

THE FUTURE OF SUSTAINABILITY



The National in partnership with

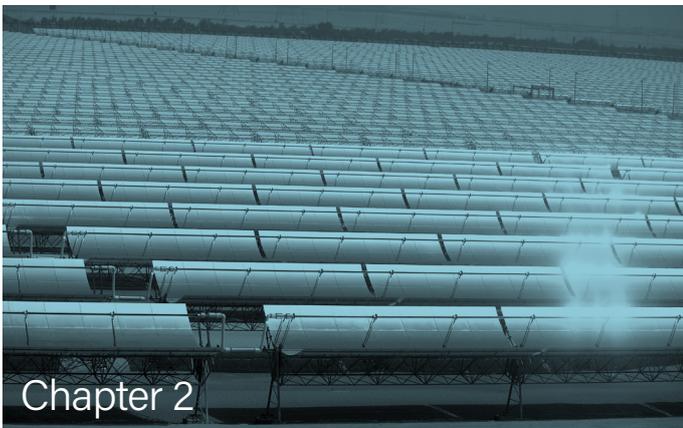
Masdar 
A MUBADALA COMPANY

 **ABU DHABI**
SUSTAINABILITY WEEK  **WFES**

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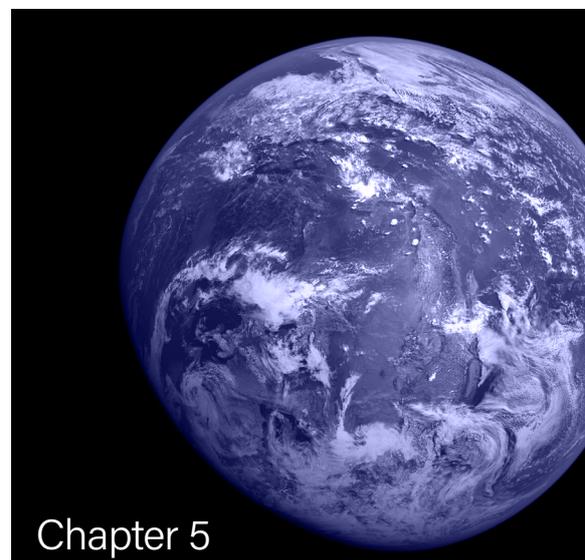
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FOREWORD



**His Excellency Dr Thani bin
Ahmed Al Zeyoudi**
Minister of Climate Change
and Environment

THE WORLD TODAY is witnessing a shift from the business-as-usual paradigm to a more sustainability-conscious one, and the UAE is leading the way, powered by its youth and the seamless collaboration between its public and private sectors.

As they bring their dynamic approach and out-of-the-box thinking to bear on the country's development agenda, the UAE continues to invest extensively in its young people to prepare them to become global citizens and leaders of tomorrow. The nation endorses the view that sustainable development largely depends on the involvement of the young generation.

However, to truly make the innovative ideas of our ambitious youth count and come to fruition, they need the guidance and financial support of the public and private sectors. When partners that complement each other well join forces to work towards a common goal, they can achieve outstanding results. A prime example of this synergy is the Climate Innovation Exchange (CLIX), a Ministry of Climate Change and Environment-led initiative that aims to connect innovative startups with forward-thinking private sector organisations that recognize the potential of investing in disruptive clean technology. Harnessing the power of public-private partnerships to empower young people is a decisive factor in the country's journey towards sustainable development.

This is where platforms such as Abu Dhabi Sustainability Week come into play. Through providing a stage for cutting-edge sustainability concepts and solutions, and enabling networking between entrepreneurs and investors, the milestone event helps the UAE spearhead clean innovation and sustainable development.

We have complete faith in the ability of our young people to realise our vision for sustainability and become agents of change. We are confident that our young generation and the private sector fully comprehend their vital roles in driving innovation and technological advancements to address current and future sustainability challenges. Through our concerted efforts, we can shape a cleaner and greener world.

AS WE ENTER 2019, the global momentum for sustainability has never been greater, with governments around the world uniting to commit to the goals set by the Paris Agreement 2015 and the United Nations' Sustainable Development Goals (SDGs).

While addressing climate change is the shared responsibility of all stakeholders, it is the convergence of various technologies that has given the world a unique opportunity to address global warming and meet its sustainable commitments. The development of a variety of hardware and software technologies – such as the Internet of Things (IoT), electric batteries, cloud computing, machine learning and, as an extension, artificial intelligence – is not only driving business efficiency and real socio-economic change, but also influencing our behavior and the ways in which we consume resources.

Entire industries have been developed around such sustainable technologies, including Masdar, the Abu Dhabi Future Energy Company, which has been a catalyst for the renewable energy industry in the UAE, the Middle East region and around the world. But sustainability is not the job of renewables alone. As the host of Abu Dhabi Sustainability Week 2019, which is being held under the theme of 'Industry Convergence: Accelerating Sustainable Development', Masdar recognises the need to bring the global community together to advance the dialogue on sustainability and drive innovative solutions to address the world's most pressing sustainability challenges. This report reflects our efforts to support sustainable development, consolidating Masdar's knowledge and experience over the past 12 years through our global renewable energy portfolio and our sustainable real estate development, Masdar City.



Mohamed Jameel Al Ramahi
Chief Executive Officer,
Masdar

It aims to shed light on the innovative technologies that governments, leading businesses, industry experts, innovators and academics believe will have the greatest impact to drive industry convergence to address the UN's SDGs, as well as emphasising the critical role youth will play in shaping future businesses and industries sustainably. The pace of technology transformation and discovery has never been so rapid. As this report details, a diverse range of technologies are expected to play a key role in improving lives, transforming industries and safeguarding the planet. Masdar has embraced new growth opportunities that have emerged as a result of technical innovation, such as the Emirates Waste to Energy Company, a joint venture between Masdar and Bee'ah to develop the Sharjah Waste-to-Energy Plant, sustainable agriculture, and floating offshore wind and intelligent battery storage through our collaboration with Equinor that enables the Batwind project to store electricity generated by Hywind Scotland.

I hope you find the report informative and join us in our drive for sustainability as part of our #WeAreCommitted campaign, which has been launched on the back of Abu Dhabi Sustainability Week 2019.

EXECUTIVE SUMMARY

AS PRESSURE MOUNTS over climate change and other important sustainability-related concerns, the individuals, businesses, and governments of the world are being forced to make changes. In the past, while it was possible for people and corporates to see themselves as separate from the causes and issues of climate change, water shortages, and other environmental challenges, research now clearly shows that it is up to every individual, corporation and government to play an active role in securing a sustainable future. With this in mind, both public and private enterprises and their people need to widen their scope and understanding of what sustainability means today, and what their roles are in defining its future. And these changes need to happen fast.

According to the International Renewable Agency's (IRENA) report *Global Energy Transformation: A Roadmap to 2050*, renewable energy needs to be scaled up at least six times faster for the world to start meeting the goals set out in the Paris Agreement on climate change. The report states that "the historic climate accord from 2015 seeks, at a minimum, to limit average global temperature rise to 'well below 2°C' in the present century, compared to pre-industrial levels. Renewables, in combination with rapidly improving energy efficiency, form the cornerstone of a viable climate solution, with the global energy system needing to undergo a profound transformation, from one largely based on fossil fuels to one that enhances efficiency and is based on renewable energy."

When it comes to energy and climate change-related innovations and technology, the Masdar Technology and Innovation in Sustainability Perception Study reveals that this particular segment is crucial to overall sustainability improvements. Respondents believe that urgent transition is imperative to change, with new technologies like carbon capture, improved mobility and technology efficiencies key to transformation in the oil and gas industry specifically. Respondents also believe that improved energy storage is important, with innovations in the design and manufacture of batteries, and even battery alternatives – such as liquid and air storage – critical to forward motion. Hydrogen as a carbon-free energy vector is believed to be important, with industry currently limited in its capacity to transition its energy mix unless it can store energy for longer periods.

As solar and battery storage systems eventually increase, peer-to-peer electricity trading (P2P) is likely to come into play more. This system effectively allows consumers to take advantage of other users who produce more energy than they need. The users can then sell their excess power for profit. Another two solar-related areas of innovation present themselves in the form of mounting systems, which play a vital role in solar arrays, securing solar panels to the roof or ground; and solar paint, that can generate clean energy from both sunlight and moisture.

Improved air conditioning is crucial to future sustainability, with the Whole Building Design Guide (WBDG), a programme of the US National Institute of Building Sciences, suggesting that Heating, Ventilating and Air-Conditioning (HVAC) systems account for 39% of the energy used in commercial buildings in the US alone. With this in mind, improved HVAC innovations are required to play a larger role in cooling and cleaning the air we breathe in a more energy-friendly manner. On the topic of air, a group of researchers from the National University of Singapore (NUS) have made headway in



pioneering a new water-based air-conditioning system that cools air to as low as 18°C without the use of energy-intensive compressors and environmentally-harmful chemical refrigerants, potentially changing the future of the cooling industry.

Respondents say that carbon capture is vital to future sustainability, with carbon-capture recycling key to reducing carbon footprint, while other innovations include work being done in Iceland, where a company called Climeworks is capturing carbon emissions and turning them to stone. 3D printing – that can be used across a range of industries, for construction or even to print 'living' tissue – could potentially offer fast and often cost-effective manufacturing solutions, and a potential reduction in raw materials, with green buildings assisting in reducing our carbon footprint. The United States Environmental Protection Agency (EPA) suggests that climate change may worsen indoor air quality and existing indoor environmental problems, and may also introduce new challenges as the frequency or severity of adverse outdoor conditions increases. It suggests that considerations for buildings should include occupant health and wellbeing, sustainability, energy efficiency and changing outdoor conditions.

This report's research highlights that nearly half the global population – 3.6 billion people – already lives in potential water-scarce areas at least one month per year, and this could increase to between 4.8 and 5.7

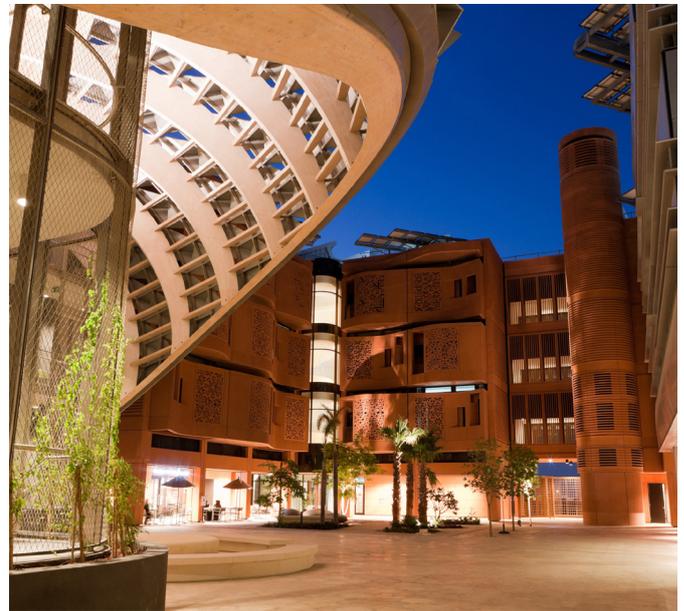
billion in 2050. Efficient water use, new techniques to maximise the reuse of wastewater, and innovative water-desalination technologies will significantly reduce energy needs. According to the perception survey respondents, achieving the use of wastewater for biofuel and higher-value products – such as fertilisers and plastics – building innovative, advanced and solar-driven nano water-treatment facilities, storing water without evaporation losses, and sourcing water from humidity in the air will all help solve the world's water challenges. Regarding desalination, the Masdar Renewable Energy Water Desalination Programme, launched in 2013, is developing and demonstrating seawater desalination technologies that are more efficient and powered by renewable energy. Survey respondents suggest that the application of smart technologies is also key to saving Earth's water, whether it's desalinated or treated, with more efficient equipment and innovations in real-time optimised pressure systems for water networks leading to more sustainable management. Fog-catching technology, graphene filters, solar-crop schemes, and water-filter books also offer unique and pioneering approaches to the water crisis.

When it comes to the mobility sector, as cities grow, the infrastructure to keep these areas moving often lags. Suffering from congestion, severe air and noise pollution, traffic-related deaths and high levels of greenhouse gas emissions, these problems are exacerbated by insufficient public transportation, among other challenges. Survey respondents believe that smart city transit technologies will lead the way to sustainable mobility, with examples of developing technologies including The Hyperloop, Electric Vehicles (EV), public and wireless charging, Autonomous Vehicles (AV), next-generation buses, and smart parking, with emerging business and regulatory models including carbon-free zones and congestion charges, digital hailing, and car and bike sharing.

Critical innovations in the space-exploration sector, meanwhile, could provide sustainable practices on Earth. Survey respondents suggest that HVAC systems are ideal for improving indoor air quality and saving energy on Earth and in space, with sustainable buildings, nanotechnology and nanofabrication, and 3D printing technology also playing vital roles.

The biotechnology industry is seeing an acceleration in the development of its innovative products and technologies that could help lower fatality rates, cure disease, feed the hungry, reduce our environmental footprint, and deliver more effective industrial manufacturing processes. There are several pioneering projects taking place across this sector, from potential advances in gene editing – that could be used to eradicate disease, develop new antibiotics or enhance crop growth – to AI that improves molecular design, 3D printing that doctors could use to create replicas of organs in the next five years, the manufacture of plastics made from renewable biomass sources, the production of biofuels that produce less carbon, and the use of microbes to clean oil and other toxic spills. Lab-grown meat, animal-free dairy products, and open-source biology already exist as a result of pioneering biotechnology work.

The technology-for-good term encompasses the idea that technology boasts vast potential to do good and improve society's living standards, with the tech-for-good ecosystem having grown into a bustling marketplace of needs, problems and solutions. Far from being static, as it progresses, this field is sure to change. Tech-for-good projects that are currently being developed and, in some cases, piloted or even used, include an emergency robot designed by an Emirati teenager, apps that determine



whether newborns have birth asphyxia, epilepsy warning bracelets, satellite broadband internet for the entire planet, 3D printers that build homes, facial-recognition powered wheelchairs, virtual reality that cures fear of heights, eReaders for the blind, AI that finds missing children, apps that track people of determination on trains, and many more.

Survey respondents believe that blockchain and the Internet of Things (IoT) will keep technology progressing, with fast and efficient smart connections – possibly brought about by a move into 4G and 5G networks, as well as enhanced data capture and storage facilities in the future – being essential to fast-tracking this area.

In 2016, the first Gen Z Global Sustainability Survey, commissioned by Masdar, was conducted to investigate the attitudes of members of Generation Z (aged 18–25) across the world towards the issues of climate change, sustainability development, renewable energy and other challenges. Key findings revealed that the youth believe that climate change will be the biggest threat to the world within a decade, that they are keen to take on more responsibilities to find solutions to climate change, and that they want policymakers to pay more attention to their views. They are also prepared to boycott non-sustainable corporates and believe that education is critical to making the world more sustainable. Survey responses showed that the youth perceive Germany, Canada, the UK and the US as clean-tech leaders, with Emirati youth being confident in the UAE's green track record. The youth also believe that solar and wind energy should be priorities for the future.

Regarding the Masdar Technology and Innovation in Sustainability Perception Study, respondents between the ages of 21 and 35 revealed that innovative water technologies that can be applied on a large scale, in communities or even cities, are vital to renewable energy transition, as are 100% renewable production methods, and using only renewable materials for mass-produced products. Smart metering was identified as a great way to create sustainable water supply across the planet, with desalination needing to transition from a fossil-fuel powered industry to a renewable-energy-powered one. Some survey respondents see EV as the transport of the future, with a reduction in the cost of installing and operating photovoltaic (PV) plants crucial to cutting back on fossil fuel usage overall. Lignocellulosic biomass' potential to replace petrodiesel in the transportation sector was also identified, although respondents acknowledged there are challenges with regards to ensuring good-quality feedstock throughout the year.

In terms of smart technology, augmented intelligence systems – that see man and machine working together – improved data analytics, and advanced storage need to be harnessed, with micro and nanofabrication technology potentially increasing devices' technical capabilities and improving the usability and feasibility of renewable-energy applications. A number of young people are already making extraordinary contributions to sustainability. These include teenage girls who have built systems to collect 'solar' power from indoor lighting to charge batteries, and devices that capture energy from ocean waves, to university students pioneering carbon-capture innovations and solving the problem of space junk through the use of tracking devices.



TOP TEN FINDINGS

- 1.** Energy and climate change innovations, in particular, are viewed as critical to fast-tracking a more sustainable future.
- 2.** Improved energy storage, including innovations in hydrogen storage, must be achieved for a successful energy transition.
- 3.** Smart networks and connectivity will facilitate improved energy management and less waste overall.
- 4.** Desalination requires a transition to renewable energy sources.
- 5.** Smart city transit technologies will pave the way to a more sustainable mobility sector.
- 6.** Critical innovations in the space-exploration sector will provide sustainable practices on Earth.
- 7.** The biotechnology industry is seeing vast development that could assist in solving serious medical, agricultural and environmental challenges.
- 8.** 3D printing is gaining traction across industries, from the medical to the manufacturing sectors, and is even printing food.
- 9.** The youth believe that climate change will be the biggest threat to the world within a decade and are taking on more responsibilities, and innovating, to find solutions.
- 10.** Education is critical to improved sustainability.

INTRODUCTION

UNDER THE THEME 'Industry Convergence: Accelerating Sustainable Development', the Abu Dhabi Sustainability Week (ADSW) 2019 gathering is set to explore how industries are responding to the digital transformation underway in the global economy, which in turn is giving rise to new opportunities to address global sustainability challenges.

With this in mind, Masdar has produced the *Future of Sustainability* whitepaper report – in partnership with *The National* – based on information provided by those students, individuals, companies and governmental organisations actively driving sustainability-related innovation across the planet.

An ADSW 2019 Technology and Innovation in Sustainability Perception Study gauged people's thoughts across pivotal sectors based on ADSW's key pillars. These pillars include Energy and Climate Change, Water, Future Mobility, Space, Biotechnology, Tech for Good, and Youth and Sustainability, with research garnered from the survey suggesting that energy and climate-change innovations, in particular, are critical to fast-tracking a more sustainable future.

Insights from the survey respondents are included across the report, with their comments providing vital information on critical sustainability issues facing Earth's population today, as well as potential future solutions and innovations.



METHODOLOGY

THE TECHNOLOGY AND INNOVATION in Sustainability Perception Study, commissioned by Masdar, was supported by interviews performed by *The National*. The report was created to investigate what students, professionals and industry experts in both public and private enterprises across the world believe the key future sustainable technology and innovations will be, and how these might enhance sustainability over the next five years.

- 151 online and phone interviews between December 7 2018 and January 3 2019, featuring respondents in a number of countries, including the UAE.
- Of the total online survey respondents, 1 was under 21, 24 were between the ages of 21–35, 70 between the ages of 36–55, and 40 over 55.
- The gender split of the survey is 88.75% to 11.25%, male to female.

Online survey participants were interviewed on future sustainable technology and innovations across their respective sectors, which were informed by ADSW's key pillars, namely Energy and Climate Change (69 respondents), Water (23), Future Mobility (2), Space (3), Biotechnology (3), Tech for Good (5), and Other, namely Government (4), Non-profit (5), and Business (21).

CHAPTER 1
**TEN
INNOVATIONS
AND
TECHNOLOGIES
THAT WILL
DRIVE THE
SUSTAINABILITY
SECTOR**

1. BIOMASS CONVERTED INTO COAL SUBSTITUTES

Agri-Tech Producers (ATP) patented its Combined Remediation Biomass and Bio-Product Production (CRBBP) Process, which cost-effectively transforms cellulosic biomass – like wood chips and bio-crops – into a substance that can be used as a clean and renewable coal substitute; as a superior raw material to supply or fuel machine or industrial processes (also known as feedstock) from which to make improved energy pellets; and as a superior feedstock from which to make biofuels. The thermal process the company utilises uses heat, in a low oxygen environment, to convert plant and wood biomass into a clean, renewable char, the solid material that stays after light gases and tar have been driven out or released from a material during the initial stage of combustion. Using this char, one can manufacture bio-based fillers to make composites and plastics that perform better; biochars that increase the productivity of poor soils; clean and renewable bio-coal that can be co-fired in coal-fired plants to reduce pollution and greenhouse gases; as well as alternatives to coal.





2. BRIQUETTES MADE USING BIOMASS

Kenya's Kayole Environment Management Enterprise uses biomass and binding materials, from paper to cow dung, to make briquettes that can be sundried and burnt for up to three hours. According to the company's director, Munywe Simon, one machine has the potential to create jobs for six people, contributing to the conservation of 31 tons of forest per month, with the forest conserving carbon dioxide emissions of up 992 tons each year. "I invented my screw-operated briquette creating machine in 2000 after the Kenyan government banned charcoal sales," he explains. "When we started our business, Kenya's forest cover sat at 1%, and today it sits at 7.5%. We hope to boost forest cover to 15% in the years to come."



3. VIRTUAL REALITY (VR) THAT INSPIRES BEHAVIOURAL CHANGE

In the coming years, interactive VR experiences will be possible for groups of up to 30 people, responding to humanity's increasing desire to be transported to another world in fully immersive environments. Thinc Design is a New-York based company that creates experiences and exhibits for museums, zoos, aquariums, and expos. The company's Head of Content, Amanda White, says that "Digital experiences are flexible, mobile and use fewer non-renewable construction resources than traditional exhibits. They are highly impactful experiences that can engage all the senses and affect people emotionally, which we know can inspire behavioural change. This makes them one of the most powerful tools for educating people about how to contribute to a sustainable future."

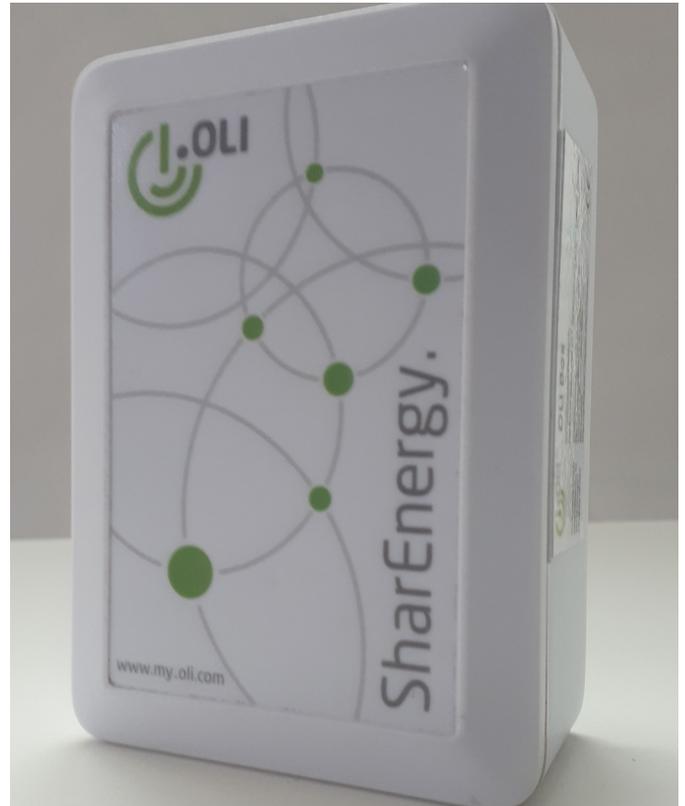


4. CITY WATER FOUNTAINS THAT SAVE WATER AND PLASTIC

Public water fountains and water refill stations that provide clean still and sparkling water for the community will help reduce the use of plastic. ProAcqua Group's General Manager, Cristiano Ferrari, says "In the last 12 months, water dispensed from ProAcqua fountains negated the need for the production and disposal of 87 million plastic bottles that would otherwise have ended up in landfills and oceans. This on top of saving 260 million litres of water and 18 million litres of oil used for the production and distribution of these bottles. Every day, we install new water refill stations around the world."

