.

GRAVITY BATTERIES

As with the pump-storage system, this uses renewable energy to raise an object from a lower level to a higher one. But instead of water, it's a heavy mass that generates gravitational potential energy. When the energy is needed, the mass is slowly dropped. The motor that raised it in the first place switches to generator mode and energy is sent off to the consumer.

How much energy is produced and how long it is generated depends on the height and weight of the lift. One company working with the technology, Gravitricity in Scotland, is investigating the use of deep decommissioned mines for gravity energy storage. The company estimates that some 14,000 mines around the world could be repurposed for energy storage.

PHOTOS: Unsplash, Energy Vault, Shutterstock, NASA

FLYWHEELS

A flywheel can be as simple as the power system in a child's friction toy or as complex as NASA's G2 system for energy storage in a spacecraft.

The flywheel is essentially a mechanical battery with a heavy weight that rotates around an axis. Energy gets the wheel spinning. And if it spins fast enough, it can store energy.

The limiting factors are friction and how much force the wheel can take before it breaks.

SAND BATTERIES

The sand battery uses sand or a sandlike substance heated to temperatures well above the boiling point of water – about 500 degrees C.

Cool air blown through pipes in the storage facility picks up the heat and can be used, for example, to convert water into process steam.

The first commercial sand battery in Finland uses about 100 tons of low-grade sand to warm homes, offices and a municipal swimming pool year-round, and its developers say the sand can hold its heat for months.

THERMODYNAMIC STORAGE USING COMPRESSED AIR

This system uses electrical energy to create high-pressure compressed air, which can be released later to drive a turbine generator. Utility-scale versions of these systems are generally located in caverns.

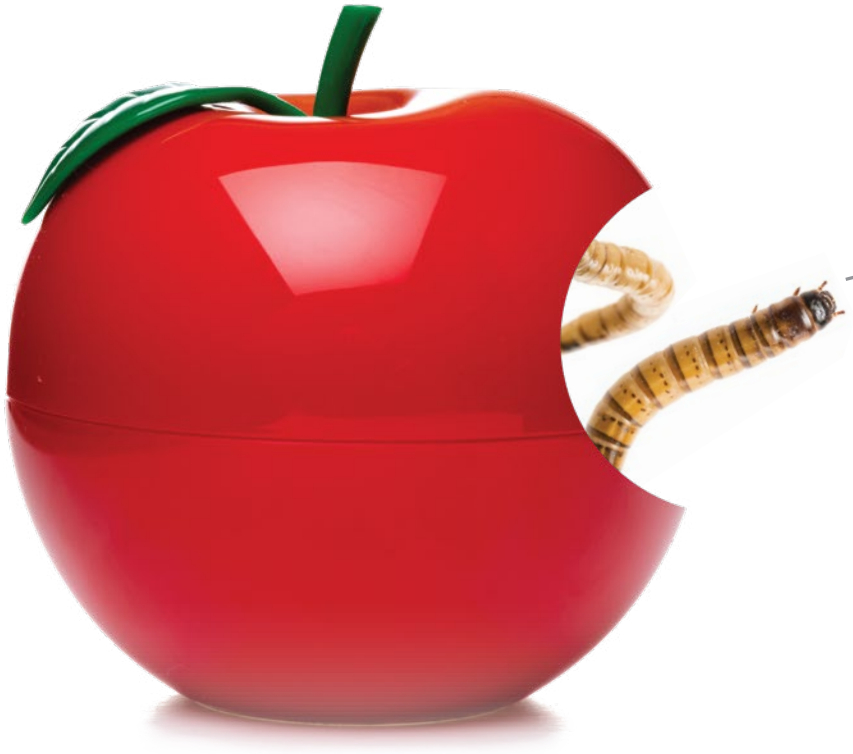
A variant of this storage system is underwater compressed air energy storage, which benefits from the constant water pressure and could be useful for coastal locations.

WOOD BATTERIES

About 30 percent of a tree – depending on the species – is lignin, the glue that holds its cellulose fibers together. The polymer lignin also contains carbon, which as it turns out is a great material for a battery anode.

Finland's Stora Enso happens to have lots of trees: It calls itself the one of the largest owners of private forest in the world. And according to the BBC, the company's engineers say they can extract the lignin they need from waste pulp the company is already producing.

Stora Enso has entered into a partnership with Swedish company Northvolt to create batteries sourced sustainably in Nordic countries. They expect to be in production as early as 2025.



This is a **story** about

Scientists look to **insects** for ideas about how to **deal with waste**

PHOTO CREDITS: Shutterstock, Unsplash

Bugs that eat plastics

By: **Suzanne Condie Lambert**

By some estimates there are more than 8.3 billion tons of plastic on the planet – more than 6.3 billion tons of that is waste. Recycling isn't an option for all of it. But scientists around the world are looking at organic solutions in the form of hungry bugs and the enzymes and bacteria they produce.

Among them: Dr. Chris Rinke and a team of researchers at Australia's University of Queensland in 2022 published a study in *Microbial Genomics* about their work with the larvae of the darkling beetle *Zophobas morio*.

It found that the so-called "superworms," which normally feed on such decaying material as dead leaves and animal carcasses, could survive on polystyrene alone. Most are able to complete their transition to adult beetles on just a diet of the synthetic resin commonly used for such items as disposable cups and surfboards.

"Our understanding is that superworms mechanically shred the polystyrene, ingest it, and then the bacteria in the worm's gut further degrade the plastic. We found several encoded enzymes associated with polystyrene degradation in the gut bacteria," Rinke tells *KUST Review*, adding that the team is also looking into the degradation of such other thermoplastics as polyethylene and polypropylene.

And, sure, your local waste-reclamation facility might set up a giant worm farm to decompose unwanted polystyrene, but Rinke tells NPR it would be cheaper and easier to reproduce the enzymes that allow the larvae to digest, say, old dishwasher parts and packing material.

A synthetic "enzyme cocktail" could be sprinkled over shredded waste. Add microbes to the material and you could create useful and more sustainable bioplastics. Rinke cautions that it will take a while before the enzymes are available for industrial use. "It will take sufficient research funding and several years of research to characterize the enzymes involved in polystyrene »»

degradation, but once we have found the most efficient enzymes, we can offer a biological solution to degrade plastic waste," he says.

In the meantime, he encourages consumers to avoid plastic, "especially single-use plastic packaging, whenever possible," he tells *KUST Review*. "If plastic needs to be used and eventually becomes waste, then one should recycle plastic waste as much as possible. Last but not least, it's also important to ask local councils to increase the amount of plastic recycling," he says.

ANOTHER HUNGRY, HUNGRY CATERPILLAR

But the *Zophobos morio* isn't the only insect bellying up to the plastics buffet. Researchers in Poland published their results on a study of Tenebrio molitor in the journal *Polymers*.

The researchers fed the insect – commonly called a yellow mealworm and another species of darkling beetle – a diet of polystyrene foam (PS), two types of polyurethane (PU1 and PU2, like kitchen sponges and commercial insulation foam) and polyethylene foam (PE, commonly used in packing materials).

The researchers concluded that genetic variances among mealworm populations could account for different rates of consumption, but say 1 kilogram of PS, PU1, PU2 and PE could be consumed over 58 days by 40.5 kg, 46.0 kg, 36.5 kg and 30.9 kg of *Z. morio*, respectively.

FROM PEST TO PROMISE

The Polish researchers mention other plastivore species, including *Galleria mellonella*, a wax moth whose palate for plastics was discovered accidentally when a researcher put the caterpillars in a plastic bag and found later that they had eaten holes in it. The information that resulted was featured in a recent study from Brandon University in Canada.

The moth caterpillar larvae, which normally invade beehives and eat wax, can digest polyethylene – the kind of plastic found in shopping bags – and excrete ethylene glycol, a form of alcohol that can be used as antifreeze. In the study, 60 waxworms consumed 30 square centimeters of the plastic in less than a week. The researchers published their results in *Current Biology*.

Although the waxworms can consume the plastics on their own, researchers also isolated an intestinal bacteria from the larvae that was able to survive on polyethylene as its sole source of nutrition for a year. Working together, the waxworms and the bacteria accelerate plastic biodegradation.

Researchers caution, however, that the waxworms and their bacteria aren't a solution to the plastics problem but point to possible future directions for waste management.

ENTER MICROBES

Different kinds of bugs – not insects but microbes – are also emerging as potential solutions to the world's plastics-waste problem. Researchers in 2016 discovered a bacterium in a Japanese garbage dump that had evolved naturally to eat plastic, and when they tweaked a promising enzyme to see how it evolved, they accidentally made the molecule even better at breaking down polyethylene terephthalate, the plastic used in soft-drink bottles.

8.3+

Billion Tons of plastic on the planet

6.3+

Billion Tons of that is **waste**

But more recently, a group of scientists in Sweden has found that microbes around the world are evolving to eat the plastic trash that has found its way into mountain peaks, ocean depths and remote tropical beaches. They published the results of their study, the first to assess the global potential of plastic-eating microbes in *mBio*.

Scanning 200 million genes, the researchers found 30,000 enzymes that could degrade 10 kinds of plastics. The number and type of enzymes they found corresponded to the amount and type of plastics in their locations. One in four organisms examined carried an enzyme that could break down plastics.

"We did not expect to find such a large number of enzymes across so many different microbes and environmental habitats. This is a surprising discovery that really illustrates the scale of the issue," Chalmers University researcher Jan Zrimec says in the Guardian.

The remarkable thing about these microbes and insects is that plastics are man-made and, in evolutionary terms, quite recent, says Khalifa University's David Sheehan. "Yet microbes clearly have evolved enzymes that can degrade them in a short period of evolutionary time. If we can identify a panel of these enzymes, we could use enzyme engineering approaches to improve their activity and substrate range and produce these commercially much as we do with biological detergents."