5. ENVIRONMENTALLY-FRIENDLY, ZERO-VOC, WATER-BASED PAINTS

Emissions from paints and coatings are a threat to the environment as they emit hazardous chemicals resulting in high-carbon footprints. Conventional water-based paints are not of a high-performance nature and cannot replace solvent-based paints in industrial applications. However, polymeric-based speciality surface coatings for high-end industrial applications offer techno-commercial benefits, including being environmentally safe, non-toxic, Restriction of Hazardous Substances (ROHS) compliant and saving customers energy, manpower, time and maintenance expenditures. According to the Managing Director of SK Formulations, Sachin Joshi, zero-VOC paints and coatings are one way to move towards a greener environment. "Our water-based coatings with high-performance properties not only replace solvent-based paints but save energy when applied on roofs, add safety with their fire-retardant properties, and enhance the life of structures with superior protection properties," he says.



6. SHARED ELECTRICITY USING BLOCKCHAIN

Through blockchain-supported software and hardware components, consumers and small-energy producers can share electricity in a neighbourhood, district, or region. The costs of energy procurement can be reduced and the benefits of renewable energy and other decentralised energies optimised. Germany-based OLI allows consumers and decentralised producers to participate in energy transition actively. In households, public institutions and businesses, the OLI-Box captures and optimises the consumption of electricity and heat, maximising the use of self-generated energy that can be shared with tenants and neighbours via blockchain, creating a network. This open approach enables additional services via the integration of apps, providing enhanced transparency, weather forecasts that improve energy management, and behavioural-pattern recognition that minimises heating needs. According to Ole Langniss, OLI's CEO and Co-owner, "With Ethereum-based blockchain, more efficient markets will be created in the power sector, allowing for better integration of distributed generation, and the addition of prosumers."



7. SUSTAINABLE COMPUTER CENTRES POWERED BY ENVIRONMENTALLY-FRIENDLY GREEN ENERGY

“The demand for energy to mine cryptocurrencies has set off a global scramble for inexpensive power, leading to the increased use of environmentally dirty fossil fuels, such as coal.” That’s according to Soluna, a blockchain company powered by its own private renewable energy. The company aims to address this problem by building computing centres powered by environmentally-clean, utility-scale renewable green energy, powering “the crypto-economy with clean, low-cost renewable energy”. To do this, Soluna is building a blockchain infrastructure and mining company that owns its own renewable energy resources. By developing renewable energy power plants dedicated to on-site, high-density computing, it will add a unique innovation to the blockchain ecosystem: vertical integration. This approach aims to generate renewable energy by consuming blockchain technology. Soluna’s energy systems and computing technology will be self-contained, distributed, scalable, and flexible, allowing it to achieve efficiencies only obtainable with utility-scale operations. According to the company’s CEO, John Belizaire, “Blockchain can play a significant role from a sustainability, climate change and renewable-energy perspective. We believe that blockchain technology has the potential to bring a new wave of innovation to the energy space. It has the potential to solve a number of problems related to bringing large waves of energy online to grids. It has the potential to help bring the cost of energy down globally. We also believe it has the ability to allow the movement of energy through micro-grid technology to different constituents in different environments which would increase sustainability in certain areas. The nature of our business is a combination of renewable energy and blockchain technology. In our particular case, we’re essentially applying the renewable resource to the transformation of that resource to powering computing technology, which will ultimately drive the growth of

the blockchain ecosystem and also the growth of other technologies. Through that combination, we’re building this large, off-grid implementation, which will be an example of how you can leverage this technology to drive the funding and support of a renewable resource in areas where it may be challenging to build. There are a host of new technological advancements that have occurred in the renewable-energy space, which we are happy to take advantage of as we build out our site. These advances are on the turbine technology side and how much that has improved, and battery technology and how much that has improved.”

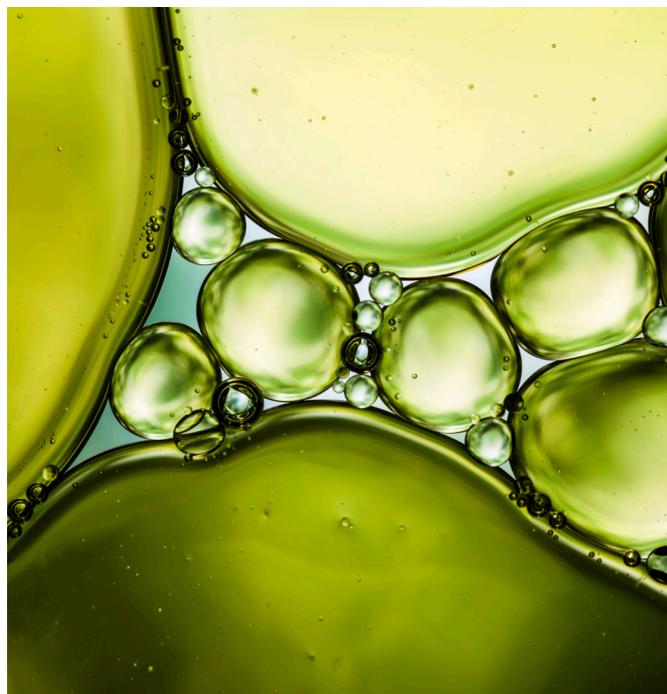
8. PEER-TO-PEER ENERGY SHARING

SOLshare is a social enterprise that offers ICT-enabled products and services, contributing to the UNDP’s Global Goal 7: Affordable and Clean Energy for All. SOLshare offers affordable solar electricity to people in Bangladesh through its peer-to-peer (P2P) solar energy trading platforms based on distributed ledger technology. SOLshare pioneers a micro-energy transition model by interconnecting solar home systems in peer-to-peer networks, monetising excess solar energy along the value chain. According to the company’s Managing Director, Sebastian Groh, “Our end-users are equipped with a SOLbox, an electricity meter that enables peer-to-peer electricity exchange between households as well as small businesses. Opportunity emerges from interconnecting existing decentralised solar energy generation and storage assets, thus linking producers, consumers, prosumers and large companies in smart grids enabling peer-to-peer energy transactions. Transaction settlement happens in real time, based through end-users’ mobile money accounts. This empowers low-income communities to earn a direct income from the sun, use their available solar power more efficiently, and have access to additional and more reliable solar power.” In the next year, SOLshare plans to install 100 grids with money from the UNDESA Powering the Future We Want Energy Grant that it was awarded in 2017, in partnership with not-for-profit rural power company, Grammen Shakti. SOLshare is set to expand into India and Africa in the near future.



9. USING WASTE HEAT FROM INDUSTRY AS A POWER SOURCE

Seramic is a UAE-based start-up that uses waste heat from industry as a power source and converts industrial aggregate into high-value ceramics for use in high-temperature applications or the oil and gas sector. Basically, Ceramic generates carbon-free value-added energy using Waste Heat Recovery (WHR) systems that substitute fossil fuels, thereby saving CO₂. According to the US Department of Energy, it is estimated that somewhere between 20–50% of industrial energy input is lost as waste heat in the form of hot exhaust gases, cooling water, and heat lost from hot equipment surfaces and heated products. "Waste heat represents an enormous potential of available energy that is 'already paid for' by the industry and is usually dumped into the atmosphere without any valorisation," Dr Nicolas Calvet, Faculty at the Masdar Institute, now part of the Khalifa University of Science and Technology, and Co-founder and CEO of Ceramic, says. "Even worse is that, very often, supplementary parasitic energy is required to cool down waste heat before filtering flue gases. Ceramic is developing a customised WHR system for installation directly on the client's site. This carbon-free energy can be re-injected in the industrial process as process heat, cooling or electricity. Very often, in addition to waste heat, factories generate solid waste, such as fly ash, steel slag, or aluminium white dross. This waste is currently considered to be a low-value by-product that cannot be landfilled and is sold, when possible, as aggregate for road construction or as an additive to cement. Ceramic recycles this waste into advanced value-added ceramics in the refractory or technical ceramics markets, potentially solving a waste management issue, depending on the future quantity of ceramic produced."



10. USING VEGETABLE OIL AND ANTIMICROBIALS TO PRODUCE POWER

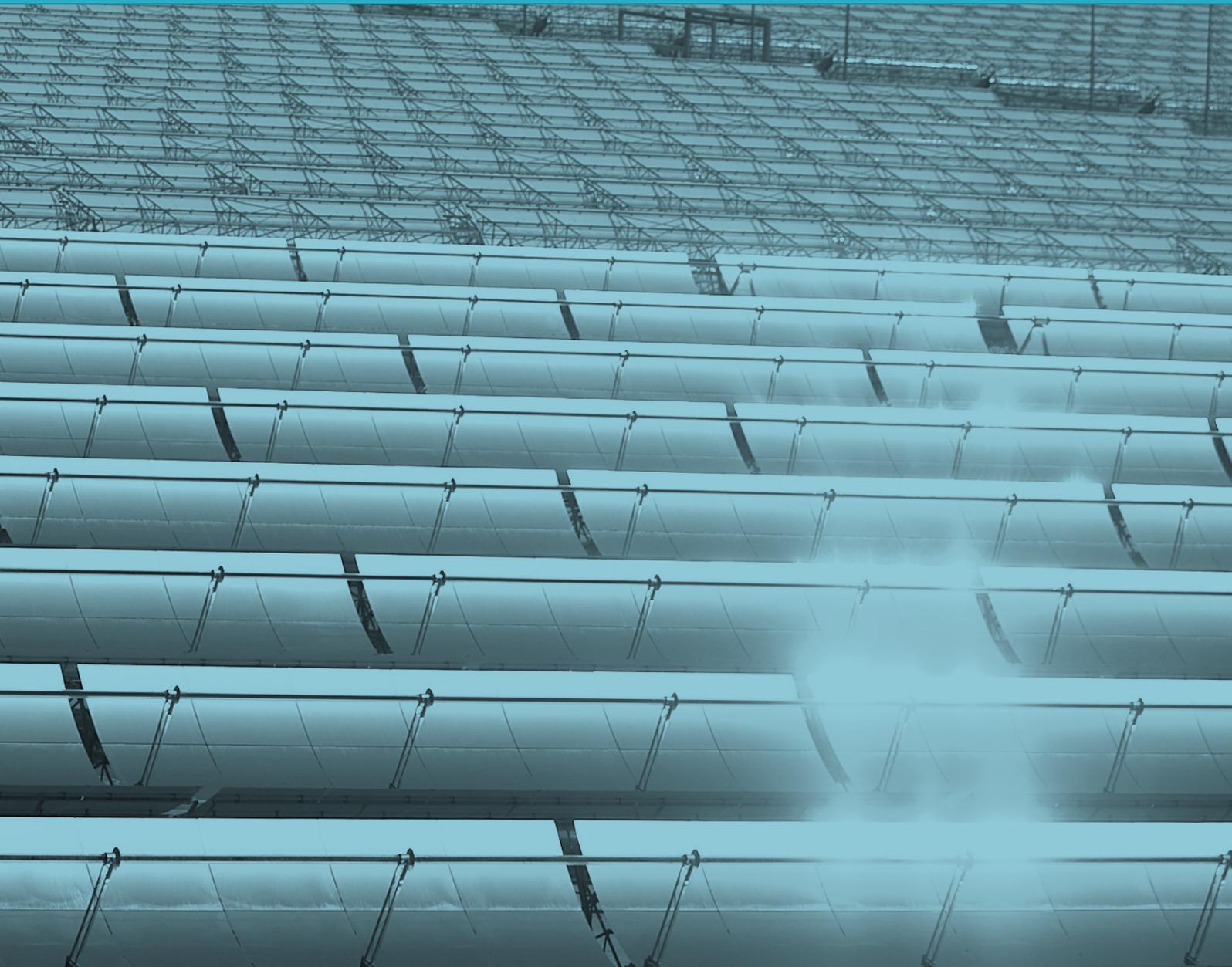
Using its own patented antimicrobials, produced from farm-waste cellulose materials, paired with medium-chain unsaturated fatty acids C6 to C12 – essentially vegetable oils – Berekotry Ltd is able to quickly and cost-effectively create biopolymer electrolytes that conduct in a solid state for potential application in energy-storage batteries, with the added potential to be 3D printed. In a YouTube demo video, the company showed how just a small amount of its biopolymer prototype conducts enough electricity to power a lamp, for example. According to the company's CEO and Patent Owner, Taslim Owonikoko, "The company is involved in agro-biomass conversion to bio-industrials for renewable biochemicals and materials, and for Health, Safety and Environment (HSE) operations in oil-spill treatments in the upstream and downstream petroleum industry. While we have made progress with our patents, we are seeking development partners."

CHAPTER 2

ENERGY & CLIMATE CHANGE



New technologies will support the shift to an increased use of renewable energy to meet the goals set out in the Paris Agreement



RENEWABLE ENERGY NEEDS TO BE SCALED UP AT LEAST SIX TIMES FASTER FOR THE WORLD TO START MEETING THE GOALS SET OUT IN THE PARIS AGREEMENT

ACCORDING TO THE International Renewable Agency's (IRENA) report *Global Energy Transformation: A Roadmap to 2050*, renewable energy needs to be scaled up at least six times faster for the world to start meeting the goals set out in the Paris Agreement on climate change. The report states that "the historic climate accord from 2015 seeks, at minimum, to limit average global temperature rise to 'well below 2°C' in the present century, compared to pre-industrial levels. Renewables, in combination with rapidly improving energy efficiency, form the cornerstone of a viable climate solution. Keeping the global temperature rise below 2°C is technically feasible. It would also be more economically, socially and environmentally beneficial than the path resulting from current plans and policies. However, the global energy system must undergo a profound transformation, from one largely based on fossil fuels to one that enhances efficiency and is based on renewable energy. Such a global energy transformation – seen as the culmination of the 'energy transition' that is already happening in many countries – can create a world that is more prosperous and inclusive."



The UN's Sustainable Development Goals website states that, through the *The Future We Want* outcome document from the 2012 Rio+20 Conference, member states express their concern about the continuous increase of Greenhouse Gas (GHG) emissions and the vulnerability of all countries, particularly developing countries, to the adverse impacts of climate change. Given these concerns, member states called for the widest cooperation and participation of all countries in an effective and appropriate international response to climate change.

With this in mind, the UN's Sustainable Development Goal 13 (SDG13) aims to "take urgent action to combat climate change and its impact" while acknowledging that the United Nations Framework Convention on Climate Change (UNFCCC) is the primary international, intergovernmental forum for negotiating the global response to climate change.



A TRANSITION TO SUSTAINABLE ENERGY SOURCES

On IRENA's website, energy transition is defined as "a pathway toward the transformation of the global energy sector, from fossil-based to zero-carbon, by the second half of this century. At its heart is the need to reduce energy-related CO₂ emissions to limit climate change. Decarbonisation of the energy sector requires urgent action on a global scale, and while a global energy transition is underway, further action is needed to reduce carbon emissions and mitigate the effects of climate change. Renewable energy and energy-efficiency measures can potentially achieve 90% of the required carbon reductions."

"Renewable energy, coupled with energy-efficiency gains, can provide 90% of the CO₂ emissions reductions needed by 2050."

irena.org

"Transition is big. Climate change takes up a lot of research. We are particularly focusing on carbon capturing and storage, and the integration of renewables. Energy and climate change are some of our top priorities. We do a lot of work in water, but this is secondary. The efficiency of transport is important to oil and gas. We are looking at solutions for mobility and improving technology efficiencies."

Comment from a major oil company in the Middle East

INNOVATIONS ELEVATING ENERGY

ACCORDING TO IRENA, energy transition involves the accelerated deployment of energy efficiency and renewable energy technologies. This requires systemic innovation, matching and leveraging synergies in innovations across all sectors and components of the system, and involving all industries. It includes innovations in Information Technology (IT), policy frameworks, market design, business models, financial instruments, enabling infrastructure and sector coupling. Improved processes, Research, Development and Deployment (RD&D) systems and cooperation networks are essential to overcoming barriers to reaching a zero-carbon energy sector.

According to IRENA's June 2017 working paper, *Accelerating the Energy Transition Through Innovation*, even with economically viable and scalable renewable-based solutions available for around two-thirds of the world's energy supply, population growth and rising energy demand could outpace energy decarbonisation without urgent investments in Research and Development (R&D). Successful innovation should encompass the complete technology lifecycle. The policy framework for innovation, similarly, must provide balanced support, addressing technologies and factors beyond technology, including systems operations, market design and regulations, and the enabling infrastructure to scale up renewables.

Countries can use IRENA's Renewable Energy Technology Innovation Policy (RETIP) process to design appropriate innovation strategies for renewable energy technologies. RETIP is a seven-step process that provides a platform for structuring policy development. Beyond strengthening innovation policy, the RETIP process identifies areas where IRENA could assist. IRENA can help countries, upon request, to choose assessment methods, identify key sectors and appropriate strategies, create coordinated policy portfolios, and define roles and responsibilities for implementation.

Improved energy storage

While hydroelectric and other renewable sources can generate power 24/7, solar and wind energies aren't as reliable, making energy storage vital to future sustainable energy. According to a 2018 article in *Forbes*, "recent

energy storage innovations have included advancements in traditional battery technology as well as battery alternatives such as liquid-air storage"

The *Forbes* article added that "in New York, one project included a megawatt-scaled lithium-ion battery storage system to replace lead-acid schemes. The liquid-air storage, however, uses excess energy to cool air in pressurised chambers until it is liquid. Rather than storing electrical or chemical energy like a battery, the process stores potential energy. When demand arises, the liquefied air is allowed to rapidly heat and expand, turning turbines to generate electricity."

Tesla also has its finger in the energy pie, contributing to nearly a third of the globe's annual energy storage deployments since 2015. "Leading the charge with low-cost lithium-ion batteries, Tesla and other innovators are bringing global capacity up quickly," *Forbes* reported. "These energy storage devices are versatile, capable of storing energy from any source – fossil fuel or renewable – and in any place, from private homes to industrial operations."

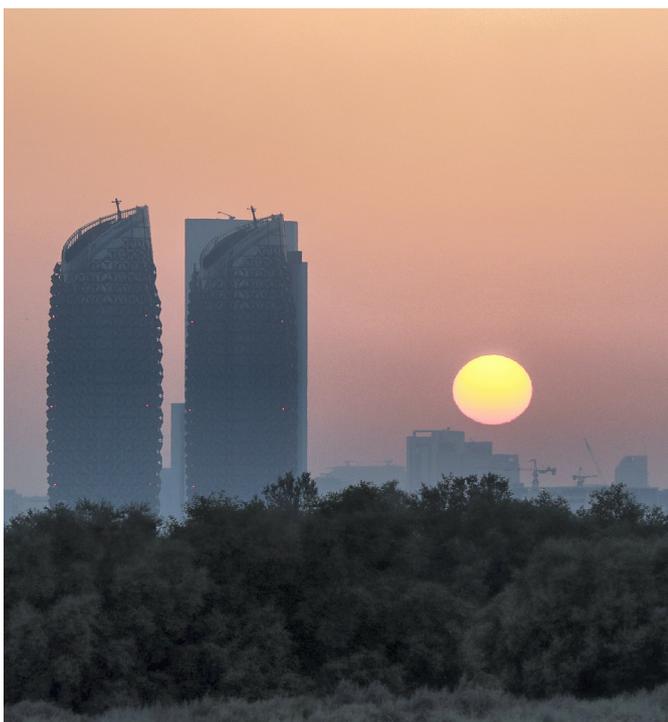
Projections from Wood Mackenzie Power and Renewables and the Energy Storage Association state that the energy storage market is expected to grow 17 times between 2017 and 2023. This projection accounts for private and commercial deployment of storage capacity, including impacts from government policies like California's solar-panel mandate. During the same interval, the energy storage market is expected to grow 14 times in dollar value.

An article on *engineering.com* has revealed that researchers at MIT have developed a new process for absorbing and retaining solar energy for on-demand use. The researchers claim that storing solar heat in the form of a chemical change (instead of storing the heat itself) is the answer to long-lasting and stable storage. No matter how effective the insulation, heat will always dissipate over time. On the other hand, a chemical storage system can keep the energy in a stable molecular form until it is time to be released. The release could be triggered by heat, light or electricity. The process is based on polymers, cost-effective materials that are a common manufacturing technology. Previous attempts at chemical-based storage materials were based on liquid systems, which limited their application. This new approach, however, is based on solids.

"We are fast approaching the time when non-utility solar and battery systems will reach their tipping points and achieve cost and performance parity with grid-delivered energy. It is essential for our utilities companies, regulators and governments to acknowledge that we are not far away. In my opinion, the first step towards managing the transition is this realisation and a mindset evaluation. The transition requires market players to utilise key emerging technologies, such as AI, cloud computing, blockchain and big-data analytics to run IoT and to enable business models that integrate embedded renewable energy and storage sources, micro-grids, prosumers, EVs and other Distributed Energy Resources (DERs)."

Aftab Raza

Head of Financial Management Sector,
Department of Energy, Abu Dhabi



HYDROGEN STORAGE

Electrolysis-generated hydrogen may provide a solution to fluctuations in renewable-sourced energy, according to National Renewable Energy Laboratory (NREL) research. Hydrogen produced by renewable electrolysis offers a promising solution for both the electric power and transportation sectors. Renewable electrolysis is a process that uses electricity produced from renewables to split water into hydrogen and oxygen. The hydrogen can function as an energy storage medium, effectively storing renewable energy until a fuel cell or engine converts it back to electricity. Hydrogen can also be recombined with captured CO₂ to produce a synthetic natural gas that can be used in power plants or transportation applications. Hydrogen can be produced during off-peak periods or times when there is excess renewable electricity. Then, because it can be converted back to electricity to provide constant power when the renewable source isn't available, it helps stabilise the utility grid. In addition, excess hydrogen can be sold as a vehicle fuel, or for other purposes.

"Something that's very important that is not getting enough attention is hydrogen as an energy vector going forward. Production of electrons can be done competitively now, and the production of chemicals and the storage of energy in the form of chemicals is currently being worked on and improved. Hydrogen as an energy vector is reaching an important milestone. We are limited in our ability to transition our energy mix unless we can store energies for long periods. Batteries are not cutting it at this time, and for seasonal energy storage, they probably never will. The need to create an energy vector is vital. Hydrogen serves as that energy vector, and it is a carbon-free alternative that scientists and experts are actively working on."

Comment from a major oil company in the Middle East

PEER-TO-PEER ENERGY EXCHANGE

As solar and battery storage systems increase, more people are talking about peer-to-peer electricity trading, also known as P2P. According to Australian solar energy and storage company Energy Matters, this system effectively allows consumers to take advantage of other users who produce more energy than they need. Those users can then sell their excess power for profit. The main benefits are that there are no middlemen, so people make deals on their own terms; everyone saves or makes money; and dealings are as transparent and respected as larger business transactions. Peer-to-peer solar energy makes sense today as many countries are already embracing the sharing economy, with Airbnb, Uber, Careem and other companies seeing people sharing their existing assets with others for profit.

Case study in citizen-based change: the UN's ActNow.Bot

The UN's new ActNow.bot is designed to fuel climate change understanding and urges advocates to take personal action via the Facebook Messenger platform. Launched by David Attenborough at the UN Climate Change Conference in Katowice, Poland, the social media tool is a fully interactive and responsive chatbot that users can find on the UN Facebook page. It suggests everyday actions, determined by the user's interaction with the bot, that can be taken to preserve the environment. These are then shared via the social media platform to encourage collective action. According to an article on *UN News*, UN Under-Secretary-General of Global Communications, Alison Smale, welcomed the launch, saying: "This new social media tool will help people learn about activities to reduce their carbon footprint, and show - and share with friends - how they are making an impact. We all need to do things differently." The campaign was created with support from Facebook and advertising company Grey, harnessing advances in Artificial Intelligence (AI) to engage people in the growing movement to take action against climate change.

ROOFTOP MOUNTING FOR SOLAR

One of the most significant areas of innovation within solar involves the mounting system, which could be considered one of the most competitive solar product markets, according to *Solar Power World Online*.

Mounting systems are a vital part of solar arrays, securing solar panels to the roof or ground. *Solar Power World Online* describes the three key types:

■ Sloped-roof mounting systems

When it comes to residential solar installations, solar panels are often found on sloped rooftops. There are many mounting system options for these angled roofs, with the most common being railed, rail-less and shared rail. All of these systems require some type of penetration or anchoring into the roof, whether that's attaching to rafters or directly to the decking.

■ Flat-roof mounting systems

Commercial and industrial solar applications are often found on large, flat rooftops, like on big-box stores or manufacturing plants. These roofs may still have a slight tilt but not nearly as much as sloped residential roofs. Solar mounting systems for flat roofs are commonly ballasted with few penetrations.

■ Solar shingles and BIPV

As the general public becomes more interested in aesthetics and unique solar installations, solar shingles may rise in popularity. Solar shingles are part of the Building-Integrated Photovoltaics (BIPV) family, meaning that solar is built into the structure. No mounting systems are needed for these solar products because the product is integrated into the roof, becoming part of the roofing structure.

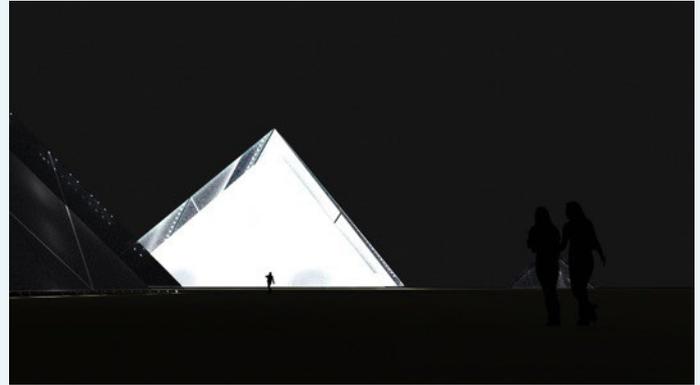
"We have witnessed the positive effects that the standardisation of rooftop mounting structures in India could have in terms of providing a solution for the serious issue of slowed down rooftop system implementation. Standardisation not only saves design and validation time but also reduces procurement and logistics time. It has already saved many man-hours for prominent Indian companies and is going to be something that will be applied to PV rooftop systems in the near future to achieve the target of 40GW by 2022."

Harshal Akhouri

Co-founder and Director,
Strolar Mounting Systems

Case study: bringing design into energy solutions

Robert Ferry and Elizabeth Monoian are the Founding Directors of the Land Art Generator Initiative (LAGI), which works to increase public acceptance of localised renewable energy infrastructures by providing models of energy generation architecture that rise to the level of contemporary public art. Every two years LAGI holds an international design competition, which has thus far been held in Dubai, New York, Copenhagen, Santa Monica and Melbourne. The design brief for the LAGI design competition contains the following baseline requirement: the artwork must capture energy from nature, cleanly convert it into electricity, and transform and transmit the electrical power to a grid connection point supplied by the city. Consideration should be made for the safety of the viewing public and for the educational activities that may occur on site. The design should be constructible (rather than theoretical), and it must respect the natural ecosystem of the design site.



Lunar Cubit: first-place winner, LAGI 2010 Dubai/Abu Dhabi

Creators: Robert Flottemesch, Jen DeNike, Johanna Ballhaus and Adrian P. De Luca

Energy Technologies: amorphous silicon

Annual Capacity: 3,500MWh



Windstalk: second-place winner, LAGI 2010 Dubai/Abu Dhabi

Creators: Darío Núñez Ameni and Thomas Siegl, with Atelier DNA

Energy Technologies: piezoelectric discs, linear alternator

Annual Capacity: 20,000MWh

Solaris: third-place winner, LAGI 2010 Dubai/Abu Dhabi
Creators: Hadrian Predock, John Frane, Chis Schoeneck, Johanna Beuscher and Heinrich Huber
Energy Technologies: Cool Earth Solar Balloon
Annual Capacity: 70,000MWh



"Aesthetic films will allow PV to proliferate across a much wider context of applications than would be possible without. This, together with falling module prices, will make solar panels the obvious choice for the exterior finish material for every new building. The technology also opens the door to the expansion of new regenerative forms of art in public spaces, such as the Solar Mural® programme at Land Art Generator. Examples of the technology include Solaxess, SolarLab and Sistine Solar."

Robert Ferry
Co-Director, Land Art

SOLAR PAINT

A 2017 *Futurism* article showcased a new solar paint developed by a team of researchers at the Royal Melbourne Institute of Technology (RMIT). The paint can generate clean energy from both sunlight and moisture, combining the titanium oxide already used in many wall paints with a new compound: synthetic molybdenum-sulphide. The latter acts a lot like the silica gel packaged with many consumer products to keep them free from moisture damage. According to a report on RMIT's website, the material absorbs solar energy as well as moisture from the surrounding air. It can then split the water into hydrogen and oxygen, collecting the hydrogen for use in fuel cells or to power a vehicle. "The simple addition of the new material can convert a brick wall into energy harvesting and fuel production real estate," explained lead researcher Dr Torben Daeneke.

"A product that will have the most positive sustainability impact over the next five years is 'smart cooling' HVAC adiabatic pre-cooling for chillers. Cooling accounts for 70% of consumed power in UAE buildings. By making a saving of about 20% per year, on average, this reduces the number to 56%, which is a huge financial saving and a reduction of GHG. Return on investment is also between 1-1.5 years, which is an excellent business proposition."

Adnan Sharafi

President and Managing Director, Gerab Energy Systems LLC

"At the moment, HVAC systems consume 70-75% of buildings' total energy consumption. Considering that the predominant typology of buildings in UAE are medium- or high-rise, and the current state of consumption is thousands of KWh per year, one can imagine the sort of environmental protection that will take place when, through passive strategies, the energy consumption of these buildings is reduced by 60-80% and the remaining energy demand is instead offered through renewable energy sources, such as wind turbines and PV."

Svilen Nickola-Todorov

Architect and Sustainability Researcher, GreenStyle Architecture Int

"As electricity demand, which is set to double by 2040 in the region, continues to grow, new generation will be added – primarily renewables. Everywhere in the world, there is a demand for reliable, affordable, sustainable energy, and I'm witnessing the same trend here in the Middle East. To achieve that we need to constantly collaborate and innovate to ensure we can generate, transmit and distribute renewable energy cost-effectively and reliably. We are continuously working on bringing the cost of renewable energy down through novel business models, innovation and technology breakthroughs. One of our key innovations this year is the Cypress wind turbine platform. We started with a 4.8MW output, which is now being scaled up to 5.3MW, providing up to a 50% increase in Annual Energy Production (AEP) and capable of producing more than 20GWh per year of electricity. This turbine is well suited to the wind characteristics of the region."

Dr. Manar Al Moneef

President & CEO, GE Renewable Energy, Middle East, North Africa and Turkey

IMPROVED AIR CONDITIONING

According to the Whole Building Design Guide (WBDG), a programme of the US National Institute of Building Sciences, Heating, Ventilating and Air-Conditioning (HVAC) systems account for 39% of the energy used in commercial buildings in the US alone. Consequently, almost any business or government agency has the potential to realise significant savings by improving its control of HVAC operations and improving the efficiency of the system it uses. The use of high-performance HVAC equipment can result in considerable energy, emissions and cost savings (10-40%). Whole building design coupled with an 'extended comfort zone' can produce much greater savings (40-70%). Extended comfort includes employing concepts such as providing warmer, but drier air using desiccant dehumidification in summer, or cooler air with warmer windows and warmer walls in winter. In addition, high-performance HVAC can provide increased user thermal comfort and contribute to improved Indoor Environmental Quality (IEQ).

Science Daily recently reported on a team of researchers from the National University of Singapore (NUS) pioneering a new water-based air-conditioning system that cools air to as low as 18°C without the use of energy-intensive compressors and environmentally harmful chemical refrigerants. This game-changing technology could potentially replace the century-old air-cooling principle that is still being used in our modern-day air-conditioners. The novel system is portable, suitable for both indoor and outdoor use and it can also be customised for all types of weather conditions.

AIR PURIFICATION

The United States Environmental Protection Agency (EPA) suggests that climate change may worsen indoor air quality and existing indoor environmental problems, and may also introduce new challenges as the frequency or severity of adverse outdoor conditions change. The agency states that the design, construction, operation and maintenance of buildings can impact the air we breathe, our energy consumption and our health. To protect all building occupants and maintain safe and healthy indoor environments, considerations for buildings should include occupant health and wellbeing, sustainability, energy efficiency and changing outdoor conditions.

According to EPA, heating and cooling buildings uses about 43% of all energy in the US. Producing this energy requires the burning of fossil fuels, which contributes to air pollution and generates large amounts of GHG that contribute to climate change. Improving the energy efficiency of buildings usually involves tightening the structures through air sealing and other weatherisation techniques to reduce having air that people have spent money to heat or cool escape. However, as buildings are renovated or repaired to save energy or increase comfort, indoor air-quality problems can be created or exacerbated. Indoor pollutants, such as radon, mould, particles and chemicals from a variety of sources, can build up to unhealthy levels unless pollutant sources, ventilation and moisture are carefully managed. Pollutants like tobacco smoke can easily migrate from one unit to another in multi-unit buildings, and lead and asbestos, which could be disturbed during renovations or retrofits, remain serious health risks in older buildings.

Protecting indoor air quality and occupant health while saving energy and money during building retrofits isn't difficult, but it requires teamwork, planning and commitment from everyone involved in building upgrades. If done right, public health can be protected, and people can reduce their reliance on fossil fuels and reduce climate change impacts. The EPA has developed a suite of three practical guides for single and multifamily homes and schools to help people involved in building renovations – whether for energy efficiency or other purposes – protect and even improve indoor air quality. These tips can be found on epa.gov.

Enhale Technology offers indoor air-purification products using needlepoint bipolar ionisation cold-plasma technology, with the technology now present in 200,000 installations worldwide. Enhale has developed products for the residential, commercial and industrial HVAC markets with a focus on reducing air pollution at a reasonable cost. The patented HVAC-mounted technology uses a precise electronic charge to create an electrical field filled with high concentrations of ions. When these ions are injected into the air stream, they break down, passing pollutants and gases into harmless compounds like oxygen, carbon dioxide, nitrogen, and water vapour. Enhale's technology generates the same ions found in nature, breaking molecules apart and naturally cleaning the air without developing detectable ozone. The technology allows the cooling coils to remain clean, reducing the load on the HVAC system and resulting in a safe, healthy environment. In a report published by the WHO, it is estimated that 7 million people die each year due to air pollution, with air pollution causing 3.8 million deaths in 2016 alone. In a report published by The University of Chicago in November 2018, it is estimated that particulate pollution can cause the average person to lose 1.8 years of their life expectancy, making air pollution a greater risk than smoking. Basim Anwer, Managing Director of Regionality GmbH, a Switzerland-based company that has been appointed as the official representative of Enhale in the Middle East, Europe and South Asia, says, "Air purification while saving energy offers a sustainable, environmentally-friendly solution. Enhale, an air-purification device that is HVAC mounted and focuses on superior Indoor Air Quality (IAQ) across a range of indoor spaces, produces zero ozone molecules and removes dangerous pathogens, pollutants and Volatile Organic Compounds (VOC) from the air we breathe inside cars, hospitals, residential and commercial buildings, factories and even stadiums. It provides up to 30% energy savings in facilities. These energy savings are hugely beneficial for the environment as they reduce the use of fossil fuels, which can generate pollutants. Superior air quality, meanwhile, helps reduce the spread of infectious diseases, allergens and existing pollutants indoors."



3D PRINTING

3D printing, or additive manufacturing, is defined as a process of making three-dimensional solid objects from a digital file. The creation of a 3D-printed object is achieved using additive processes in which something is created by laying down successive layers of material until the object is created. Each of these layers can be seen as a thinly sliced horizontal cross-section of the final object. 3D printing is the opposite of subtractive manufacturing, which is cutting out/hollowing a piece of metal or plastic with, for instance, a milling machine. 3D printing enables a person to produce complex (functional) shapes using less material than traditional manufacturing methods. It can be used across a range of industries, from building manufacturing to art and – more complexly – even creating human organs and food. For instance, Novameat recently printed a meat-free steak using vegetable proteins, posing a potentially interesting solution to the dairy and meat industry’s contribution to global warming

CARBON RECYCLING

Carbon Recycling International (CRI) focuses on power-to-methanol technology, producing renewable methanol from carbon dioxide, hydrogen and electricity for fuel applications, and greener chemicals and products. The company builds turn-key methanol production plants and works with partners in the manufacturing and power industries on transformative projects, increasing process efficiency and creating valuable products from waste streams. According to its website, its solutions are environmentally friendly and do not impact the food chain or land use.

CONVERTING CO2 TO STONE

In October 2017, at a geothermal power plant in Iceland, Climeworks inaugurated the first system that does direct air capture and verifiably achieves negative carbon emissions. Although it’s still at pilot scale – initially capturing 50 metric tons of CO₂ from the air each year, about the same emitted by a single US household or 10 Indian households – it’s the first system to convert emissions into stone, thereby ensuring they don’t escape back into the atmosphere for millions of years. In 2018, capacity was scaled up to 2,500 metric tons a year.

“Organic food waste is sent to landfills, which damages the environment due to emissions. This needs to be reduced by using food-composting units and constructing green buildings or net-zero buildings that will save energy, water, waste and natural materials.”

Sarfaraaj Khan
SOZO Consultant

CARBON CAPTURE INNOVATIONS

Deployment of Carbon Capture and Storage (CSS) technology is “not optional” if the world hopes to meet the targets set out in the Paris Climate Agreement, the International Energy Agency (IEA) said recently. “IEA scenario analysis has consistently highlighted that CCS will be important in limiting future temperature increases to 2°C, and we anticipate that this role for CCS will become increasingly significant if we are to move towards well below 2°C,” IEA executive director Dr Fatih Birol wrote in the foreword to *20 Years of Carbon Capture and Storage: Accelerating Future Deployment*.

Canada has three large-scale CCS projects in commercial operation, including SaskPower’s CCS facility at the Boundary Dam Power Station near Estevan, Sask; the Weyburn-Midale enhanced oil recovery projects operated by Cenovus Energy and Apache Canada; and the Shell Quest project at the Scotford Upgrader near Edmonton.

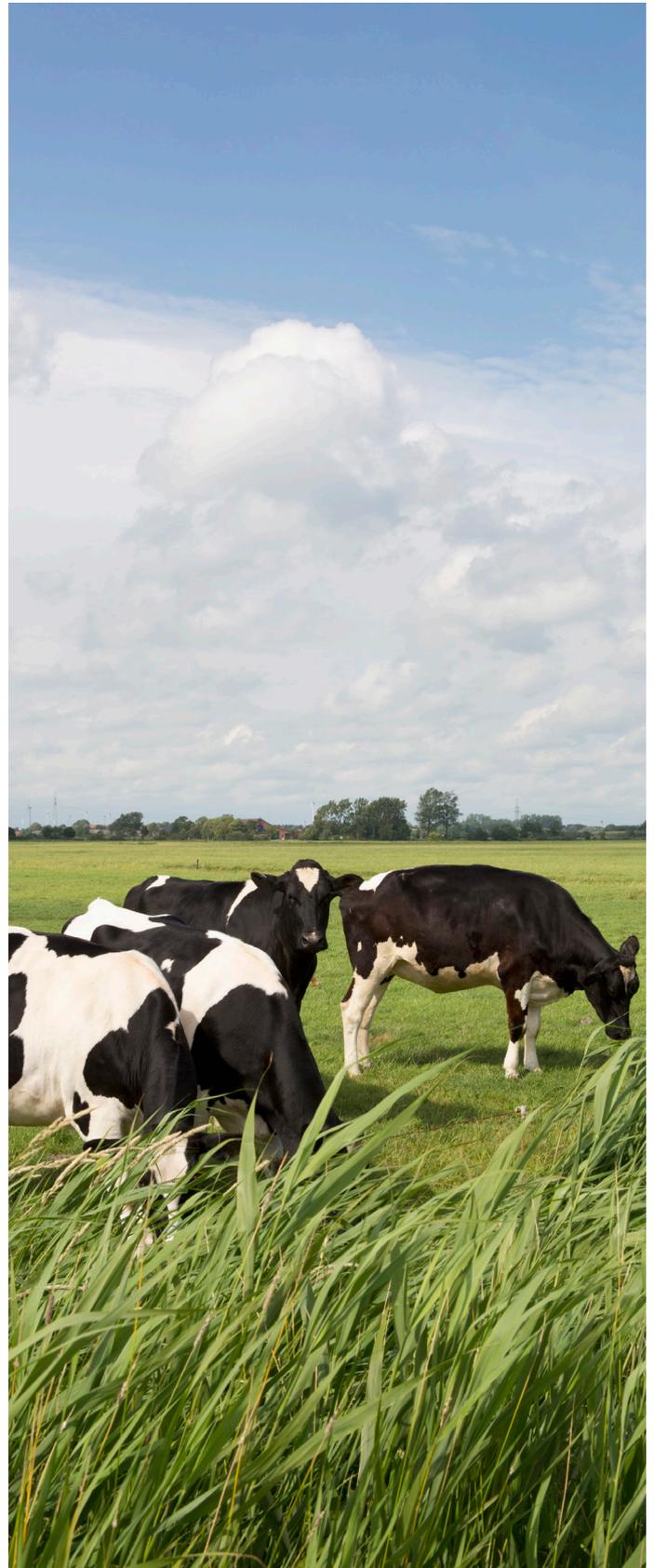
“Efficiency comes first. Oil and gas Carbon Capture and Storage (CCS) is big now, but we need to see more commercial large-scale projects in order to add more sustainability to the oil and gas industry. The hydrogen fuel cell is a device that is maturing and will be an important contributor to sustainability in the future. There is a genuine and major transition in the mindset and the actions of the oil and gas industry, with the Oil and Gas Climate Initiative (OGCI) seeing action-based organisations making joint investments with 13 of the largest oil companies in the world. Change is taking place. We would point to this oil and gas climate initiative, and other public efforts, as examples of initiatives, as they are investing in technologies that will advance the commercialisation of the tech involved in this change.”

Comment from a major oil company in the Middle East

Case study: Emissions impossible

An article on *phys.org* cites a report released by researchers at the Institute for Agriculture and Trade Policy (IATP) and GRAIN. *Emissions Impossible: How Big Meat and Dairy Are Heating Up the Planet* is a discussion regarding an analysis the groups did on the impact that meat and dairy industries have on global warming. One of their major findings is that large meat and dairy corporations are set to overtake large oil companies as the biggest emitters of GHG. The report states that “most of the top 35 global meat and dairy giants either do not report or underreport their emissions. Only four of them provide complete, credible emissions estimates. Fourteen of the 35 companies have announced some form of emission reduction targets. Of these, only six have targets that include supply-chain emissions, yet these emissions can account for up to 90% of total emissions. The six companies that do pledge cuts in supply-chain emissions are simultaneously pushing for growth in production and exports, driving their overall emissions up regardless of their intention to reduce emissions per kilo of milk or meat produced.”

In the report, the researchers also suggest that it is time to expand the field of corporations that get the major share of attention surrounding global warming. They make the case that meat and dairy producers have flown under the radar for years and that the time has come to include them. According to GRAIN’s website, a new Greenpeace report finds that “average per capita meat consumption must fall to 22kg by 2030, and then to 16kg by 2050, to avoid dangerous climate change”.



GREEN BUILDINGS

Architecture 2030, a non-profit, non-partisan and independent organisation established in 2002 in response to the climate change crisis, issued the 2030 Challenge in 2006, asking the global architecture and building community to adopt the following targets by 2030:

■ All new buildings, developments and major renovations should be designed to meet a fossil fuel, GHG-emitting, energy consumption performance standard of 70% below the regional (or country) average/median for that building type.

■ At a minimum, an equal amount of existing building area should be renovated annually to meet a fossil fuel, GHG-emitting, energy consumption performance standard of 70% of the regional (or country) average/median for that building type.

■ The fossil fuel reduction standard for all new buildings and major renovations should be increased to:

- 80% in 2020
- 90% in 2025
- Carbon-neutral in 2030 (using no fossil fuel GHG-emitting energy to operate).

With the above in mind, architects of the future have an incredible opportunity to design new buildings that limit carbon emissions and act resiliently in the face of changing climate conditions. Fortunately, new chemistry and material science innovations – as well as 3D printing – are heralding pioneering materials and building systems, making the Architecture 2030 challenge easier. According to a 2018 article on *archdaily.com*, these eight energy-efficient materials are what architects should be looking at:

1. Smarter windows that power up with nanotechnology.
2. Engineered wood products that can potentially replace emission-intensive materials, such as steel or cement.
3. Structural Insulated Panels (SIPs) to reduce energy usage.
4. Vacuum Insulation Panels (VIP) that offer high levels of insulation performance with very low thermal conductivity.
5. Daylighting (illumination of buildings using natural light) getting an efficiency boost.
6. Next-generation wall panels that save energy.
7. Vegetative roofing systems (also known as 'green' roofs) that offer long-term resilience.
8. Innovative 3D printing that improves thermal performance.

"Tomorrow's habitat will comply with all dimensions of comfort. Everyone wants to enjoy a sense of wellbeing in their home, to feel safe, protected from the negative aspects of the outside world, comfortable and healthy. Saint-Gobain provides aesthetic solutions (windows, coloured mortars, paintable fabrics, etc.), and solutions to improve air quality, and manage light and acoustic comfort (ceilings and plasterboards)."

Kenny Leroy
Saint-Gobain Business
Development Director, Middle East

BIOMASS

The US Energy Information Administration defines biomass as an organic material that comes from plants and animals, which can be used as a renewable source of energy. Biomass's unique property is that it contains stored energy from the sun. Plants absorb the sun's energy during photosynthesis so, when biomass is burned, the chemical energy in biomass is released as heat. Biomass can be burned directly or converted to liquid biofuels or biogas that can be burned as fuels.