Why do we care about PLASTIC WASTE?

50%

Of all plastics manufactured, **half were made in the past 15 years.**

448 MILLION TONS

Production increased from 2.3 million tons in 1950 to **448 million tons by 2015**.

Production is **expected to double by 2050.**

400 YEARS

Plastics often **contain additives** to make them stronger, more flexible and durable. They can also extend the time it takes plastics to break down. Estimates suggest **it will take at least 400 years** for some to break down.

8 MILLION TONS

About **8 million tons of plastic waste** from coastal nations finds its way into the oceans every year. To put that into perspective, **it's** like setting **five garbage bags of trash on every foot** of the planet's coastlines.

Plastic facts from **Nationalgeographic.com**

BUILDING BLOCKS OF SUSTAINABILITY

Researchers investigate ways to reduce plastic waste into smaller pieces that can be used again

By: **Suzanne Condie Lambert**

Since their discovery in the early 20th century, polymeric materials have revolutionized many aspects of our lives. Perhaps the most recognizable polymers in our daily lives are plastics.

Despite their enormous value, we produce more plastic than we recycle, and this is becoming a major environmental challenge. The figures are staggering: Approximately 9 percent of the global supply of plastic is recycled. Most plastic is incinerated or placed in landfills, leading to pollution. A significant amount of plastic waste is also found in the seas, creating not just an eyesore but damage to aquatic life and marine ecosystems.

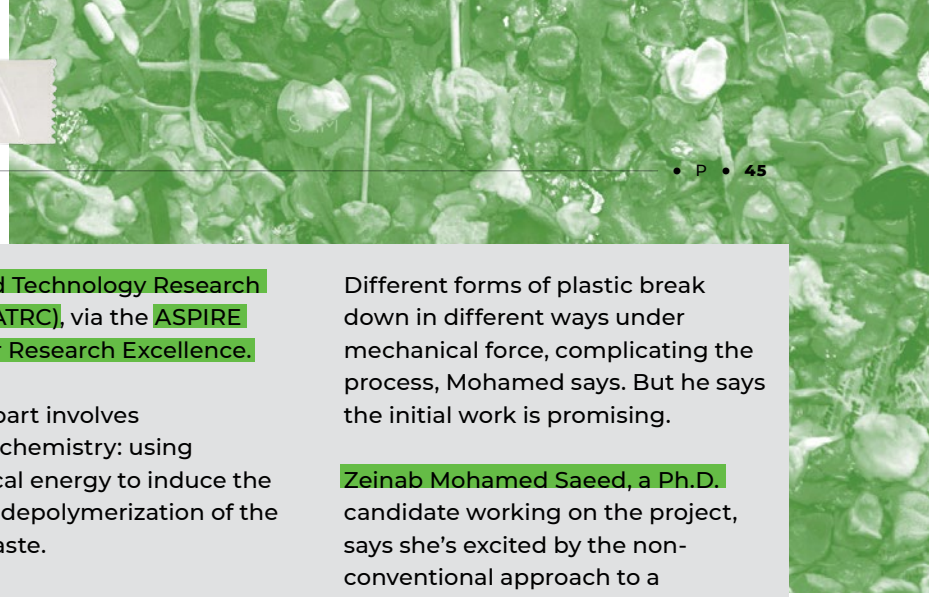
At Khalifa University, Sharmarke Mohamed and his team at the Advanced Materials Chemistry Center (AMCC) are developing a new method for recycling post-consumer plastic waste that uses a combination of mechanical force (as part of mechanochemistry), light and enzymes.

While mechanical methods are common as a means for reducing the size of plastics prior to recycling, it is not possible to apply this for the depolymerization of most plastic waste. Instead, the researchers are looking for ways to perform low-cost recycling using a range of stimuli.

"Despite the enormous environmental challenge posed by plastic waste, we felt a sense of duty to develop these new mechanochemical tools. Most researchers around the world are exploring mechanical force as a means to build new chemicals. In other words, building complexity from simple structures. We decided to use the same principles and use mechanical force as well as light and enzymes to break down complex polymer waste materials into smaller building blocks that can then either be recycled or upcycled," he says.

"Solar energy is responsible for the photodegradation of plastics in the environment, particularly in the

IMAGES: Unsplash



UV region of the electromagnetic spectrum. We also know that some enzymes are adapted to using organic macromolecules such as plastics as fuel sources. So in essence, we are learning from nature as we try to develop a lab-scale protocol that uses these tried-and-tested methods for turning plastic waste into high-value chemicals," Mohamed says.

"As the UAE declares 2023 to be the Year of Sustainability, our research group is very much leading this effort in a challenging area. But we are motivated by solving the environmental challenges posed by plastic waste," Mohamed says.

About 380 million metric tons of plastic are produced each year. Of that, only about 9 percent is recycled, Mohamed tells the KUST Review. Some plastics are treated with harsh chemicals, like acid. But most plastic is incinerated, he says.

"But the problem (with incineration) is that it releases carbon dioxide and adds to the global carbon footprint. The other problem is that if you burn the plastic you can't reuse it. Our group is trying to take the end-user plastic and come up with new low-cost mechanical methods that are able to break down these polymers into their constituent parts."

Those constituent parts might then be reused to make new plastic products or chemicals for other uses.

Mohamed's team is working on a three-year project to investigate a three-part process for recycling plastics. This research is supported by AMCC and funded by ASPIRE, the technology program management pillar of Abu Dhabi's Advanced Technology Research Council (ATRC), via the ASPIRE Award for Research Excellence.

The first part involves mechanochemistry: using mechanical energy to induce the chemical depolymerization of the plastic waste.

"Mainly we use ball milling machines to grind the polymers in the presence of proprietary chemicals we are developing in our lab. This leads to the polymer essentially breaking down and releasing its constituent building blocks, known as the monomers. Preliminary results in our lab suggest this process can be done under ambient conditions in the solid-state with yields up to about 70 percent or higher," he says. The value of this technology is that it uses no corrosive or harmful chemicals, which is important as it makes the entire process much more environmentally friendly than incineration or land-filling the plastic waste.

The next step is to examine the influence of light on the process, followed by experiments with enzymes to break down plastics.

"Once we understand each of these processes on their own, we can see how they can be stitched up together to create what we refer to as a photolytic and mechanoenzymatic degradation (PMED) protocol. We envisage the PMED process will be implemented serially as part of a batch process, much like a conveyor belt in a factory. Our long-term goal is to take post-consumer plastic waste and to efficiently produce the chemical building blocks of the plastic waste via our PMED process."

Different forms of plastic break down in different ways under mechanical force, complicating the process, Mohamed says. But he says the initial work is promising.

Zeinab Mohamed Saeed, a Ph.D. candidate working on the project, says she's excited by the non-conventional approach to a long-standing problem.

"The field of polymer degradation was there for decades," she says. "People have been trying to come up with different ways to tackle the issue using their expertise, and now we are trying to think outside the box and look at the problem from a non-conventional perspective using a mechanocatalytic approach. I find this research challenging but exciting, and can't wait to see what kind of results we will end up with."

Among the challenges, however, is creating vessels that can hold the material but also allow in light of a certain wavelength. And the enzymes known to break down plastics are expensive.

The hope, however, is to scale up the technology to levels required by industry. That's still some time off, however.

"Now we can do up to a gram or two. This is fine for feasibility and patenting," Mohamed says.

The Advanced Materials Chemistry Center (AMCC) was formed in 2022 and combines expertise from different disciplines to tackle major environmental problems. Its methods for treating plastic waste "align with the UAE's ambitions to transition to a green circular economy and achieve its net-zero targets" Mohamed says. ●

Urban areas are evolving to protect human health and combat climate change with technology. But there are risks. Here's how we deal with them.

SECURING SMART CITIES

By: **Steve Griffiths**

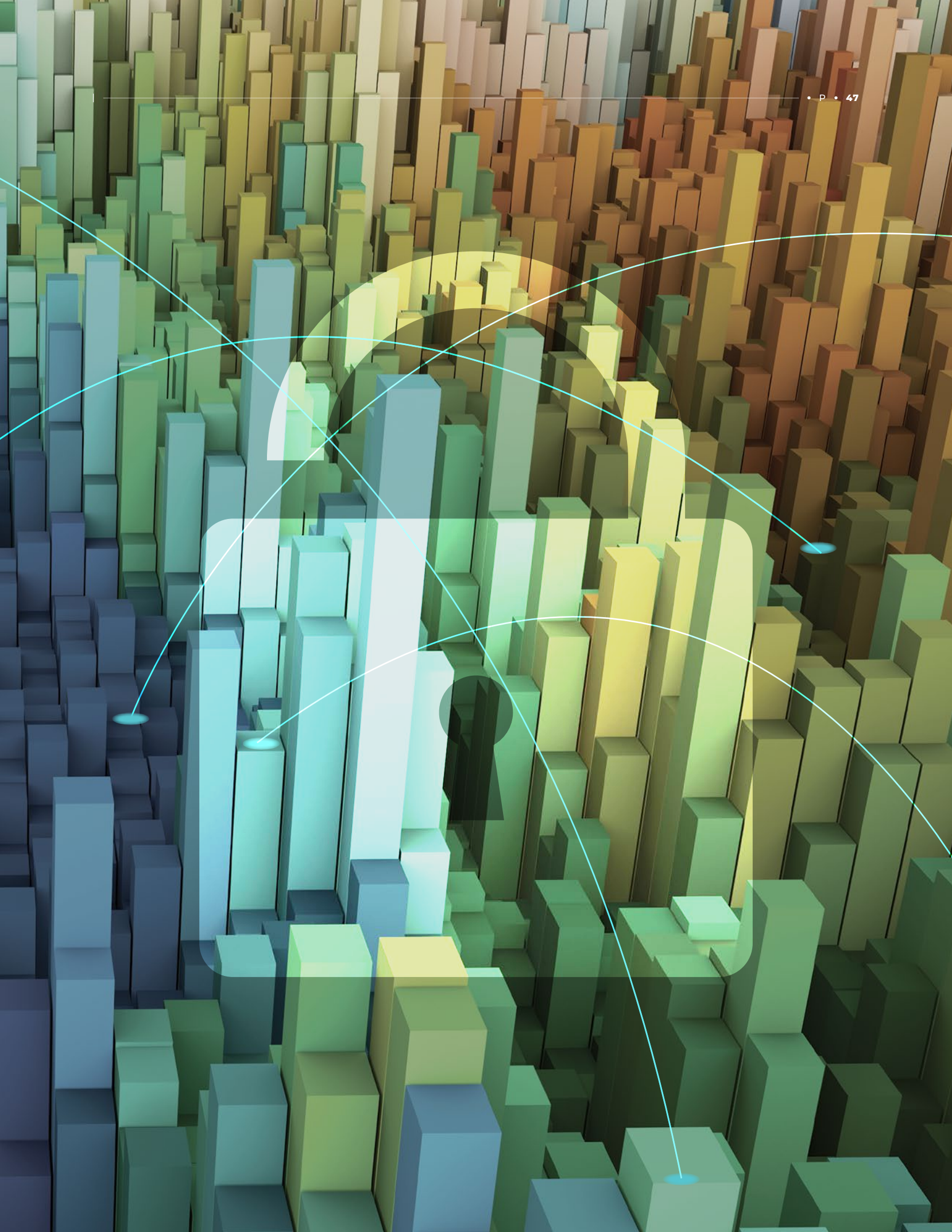
Today, more than half of the world's population lives in cities, and by 2050 this percentage is expected to rise to nearly 70 percent.

In parallel to rapid growth in urbanization, technological progress has led to the mass proliferation of digital information about people, places and things that can be rapidly transmitted and analyzed with increasingly powerful networking technologies and analytical tools. This digital proliferation is synonymous with the internet-of-things, or IoT, and has converged with urbanization to create the paradigm of "smart" cities.

A smart city is not just technologically advanced; it is a platform for the sustainable and inclusive enhancement of nearly all aspects of society. However, achieving such positive outcomes as smart cities evolve is not a simple task. »»

IMAGE: Freepik

⊙ **RIGHT:** Smart cities leverage technology to enhance various aspects of society



THE EVOLUTION OF SMART CITIES

While urbanization and technology have laid the foundation for smart cities, the COVID-19 pandemic that emerged in 2020 may ultimately shape long-term implementations.

As a result of social-distancing mandates implemented to mitigate disease spread, smart-city technologies and services for health care, work, education, retail, finance, security, entertainment, food services, mobility and essentially any other activity requiring human interaction have undergone both acceleration and transformation.

Although the fundamental architecture of smart cities remains centered around an IoT foundation upon which applications are built for defined use cases, the use cases themselves have both evolved and accelerated in their implementation.

In health care alone, activities such as telemedicine, contact tracing, public health messaging, mobility pattern analysis and robotic patient care have emerged and begun to transform the notion of health-care delivery from one of in-person interaction to one of digital engagement.

Likewise, urban transportation is seeing significant changes due to changing social practices resulting from the pandemic and government policies being implemented for pandemic recovery. Digital technologies will play a key role in these changes as efforts to re-establish demand for public transportation increasingly focus on flexible transit scheduling and planning and the development of multimodal digital platforms that integrate public transportation with bikes, scooters, ride-hailing and other mobility modes.

In short, even the most established smart cities face the innovation challenge of re-imagining city operations for a new era of heightened concerns for health and resiliency, the latter of which additionally factors into climate-change considerations.

Similar to the COVID-19 pandemic, climate change is now generally recognized as a globally disruptive and destructive issue that must be mitigated through increased government efforts that include the design, implementation and operation of smart cities.

While the noted trend toward increased city intelligence through digitalization affords many opportunities for improving the lives of citizens, it also creates a number of security concerns.

The rapid growth in digital-information collection, storage and use has opened up multiple new attack surfaces for cyberterrorism, cyberwarfare and cybercrime. While cyberterrorism and cyberwarfare often have social and political motivations, cybercrime is tied largely to commercial and economic interests and can impart significant financial costs on victims.

Indeed, the financial impact of cybercrimes is expected to amount to as much as U.S.$6 trillion in 2021, considering damage and destruction of data, stolen money, lost productivity, theft of intellectual property, theft of personal and financial data, embezzlement, fraud, post-attack disruption to business operations, forensic investigation, restoration and deletion of hacked data and systems and/or reputational harm.

This considerable cost is expected to rise to as much as U.S.$10.5 trillion by 2025 as the storage of digital data rises in the coming years. The accumulation of digital data has only hastened as a result of the COVID-19 pandemic as the extent of consumer online interactions has been accelerated by three to four years and the extent of business product and service digitalization has been accelerated by six to 10 years.

The rapid, and now accelerated, pace of digital activity places a great burden on smart city infrastructure as operational technologies (OT) and information technologies (IT) converge to offer new services and capabilities.

Legacy OT systems that are not secure combined with the proliferation of novel, but insecure, digital devices combine to make cybersecurity and cyber resilience urgent for smart cities.

Preservation of the confidentiality, integrity and availability of information in cyberspace coupled with the capacity for rapid recovery from cyber incidents must sit at the top of cyber-secure and cyber-resilient smart city agendas.

A FORWARD-LOOKING AGENDA FOR SMART CITIES

The sharing of international expertise, technologies and best practices can play an important role in achieving cyber-secure and cyber-resilient smart cities.

The United Arab Emirates, Singapore and Israel are highly urbanized countries that are aligned in their ambitions for innovation and security in the urban context. While each country scores highly in international innovation rankings, Singapore is particularly advanced in smart city technology while Israel is a global leader in cybersecurity innnovation.

The UAE has rapidly built smart city visibility, particularly related to developments in the emirates of Abu Dhabi and Dubai, and has visible initiatives to ensure that these cities are cyber-secure and -resilient, including the 2020 formation of a Cybersecurity Council headed by a recently appointed government head of cybersecurity.

Among emirate-level initiatives, Dubai has established a Cyber Security Strategy. In Abu Dhabi, the Advanced Technology Research Council (ATRC) was formed in 2020 and set forth a research-and-development strategy that puts cybersecurity at the forefront by including cryptography, digital security and secure systems as three of seven top priority research areas.

An agenda for smart city collaboration among the UAE, Singapore and Israel would certainly involve the exchange of best practices regarding legal and regulatory frameworks as well as engagement in technology investment and trade.

However, ecosystem development is what underpins long-term sustainability, hence international collaboration should entail targeted initiatives addressing human capital, R&D and innovation. Human-capital development is very important given the growing shortage of skilled cybersecurity manpower. R&D supports the development of human capital and further brings value to the development of cutting-edge approaches to smart city services, security and resiliency.

R&D topics of particular merit within the cybersecurity context include protecting edge devices, applying artificial intelligence techniques, applying blockchain and, in the coming years, implementing quantum technologies. Innovation further builds on human capital and R&D advances to establish commercially viable new technologies tailored to applications.

On this latter point, R&D and innovation collaboration may focus on specific smart city sectors of common interest and growing importance. Given that both health care and transportation are being re-imagined as a result of COVID-19, focused initial collaboration efforts in these domains, for instance, could lead to large rewards for all involved.

Urbanization and technological trends make the rise of smart cities inevitable. Smart cities, however, will inherently face threats and challenges. Collaboration among countries that have common interests in securing a successful future for their smart cities can help mitigate these threats.

The UAE, Singapore and Isreal are three countries that can reap the benefits of collaboration through a holistic partnership that addresses human capital, R&D and innovation while taking into consideration applications with both near- and long-term importance.

PHOTOS: Shutterstock

Steve Griffiths is the senior vice president of Research and Development and professor of practice at Khalifa University of Science and Technology.

BUILDING A BETTER CONCRETE

Graphene could make the high-emission construction material greener and stronger

By: **Suzanne Condie Lambert**

PHOTOS: Unsplash

Of the major carbon producers, aviation often gets the most attention. But underneath the soaring aircraft are the buildings, driveways, bridges, dams and sometimes roads that are made from an even bigger offender: concrete.

The building material accounts for at least 8 percent of the world's total CO2 emissions. The aviation industry produces about 2.5 percent, although estimates vary.

Most of the concrete emissions are produced when limestone (calcium carbonate) is heated with clay to about 1,400 degrees C in a kiln to make cement, a key ingredient.

The heating process fuses the calcium carbonates into calcium silicates, or as they're known in the industry, clinker.

Clinker is the binding agent that gives concrete its structural properties. But the process also produces CO2. And a lot of it. About 650 to 900 kilograms of carbon dioxide are produced and released into the atmosphere for every ton of cement in this process.

According to the International Energy Agency, cement production increased about 1.5 percent a year from 2015 to 2021, with demand expected to only increase worldwide. But for net-zero goals to stay on track, the agency says, the industry needs to see 3 percent annual declines by 2030.

An innovative material

Strategies for reducing those emissions include improving energy efficiency; using lower-carbon fuels; making the process more efficient so less scrap is produced; and switching to construction techniques such as pre-cast modules that reduce concrete use.

Another strategy: using innovative materials to make a better concrete. One innovative material that is showing promise in the concrete industry is graphene, a single layer of carbon atoms that form a hexagonal lattice. Graphene is light, flexible, tough and has high resistance. It's 200 times stronger than steel and five times lighter than aluminum.

And it passes many of those properties along when added to concrete, also reducing the amount of CO2-producing clinker needed without diminishing performance.