Examples of biomass and their uses for energy include:

- Wood and wood-processing wastes: these can be burned to heat buildings, to produce process heat in industry and generate electricity.
- Agricultural crops and waste materials: these can be burned as a fuel or converted to liquid biofuels.
- Food, yard and wood waste in garbage: these can be burned to generate electricity in power plants or be converted to biogas in landfills.
- Animal manure and human sewage: these can be converted to biogas, which can be burned as a fuel.



BLOCKCHAIN

The World Economic Forum defines blockchain as a way for consumers and suppliers to connect directly, removing the need for a third party, like a bank. Using cryptography to keep exchanges secure, blockchain provides a decentralised database, or 'digital ledger', of transactions that everyone on the network can see. This network is essentially a chain of computers that must all approve an exchange before it can be verified and recorded. In the case of Bitcoin, blockchain stores the details of every transaction of the digital currency, and the technology stops the same Bitcoin being spent more than once. In theory, if blockchain goes mainstream, anyone with access to the internet would be able to use it to make transactions. However, currently only a very small proportion of global GDP (around 0.025%, or \$20 billion) is held in the blockchain, according to a survey by the World Economic Forum's Global Agenda Council. But the forum's research suggests this will increase significantly in the next decade, as banks, insurers and tech firms see the technology as a way to speed up settlements and cut costs. Companies racing to adopt blockchain include UBS, Microsoft, IBM and PwC. The Bank of Canada is also experimenting with the technology. A report from financial technology consultant Aite estimated that banks spent \$75 million last year on blockchain. Silicon Valley venture capitalists are also queuing up to back it.



CHAPTER 3

WATER



Nearly half the global population – 3.6 billion people – already lives in potentially water-scarce areas at least one month per year, and this could increase to between 4.8 and 5.7 billion in 2050 (UNESCO, 2018)



UNDERSTANDING THE WORLD'S FRESHWATER NEEDS

WHILE THERE ARE more than 1,400 million cubic kilometres of water on our blue planet, there's actually a shortage of clean drinking water. Water covers more than 71% of the Earth's surface, but 97% of it is made up of seawater. This means that only a relatively tiny fraction of all water on our planet – 13,500 cubic kilometres or 1/100,000 of the total water – is fresh, drinkable and usable.

With global consumption of water doubling every 20 years, and at more than twice the rate of the world's population growth, securing clean water is a serious issue for the world's major cities. Climate change will also contribute to water scarcity. For each degree of global warming, approximately 7% of the global population is projected to be exposed to a decrease of renewable water resources of at least 20%.

Efficient water use, new techniques to maximise the reuse of wastewater, and innovative water-desalination technologies will significantly reduce energy needs. The United Nations (UN) has created a Sustainable Development Goal to "ensure the availability and sustainable management of water and sanitation for all" as part of the UN's Sustainable Development Agenda. In response to the UN's call to action, countries are attempting to help solve global water shortage through a variety of demand-side and supply-side solutions, the latter including desalination of brackish and seawater.

While desalination currently provides only around 1% of the world's drinking water, this percentage is increasing year on year. Depleting natural freshwater resources, rising demand for safe water, and the falling costs of desalination technologies are all contributing to growing investment in desalination plants. However, with the high energy consumption and environmental footprint associated with desalination, the pressure is on to develop more sustainable desalination solutions.

When it comes to wastewater, it is likely that over 80% of wastewater is released to the environment globally without adequate treatment, according to a 2017 UNESCO report. But the report adds that the opportunities from exploiting wastewater as a resource are enormous. Safely managed wastewater is an affordable and sustainable source of water, energy, nutrients and other recoverable materials.

"By 2030, global demand for water is expected to grow by 50%."

**UN-Habitat 2016 World
Cities Report**

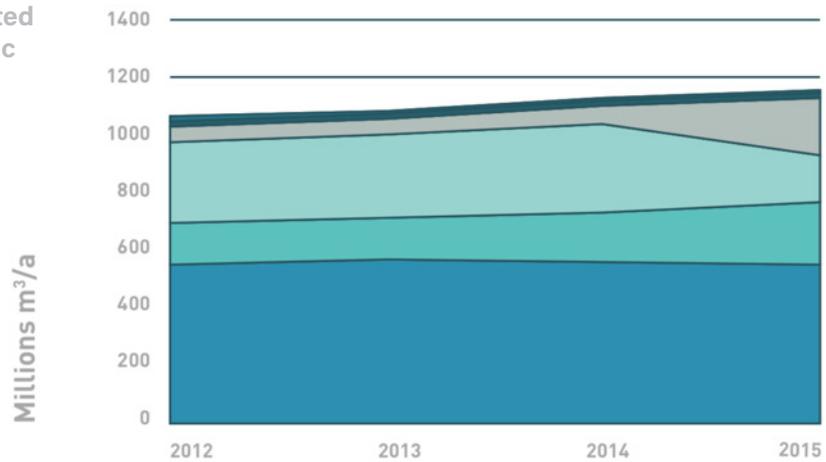


DESALINATION IN THE ARABIAN GULF AND THE UAE

According to the Abu Dhabi Environment Agency, desalinated seawater accounts for 31% of the total water supply in Abu Dhabi, and it has become the main source of drinking water.

Consumption of desalinated seawater across economic sectors in the Emirate of Abu Dhabi

- 03% Other
- 02% Industry
- 17% Agriculture
- 14% Government
- 19% Commercial
- 48% Domestic





LOOKING AHEAD: INNOVATIVE WATER DESALINATION TECHNOLOGIES

Five new solutions as part of Masdar's desalination programme

The Masdar Renewable Energy Water Desalination Programme, launched in 2013 near Ghantoot in Abu Dhabi, includes developing and demonstrating seawater desalination technologies that:

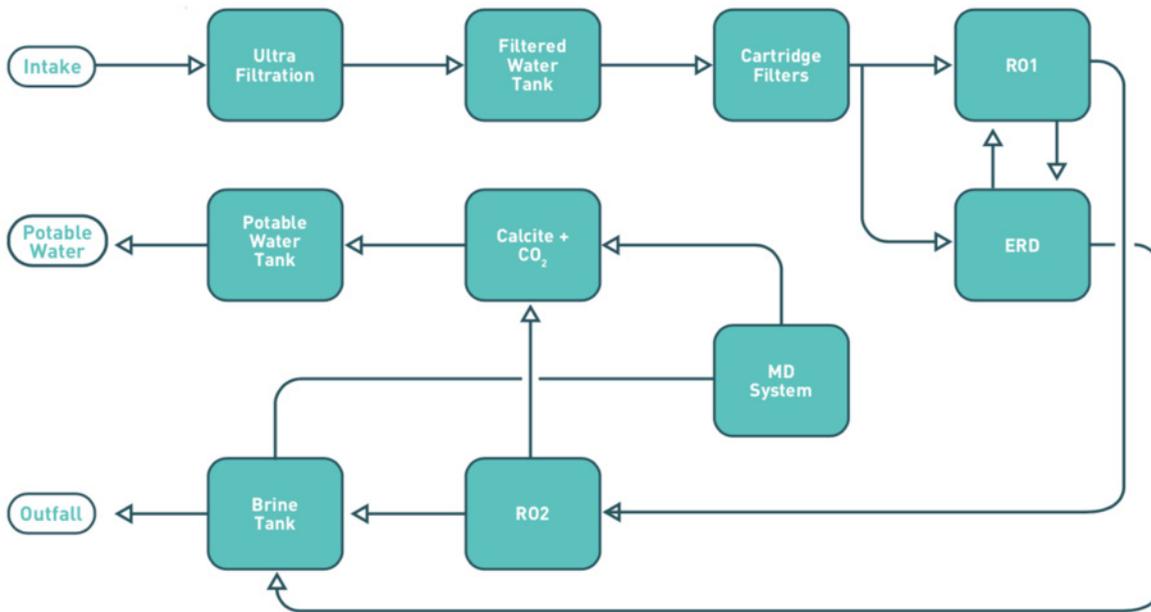
- Are more energy efficient than current systems.
- Are suitable to be powered by renewable energy sources.
- Are cost-competitive compared to seawater desalination powered by non-renewable energy.
- Have minimal environmental impact.
- Are resilient in challenging seawater and environmental conditions.

The Masdar Renewable Energy Water Desalination Programme includes solar-powered Reverse Osmosis (RO) solutions boasting techniques in which salt water is purified through membranes.

International technology providers, industry experts and professors from the Masdar Institute, now part of the Khalifa University of Science and Technology, all contributed to the programme.

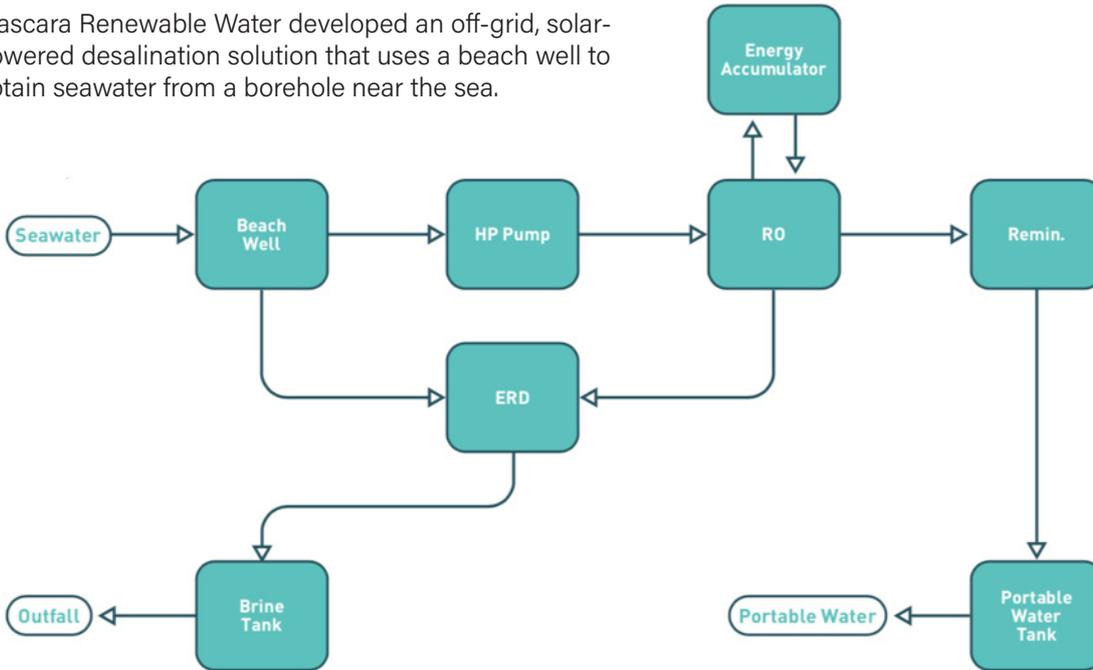
1. ABENGOA

This desalination system uses a Reverse Osmosis (RO) system.



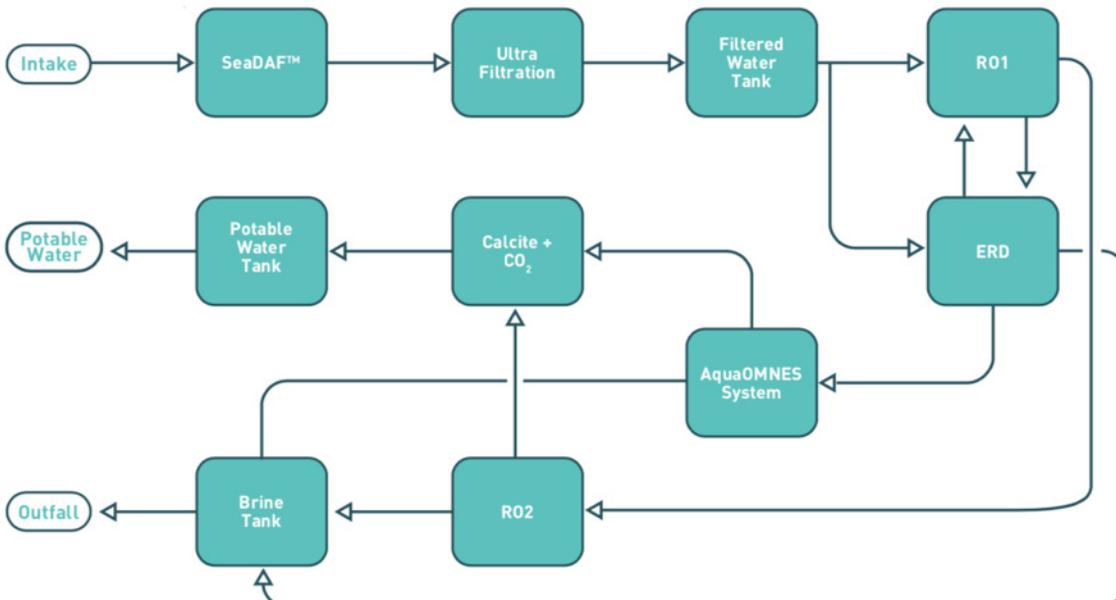
2. MASCARA RENEWABLE WATER

Mascara Renewable Water developed an off-grid, solar-powered desalination solution that uses a beach well to obtain seawater from a borehole near the sea.



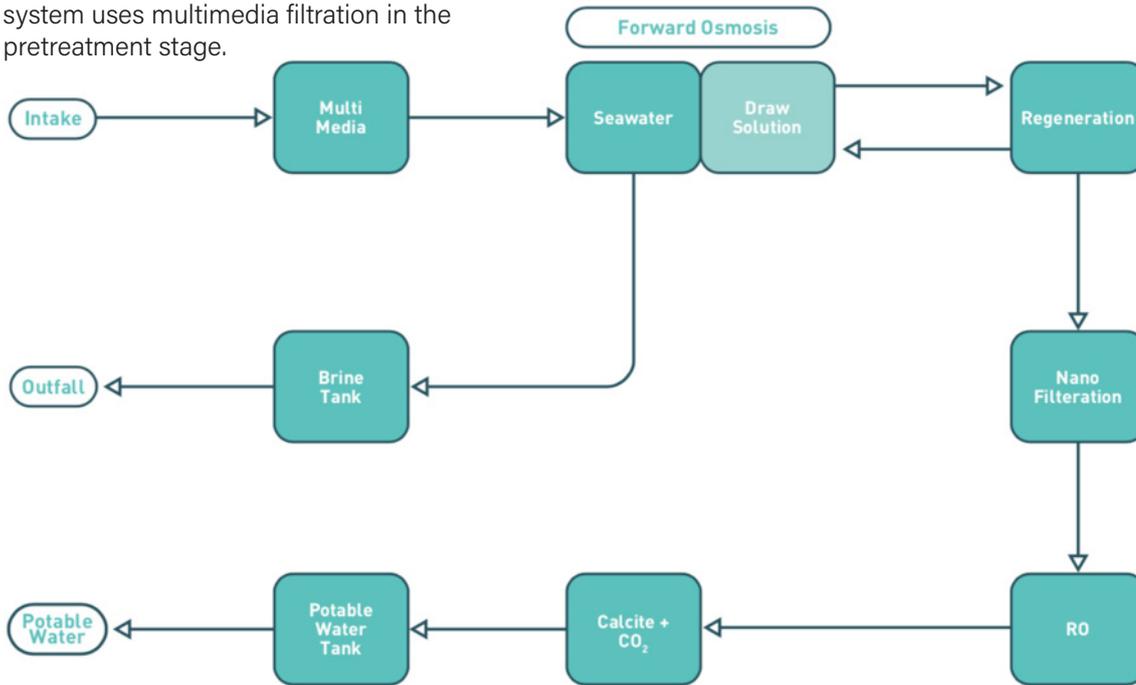
Suez

SUEZ's 100 cubic-metre/day pilot plant combines an advanced RO system with an innovative brine-treatment system.



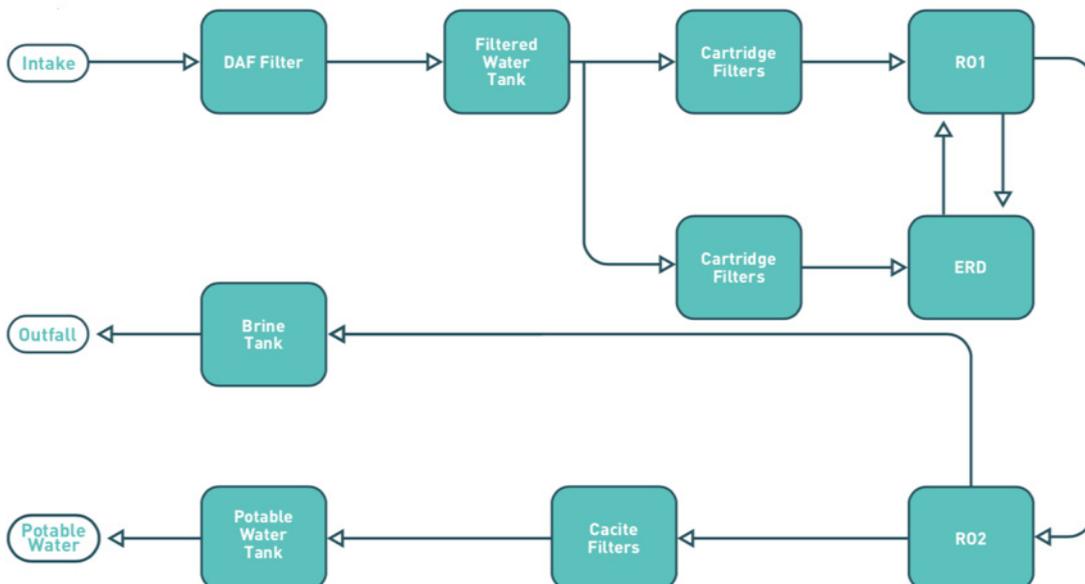
3. TREVI SYSTEMS

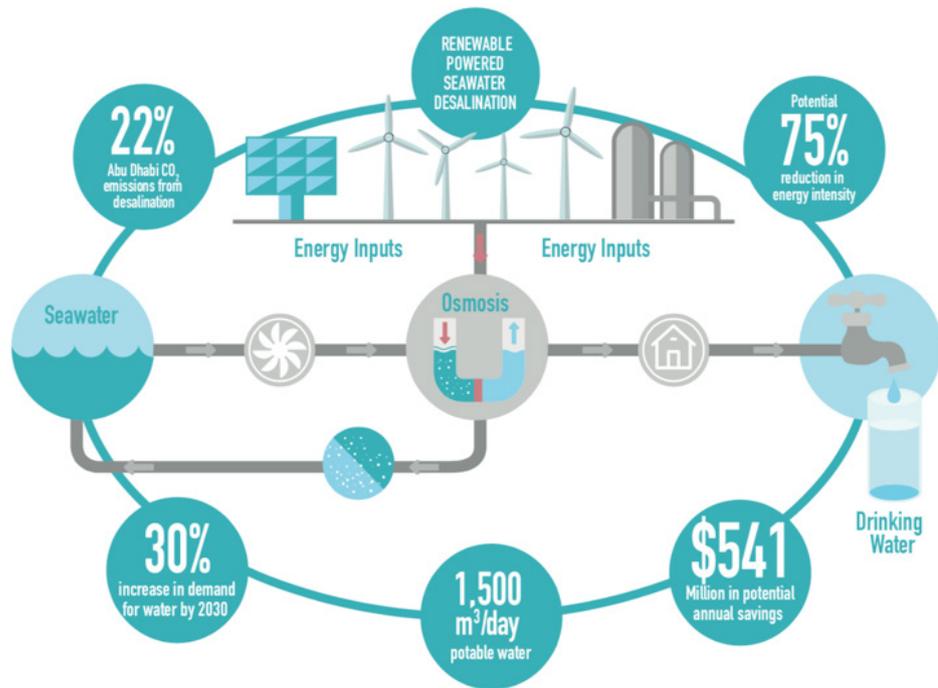
This Forward Osmosis (FO) desalination system uses multimedia filtration in the pretreatment stage.



Veolia/SIDEM

The pilot plant, developed by SIDEM, combines Dissolved Air Flotation (DAF) and gravity dual-media filtration into a single unit for the pretreatment of seawater.





- 1 Increased energy efficiency
- 2 Reduced cost of desalination
- 3 Decreased environmental impact
- 4 Diversification of energy supply

“Reverse osmosis combined with solar power is a commercially viable option to provide for the water needs of Arabian Gulf countries over the long term. Energy efficiency improvements of up to 75%, compared with technologies mostly used in the UAE at present, were also demonstrated through the programme.”

Mohamed Jameel Al Ramahi
Chief Executive Officer, Masdar

“Water for drinking and industrial use is expensive due to the energy spent in purification. The less energy spent, the cheaper the water will be and the more sustainable it will become.”

Karan Cherubala
Veolia-SIDEM

WASTEWATER: A GLOBAL PERSPECTIVE

Wastewater is water that comes from flushing toilets, doing laundry, washing dishes or anything else that sends 'used' water into a drain. It also encompasses commercial and industrial operations and rainwater run-off in areas where rain isn't handled with separate pipes. In most urban areas, wastewater is collected via regional and municipal pipe systems that flow underground to treatment plants where the water is then treated and safely released to local waterways.

But treating wastewater for safe redistribution isn't the only aspect of wastewater that countries are looking at. According to a 2018 report by the International Water Association (IWA), recovering the water, energy, nutrients and other precious materials embedded in wastewater is a key opportunity.

Looking ahead: wastewater innovations

According to a 2017 *Eco-Business* article, some inspiring examples of future solutions in the wastewater sector include Dutch professor Mark van Loosdrecht's innovation Anammox, a process that uses special bacteria to remove pollutants from water using less energy, oxygen and chemicals than similar water-treatment solutions. The technology can save water-treatment plants up to 60% in operational costs, while also decreasing their carbon footprints. The professor, who won the prestigious 2012 Lee Kuan Yew Water Prize for his innovation, is now looking at ways to recover useful raw materials from the water-treatment process to turn the normally expensive procedure into a profitable one.

Another low-cost example is technology BioGill, a solution from Australia that can clean up wastewater that is too dirty or oily for other systems to process. At the core of the system is a patented surface called a 'nano-ceramic membrane' that is conducive to the growth of bacteria that can remove water pollutants. The system uses a low-energy pump to draw water up from treatment tanks and spray it over the bacteria-covered membrane, where the water is cleaned. Because of its minimal energy requirements, the technology can save companies money.

"We collaborate with more than 20 universities and research centres, with our main efforts being aimed at achieving the use of wastewater for biofuel and higher-value products, such as fertilisers and plastics."

Frank Rogalla

Director of Innovation and Technology, Aqualia

"Building innovative, advanced and solar-driven nano water-treatment facilities is the ideal solution for the shortage of fresh water."

Dr Bassam Tawabini

Associate Professor, King Fahd University of Petroleum and Minerals (KFUPM)

"We already have the technologies to sort, count and treat sorted wastewater. Now it's only a question of our methods and habits."

Laurent Sohier

Helio Pur Technologies

"Storing water without evaporation losses enables supply to meet demand more effectively, reducing wastage and pollution from urban areas to oceans."

Craig Flavel

Senior Groundwater Engineer/
Hydrogeologist, Water Technology

"With water in the air – in the form of humidity – being plentiful, why not simply convert this resource into water for all? With efficient technologies now available, the only barrier is will and action."