A team from the UK's Exeter University in a 2018 paper found that such nanoengineered concrete showed "an unprecedented range of enhanced properties when compared to standard concrete. These include an increase of up to 146 percent in the compressive and 79.5 percent in the flexural strength."

The researchers also reported a decrease in water permeability by 400 percent, suggesting that the composite material might be ideal for structures in areas subject to flooding. And there was more.

"Including graphene we can reduce the amount of materials required to make concrete by around 50 percent – leading to a significant reduction of 446kg/ton of the carbon emissions," co-author Monica Craciun said in 2018.

More recently, a team of researchers from French and Polish universities in 2021 concluded that integrating graphene-family materials into concrete could impart functions that might enable smart and multifunctional buildings. Used as a sensing material, graphene might help buildings monitor themselves for damage.

Overcoming obstacles

Although the Exeter team was bullish about the potential for graphene additives, it also encountered issues that made wide-scale implementation difficult. It found dispersing the material into the dry cement matrix expensive, complex and difficult to scale up. »»

Timber might be the new concrete

In the race for more sustainable building materials, wood is making a comeback.

Of course, it isn't old-style timber. Mass timber – engineered wood products created from layers of wood bound together – is being increasingly seen as a more environmentally friendly alternative to steel and concrete.

Proponents of the technology point to its aesthetics, structural strength and ease of construction. There's also a lighter carbon footprint.

"The amount of energy to produce mass timber is a fraction of what it would be to produce the same materials in steel or concrete," Antony Wood, director of Tall Buildings and Vertical Urbanism at the Illinois Institute of Technology and president of the Council on Tall Buildings and Urban Habitat, tells BBC.com.

And there's another benefit. "While it's producing itself, it's sequestering carbon out of the atmosphere."

Storing carbon in concrete

A better way to sequester carbon may be as close as your sidewalk. Two companies, Heirloom Carbon Technologies and CarbonCure, in early 2023 tested a process to inject recovered CO2 into freshly poured concrete.

It was a small test, using only about 37 kilograms of carbon, but the process shows promise that, if scaled up, it could help the concrete industry reduce its footprint, they say.

"In the broader carbon-removal ecosystem, this is meaningful," Anu Khan, of the environmental group Carbon180, tells the Washington Post. Finding a way to permanently store carbon is a major bottleneck, she says.

First Graphene, a company that originated with support from the University of Adelaide in Australia, however, has been working to solve the issues identified by the 2018 research.

"We are advancing commercial-scale trials into strengthening cement/concrete and reducing the CO2 emissions," Michael Bell, First Graphene's managing director and CEO, tells *KUST Review*.

These trials are expected to show how much clinker reduction can be expected. That, combined with increased strength that might lead to thinner cement slabs and panels, will give better information about how much CO2 reduction the material can provide.

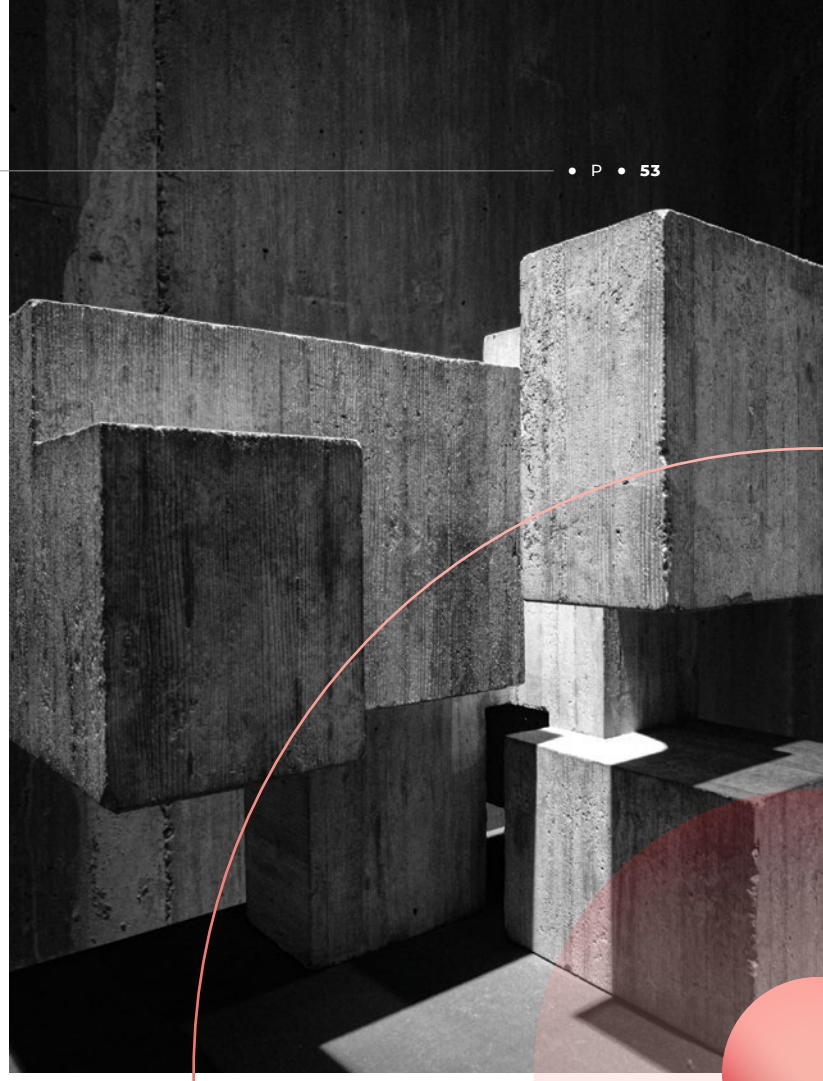
First Graphene also collaborated with Australia's Wollongong University and an Australian municipal water authority to investigate how using graphene-enhanced materials might prolong the life of wastewater pipes. They published their results in 2022.

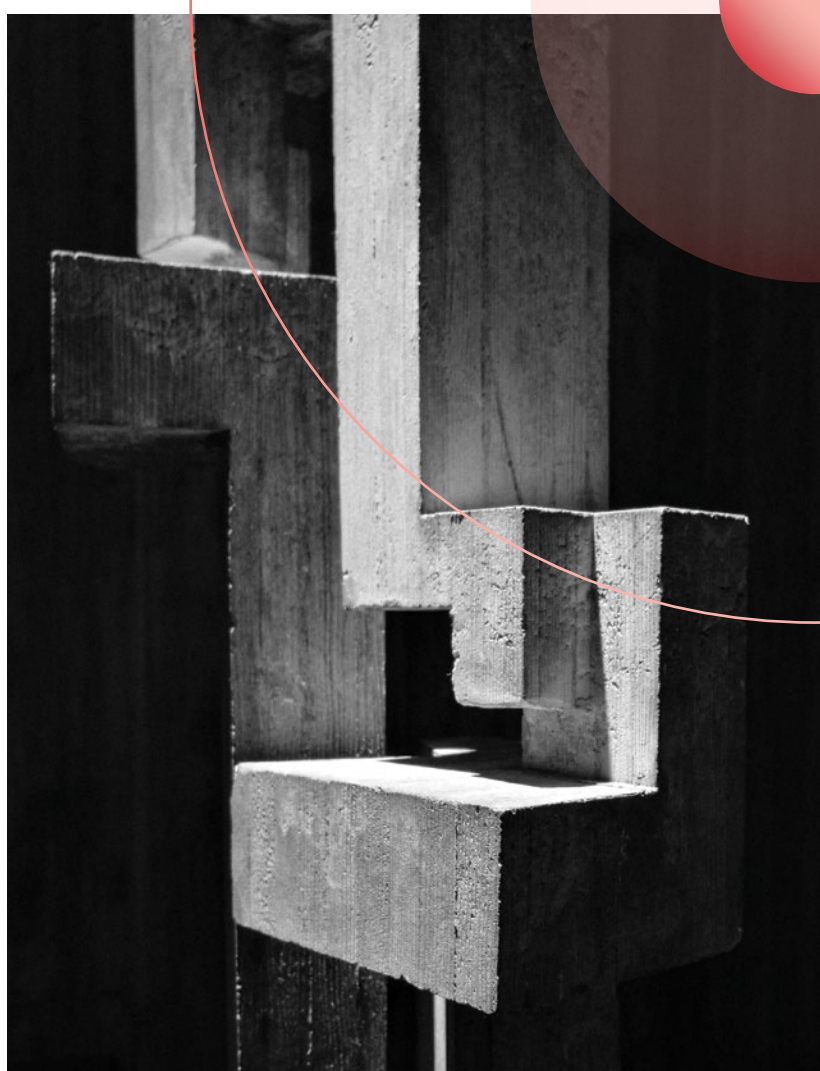
"This was positive in showing graphene's strength-increasing capability and also improved resistance to sulphate and chloride erosion," Bell says.

Challenges in the Middle East

Khalifa University is also looking at ways to improve concrete performance with graphene, and the material shows promise under the GCC region's severe conditions of humidity, temperature and salinity, says Hassan Arafat, the senior director of the university's Research & Innovations Center for Graphene and 2D Materials.

"Graphene is known to be highly hydrophobic, which means it repels water and is not easily affected by high-humidity environments," Arafat tells *KUST Review*. "This property makes graphene a promising material for improving the durability of concrete in high-humidity environments. »»





In fact, research has shown that graphene-enhanced concrete has increased resistance to water absorption, which can reduce the potential for corrosion of steel reinforcement in the concrete."

Temperature is also a factor, as concrete poured on hot days can shrink and crack. Arafat cites studies in *Construction and Building Materials (2019) and Composites Part B: Engineering* (2020) that suggest graphene can improve concrete's performance at high temperatures.

"Overall, the potential benefits of using graphene in concrete are vast and could have a significant impact on many different industries," Arafat says. "As research in this field continues to develop, it will be interesting to see which industries will be the first to adopt this technology and benefit from its unique properties."