Michael Bourgon
COO, Drinkable Air

Vertical farms in Dubai

According to their website, Dubai's Badia Farms is a vertical farm that grows microgreens and herbs using hydroponic technology and 90% less water than open-field farming. The farm, launched in March 2018, recycles the water it uses and combats the carbon footprint of international food imports that typically travel thousands of kilometres to reach local restaurants.

Air-to-water systems

A partnership between Eshara Capital and Veragon Water Solutions has seen the launch of new technology that creates water out of thin air. Veragon's innovative air-to-water system can produce up to 1,000 litres of potable water per day in hot or tropical environments for as little as AED0.03 per litre. The water is certified to World Health Organisation standards and approved for use in the UAE.

Soil-amendment technology

Porous Alpha technology is a soil-amendment solution launched by Tottori Resource Middle East, a joint venture between Emirati entrepreneur Muntaser Al Mansouri and Japanese firm Tottori Resource Recycling. It is expected to save 50% of water consumption in agriculture and urban greening, increasing yields by 20%.



GETTING SMART

The application of smart technologies is also key to saving Earth's water, whether it's desalinated or treated. As the market matures, the efficiency gains and waste-reduction rates will rise concurrently. Efficient management of water provision and the reduction of waste will improve as smart water-management solutions permeate the utilities industry. The market value of such smart solutions is predicted to push past \$20 billion by 2021.

"As water tariffs in the Middle East become increasingly competitive, there is room for even lower tariffs. Developers will focus on equipment boasting the highest power efficiency to lower operating costs. They will also seek more automation and digitalisation to reduce operation and maintenance costs."

Nagy El Ashmawy

Vice President, Tendering and Engineering, Haji Abdullah Alireza & Co

"Current reuse relies solely on the irrigation of landscape areas, and this demand is seasonal, which means maximum demand in summer but limited demand in winter. Integrating technologies and policies will take us towards 100% reuse, and reduction of unsustainable groundwater abstraction in certain sectors."

Eryl Edwards

Commercial Manager, BESIX Concessions and Assets Middle East

"We are working towards achieving global leadership in maintaining real-time, optimised pressure on water networks based on actual demand. This will lead to the management of water networks in a smart and sustainable way, providing safe and effective services that meet customers' aspirations and expectations in line with Abu Dhabi's objective of building sustainable utilities and ensuring optimal use of natural resources."

Mohamed Ameenudeen Yasir Rasmy

Irrigation Engineer, Irrigation Department (Eastern Province), Sri Lanka

"We can create sustainable water-network performance by using equipment that reduces water consumption, improving network performance, contracting operators that maintain a high-quality network performance that results in reduced water depletion and chemical optimisation, by controlling and monitoring all systems, and using networks to communicate and sense information around populations using water."

Mohamed Farhaoui

Head of Water Production Department, National Office of Electricity and Drinking Water, Morocco

“Developing innovative technologies that can sustainably source clean water is vital, not only for the UAE but for countries throughout the Arabian Gulf and around the world.”

Mohamed Jameel Al Ramahi
Chief Executive Officer, Masdar

FOUR INNOVATIONS SOLVING THE WATER CRISIS

Fog catching

According to a 2016 UN Climate press release, Dar Si Hmad – a women-led NGO in Morocco – designed and installed what is now the world’s largest operational fog-water harvesting system. It is an innovative solution to persistent water stress in a place where fog is abundant, using a technique inspired by ancient water practices. The Dar Si Hmad project provides accessible potable water to more than 400 people in five villages, most of them women and children.

Graphene filters

Stronger than steel, thinner than paper and highly flexible, graphene was first isolated by University of Manchester scientists Andre Geim and Konstantin Novoselov, who were jointly awarded the Nobel Prize in Physics in 2010 for their groundbreaking experiments to characterise the material. Graphene’s unique properties can be used for a range of applications in the future, including energy-storage solutions, water-purification technology, lightweight aeroplanes, mobile phones, and even clothing. Scientists from the Khalifa University of Science and Technology and the University of Manchester have been pursuing a number of R&D projects in graphene. These include developing 3D-printed foams for the aerospace and robotics industries; using graphene sheets to enhance water treatment and desalination technologies; and producing graphene-based inks as micro-sensors for energy and other industry applications. Masdar opened its Masdar Building, which houses The University of Manchester’s Graphene Engineering Innovation Centre (GEIC), in December 2018. Masdar is the principal funder of the purpose-built facility that will focus on graphene innovations.

According to an article in *The Guardian*, Lockheed Martin has also developed and patented a Perforene graphene filter that could potentially reduce the energy cost of conventional RO desalination by 20% while still standing up to higher pressure and temperatures. The perforated, hyper-permeable filter, about one atom thick, could enhance water’s flow by 500% compared to conventional methods. The technology could be hugely beneficial to the oil and gas sector, which is said to produce 18 billion gallons of wastewater each year. Lockheed Martin is also researching other applications for the technology, including in food and energy generation.





Taking water from air

This project, designed by VICI Labs, is being tested by the National Peace Corps Association. Planted six feet below the surface, the WaterSeer uses the environment to take water from the air. According to the WaterSeer's website, the wind-powered device features a lower chamber surrounded by earth, and an above-ground turbine with fan blades that spin and send air into an internal condensation chamber. As warm air cools, vapour condenses on the sides of the chamber. Water then flows to the lower chamber and can be removed using a pump and hose, collecting up to 37 litres per day.

Solar-crop schemes

CGIAR, in partnership with the International Water Management Institute (IWMI), incentivises farmers using solar pumps to sell excess power back to the state. In this way, farmers earn money, the state takes advantage of electricity reserves and water is conserved, with carbon emission reduction being another benefit. IWMI estimates that by solarising India's 20 million irrigation wells, there could be a carbon emission reduction of up to 4-5%.

Water filter books

According to an article in the *Scientific American*, a group of researchers from Carnegie Mellon University, in collaboration with non-profit Water is Life, has designed a book with silver-impregnated pages that can be used to filter contaminated water. One page from this 'drinkable book' can potentially filter up to 100 litres of drinking water and could provide a cheap, sustainable solution for communities suffering from severe sanitation problems.

"Any new technology that reduces electricity and water consumption will become the focus of commercial, industrial and service sectors. It will also be of primary concern to individuals looking to reduce electricity and water bills. Government agencies' support for these technologies will become paramount and will also support the localisation of these technologies. Changes need to take place across many technologies to save water and energy, from solar energy and air conditioning to lighting, heat-insulation materials and water-saving technologies."

Bader Swailem
Aknaf Specialized Co.

"We want the world to have the best warm-water hygiene. We could potentially store excess photovoltaic (PV) electricity in heat and, with our ASKO Cloud, energy consumption could be visualised, optimised and directed entirely to consumers for batteries, electric cars, ASKO Heat, air conditioning, heat pumps and more, maximising photovoltaic power consumption."

Andreas Pirner
Head of Sales and Marketing, ASKOMA AG

CHAPTER 4

MOBILITY



The need for more efficient and sustainable forms of transport has never been greater

Emerging technologies, such as autonomous cars, zero-emissions vehicles and the Hyperloop, will make transport easier, faster and safer.

01
QUINTERO

AS CITIES GROW, the infrastructure to keep these cities moving often lags. Whether high-income or low-income, dense or sprawling, cities suffer from congestion, severe air and noise pollution, traffic-related deaths and high levels of greenhouse gas emissions. These problems have been exacerbated by insufficient public transportation, among other challenges. As existing cities evolve and new greenfield cities emerge, it is essential that public transport is improved, along with the management of private transportation. With existing transportation models being resource intensive and major contributors to global carbon emissions, innovations are more critical than ever.

We believe that smart city transit technologies will lead the way to sustainable mobility.

These include developing technologies, such as:

1. The Hyperloop
2. Electric Vehicles (EV)
3. Public and wireless charging
4. Autonomous Vehicles (AV)
5. Next-generation buses
6. Smart parking

Emerging business and regulatory models:

1. Carbon-free zones and congestion charges
2. Digital hailing
3. Car and bike sharing

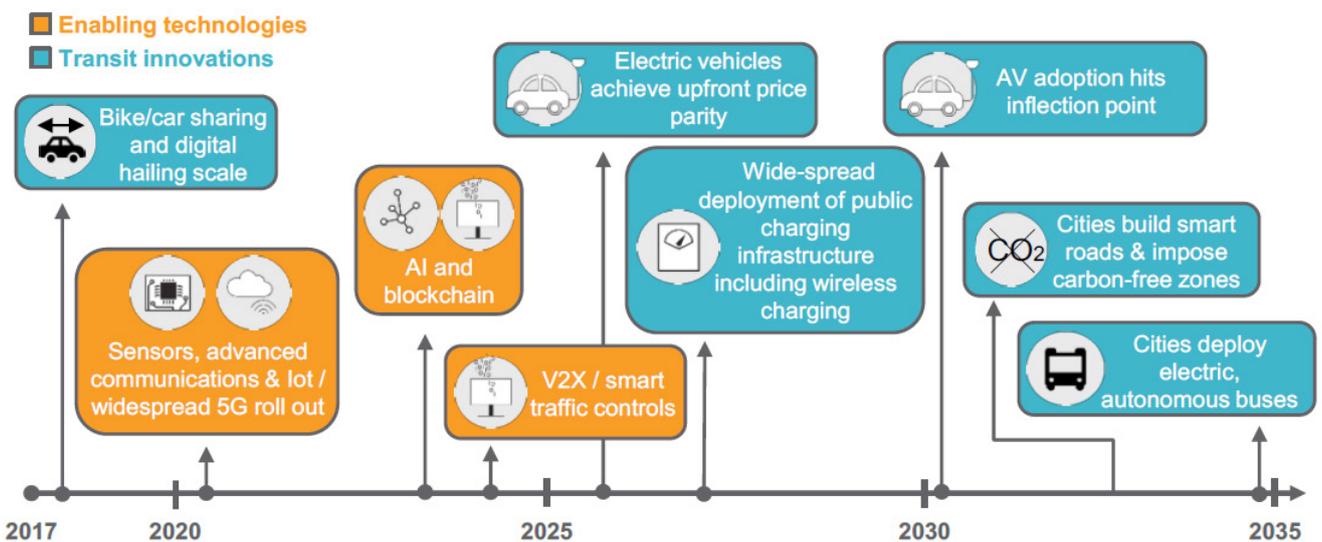
THE COMBINATION OF NEW TECHNOLOGIES AND BUSINESS MODELS PRESENTS AN ARRAY OF POSSIBILITIES FOR SUSTAINABLE URBAN TRANSIT

Using new technologies and business and regulatory models to promote smart city transit

	Smart roads	Next-generation buses	V2X networks	Smart traffic control systems	City-wide transit payments	Smart parking
Technologies	Electric drivetrains					
	EV charging					
	Autonomous vehicles					
	Machine learning					
	Sensors & IoT					
	Advanced comm networks					
	Blockchain					
Business & regulatory models	Digital hailing					
	Car & bike sharing					
	Carbon-free zones					

Source: Bloomberg New Energy Finance.

Illustrative timeline of potential smart city transit initiative roll-outs



Source: Bloomberg New Energy Finance.

DEVELOPING TECHNOLOGIES

"The concept provides novel technology to solve the ecological issues that all major transport companies face in relation to the mass movement of people and freight over long distances."

Bibop Gresta
Chairman and Co-Founder,
Hyperloop Transportation
Technologies

HYPERLOOP - A GAME-CHANGER?

A potential transport innovation that could entirely change the way the world's people move is Hyperloop technology. Working by propelling pods through a large tube at speeds of about 750mph (1,207kph) using magnets, the idea was publically mentioned by Elon Musk in 2012, with the pioneering form of transport getting closer to becoming a reality every day.

Market landscape

Hyperloop Transportation Technologies (HTT) has signed an agreement with Aldar Properties, the developer behind Yas Island, to begin construction of a Hyperloop system for Abu Dhabi. A tweet by the Dubai Media Office in June 2018 stated that, in theory, Hyperloop technology could cut travel time between Dubai and Abu Dhabi to just 12 minutes, compared to an hour and a half otherwise. That could save an estimated \$800 million in lost working hours.

Future outlook

There are several competing companies vying to make the breakthrough on Hyperloop technology around the world. Some have questioned the overall economic and commercial viability of this innovation. However, in terms of promising, clean mass-transport systems, it has generated much excitement and media attention.



ELECTRIC VEHICLES ON THE RISE

Electric vehicles (EV) – which run either partly or entirely on electricity – could help cities reduce both emissions and pollution. They are also quieter, meaning greater adoption in cities could reduce noise pollution.

In the last decade, the number of electric-vehicle models has ballooned from a handful to over 150.

Technology overview

Lithium-ion batteries have been widely adopted for EV due to a combination of technical performance and an established supply chain serving the consumer electronics market. By 2025, *Bloomberg New Energy Finance* expects the traditionally expensive EV lithium-ion battery pack to fall to below \$100 per kilowatt-hour (kWh). If trends hold, EV lithium-ion battery packs will drop to around \$70/kWh by 2030. This means electric vehicles may reach upfront price parity with internal combustion engine (ICE) vehicles between 2025 and 2030 (depending on vehicle segment and country).

Market landscape

The top five EV manufacturers – Nissan, Tesla, BYD, General Motors and Volkswagen – have collectively sold over 1 million electric vehicles since 2011 and captured nearly 50% of the EV market. Volkswagen aims to sell three million EVs annually by 2025 and electrify all its roughly 300 models by 2030.

China's recent New Energy Vehicle (NEV) quota – which requires automakers to sell a minimum share of EVs – is the single most important policy driving the global EV market forward.

Case studies

Studies show that the Gulf region proves challenging for battery systems due to the heat, with a pilot project by Masdar and Mitsubishi demonstrating that a battery system needs to be customised for hot weather. Pilot projects featuring an electric shuttle bus developed by Phoenix Motors revealed the same. Masdar City has partnered with Hafilat Industry and Siemens to produce the Eco-Bus, which is suited for the climate and requirements of Abu Dhabi.

“Changes in transportation, such as increased use of EV and autonomous vehicles (AV), will dramatically improve the efficiency of the way newspapers are distributed, reducing emissions.”

Mustafa Alrawi

Assistant Editor-in-Chief,
The National

"Most importantly, every electric car, Tesla or otherwise, matters to the environment we all share. Every time someone chooses electric, the future gets a little bit brighter!"

Tweet by Elon Musk

Tech Entrepreneur, Investor and Engineer, 27 December 2018

"In the future, oil (for transportation) and energy will be the two most important aspects to running any kind of industry. For transportation, electric vehicles will play the most vital role, and for energy, it'll be solar PV."

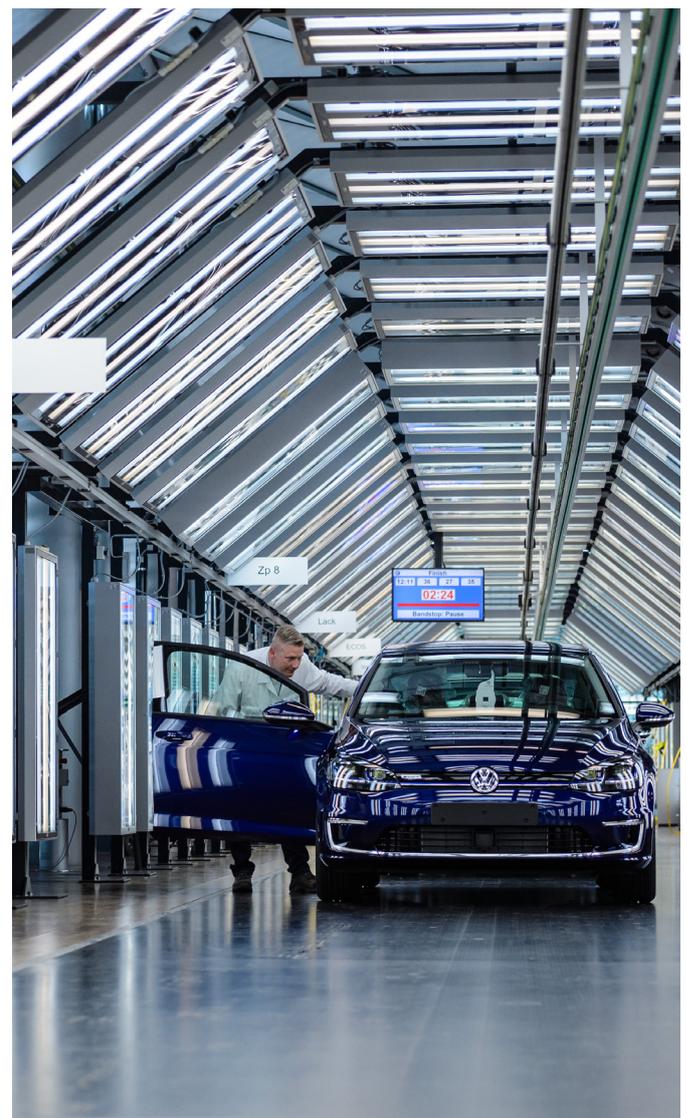
Abhijeet Chaudhary

Design Engineer, GE3S

Future outlook

While EV sales will likely remain relatively low leading to 2025, a turning point will occur between 2025 and 2030 as EVs become economical on an unsubsidised total cost-of-ownership basis across mass-market vehicle classes. Falling battery prices will be the primary enabler.

Given that batteries account for over 40% of the total component costs of an electric vehicle today, lower prices will have an outsized positive impact on EV cost-competitiveness.



PUBLIC CHARGING CHALLENGE

The number of public EV chargers has grown significantly in the last five years, but more are needed. Even after EVs reach cost parity with ICE vehicles in the latter half of the 2020s, lack of public charging could be a barrier to adoption in the 2030s. The problem could be particularly challenging in urban areas as apartment dwellers often lack access to EV Supply Equipment (EVSE). Cities interested in reducing air pollution or greenhouse gas emissions through EV adoption will need to ensure build-out of public charging infrastructure.

Technology overview

The global cumulative number of public EV charging points increased from under 100,000 in 2012 to over 360,000 in 2016, but these chargers differ along two interrelated metrics: charging level (speed of charging) and charging interface standard. There are four primary levels of public charging: standard (3kW), mid-accelerated (5-7kW), accelerated (22-43kW) and fast (43-120kW). As of 2016, charging rates of 5kW to 7kW were the most common, accounting for 49% of all public charging points globally. Fast chargers made up only 14% of available charging points globally. Lower-speed chargers are more common because fast chargers cost more to both build and operate.

Market landscape

The global number of public charging points has grown in recent years, but total refuelling capacity is small compared to gas stations in many large markets. China has the greatest capacity of EV chargers (4,762MW) – around four times more than either the US or Europe. Japan and the UK are the leaders in terms of their share of fast chargers; nearly 26% of chargers in Japan and 18% of chargers in the UK are fast.

Future outlook

Utilities, automakers and government entities have been active investors in public charging stations and are likely to continue their investment in the future to 1) drive higher demand for electricity, and 2) make EV purchases more attractive to consumers.

"We realised that 70% of CO2 emissions are caused by transportation. We decided to tackle this issue by being an enabler of the electrification of transportation by developing EV charging networks in Egypt."

Mohamed Mansour

Managing Director, Infinity Solar

“One major Aqualia project is All-gas, carried out under the EU FP7 programme that demonstrates, on a large scale, the sustainable production of algae biofuels using municipal wastewater. The complete process chain has been built with a cultivation area of two hectares, making wastewater-treatment energy self-sufficient, capable of powering up to 40 cars, and recycling the nitrogen and phosphorus into microalgae biomass and bioenergy.”

Alberto Justel Lera
International Communication
and Marketing Executive,
AqualiaMACE

WIRELESS CHARGING

Many cities are interested in increasing EV utilisation at the municipal, private and commercial levels, but urban environments are challenging for the deployment of public charging infrastructure, and home charging is less readily available. Wireless charging could make charging more accessible and convenient for a wide array of electric vehicles, including electric public buses that could have smaller batteries and avoid the problem of wasting time at charging stations. Cities could also deploy wireless charging infrastructure to generate new streams of revenue from private EV drivers. When urban vehicles are autonomous, wireless charging will allow refuelling without driver assistance.

Technology overview

Wireless charging works on the principle that a changing, or alternating, electric field applied to a coil of wire will induce an oscillating magnetic field around the coil, and vice versa.

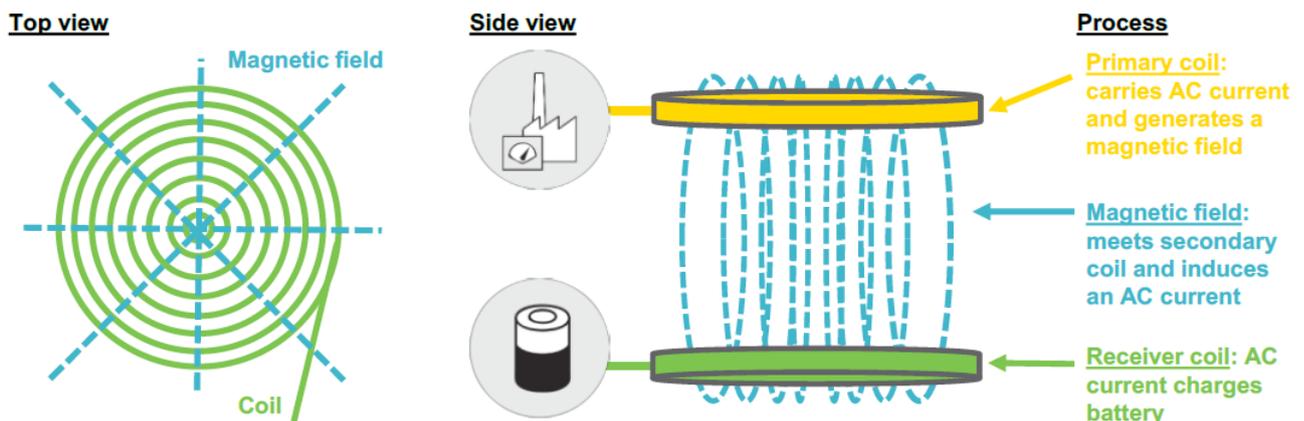
Market landscape

The market for wireless charging for EV is currently small and is driven by consumer aftersales purchases and limited electric bus contracts. Start-ups led most of the initial work in wireless charging for electric vehicles, but large automotive and technology companies have started to move into the sector.

Future outlook

Since 2011, wireless charging for EV has grown from a non-existent market to an annual market of over \$100 million. While wireless charging is currently only available for light-duty personal vehicles and public buses, it could eventually be adopted widely in Autonomous Vehicles (AV) or integrated into roads. AV, for example, will require a means for charging themselves if they are to become fully independent of human drivers.

Electromagnetic induction (wireless charging)



Source: Bloomberg New Energy Finance.



AUTONOMOUS VEHICLES

Autonomous vehicles (AV) could help cities reduce traffic congestion and cut, or even eliminate, vehicle accidents. Although the technology is still in its early days, cities could improve the safety and efficiency of transit by encouraging the use of autonomous cars.

Technology overview

For over a decade, automakers have been developing sensor-based Advanced Driver Assistance Systems (ADAS) that include sensors, actuators, control units and integrating software to improve vehicle safety. Many ADAS solutions are available today (i.e. Level 1 and 2 automation), but more complex systems – in which added data is captured, analysed and acted on – are expected in the near future.

Market landscape

There are over 140 vehicle models with Level 2 automation available to consumers. These offer at least two types of driver assistance (for example parking and lane-keeping assistance). The technological jump from Level 2 to Level 3 is much greater than from Level 1 to 2. Under Level 3, the autonomous driving systems must always monitor the driving environment and assess when human intervention is needed.

Future outlook

A select group of companies is testing AV on public roads and in advanced computer simulations. Google appears to have a sizeable lead. Companies with more miles of real-world and virtual testing will likely find it easier to convince regulators and ride-hailing services that their AV technologies are ready for commercial deployment. Over the long term, AV could replace a significant share of the global vehicle fleet. However, an infrastructure framework that provides data collection, analysis and communications networks to keep AVs safe and effective is key to AV roll-out.

“Hydrogen fuel cells will provide green energy for transport, homes and businesses.”

Peter Kelly

Head of Research Development,
Manchester Metropolitan University

“Autonomy will allow for the use of specialised vehicles that are tailored for – and a better fit for – the mobility task at hand, decreasing energy resources used. Continued advances in Careem’s platform, like predictive demand and pooling, among other planned advances, allow for more efficient use of the fleet.”

Bassel Al Nahlaoui

Managing Director, Careem Gulf

Autonomous Vehicle Taxi Service – Dubai’s Roads and Transport Authority (RTA) signed a contract for 200 Tesla Model S sedans and Model X SUVs equipped with autopilot software. The first 50 vehicles will be used to kick-start Dubai’s AV taxi service in the future.

2020 Smart City Outlook – Predominantly wealthy urban centres with significant levels of autonomous governance will have learnt from their pilot projects and partnerships and implemented sensor networks to collect data.

“I am the president of three campuses at an Italian public university. The use of electric buses for the students’ mobility to and from these campuses will contribute to significantly reducing global CO2 emissions related to our activities and improve our position in international rankings dealing with sustainability in the university sector.”

Federico Delfino
Professor in Power Systems
Engineering, University of Genoa

NEXT-GENERATION BUSES

While they’re cheaper and easier to deploy than light rail or subway systems, most buses are powered by diesel or compressed natural gas and produce high levels of particulates and greenhouse gas emissions. Next-generation buses will utilise electric powertrains to eliminate negative air-quality impacts and employ Artificial Intelligence (AI), AV technologies, wireless charging and digital hailing to improve bus safety, availability and reliability.

Market landscape

While buses that incorporate all of these technologies remain in the planning stages, the shift to electric powertrains is underway. Yutong, BYD, Proterra and others offer a variety of electric buses with 100–450kWh batteries (and 50–250 mile/80–402 kilometre ranges) and have made sales to public transit agencies in cities throughout North America, Europe and China. AI and AV technologies are being applied to buses at a small-scale rate today and are likely to gain traction over the medium term. Wireless charging and digital hailing will likely only have applications for buses in the long term.

Future outlook

China is the largest producer and user of electric buses due to national sales targets, supportive subsidies and municipal-level air-quality targets. Of all electric bus sales to date, 99% have been in China. In 2016, 26% of new bus sales in China were electric, equating to 137,000 sales of electric buses. The numbers of electric buses in Europe and the US are tiny by comparison. At the end of 2016, there were roughly 300 electric buses in the US and 1,600 in Europe.

Case studies: Examples of companies working on next-generation buses

Company	Country	Description
	China	The city of Shenzhen plans to electrify its entire public bus fleet by the end of 2017 using (primarily) buses from BYD. Shenzhen first began piloting electric buses in 2011.
	U.S.	Proterra is testing autonomous electric buses in three cities in Nevada in collaboration with the University of Nevada, Reno.
	Germany	Mercedes-Benz is working on a semi-autonomous city bus called the Future Bus. The bus utilizes multiple cameras and radar systems enabling it to communicate with traffic lights.

Source: Bloomberg New Energy Finance, logos from company webpages.

Spotlight: Reaching Nevada for autonomous buses

In January 2017, U.S. electric bus manufacturer Proterra began working with the City of Reno (U.S.) to explore how it might be possible to utilize autonomous buses in public transit. The first goal of the collaboration is to determine which sensors and communication networks the city needs to deploy before testing autonomous buses. To this end, Proterra has outfitted a number of buses with advanced cameras and heat sensors, and is measuring how effectively these sensors are identifying pedestrians, cars and other potential street obstacles. Data from these sensors, in addition to data collected from smart street lights, will then be utilized to code perception algorithms for use in autonomous buses.



2030 Smart City Outlook –
Data collected from smart cities will be used to create dynamic electric bus routes, smart parking systems and intelligent traffic control.

In San Francisco, the Municipal Transportation Agency (SFMTA) found that enabling dynamic pricing for parking increased revenues by \$1.9 million over two years.

SMART PARKING

In any city, even one with near-perfect public transportation, parking is needed for private vehicles. The placement of parking, the types of fees, and the way that a city directs vehicles to specific parking spots could reduce congestion, encourage the inclusion of public transit in more journeys, and reduce idling, which leads to air pollution.

Technology overview

Efficient data collection from mobile sensors can inform transport officials of the most congested transport routes, and driver behaviour. Analytics can support urban planning for incentivising alternative routes and new infrastructure. One application being explored by many city authorities is the installation of sensors in parking spots to determine whether space is vacant or occupied, with data transferred to a parking management platform, commonly on low-power, wide-area networks. Data can then feed into a parking application operated by the relevant government authority, or be made publicly available via an Application Programme Interface (API). Applications are then developed to link drivers on the road with vacant parking spots, and then guide the drivers to the parking spots through the least congested routes.

Future outlook

An increase in shared vehicles or AV increases opportunities for urban planning, with fewer requirements for parking spaces as vehicles circulate continuously throughout the city rather than remaining in idle mode. This should free up high-value land in city centres that can be held by the city government or auctioned for other purposes. The land can also be used to reduce road congestion by opening up new lanes, such as privileged bus or bike lanes, or for something completely different like urban green spaces. This can have some knock-on effects on municipal funds as revenues from parking meters decrease. In this case, road charges in city centres may become more common to account for this loss, and new vehicle identification and payment infrastructure may be deployed.



Case study: Dynamic pricing for parking in San Francisco

In April 2011, San Francisco Municipal Transportation Agency (SFMTA) initiated SFpark, a smart parking system which implemented dynamic pricing for on-street parking to open up parking spots on each block and reduce vehicle circling or double-parking. Funded through a \$19.8 million grant from the U.S. Department of Transportation, the project aimed to provide:

- Easier parking, by ensuring that 15% of all parking spots were available at all times;
- Safer roads for pedestrians and bicyclists by making parking simpler for drivers;
- Better businesses for neighborhoods;
- Faster public transit, by reducing the number of vehicles causing congestion on the roads.

Parking rates

Rates were adjusted according to the location, time of day, day of the week, and existing usage of parking spots. Where parking spaces were easily available, rates would go down to fill the spots, and rates would increase progressively in areas with limited parking until at least one spot per block would open. They could not be adjusted by more than a \$0.50/hour decrease or \$0.25/hour increase, and could only be adjusted once per month.

Outcomes

Electromagnetic interference from overhead transit lines and early battery degradation caused some sensors to fail two years earlier than expected. By the end of the project, two sensors had to be included in almost every parking spot.

The SMFTA found that reducing the number of cars parked across two spots could lead to improvements in transit speeds: transit speeds increased from 6.4mph to 6 mph along corridors where vehicles were each parked in just one spot.

EMERGING BUSINESS AND REGULATORY MODELS

"Cairo is very polluted; we see it every day, first hand. The government also pays many subsidies on gasoline. To kill two birds with one stone, we decided to go the EV route and encourage the transition from gas to electronic."

Mohamed Mansour
Managing Director, Infinity Solar

CARBON-FREE ZONES AND CONGESTION CHARGES

Cities face increasing public pressure to reduce traffic congestion, address urban air pollution and reduce their carbon footprints. Carbon-free zones and congestion charges are two means by which to achieve this. They could also increase the uptake of EV by private drivers and private mobility services or encourage more city dwellers to use clean public transit.

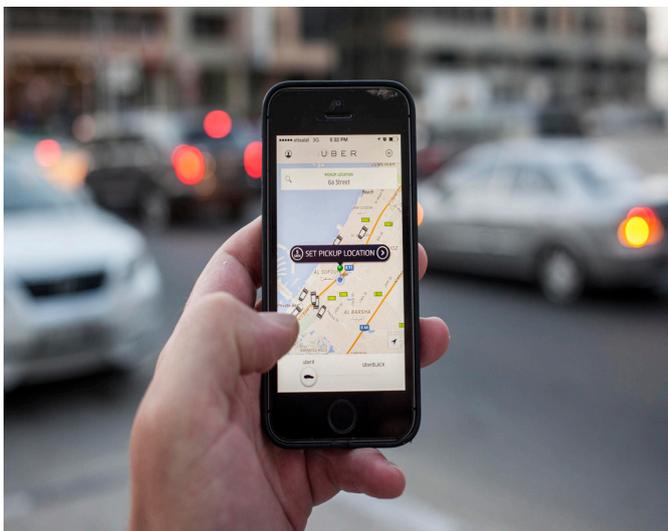
Market landscape

Cities around the world have proposed diesel bans or announced intentions to do so, with many cities announcing plans to buy only zero-emission buses from 2025 and make a significant area of their public space emission-free by 2030. Many of the diesel bans are in Europe, with diesel cars having over 50% penetration.

Future outlook

Municipal or nationwide diesel bans are politically demanding. While it is a challenge to assess the feasibility and impact of plans for carbon-free zones, there is growing interest by municipal and national governments in banning diesel and cleaning up city air.





DIGITAL HAILING

Digital hailing (car and bike sharing) is at the heart of the transition from asset-based personal mobility to services-based personal mobility (transport-as-a-service) and a precursor to future AV networks.

Market landscape

Over 600 million people are users of ride-hailing services, and at least 33 million drivers work as ride-hailing drivers in some capacity.

Case studies

Technology companies view ride-hailing networks as an ideal platform on which to launch the autonomous driving technologies they are racing to bring to market, although some automakers are wary of the threat to personal car ownership. Didi Chuxing (China), Uber (USA), Ani Technologies (Ola), Lyft and Grab Taxi have a combined valuation of about \$130 billion and close to 500 million users today. Consolidation and localisation are two of the most important trends. Uber recently sold its operations in China and Russia to local competitors. Ford and General Motors, meanwhile, have plans to test Level 4 autonomous vehicles in Lyft's ride-hailing service.

Future outlook

Ride-hailing companies are working to decrease costs in two ways.

Short term: offering shared ride-hailing services.

Long term: reducing operating costs by adopting autonomous, electric fleets (lowering labour costs and making ride-hailing more cost competitive).

According to a study by Arizona State University, the arrival of ride-hailing services led to a significant decrease in both traffic congestion and greenhouse gas emissions in select US cities.

“ekar introduced the first ‘peer-to-peer’ carshare solution in the region, where owners can insert their cars to monetise assets at their leisure. ekar is also the first carshare in the region to offer company fleet solutions via white-labelling. The ekar fleet reduces levels of air pollution, lessens parking issues, decreases road expansions, and allows more resources for park development and urban green spaces. For every one carshare car on the road, 17 owned cars are off it. In 2017, ekar reduced carbon emissions by 3,000 metric tonnes with over 4,200 cars taken off UAE roads. In 2018, ekar is on track to triple these results. ekar also recently signed an agreement with Tesla and Masdar City to provide the first electric solution in the region. Companies such as Saudi ARAMCO are working with ekar to make its company cars fully smart through ekar technology, improving vehicle utilisation and decreasing staff car requirements by up to 35%.”

Vilhelm Hedberg

Co-founder and CEO, ekar

CAR AND BIKE SHARING

Car and bike sharing is the ideal complement to public transportation, offering improved mobility access, last-minute transit solutions, on-demand (often zero-carbon) access to mobility, and a reduced need for parking spaces.

Market landscape

From 2006 to 2014, the number of vehicles in car sharing fleets increased tenfold globally. The number of members in such services jumped to 5 million. US bike sharing customers today complete around 27 million rides annually. Two variables differentiate business models:

Vehicle ownership: privately owned vehicles versus maintaining a fleet.

Rental flexibility: allotted parking spots versus a floating model (parked anywhere at the end of a trip).

Car-sharing schemes are generally company owned and charge on a per-mile or per-minute basis, with some charging an annual or monthly fee. They generally cover fleet-based point-to-point schemes (the car must be returned to the same place it was collected); fleet-based flexible schemes (one-way journeys and cars can be dropped off anywhere within a specified zone); and peer-to-peer or P2P schemes (similar to ‘round-trip’ car sharing, in that users return cars to the same location they were collected, with the car sharing fleet being decentralised – meaning owned by private individuals, not by a central operator). Bike-sharing systems see fleets owned by companies and services almost always flexible. Stations are often co-located near transit hubs, in areas underserved by public transit, and in areas where demand for transit overwhelms existing bus and subway systems.

Future outlook

The expansion of bike-sharing services, coupled with investments in cycling lanes, could help cities spur a shift away from car ownership.

CHALLENGES TO MOBILITY INNOVATIONS

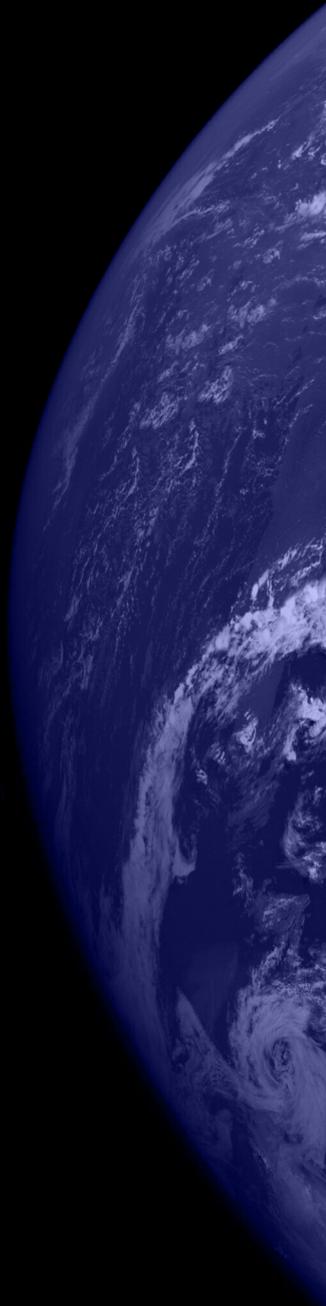
Funding smart transit projects could be one of the biggest barriers. Today, cities raise money for infrastructure projects via means such as tenders, bonds and taxes. While only eight were announced in 2016, there were 35 announcements in 2017, indicating growing interest. The rise in popularity of green bonds could be a route for cities to raise money for smart city transit projects.

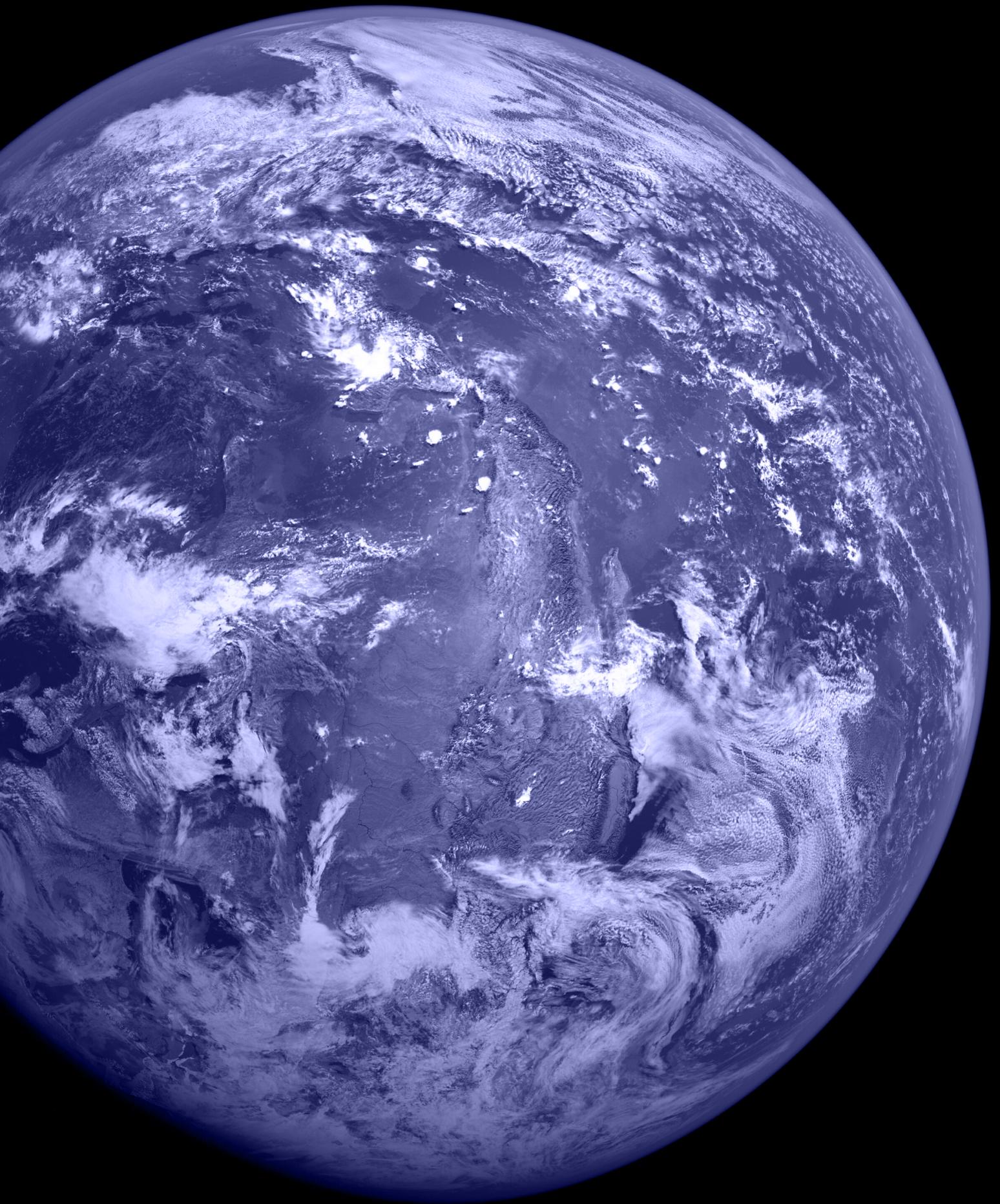
Masdar City is a good example of how targeted investments by governments, along with strategic collaborations between public- and private-sector entities, can support the testing, scale-up and eventual commercial deployment of systems that enable efficient smart transportation and its management around the world.

Procurement via well-structured competitive tenders can also help cities to choose the most appropriate technologies while keeping costs low. Many smart city transit projects can also offer cities new ancillary revenues via careful monetisation of the data generated once the projects are commissioned.



CHAPTER 5
SPACE





CRITICAL INNOVATIONS IN THE SPACE-EXPLORATION SECTOR WILL PROVIDE SUSTAINABLE PRACTICES ON EARTH

A 2018 ARTICLE written for the Abu Dhabi Sustainability Week website by H.E. Dr Ahmad bin Abdullah Humaid Belhoul Al Falasi, Minister of State for Higher Education and Advanced Skills and Chairman of the UAE Space Agency, considers the connection between space exploration and sustainability on Earth. In his piece, His Excellency Al Falasi writes, "Some may wonder why a space agency, which focuses on furthering human knowledge of the universe, is concerning itself with environmental protection. One of the biggest differences we can make – whether on an individual or a global scale – is to improve efficiency in the way we use resources. By reducing the amount we consume, we decrease both our net waste and emissions. Here, we have already learned a great deal from space exploration, which requires highly efficient processes as a result of strict weight limits applied during launches."

His Excellency Al Falasi cites an example from the University of Kenitra in Morocco, of an organisation filtering and purifying nearby groundwater supplies using techniques that were initially developed for recycling wastewater into drinking water for astronauts. He says, through its far-reaching impact, the space sector operates at the intersection of other key industries related to sustainability – from renewable energy and oil and gas to logistics and construction. According to a 2017 article in *The Ethicalist*, the space technologies industry is estimated to be worth around \$300 billion globally and is growing by around 8% annually. The UAE's investments in space technologies have exceeded AED20 billion (\$5.5 billion), with players including satellite data and TV broadcast company Al Yah Satellite Communications Company (YahSat), mobile satellite communication company Thuraya Satellite Telecommunications, and Earth-mapping and observation systems DubaiSat-1 and DubaiSat-2.

"HVAC systems are ideal for improving indoor air quality and saving energy."

Samia Mhenni
Art Time

"Passive strategies for sustainable buildings, for example reducing solar heating on building envelopes through passive measures like increasing heat insulation on the walls and shading glass surfaces, could drastically reduce electricity consumption, making an immense impact on sustainability."

Svilen Nickola-Todorov
Architect and Sustainability Researcher,
GreenStyle Architecture Int.

"Nanotechnology and nanofabrication will increase innovative devices' technical capabilities and performance, boosting both the usability and feasibility of renewable-energy applications."

Dr Mohammed ALSaidi
Assistant Professor, Engineering Department,
Ministry of Higher Education, Oman

"3D printable technology is going to make a sizeable difference in industry as it will reduce all forms of uncertainty in terms of skill and product quality. Standardised products are key to stopping material wastage and improving productivity."

Jithin John
Civil Engineer, Nael General Contracting L.L.C

"Additive Manufacturing (AM, otherwise known as 3D Printing) has recently made the jump out of the traditional research laboratory and into serial production of high-end, complex metal parts. By utilising an entire digital end-to-end process, from design to simulation to manufacturing and quality control, it is possible to accelerate the development of new components with the highest material and technology requirements, and bring these advancements to market faster. For example, Siemens tested a new blade design for gas turbines with a completely revised and improved internal cooling geometry manufactured using AM technology. Design and manufacturing advancements like these allow us to significantly improve overall performance and efficiency of new and existing power-generation assets, which results in cleaner electricity being provided to more people around the globe."

Lisa Davis
CEO Energy, Siemens AG



THE NEXT FRONTIER: MARS

Dubai's Mars City

In 2017, His Highness Sheikh Mohammed bin Rashid Al Maktoum, Dubai Ruler and Vice President and Prime Minister of the UAE, announced plans to construct a Martian city in the desert. The project is part of the UAE Mars 2117 Project, which sees the nation aiming to establish the first human settlement on the Red Planet by 2117.

According to a piece in *The Ethicalist*, the construction of the Mars Scientific City – where engineers aim to replicate conditions on the Red Planet for research purposes – will be designed by Danish architect Bjarke Ingels in partnership with Emirates scientists and engineers. It will be made up of a series of futuristic glass domes that could house up to 600,000 people. The Mars colony plan is being implemented by the Mohammad bin Rashid Space Centre, where scientists began preparing a 100-year plan for the project's implementation in 2017. According to government documents, "the centre's plan will focus on preparing specialised national cadres and developing capabilities in the fields of space science, research, artificial intelligence, robotics and advanced space technologies". Specifically, the site will allow scientists to solve some of the technical problems that must be overcome for colonists to survive on our neighbouring planet, and will act as an enormous living laboratory that will simulate conditions Mars settlers will face. The city, which will be spread across 177,000 square metres (1.9 million square feet), is set to cost around AED500 million (\$137 million). Sheikh Mohammed bin Rashid calls it "an extraordinary national project", one that will also be open to the public, once complete. Several other manned missions to Mars are in place globally, but the UAE is among the top nine national investors in space sciences, aiming to attract the world's top space scientists, designers and engineers to develop the Mars 2117 Project.