Among the industries he sees potential for:

Aerospace: "Graphene-enhanced concrete could be used to construct lightweight and durable structures for spacecraft, satellites and other aerospace applications."

Energy: "This could lead to the development of more efficient and durable infrastructure that is better able to withstand harsh environmental conditions."

Infrastructure: The use of graphene in concrete could improve the durability and lifespan of roads, bridges and tunnels, he says.

More research is needed, Arafat stresses. "There are still challenges that need to be addressed in using graphene as a concrete additive, such as the cost of production, the potential toxicity of graphene, and the need to optimize the amount of graphene used in the mix to achieve the desired performance.

These aspects are dependent on the region and its local conditions and applied concrete mixes. "Our research center is working to explore the full potential of these materials and develop new applications that could have a significant impact on our Emirati society and beyond," he says.

Graphene is known to be highly hydrophobic, which means it repels water and is not easily affected by high-humidity environments.

— Hassan Arafat

16 MILLION CUBIC METERS

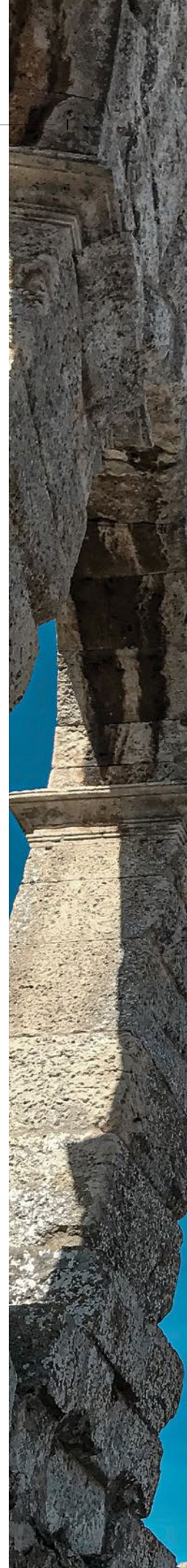
The heaviest concrete project in the world is the Three Gorges Dam across the Yangtze River in China, with 16 million cubic meters.

SOURCE: nationalgeographic.com

18 BILLION METRIC TONS

More than 18 billion metric tons of concrete are used a year.

SOURCE: EKA Concrete



THE ROMANS DID IT BETTER

While modern concrete can crumble in 50 years or less, Roman concrete construction has stood for thousands of years in a variety of climates and seismic zones.

Some examples still hold up in direct contact with corrosive seawater. A team of researchers wanted to know why. The team, with members from the United States, Italy and Switzerland, took samples from Italian archaeological site Privernum. They found that white chunks called lime clasts, previously dismissed as evidence of sloppy mixing or poor construction materials, may give the material the ability to heal cracks.

The findings suggest that using quicklime – rather than or in addition to the slake lime commonly used today – combined with a high-temperature process called "hot mixing" creates the lime clasts and a more durable material.

To test their theories, the researchers made two samples of concrete: one with the Roman-style formula, the other from a modern recipe. Each sample was deliberately cracked. Two weeks later, water passed through the modern concrete but was stopped by the Roman variety.

The researchers theorize that the lime clasts dissolve into cracks when exposed to water, then recrystallize, preserving structures over time.

They also suggest that adapting the formula for modern construction could lead to more durable, resilient and sustainable builds that could help shrink the carbon footprint of concrete around the world.

A FAIR WIND

Emissions-free offshore farms show promise for energy production and economic growth

By: **Maggie Kinsella**

Offshore wind farms could potentially produce more energy than the world currently consumes, but procedures, permits and regulatory administration present challenges.

A 2019 report by the International Energy Agency estimates that the offshore wind potential is equivalent to approximately 18 times the global energy expenditure.

And this industry is growing: Many countries around the world are developing offshore wind farms and investing in the sector. By 2030, an estimated 35 countries will have offshore wind turbines — nearly double the number of countries participating today.

Global Market Insights report the "offshore wind energy market passed U.S.$47.5 billion in 2022," and estimates a compound annual growth rate in excess of 16.2 percent between 2023-2032.

Rebecca Williams, global head of offshore wind at the Global Wind Energy Council (GWEC), believes offshore wind will be at the heart of the world's energy system by 2050.

And for good reason. First, they are emissions-free. No wildlife is displaced as wind farms don't need large land masses, and there are no neighbors to bother with noise pollution. Plus, being offshore, they aren't subject to the dying winds that plague land turbines. Higher wind force and consistent movement means more electricity.

Environmental perks aren't the only benefits offshore wind farms provide. Experts see potential for economic growth in this sector, possibly creating millions of jobs globally. However, in order to achieve the 1.5-degree global temperature increase limit set out by the 2015 Paris Agreement, offshore wind turbine production would have to quadruple, according to the energy council. »»

MANY MARKETS NEED TO BUILD A SECTOR FROM THE VERY BEGINNING.

Rebecca Williams

PHOTOS: Shutterstock, Unsplash

"Offshore wind is at the very center of global ambitions to deliver a fossil-fuel free future that limits global heating to 1.5C," the council's Williams says. However, to achieve this, "global capacity should exceed 365 GW by 2030."

The International Renewable Energy Agency agrees, requiring a further growth to an estimated 2 terawatts by 2050 to meet the 1.5C goal. However, current pace of development suggests global production will achieve only 66 percent of this target by 2030.

Even countries rich in other resources are looking into offshore wind's potential.

In the UAE, the government's renewable-energy company Masdar and the National Petroleum Construction Co. in 2022 entered into an agreement to investigate the technology.

"By leveraging each other's world-class expertise in our respective fields, our combined efforts could play a vital role in achieving the UAE's clean energy objectives and support our nation's net-zero commitment," Mohamed Jameel Al Ramahi, Masdar CEO, says in offshorewin.biz.

Masdar also has a stake in the Hywind Scotland offshore wind farm and in 2022 signed an agreement with Cosmo Energy Holdings Co. to explore offshore wind projects in Japan. Hywind is the world's first floating wind farm. Offshore wind energy faces obstacles, however.

The farms are difficult to build in deep waters. They are expensive, hard to maintain and risk damage from high waves and winds during storms. Hitting the 2 terawatt target would translate to roughly U.S.$500 billion in capital expenditure this decade, and U.S.$3 trillion by 2050, according to Williams.

Currently, two types of offshore turbines are in use — those that are fixed to the ocean floor and those, like Hywind, that float. The deepest fixed-bottom turbine currently reaches a depth of 57.4 meters. This means they need to be closer to shore in shallower waters.

Floating turbines, however, can be built in much deeper water. Turbines in deeper water and farther offshore generate significantly more power, utilizing high, consistent winds and have no barriers nearby to block them.

Because so much more power can be generated from these deep-water titans (some stand over 490 feet tall), a lot of time is spent minimizing the challenges they face. One such challenge is hurricanes.

In search of a possible way to mitigate this risk, a team of researchers at the University of Colorado recently collaborated on a new blade design inspired by something that handles strong storms well — the palm tree.

The design uses lighter materials, which could bring down the cost and leave the structure less vulnerable to damage in high winds. It could also make it possible to have one big turbine as opposed to many smaller ones. This would reduce installation and material costs.

The team also hopes that its design will outlast current turbines, which have a lifespan of approximately 20 years. While protecting turbines is a priority for some, other countries battle to get projects off the ground due to governmental regulations.

A country like Vietnam, for example, with a lengthy coastline of over 3,000 kilometers and winds that can reach up to 10 meters per second, has the potential to be the leader in offshore wind in Southeast Asia.

But a 2022 study by the International Renewable Energy Agency estimates the process to get from the beginning phase of a project to actual operation is approximately seven years — the first five years of which is simply project development.

"Many markets need to build a sector from the very beginning," Williams says.

One of the major hindrances to acquiring approvals is uncertainty about the effects on marine life. Development in offshore wind energy may offer a limitless supply of energy but protecting the oceans' ecosystems is also important.

⊙ **RIGHT:** High, consistent winds in deep water help turbines generate more power than those on land or close to the shoreline.

OFFSHORE WIND ENERGY MARKET PASSED U.S.$47.5 BILLION IN 2022.

Global Market Insights

Currently, information about the impacts of offshore wind farms on marine life is sparse or conflicting. A 2022 study by a team at Basque Research and Technology Alliance suggests that more data is needed.

The team proposes the full impact will be known only when more studies are done across greater-sized areas — currently most publications are based on studies on small areas, quite close to the shore, and farms with few turbines. It also recommends monitoring specific and protected ecosystems.

One organization that is working to ensure the protection of marine life from offshore wind development is U.S. National Oceanic and Atmospheric Administration. It works to provide wind developers with research on marine-life impact that can assist with decisions on where to build, the construction process, and functionality once the farm is up and running.

Overall, Williams is positive for the future of offshore wind farms, both floating and fixed: “There are challenges in delivering on this huge potential, but the sector is also a beacon of hope for international collaboration that delivers climate action.

Initiatives like the Global Offshore Wind Alliance, which was founded by GWEC, (the International Renewable Energy Agency) and the government of Denmark, are bringing together countries all over the world, with big and small offshore markets, to share expertise and knowledge that will help make potential clean energy into actual clean energy.” ●

Closing the loop

Dubai company reduces plastic waste, educates the public

By: **Maggie Kinsella**

Kris Barber, owner of Dubai company DGrade, has been working in textiles most of his career, but it was his love of surfing that fueled a desire to rid the world's oceans of plastic. He just never guessed he'd end up wearing it.

Barber, a U.K. native, over time noticed an increase in plastic waste in the oceans. This is why he decided to make a shift from full-time textile production to sustainable textiles.