"The UAE is a great country with vision and understanding of the challenges we face and the rapid changes our world is experiencing. The landing of people on other planets has been a long-time dream for humans. Our aim is that the UAE will spearhead international efforts to make this dream a reality."

His Highness Sheikh Mohammed bin Rashid Al Maktoum
Vice President and Prime Minister of the UAE and Ruler of Dubai

The Hope Mars Mission and other UAE space achievements

In order for the UAE's Mars 2117 Strategy to work, scientists and planners will also need data from the Red Planet. That's where the Emirates Mars Mission comes into play. The UAE developed the Hope space-exploration probe mission to Mars, and it is set for launch in 2020. The nation hopes that the probe will reach Mars in 2021, the UAE's 50th anniversary.

According to *The Ethicalist*, the probe will study the atmosphere around Mars and design complex models to predict the climatic conditions settlers will face. The Hope programme – the first space mission by an Arab-Islamic country – will be managed by the UAE Space Agency with support from international partners. The data collected by the car-sized probe will allow scientists to create a model of conditions on the planet's surface, with data shared freely with over 200 global academic and scientific organisations. Earth and Mars only align once every two years. To take advantage of this proximity and reach the destination by the target date, the craft will have to launch in July 2020 to reach Mars in 2021. As the UAE Space Agency states: "The UAE government sees the Red Planet project as a turning point in the nation's development. It will establish the space technology sector as a key economic sector for years to come. The UAE aims to be among the top countries worldwide in the field of space technology by the time the orbiter arrives at Mars in 2021."

The UAE also launched MySAT-1, a small cube-shaped satellite ('CubeSat') built by students at the Khalifa University of Science and Technology, in 2018 – just weeks after the first-ever Emirati-designed satellite, KhalifaSat, was launched from Japan.

MeznSat is another UAE space project in the pipeline. According to the MeznSat website, UAE university students are primarily involved in developing 3U CubeSat, which is being built and tested primarily to detect Greenhouse Gas (GHG) concentrations. The project aims to offer the UAE space industry qualified, well-trained graduates who have gained hands-on experience through projects like this. In addition, the CubeSat project opens windows for advanced space-oriented research relevant to the UAE. In terms of sending people into space, the ambitious UAE Space Agency aims to send the first Emirati astronaut to the International Space Station in 2019.

Case study: Masdar Institute Students' Take on Mars Innovations

In 2016, the Masdar Institute, which now forms part of the Khalifa University of Science and Technology, won two awards for presentations on Space Technology at the second annual Emirates Mars Mission (EMM) Science Workshop's 'Explore Mars Poster Competition'. Students and faculty won two of the three awards - the first and the third - for their presentations on space systems and technology.

Established in collaboration with the Al Yah Satellite Communications Company (YahSat) and Orbital ATK, the programme fosters advanced research areas in space science and technology. These are needed to support the UAE's national space programme as well as other space-related areas covering human resources, technical advancements and infrastructure. Organised by the Mohammed bin Rashid Space Centre (MBRSC), the event aimed to address the scientific challenges posed by the Martian atmosphere.

The first prize was awarded to a poster titled 'Novel UAE Native Microalgae Species to Support Martian Human Habitable Environments', presented by the Masdar Institute's Ahmed Al Harethi, a Chemical Engineering PhD student. Dr Ayesha Al Marzouqi and Dr Hector Hernandez, both assistant professors in chemical and environmental engineering, were co-authors of the winning poster. The aim of this research was to develop biological and sustainable processes to support human living conditions on Mars. This research could provide oxygen for life, support food production for human consumption, transform organic waste into bio-fertilisers, and recycle water for use on Mars. This was the first research that addressed the production of a habitable atmosphere on Mars that has ever taken place at the Masdar Institute.

The third prize was awarded to Engineering Systems and Management student Abdullah Essa Sharif, along with Mechanical Engineering students Adham Mohammad Aqil Hadi Alkhaja and Manar Almazrouei, who presented a poster titled 'H2OBOT: A Robotic Mission to Explore Martian Liquid Salty Water and its Possible Use for Future Human Exploration'. The three students belonged to the Space Systems and Technology Concentration programme sponsored by YahSat.

"Strata's Research & Development (R&D) unit is focused on developing advanced manufacturing technologies to support Strata's current and future programmes and execute R&D initiatives in collaboration with local universities, technology partners and Original Equipment Manufacturer (OEM) customers. The execution of the projects is performed at three dedicated labs created for this purpose: one located at Strata in Al Ain, UAE, and the other two at Khalifa University and the Masdar Institute in Abu Dhabi. Currently, the programme encompasses several main R&D projects that involve 22 engineers, academic researchers and UAE national students. The projects include developing technology solutions in critical areas, such as automation, robotics, inspection, 3D printing, composite processing, and emerging Digital Factory 4.0 themes, such as the Industrial Internet of Things (IIoT), connectivity and blockchain, to enhance Strata's competitiveness in the aerospace industry. In one of the collaborative projects with Khalifa University, Strata has an ongoing project aimed at utilising aerospace materials that have exceeded their shelf life to manufacture bicycles and other sports goods."

Ismail Ali Abdulla

CEO, Strata Manufacturing PJSC

GROWING FOOD ON MARS

A piece in *Science Daily* covers studies by the Botanical Society of America, with its researchers trying to understand how plants respond to the space environment. This information is critical to successfully providing fresh food to astronauts.

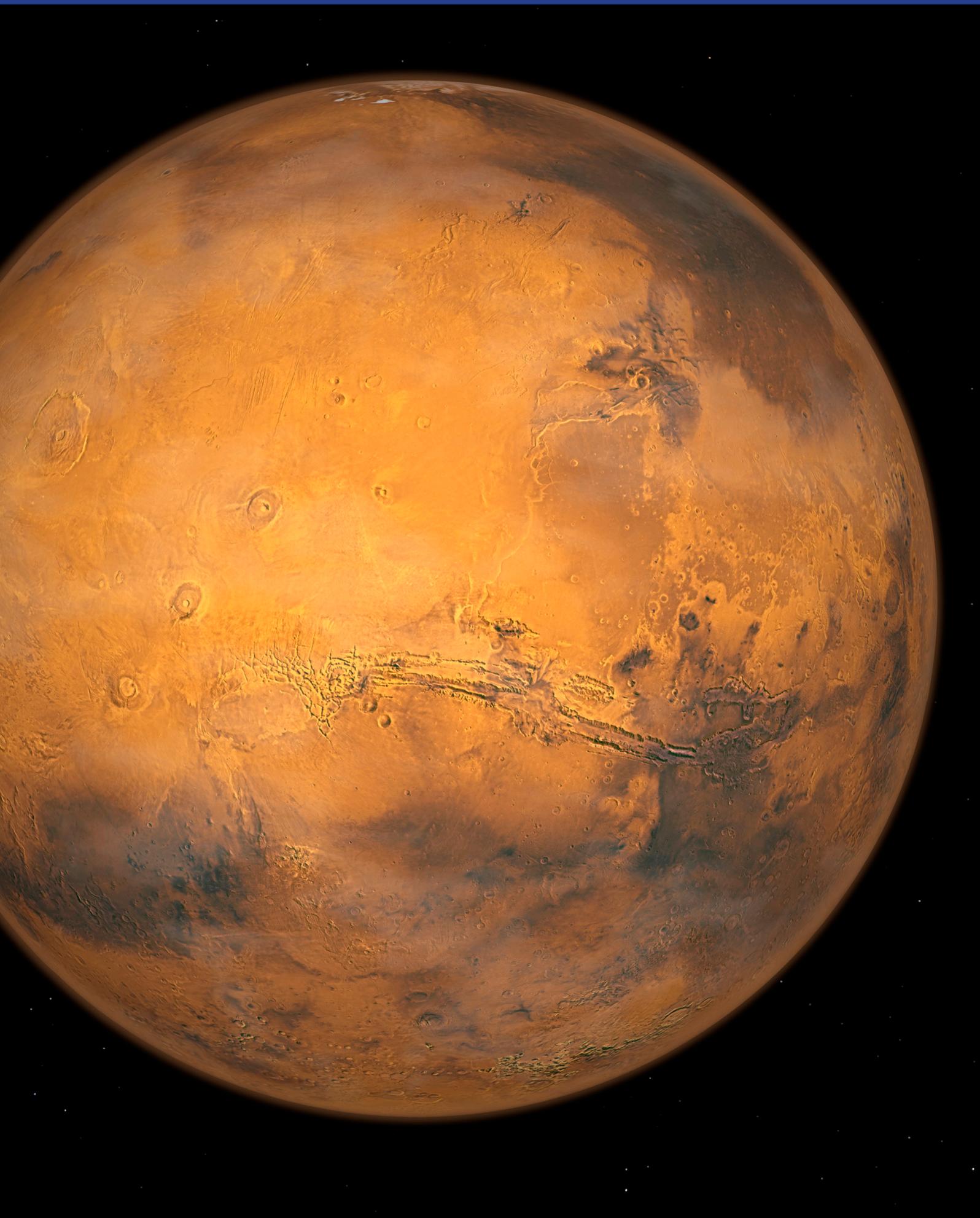
Science Daily reported on researchers who compared two methods of analysing which genes are expressed (the 'transcriptome') in plant tissue, specifically in the root tip. The results reveal how plants adapt to the microgravity space environment and can help guide the research needed for the successful utilisation of plants in future exploration initiatives. Both techniques – which are called RNA-Seq and microarray – quantify mRNA transcripts, the intermediary molecule between genes and the proteins those genes encode. This provides a wealth of information about how an organism is responding to environmental cues.

"The information gained by the spaceflight and exploration research community today will guide the plant biology and habitat engineering required for the successful utilisation of plants in future exploration initiatives."

Dr Anna-Lisa Paul

Space Biologist and Study Author,
University of Florida Space
Plants Lab





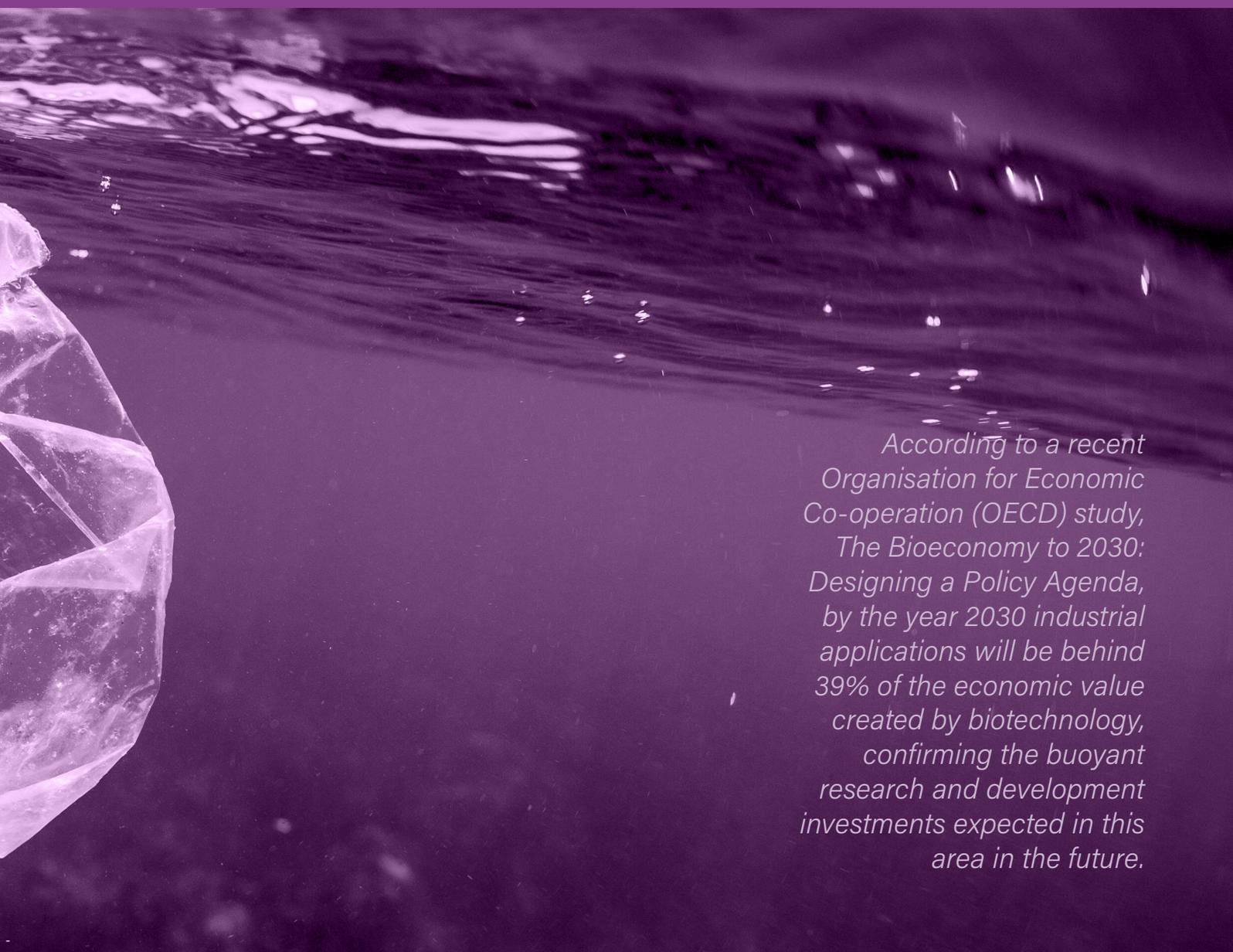
CHAPTER 6

BIOTECHN



Modern biotechnology is speeding up the development of innovative products and technologies that help reduce fatality rates, cure disease, feed the hungry, reduce our environmental footprint, and deliver more effective industrial manufacturing processes

IOLOGY



According to a recent Organisation for Economic Co-operation (OECD) study, The Bioeconomy to 2030: Designing a Policy Agenda, by the year 2030 industrial applications will be behind 39% of the economic value created by biotechnology, confirming the buoyant research and development investments expected in this area in the future.

SAVING THE CLIMATE THROUGH BIOTECHNOLOGY

SOLVING THE PLASTIC PROBLEM

A *Biotech-Now* article suggests that biotechnology might be key to solving the world's plastic problem, an issue that contributes significantly to the world's climate challenges. The article claims that there are "12.7 million tons of plastic floating in our oceans alone", not counting the tons on our streets and in landfills. It adds that "most of the 300 million tons of plastic manufactured each year are harmful to the environment because they aren't biodegradable and are made from chemicals derived from oil, natural gas and coal – otherwise known as petroleum-based plastics – which release Greenhouse Gases (GHG) into the environment". Thanks to biotechnology, however, new bio-based plastics derived from renewable biomass sources are being developed as viable replacements. These bio-based plastics are recyclable and often biodegradable, breaking down naturally in the environment and leading to fewer greenhouse gas emissions. Coca-Cola and Ford are already investing in bio-based plastics, using the plastic alternatives for items such as drink bottles and foam for car seats.

DRIVING DECARBONISATION

According to the US Environmental Protection Agency (EPA), transportation fuel is the biggest contributor to GHG, making up over a quarter of total emissions in the US alone. In total, the world uses 50 million barrels per day of carbon-emitting fossil fuels to power cars, planes and ships. Unlike transportation fuels that come from fossil fuels, biofuels are manufactured from living matter – usually corn – and don't emit as much carbon. By boosting our use of biofuels, for example ethanol, we can make massive progress in lowering the transportation sector's impact on the environment. Biofuels can also be produced from sources that would otherwise emit GHG, for example, factory or animal waste. Innovations like this allow biorefineries to transform waste into cleaner fuel.

"Agri-horticulture waste used for bioethanol manufacturing is going to have a positive impact in the future."

Sandip Mukherjee

Development Consultant, Virtual Green (OPC) Private Limited

Case study

Richard Branson's Virgin Atlantic Airlines recently tied up with LanzaTech, a company pioneering the use of biotechnology to develop fuels. Virgin used LanzaTech's next-generation advanced fuel, recycled from industrial waste gases, to power a flight from Orlando to London. Estimates showed that this fuel blend dropped GHG by over 70% when compared to burning conventional jet fuel.

Waitrose delivery vans fuelled by food waste

In 2017, British supermarket chain Waitrose unveiled its eco-friendly delivery vans that run on food waste. The vans are powered by biomethane, a sustainable green alternative to fossil fuels.

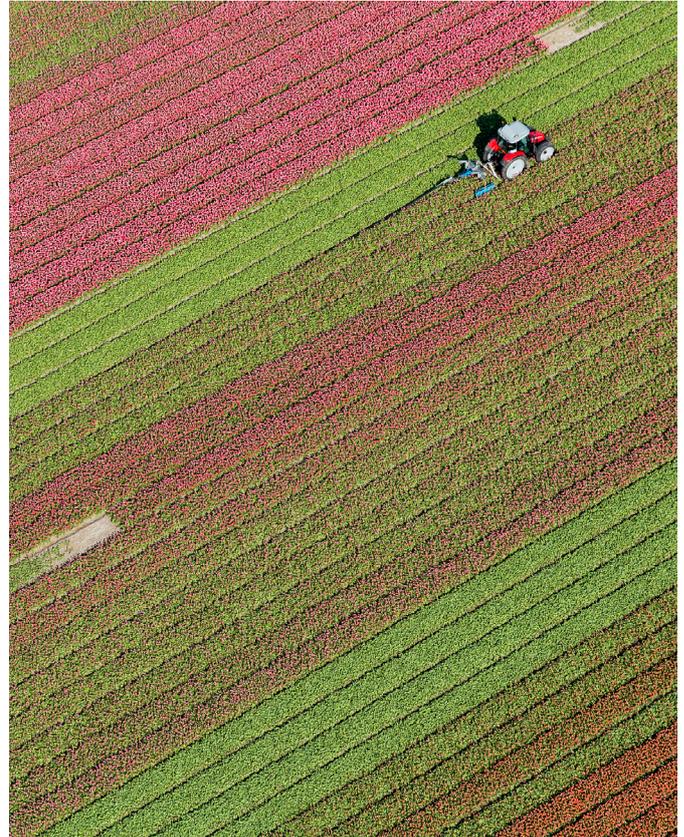


EFFICIENT AGRICULTURE THAT FEEDS THE WORLD

Biotechnology innovations can also help us grow food on a larger scale and in a more environmentally-friendly manner. Biotechnology – including gene editing tools like CRISPR – have enormous potential regarding the creation of drought-tolerant or disease-resistant crops. Since biotech crops were introduced in 1996, pesticide use has dropped by over 8%. In one year, the use of biotech crops and no-till farming systems saw CO2 emissions falling by 27.1 billion kg. That's equal to removing 16.7 million cars off the road. To stop the planet from overheating, however, innovations are needed – especially in areas where most food is grown. Ag microbial technology is a new biotech innovation that might help. There are billions of microbes – tiny organisms like bacteria and fungi – in a plant's soil. These exist to give the plants the nutrients they need to grow. Through biotechnology, microbes can be engineered to enhance a plant's growth to the desired effect.

Case study

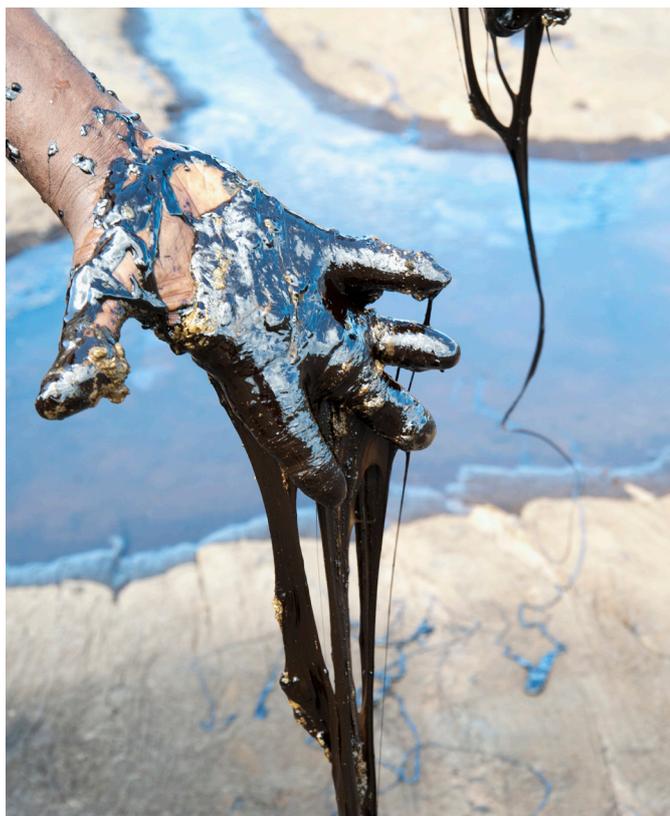
American company Pivot Bio is engineering microbes to offer plants more nitrogen, which is critical to plant growth and health. This reduces the need for nitrogen fertilisers, which often run off, polluting waterways and increasing GHG emissions. Research into ag microbials has caught investors' attention, with some offering to fund Pivot's efforts. These include Breakthrough Energy Ventures, the investment fund led by Bill Gates, with contributions from billionaires like Amazon's Jeff Bezos and Virgin's Richard Branson.



"Strengthening the circularity and sustainability of the bioeconomy is a core issue. The importance of understanding the effect of the bioeconomy on natural resources and the ecosystem's services should be of utmost priority, while a deeper exploration of the relations between the biosphere and economic activity is needed for a better understanding of the bioeconomy itself. One important challenge is strengthening education and knowledge of the bioeconomy, especially in agriculture, the agri-food value chain, and bioenergy production. It is important to identify value-added activities that support investment in production, research, processing, retail and marketing."

Dr. Apostolos Malamakis

Mechanical Engineer, Aristotle University Thessaloniki



MICROBES HELPED CLEAN UP BP'S OIL SPILL

An article in the *Scientific American* reveals how microorganisms were "a big reason why BP's 2010 oil spill in the Gulf of Mexico was not far worse." According to Chris Reddy of the Woods Hole Oceanographic Institution, "The microbes did a spectacular job of eating a lot of the natural gas." The article states that the small hydrocarbon molecules in natural gas were the easiest for the microorganisms to eat, with the microbes getting help from the nature of the oil spill: so-called Louisiana light, sweet crude mixed with natural gas, as opposed to bitumen or other heavy, gunky oils. "More than 150 different molecules make up the toxic stew of hydrocarbons that spewed from BP's Macondo well on the Gulf of Mexico seafloor," the piece reported. "The microbes chewed through the smaller, dispersed hydrocarbons (and the dispersants themselves) relatively quickly, helped by the fact that these molecules can dissolve in water. Ocean currents, in addition to keeping the spilt oil offshore, spurred microbial activity amidst the oil spill. That continuous mixing of the water allowed a bacterial bloom to turn millions of barrels of oil into an estimated 100 sextillion microbial cells of ethane-consuming *Colwellia*, aromatic-eating *Cycloclasticus*, alkane-eating *Oceanospirillales*, oil-eating *Alcanovorax*, methane-loving *Methylococcaceae* and other species, including at least one previously unknown to science. But even the ravenous microbes could not clean it all—and much of what they consumed (natural gas components like methane, ethane, butane, propane and pentane) does not legally count as part of the oil spill. Plus, plenty of tarlike hydrocarbons—which are far too big for microbes to chew up—spilt, too." Scientists are still trying to understand the impact of this oil spill, and the role that nature itself plays on helping to clean it up today.