"When I came across the technology to convert plastic bottles into clothing, I began to see that recycling could be a significant way to decrease plastic pollution and also provide a sustainable solution for textile production," he tells *KUST Review.* »»

with textiles

IMAGES: Shutterstock, Supplied

He also began organizing beach clean-ups and recycling drives to get his community involved.

It was in 2010 when Barber moved with his wife to Dubai and discovered there were no options for sustainably made clothing that he started DGrade. “At that time there was very little interest in recycling and sustainability in general, but I knew the market would shift,” he says. “I saw there was a gap in the market for sustainable clothing supply and a necessity for plastic recycling programs.”

DGrade, an eco-clothing company based in Dubai, developed its trademarked Greenspun yarn, in which plastic water bottles are converted into polyester yarn. The plastic flakes are used to create yarn and ultimately fabrics. The Greenspun yarn produces 55 percent fewer carbon emissions, uses 50 percent less energy and 20 percent less water and doesn't require any oil compared with making conventional polyester yarn.

“We can produce more than 200 types of fabric including jersey, quick-dry, twill and denim to make customized clothing and accessories for our (business-to-business) customers. We manage this production process through our supply-chain partners,” Barber tells *KUST Review.*

While many other companies around the world are creating fabric out of plastic and those fabrics are being used by household brands such as Nike and Patagonia to create product, DGrade offers full-service partnerships to its business-to-business clients. This means DGrade does it all — from placing the bins to collecting plastic to producing specific clothing items for businesses and then offering advice on possible next phases for the items — thereby assisting its clients with closed-loop recycling.

Closed-loop recycling is the process of collecting goods and reprocessing or recycling them into new, usable products.

Once the clothing is no longer wearable, DGrade encourages its partners to take advantage of clothing charity bins placed around the city. The discarded clothing is passed on to communities, or if not in good enough condition to be re-worn, is shredded and used as filling for pillows and mattresses or made into carpets. One of DGrade’s partners is YAS Marina Circuit in Abu Dhabi. DGrade collects used water bottles from the venue and events and recycles them at the DGrade Recycling Factory.

ABOVE: Kris Barber started DGrade in Dubai to create sustainable textiles and help keep plastics out of the world’s oceans. "When I came across the technology to convert plastic bottles into clothing, I began to see that recycling could be a significant way to decrease plastic pollution," he says.

DGrade also supplies uniforms made from recycled plastic bottles for the Yas Marina Circuit team. This helps the track lower its carbon footprint. DGrade also has a stand set up in the sustainability area during the Abu Dhabi Grand Prix where it can educate the public about closed-loop recycling.

“Through this partnership, Yas Marina Circuit can demonstrate that they divert more than 50,000 plastic bottles from landfill during the Formula 1 event, saving energy, water and carbon emissions,” he says. Every Greenspun T-shirt created saves 25 plastic bottles from landfills, he adds.

Though DGrade participates in initiatives like the Yas Marina’s, there is still a lot to be done to reduce plastic waste. In the UAE alone, 4 billion plastic water bottles are manufactured annually, and less than 8 percent are recycled — that means 320 million water bottles end up in landfills every year. Of these, the DGrade Recycling Factory managed to repurpose 60 million in the first six months of 2022. This is due in part because of its Simply Bottles program.

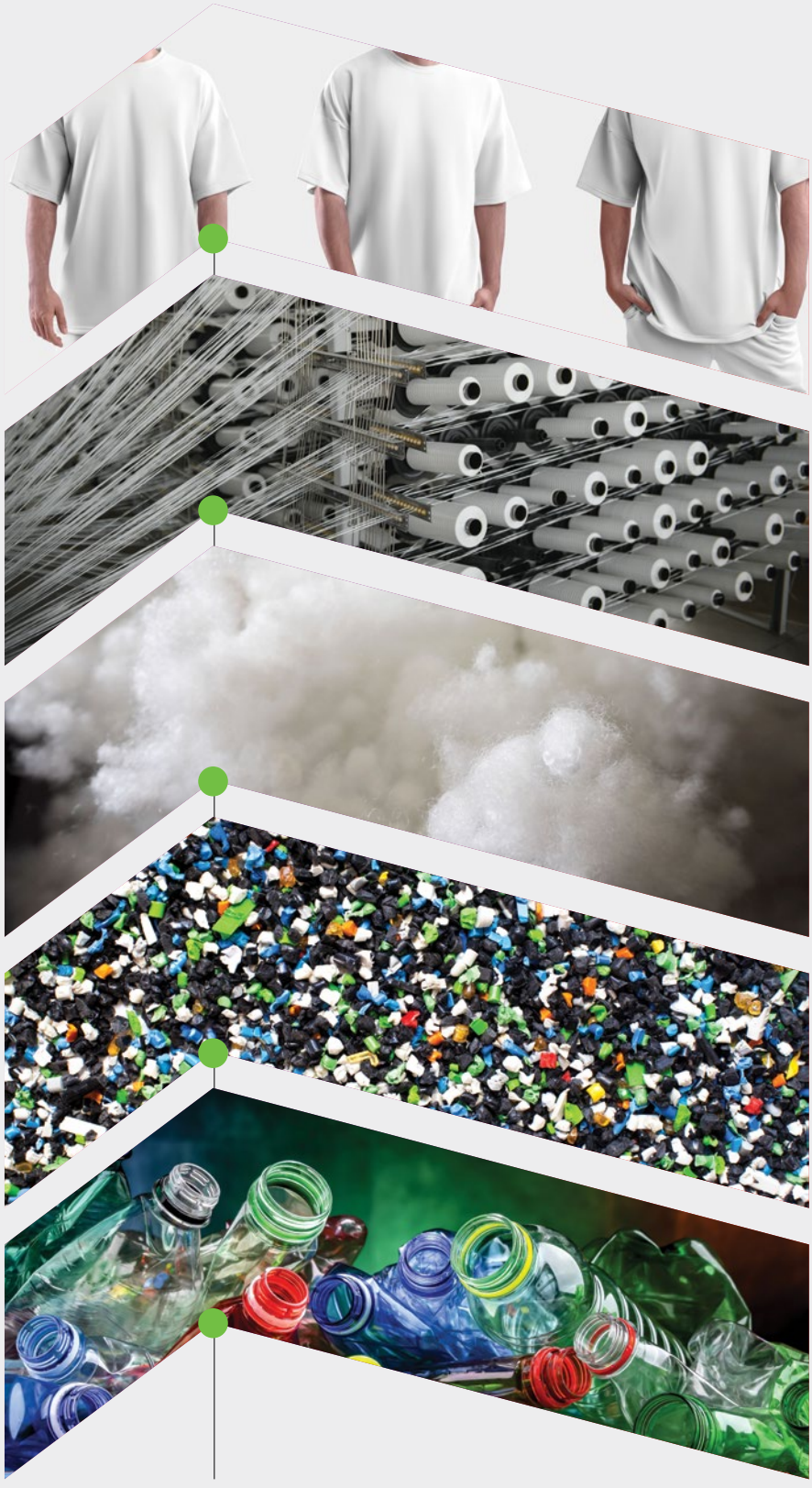
Simply Bottles works with schools and communities to ensure waste made with Type 1 plastic — typically used for water, juice or food containers — is recycled. Participants can choose their level of involvement ranging from

collecting plastic to learning about the impact of plastic waste on the environment. More than 250 schools across the UAE participate in the program. Simply Bottles also works with universities, events, hotels and corporations — like Yas Marina Circuit. “We believe that DGrade can and will play a significant role in helping the UAE government reach their waste and recycling goals for 2030 by facilitating collection and raising awareness of plastic recycling and a closed loop through our Simply Bottles program,” Barber says.

DGrade has been recognized by the Gulf region on numerous occasions. Awards include Best Sustainability Education or Awareness Program (the Gulf Sustainability Awards); silver in Sustainable Project of the Year (Prime Awards Middle East and Africa); and Most Innovative Technology Product for its Greenspun Yarn (International Business Magazine).

What’s next for DGrade? As the UAE prepares to host the COP28 in November–December 2023, it plans to assist companies with green initiatives. This includes working with them to recycle plastic bottles, delivering employee education and engaging activities to their teams through its Simply Bottles program, as well as supplying sustainably made uniforms

“DGrade is committed to combating pollution by providing sustainable solutions for plastic and textiles. We do our utmost to contribute to a sustainable future every day through our actions and business model. However we also believe that collaboration and commitment from businesses, government and communities is essential to ensuring a sustainable future for generations to come,” Barber says.



THE PROCESS: Used bottles are collected, washed and shredded; the plastic flakes are heated and turned into polyester fibers; the fiber is spun into yarn; and finally the yarn is woven to make clothing and accessories.

يا للتحلية جميد

ICE, ICE BABY

Freeze desalination may be nature's lower-energy solution to the world's water woes

By: **Jade Sterling**

Life on planet Earth needs water. Fresh water. Water scarcity affects one-third of the world's population, approximately 2.3 billion people, with this water crisis tipped to become more acute over the next 50 years as the global population increases.

Yet water covers nearly three-quarters of the planet. It's salty and unpotable, but a practical, economically viable desalination process could be the answer to our collective thirst. The most popular method of desalination is reverse osmosis, where large quantities of seawater are pushed through a semipermeable membrane to remove the salt from the water.

Although an effective means to sieve through and catch the salt and other impurities, this is a high-pressure, high-cost process requiring robust pumping and expensive pretreatment.

It's energy-hungry, and while the process has steadily improved and evolved, there are systemic problems, including polluting chemicals, membrane fouling, capacity limitations and expensive construction materials. Freeze desalination, on the other hand, is a natural process: Ice made from saltwater is salt-free.

Isam Janajreh, professor of mechanical engineering at Khalifa University's Center for Membranes and Advanced Water Technology, says freeze desalination technology has the potential to avoid common desalination challenges: "Desalination is the solution for water security in regions with insufficient resources but this comes at a high energy cost. Freeze desalination is emerging as an attractive low-energy and less corrosive alternative to providing fresh water."

Freeze and repeat

The process is simple: Partially freeze the water, during which ice crystals form and grow, displacing impurities into the remaining brine solution. Separate the ice blocks from the brine, wash them off, and melt them back down again to provide clean water.

The salty brine can then be frozen again, forming more ice and another more concentrated brine solution. As the salinity increases, the freezing point dips until it reaches the point where salt crystallizes simultaneously with ice.

So far, however, the process has been limited to laboratories and small pilot plants. Janajreh says this is due to the incurred capital cost and the complex operation of separating the ice and melting it.

"The process of salt rejection during the process is still far from being completely understood, especially when the parameters change. One big challenge is salt entrapment between the ice crystals making a super salty saltwater pocket in the ice. This requires further treatment and recrystallizing, which just raises operating costs."

Abdul Najim, of the Indian Institute of Technology Bombay, says this is the essential requirement for developing the technology — understanding the process of crystal growth to avoid the saltwater pockets.

"This is a process difficult to study analytically. Numerical models can enable the analysis and visualization of different transport processes and computational fluid dynamics (CFD) modeling can also be a valuable tool," he says. Najim also says efforts should be directed toward hybrid models where crystallization, ice separation and thawing are carried out in a single unit.

This requires novel crystallizers that can be scaled to industrial capacity — quite the engineering challenge right now. Moving from a batch-mode model to uninterrupted potable-water production should also be the focus of research in this area.

Freeze desalination may be a process seen in nature, but converting it to a manmade industry will still require a lot of energy. Janajreh says freeze desalination needs just half the energy conventional reverse osmosis consumes, but that's still a tall order.

Pair the process with the cold energy from regasification of liquefied natural gas (LNG) and you could have a solution. Or, stick with batch production and use your home fridge/freezer as Fekadu Melak did.

Removing other contaminants

PHOTOS: Unsplash

Melak, assistant professor of environmental biotechnology at Bahir Dar University, Ethiopia, investigated freeze desalination as a water-treatment technology for the tanning industry using home-use freezer units. "Wastewater generated by leather tanning is one of the major contributing sources of chromium pollution in water.

Among the various tanning methods used around the world, more than 90 percent of the leathers tanned globally contain chromium, with 30 to 50 percent of the chromium used in the process leaching into the environment. Freeze-melting and removing the contaminants is an alternative physical process which can be used for desalting."

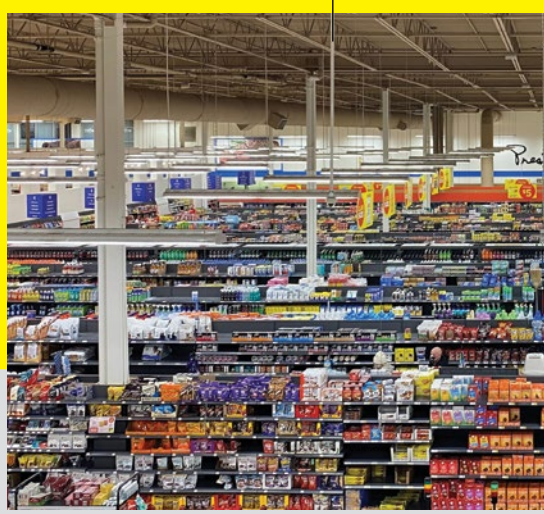
It worked. Melak's study saw efficiency as high as 85 percent for cleaning chromium-spiked tap water, and while technical challenges remain — including washing off the chromium adhered to the ice surface after freezing — the cost of freeze desalination was 50 percent lower than other wastewater-cleaning methods.

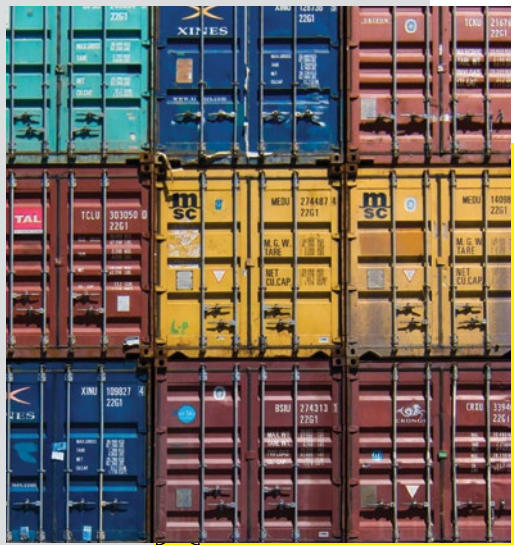
"In terms of the water quality produced and how cost-effective it is, freeze desalination is a pertinent option for a desalination technology," Melak said. Freeze desalination is gaining traction as a research interest but until projects can scale up to industrial levels, it's doable at home.

Ask the experts:

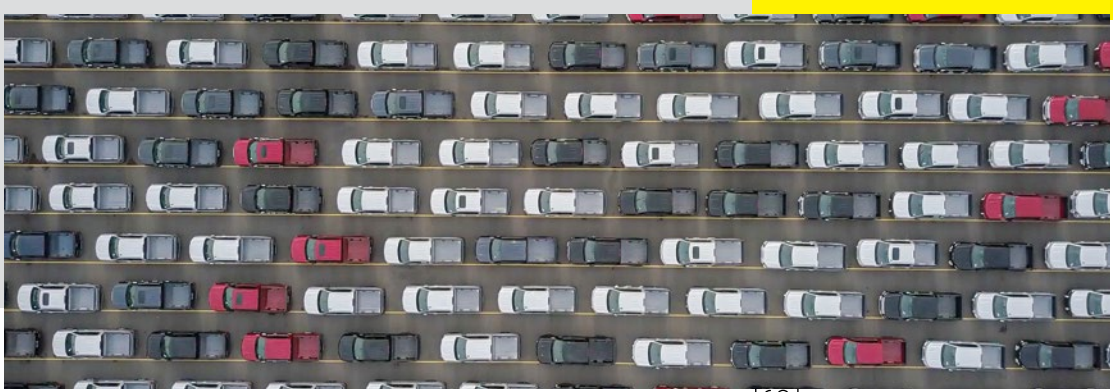
HOW DO WE KEEP THE FOOD SUPPLY STABLE?

3 industry leaders who work in the Gulf region weigh in





In light of the COVID-19 pandemic and other potential disruptions to global supply chains, how can technology be used to help farmers and food producers better anticipate and respond to changes in demand and ensure that food supplies remain stable and reliable? We asked three experts in the field. This is what they said. »»



PHOTOS Unsplash

GRAPHICS Abjad Design

TECH CAN HELP KEEP GULF COUNTRIES FED

One strategy for addressing supply chain disruptions and food crises is through enhancing agricultural output at home and reducing reliance on imports.

For the GCC, the task is particularly challenging due to the region's limited arable land and water resources, and further exacerbated by the impact of climate change. Producers can enhance local agriculture production and ensure food supplies remain stable and reliable by leveraging various technologies, including:

PRECISION AGRICULTURE is a technology that uses satellite imagery, sensors and drones to help farmers optimize their crop growth. By monitoring temperature, humidity and soil moisture levels, farmers can optimize irrigation schedules and significantly reduce water usage.

Using artificial intelligence can improve weed detection and crop-growth efficiency, and administer herbicides and fertilizers at the amount needed, when needed, and where needed, significantly reducing time, costs and the associated environmental impact.

INNOVATIONS IN SUPPLY CHAIN MANAGEMENT such as blockchain ensure food safety and reduce losses throughout the farm-to-table journey by tracking every transaction in the supply chain, including storage conditions, and improve early contamination detection and batch recall.

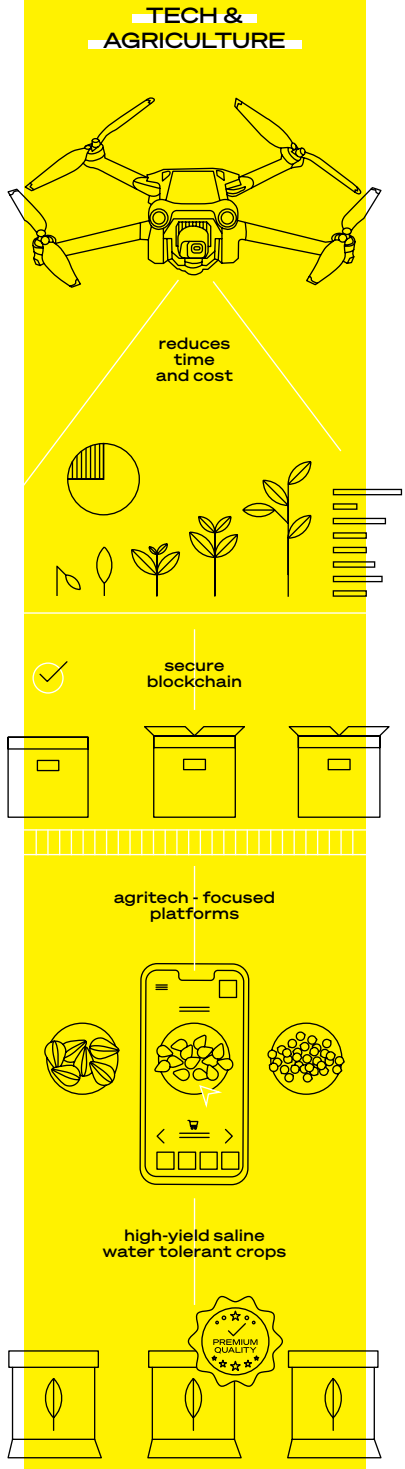
AGRITECH-FOCUSED PLATFORMS provide increased efficiencies in food production. Marketplace applications connect various stakeholders, including farmers, buyers and suppliers, to streamline product and service exchange.

Applications vary from connecting farmers with buyers, equipment suppliers, seeds and fertilizers providers, to providing market data on crop demand as well as weather patterns, which increases efficiency and reduces losses.

INNOVATIONS IN BIOSALINE AGRICULTURE help increase agricultural output through the development of high-yield saline water-tolerant crops. The International Center for Biosaline Agriculture in the UAE conducted significant work toward achieving sustainable food production in a changing climate in marginal environments.

Challenges to adopting these technologies include the relatively high capital costs associated with some applications, resistance from farmers to adopt novel technologies, enabling an updated regulatory framework, and supporting policies that promote the integration of novel technologies in agriculture.

WALID SAAD *is an expert in sustainable production and consumption. He has a Ph.D. in chemical engineering from Princeton University.*



A MORE SUSTAINABLE SUPPLY CHAIN

We have all felt the impact of supply-chain disruptions. Go to your favorite lunch joint. At one point your meal became notably costlier thanks to some distant problem, perhaps a ship blocking the Suez Canal or the ongoing issues created by the pandemic.

The problem isn't just reliability, it is also sustainability. The food system generates over one-third of greenhouse-gas emissions, consumes over 90 percent of fresh water and uses 50 percent of the world's habitable land. The GCC region is particularly exposed, importing 85 percent of its food needs.

Severe as these challenges are, we can use technology to enable the GCC to meet its food needs and combat climate change.

CONTROLLED ENVIRONMENT AGRICULTURE: Control what plants need in a closed environment (light, temperature, humidity, and nutrients) such as by stacking them indoors (vertical farming) or in greenhouses. That way you can grow vegetables in cities near restaurants — no need for lengthy, polluting supply chains. Already, Saudi Arabia's public investment fund has a joint venture with AeroFarms to operate indoor vertical farms.

PRECISION FERMENTATION: Use energy and a handful of ingredients to precision ferment proteins and other food ingredients with minimal environmental impact.

This emerging "energy-to-food" technology is an opportunity for GCC countries. With their cheap, abundant renewables, GCC countries have an advantage as energy is the primary cost driver.

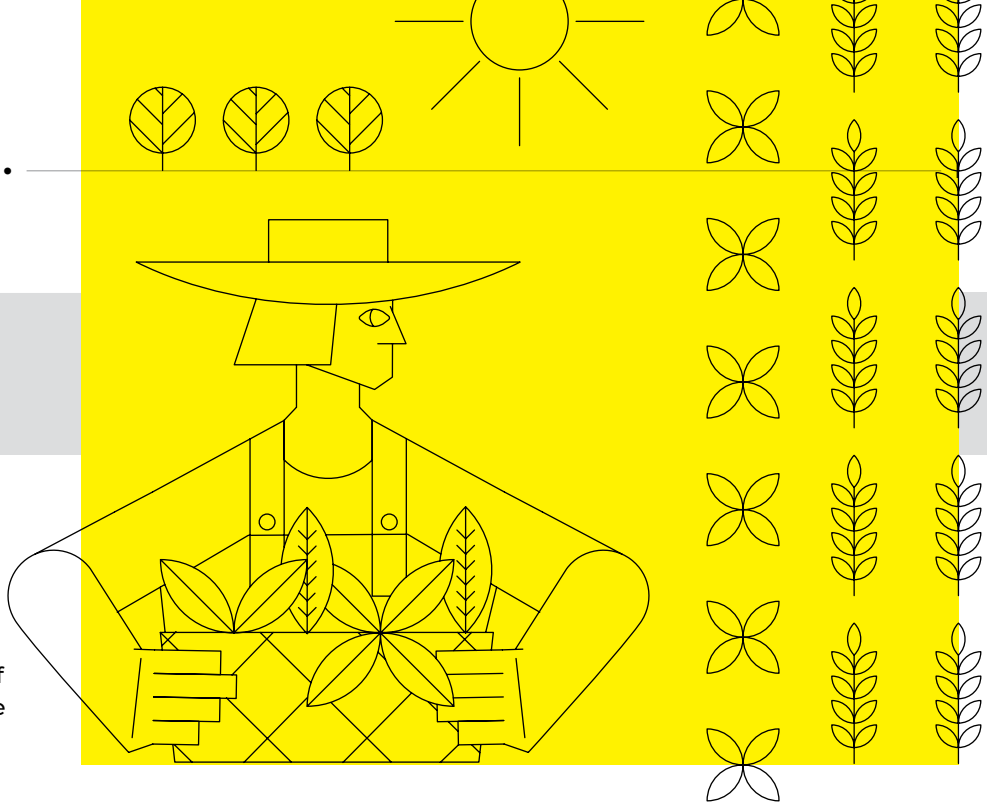
AGRICULTURAL ROBOTICS: Automate fruit-picking, harvesting, planting, transplanting, spraying, seeding and weeding.

DESERT FARMING: Use target irrigation, thereby increasing the soil's water retention capabilities and increasing yields.

SEAWATER FARMING: Use abundant saltwater for agriculture activities and enrich soils in coastal regions.

Today, there is a unique opportunity for universities to play a critical role in accelerating the adoption of such technologies by providing interdisciplinary education, introducing experiential learning and becoming hubs to drive the innovation and prepare the talent of the future. »»

ROGER RABBAT *is a partner with Strategy& and a member of the firm's Government and Public Sector practice in the Middle East. Rabbat has served the senior agenda of leading government organizations on agribusiness privatization programs, agrifood companies establishments, rural development agricultural strategies, agricultural subsidies rationalization and transformation of agriculture services.*



THE BIGGEST IDEA IS KEEPING IT SMALL

As the co-founder of FarmHub, an agtech startup powering hydroponic, aquaponic and aquaculture farms around the globe, I believe that the future of farming hinges on the smart use of technology in fostering small commercial farms.

In sunny regions, where large-scale indoor farming is neither economical nor beneficial, the focus should be on facilitating smaller farms that empower local communities, diversify wealth, and reduce food miles, while enhancing biodiversity in our food offering.

The decentralization of food production through smaller farms not only mitigates risk in the face of global supply chain disruptions, but also offers increased adaptability to changes in demand. FarmHub's journey in the Middle East serves as a testament to this approach, where we encountered and surmounted various challenges.

One of the most significant hurdles was managing change among traditionally minded farmers. It required demonstrating the tangible improvements that technology could bring to crop growth, size, output and quality. By showcasing these results, we were able to change their mindset and bring them onboard with the novel farming methodologies.

In addition, we had to tackle changes in demand. It was not unusual for customers to be skeptical about paying more for higher quality produce. We addressed this by emphasizing the narrative around food insecurity, independence, and the pride in supporting local farms over imported goods. This approach allowed us to shape a new understanding and appreciation for the value of local, sustainably grown produce.

Lastly, we faced the challenge of convincing our clients that they did not necessarily need the most advanced tech available. It was crucial to strike a balance between introducing technology that improved their operations and ensuring the investment cost and operational overhead were not prohibitive.

While the challenges were many, the successful adoption of technology in farming practices and the resultant positive impact on food security and sustainability was a rewarding outcome. I believe that small, technology-empowered farms are key to a more resilient and sustainable global food system.

The optimal strategy lies in harmonizing our agricultural ecosystem. It's easy to get drawn toward the allure of the most advanced AI technology, colossal farms and autonomous food production. However, what truly propels us toward sustainability and resilience are diversified farms, each leveraging technology to enhance their unique modes of food production, tailored to their respective communities' needs.

When farming scales up excessively, the focus shifts from selling locally to exporting, transforming food from a nutrient source to a commodity. To counter this, it's imperative we maintain a close proximity between the sites of food growth and consumption, ensuring we sustain food as a life-sustaining resource rather than a mere tradeable good. ○

JONATHAN REYES *is the co-founder of FarmHub, an agtech startup that leverages technology to empower hydroponic, aquaponic and aquaculture farms worldwide. Reyes' work focuses on enabling sustainable farming practices, improving food security, and combating climate change.*

NEXT ISSUE

Exploration of the solar system and beyond is heating up among governments and the private sector.

GIVE US SOME SPACE

In the **next issue of *KUST Review***, we look at the 2D materials that may make space exploration possible, explore why mushrooms might be the secret to protecting astronauts from cosmic radiation and share stunning photos from some of the Middle East's best astrophotographers.

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CREDIT: Astrophotographer Anas Albounni

DIVING INTO ACTION

The oceans generate **50% of the oxygen we need to breathe**. They also absorb **25% of all carbon emissions** and **90% of the extra heat** those emissions cause.

Mitigating climate change is important. Protecting the health of our oceans is a big part of doing that.

Here are a few projects researchers at Khalifa University's Center for **Autonomous Robotic Systems** are working on to look after ocean health:

25%

RELY ON REEFS

ROBOTS TO AUTONOMOUSLY INSPECT & CLASSIFY THE HEALTH OF CORAL REEFS.

About 25 percent of all marine species rely on reefs at some point in their life cycle. Healthy reefs also protect coastlines from storms and erosion.

IN FOOD PRODUCTION

AQUACULTURE ROBOTS TO AUTONOMOUSLY IDENTIFY DEFECTS IN FISHNETS & MONITOR FISH HEALTH.

Well-managed aquaculture projects can increase food production, boost economic growth in coastal and rural areas and help keep waterways clean.

3

BILLION PEOPLE THREATENED

OCEAN-CLEANING ROBOTS TO LOCATE & REMOVE PLASTICS WASTE IN THE SEABED.

This pollution threatens marine life and human health and endangers the livelihoods of 3 billion people, most of them in developing countries, according to UN.org.

Find more stories about robotics, plastics and ocean health at KUSTReview.com.