"Biocarbon can clean fossil carbon with an efficiency of 200%."

Taslim Owonikoko
CEO and Patent Owner,
Berekotry Ltd

THREE BIOTECH PRODUCTS WE COULD BE USING SOON

1. Cow-free milk

Singularity Hub reports that “cellular agriculture uses biotechnology to develop proteins and biomolecules that are usually derived from animals. These distributed cellular factories let us brew food and beverages more locally and sustainably, creating synthetic dairy and other food items. It is believed that this technique could alleviate the environmental impact of livestock farming and improve food security.” The piece reveals that food company Perfect Day’s cow-free milk contains the same proteins that are produced by an actual cow, just without any cows involved whatsoever. The brand’s cow-free milk does not have any lactose either, and boasts a shelf life of six months.

2. No-animal meat

Clean meat startup Memphis Meats recently made waves bringing lab-grown beef and chicken to the masses, according to a piece in *Singularity Hub*. The article says that the company has raised \$17 million from investors, including Bill Gates and Richard Branson, to transform the way we eat meat. With some aspects of livestock farming being problematic – contributing to around 18% of global greenhouse gas emissions (although some scientists claim the figure is much higher), fostering deforestation and habitat loss, encouraging routine antibiotic use, and causing large-scale animal suffering – inexpensive, scalable, and locally brewed meat could be a transformative solution, with only small animal biopsies required to extract the cells needed to grow edible meat. *Singularity Hub* adds that, in the future, programmable food – constructed molecule by molecule in cellular factories – could metamorphose what we eat, and how we eat it. Egg-free egg whites, shrimp-free shrimp, and sushi-free sushi are being developed too.



3. Open-source biology

A startup, Cell-Free Tech, “is breaking a billion-year-old processor out of the cell to let anyone, anywhere, build biomolecules with easy-to-use kits – only without the actual cells.” That’s according to *Singularity Hub*. “This renders biology more user-friendly as it eliminates the need for microbial culturing, training, and equipment. Making cell-free systems available to all could kick off a new era of ‘deculturised’ do-it-yourself biology.” Interested open-source biologists get access to plasmids carrying the genetic software instructions, similar to an app. They then programme the ribosome, essentially a 3D-protein printer, to produce different proteins. *Singularity Hub* says they “could be custom-fluorescent colours, vanilla smells, glow-in-the-dark ink” or something else. One day they could even be medicines. Along with an open-source tool, the cell-free kit allows people to make biopixels so they can follow the production of their mini biofactories via an app.

CHAPTER 7

TECH FOR



GOOD



TECH CAN BLOSSOM INTO SUSTAINABLE SOCIAL VENTURES OPERATING AT SCALE

"Water is becoming scarcer by the day, and electricity is still mostly dirty to generate and expensive to buy. Linked power and water-monitoring devices will help manage resources, save money and improve lives in emerging markets."

Matthias Eckert
CFO, emc2invest

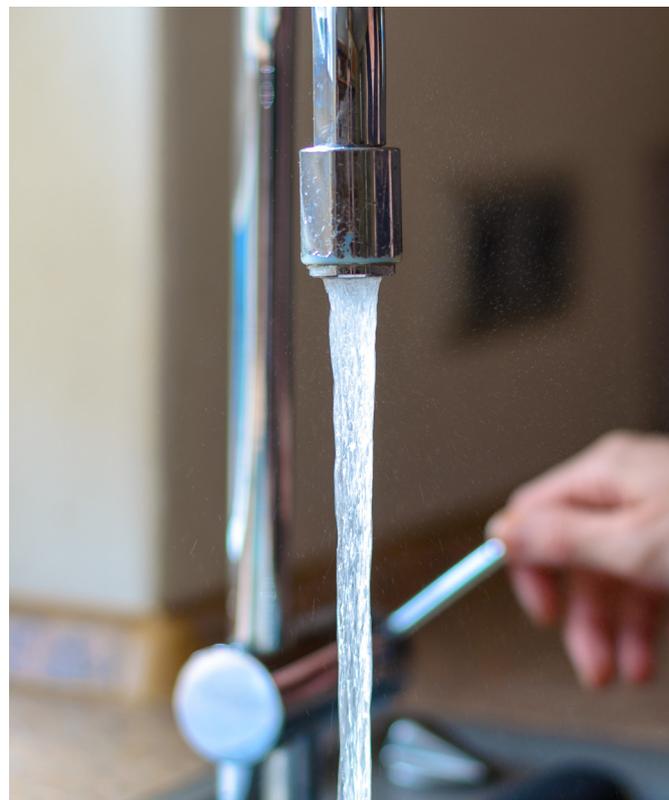
TECHNOLOGY FOR GOOD encompasses the idea that tech boasts vast potential to do good for society, and can enhance people's living conditions. The term was first coined in the 1990s when web developers joined forces with everyday people at events, often on weekends, where they worked together to hack solutions to social challenges, seeding hundreds of ideas and prototypes. Today, tech for good covers a community of people, projects, organisations and funders promoting the role of technology to improve social, environmental and economic outcomes – and it's bigger than ever. Companies use something called the Triple Helix of social innovation to enhance tech-for-good's value. According to the Nominet Trust paper, *The Triple Helix of Social Tech Innovation*, the word 'triple' covers the types of value (economic, social and user) that social-tech ventures need to articulate, develop and evidence in order to blossom into successful, sustainable social ventures operating at scale. The word 'helix', meanwhile, describes the way these values converge at different stages of the venture's development, pointing to the ever-changing nature of the ways in which these values are shared and showcased as time progresses. There are now numerous accelerator programmes for social-tech startups, as well as funding for charities and organisations that want to use their tech to benefit power, water, people, and the earth. The tech-for-good ecosystem has grown into a bustling marketplace of needs, problems and solutions and, far from being static, as it progresses it will change. That is why many active developers, researchers, scientists and engineers stress the importance of continually asking 'what is tech for good?' as this will help society ensure that the field remains inclusive and continues connecting people and projects.

SOLAR MICROLEASING

A 2018 *Business Tech* article reported on a South African buy-to-lease solar startup that recently received a \$500,000 seed investment from Alhabit, a multi-million dollar hedge fund. The Cape-Town based business, Sun Exchange, announced a partnership with the UN Development Programme to pilot blockchain-based finance for solar in Moldova in May 2018, and a partnership with Leonardo DiCaprio-backed Powerhive in July 2018, with the latter facilitating funding for “six fully operational solar projects in South Africa through its solar micro-leasing platform” according to the article. “The projects power organisations such as schools, small businesses, wildlife protection parks and non-profits,” the article continues. “The company is currently running a crowd-sale for its seventh project, which will solar power Sacred Heart College in Johannesburg, South Africa. By leveraging the borderless, decentralised nature of cryptocurrency, Sun Exchange enables practically anyone, anywhere in the world, to buy into their solar projects and receive a stream of monetised sunshine from the power generated by the projects.” The article adds that “Sun Exchange also recently introduced SUNEX, its own digital rewards token, which can be earned to get discounts on the Sun Exchange marketplace and can be staked into a ground-breaking solar project insurance fund”.

A CHEAP WAY TO REDUCE WASTEWATER

In 2018, AbilityNet’s Tech4Good Awards revealed the Water Watcher, developed by four home-educated students, Alex Lynch (16), Elye Cuthbertson (14), Atticus Ticheli (12), and Saul Cuthbertson (9). Looking to offer an easy, inexpensive solution to running taps and water wastage, the device was part of an engineering competition, with the students inspired to find a solution to a problem that one of the team was experiencing. Being dyslexic and encountering memory lapses, one of the boys behind the design forgot to turn the tap off once, flooding a friend’s bathroom. A small device that fits on any tap, the Water Watcher is activated by the vibrations of the water, using a timer and alarm system to alert the user if the tap is left on too long. Using a BBC Micro:bit with an accelerometer to sense vibration, a battery pack, a simple speaker and a silicone coin purse (to protect it from water), the device doesn’t need plumbing and can be strapped onto any sized faucet. The device’s potential to save water and prevent flooding has been recognised by organisations such as Thames Water, WaterWise and the Alzheimer’s Society, with a company interested in taking the Water Watcher into production.



Case study: the Climate and Sustainable Finance Data Initiative

In a 2018 article for the Abu Dhabi Sustainability Week website, Felicia Jackson, author and founding editor of *Bloomberg New Energy Finance*, says that local data is key to future sustainable development, with our focus needing to “urgently shift towards providing investors with the information they need to commit sufficient funds and create conditions within which local markets can grow to rise to the challenge” of climate change, keeping the United Nations’ Sustainable Development Goals (SDGs) in mind. “First and foremost,” Jackson writes, “this means providing stable, reliable, standardised and comparable data to guide investment decisions. Second, it means taking a more holistic approach to how we assess the impact of business decisions, looking across the pillars of action to achieve the SDGs and accelerating domestic ownership of knowledge and entrepreneurial growth in local markets. Evidence, knowledge and local understanding are critical to achieving this.” Jackson adds, “Recognition of the systemic impact of our economic choices is also vital. That means building knowledge of investment and performance in energy and climate change, water, agriculture, electrification and mobility, biotech, as well as facilitative technologies from the Internet of Things (IoT) to Artificial Intelligence (AI). The only way to really do this effectively over time is at a local level, where people have a visceral understanding of how the world around them is changing. We cannot succeed at this without finding new ways to access, analyse and assess the data underlying financial decisions and their impact.”

“At SOAS University of London, we are developing a project that aims to transform that situation, with

the launch of the non-profit Climate and Sustainable Finance Data Initiative,” Jackson, who is a teaching fellow at the university, writes in her article. “This initiative is intended to be a global network, owned and operated by research centres in member countries around the world (from Burkina Faso to Bangladesh).”

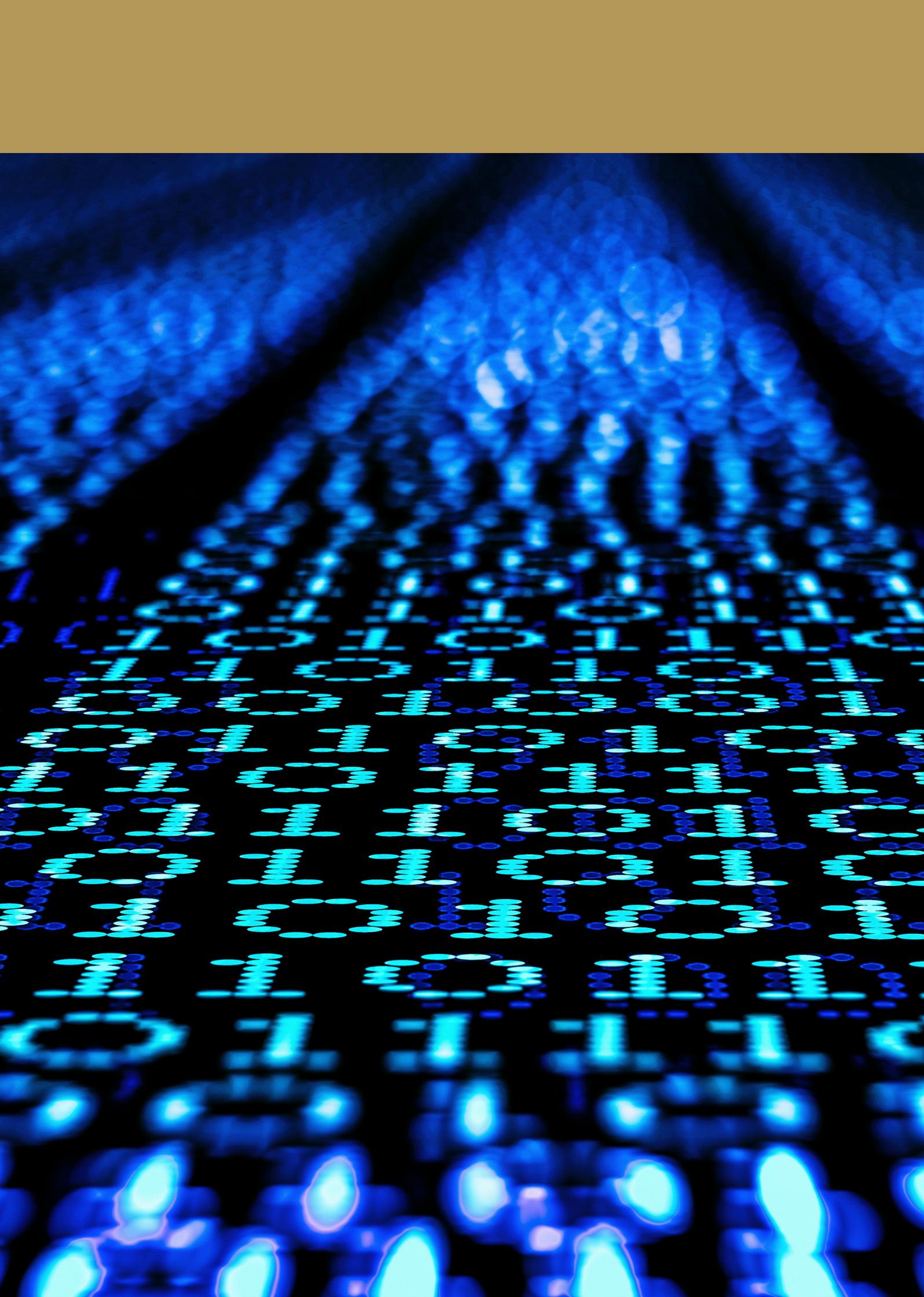
A standardised database will be shared between members, ensuring the robust and methodical collection of data in domestic markets. The initiative will provide up-to-date tracking of the developing stock of private and public actors’ commitments in sustainable and climate finance. The database will include both quantitative and qualitative data, providing researchers around the world with a wealth of original data to research and analyse. The Climate and Sustainable Finance Database will enable researchers, practitioners and others with an interest to see not only how much public and private money is flowing to and from developing and transition economies, but also understand both positive and negative impacts, enabling factors, and barriers.

“This information can, in turn, be used to accelerate further flows of finance and enhance the effectiveness of existing investment,” Jackson writes. “Critically, the initiative will provide database and research training as well as digital learning on climate and sustainable finance to centres in the developing world. The long-term goal is for domestic research groups to become centres of climate and sustainability entrepreneurship, sharing financial and business models which work for specific markets.”

“Most devices are becoming mobile, and this means that a huge amount of energy is required to run them. With that in mind, high-density, heavy-duty energy-storage solutions are needed.”

Vimal Kumar

Co-founder and COO, Finnovista



CHAPTER 8

YOUTH & SUSTAINAB

Youth say that climate change will be the biggest threat to the world within a decade

ILITY

"These young people are the policymakers, industry leaders, technical experts and consumers of tomorrow – it is fundamentally important that they are engaged in our drive to accelerate the long-term adoption of renewable energy and clean technologies."

Mohamed Jameel Al Ramahi,
Chief Executive Officer, Masdar



YOUTH AND SUSTAINABILITY - A GLOBAL PERSPECTIVE

THE FIRST Gen Z Global Sustainability Survey, commissioned by Masdar, was conducted to investigate the attitudes of members of Generation Z (aged 18–25) across the world towards the issues of climate change, sustainability development, renewable energy and other challenges. Including about 5,000 respondents from 20 countries across the Middle East and North Africa, Europe, the Americas, Asia and sub-Saharan Africa in March 2016, the survey offered comprehensive insight into the thoughts, fears and hopes of a generation that is extremely concerned about the environmental legacy that they stand to inherit. Today's youth value the environment over financial gain and see social change, public demand for change, and good education – including world-class universities – as key enablers for green technology. UAE youth also see a good education system as most important for fostering green technology (43%), with education contributing to awareness of environmental issues, as well as building the skills required to develop and deploy green technologies and supportive policies. To successfully address Gen Z and encompass more lofty goals, policymakers, NGOs and the media need to supplement their focus on the economic gains of renewable energy, such as increased employment.

"In the Arab world alone, around a third of the population is between the ages of 15 and 29."

Mohamed Jameel Al Ramahi
Chief Executive Officer,
Masdar, Gen Z Global
Sustainability Survey

The Gen Z Global Sustainability Survey represented a sample of developed (US, UK, France, Germany, Spain, Japan), emerging (Brazil, China, Egypt, India, Mexico, Morocco, Russia, Saudi Arabia, South Korea, South Africa, UAE), and frontier (Jordan, Kenya, Nigeria) economies. Key findings include:

1. Youth say that climate change will be the biggest threat to the world within a decade.
2. Young people are keen to take on more responsibilities to find solutions to climate change, and they want policymakers to pay more attention to their views.

How they are behaving in a sustainable manner



How they are spreading messages about environmental issues



3. Government regulations are necessary, but youth want corporations to take equal responsibility.

4. Youth are doing more to be 'green'



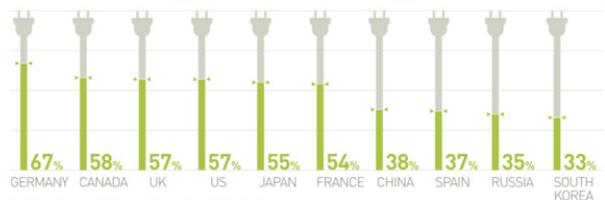
5. Youth are prepared to boycott the world's non-sustainable companies.

6. Behavioural change is needed to help renewable energy investment.

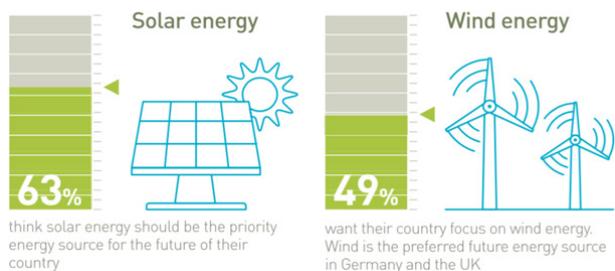
7. Education is seen as critical in making the world more sustainable.

8. Germany, Canada, the UK and US are perceived as clean-tech leaders, with Emirati youth confident in their own country's green track record.

The countries that the youth believe are leading in renewable energy and clean technology



9. Youth believe that solar and wind energy should be priorities for the future.



10. Young people in frontier countries are more committed to creating a sustainable future.

How the global youth rate their country in terms of 'greenness'



21- TO 35-YEAR-OLD PERCEPTION STUDY RESPONDENTS ON WHAT TECHNOLOGY WILL SHAPE THE FUTURE OF SUSTAINABILITY

"In the GCC, water is energy. It's necessary for people's wellbeing and creating urban environments that promote wellness. Innovative technologies that can be applied on a large scale, in communities or even cities, are important to facilitate a healthy and happy lifestyle."

Abeer Manneh, Associate, 5 Plus Design

"Current stagnant business conditions need a transformation, especially in industries that keep consuming non-renewable minerals at a rate that can't be replenished. Using renewable production methodologies and only renewable materials for mass-produced products is the only way to kill current economic stagnation. When there is enough renewable material available, there won't be bottlenecks that require us to go in search of new sites to extract raw materials. If we consider our current economic patterns and view raw materials as savings, it seems like we're just spending them for short-term benefits. We already have sufficient tech to get our energy requirements from 100% renewable energy. Maybe we should save oil for a rainy day. In a few years it may fetch more than it does now."

Jithin John, Civil Engineer, Nael General Contracting L.L.C.

"Smart metering is a great solution and key enabler regarding the creation of sustainable water supply across the world. Smart metering lights up the water distribution network to indicate where exactly problems lie. Whether it is a leakage, theft or a pipe burst, the utility gets the right knowledge at the right time, enabling it to take corrective actions. This not only results in water savings but also ensures efficient time and manpower management."

Kriti Sharma Golwala, Marketer, Kamstrup

"Renewable energy is getting better and more efficient every day. The cost of installing and operating a solar PV plant can now be practically considered and implemented. This allows us to cut back on our dependence on fossil fuels."

Mudabbir Shan Ahmed, Senior Technical Officer, G.E.L Gresham Eastern

"I think EV and solar PV, along with the use of data analytics, will be the most impactful technology combination in the coming years."

Abhijeet Chaudhary, Design Engineer, Global Energy and Environmental Engineering Services (GE3S)

"We are now beyond Industry 4.0 and on our way to Industry 5.0, where man and machine work together to create augmented intelligence systems that will improve asset longevity and efficient use of resources, and increase productivity."

Navin Kumar Selvaraj, Executive Director, Navsar Engineering International Pte. Ltd

"At the moment, billions of people live in water-stressed areas, and this will only increase in the future. With water desalination technologies we can access the world's largest water sources, which are in the oceans. However, at the moment, most of the desalination technologies are fossil-fuel powered. This is not sustainable, polluting and extremely costly. The cost of desalinated water is strongly correlated to the price of fossil fuels. We need to step away from burning fossil fuels and help enable the energy transition within the water-desalination industry by incorporating water desalination through renewable energy sources, such as solar."

Jiajun Cen, Technical Director, Desolenator B.V.

"In the US, lignocellulosic biomass has the potential to replace petrodiesel in the transportation sector. However, there are a lot of challenges with regards to ensuring good-quality feedstock all year round. As research-focused technology improvements occur, this becomes achievable."

Temitope Soneye, Graduate Energy Engineer, Auburn University

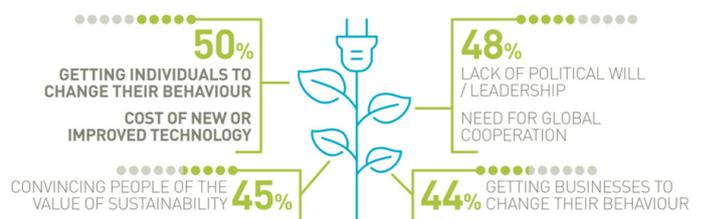
GEN ZS AROUND THE WORLD BELIEVE...

1. More investment in renewables, from both the public and private sectors, is critical to a sustainable future. When it comes to renewable energy and clean-tech, specifically, global youth are thinking primarily about the non-economic benefits: lowering pollution, preserving endangered species and providing clean water.

Today's youth see their behaviour as particularly important when it comes to supporting clean technology. Half (50%) believe that getting individuals to change their behaviour is one of the main barriers to investing in renewable and clean technology. While the cost of new technology is cited by 50%, the remaining four barriers are all to do with changing behaviours and mindsets: lack of political will (48%), the need for global cooperation (48%), convincing people of the value of sustainability (45%) and getting businesses to change their behaviour (44%).

Common sense suggests that the falling price of renewable energy, particularly wind and solar power, should be a driver for adoption. In addition, other environmentally friendly products, such as LED lights and electric and hybrid vehicles, have reduced the cost of green technologies. Additionally, the removal or reduction of energy subsidies in some of the respondent countries, particularly in the MENA countries surveyed, should also make clean-tech alternatives more attractive as traditional energy resources become more expensive.

Gen Z believe these are the main barriers to investment in renewable energy and clean technology



2. Gen Zs are prepared to take on responsibility for finding sustainability solutions, and they want policymakers to pay more attention to their views.

3. They are active in discussing environmental issues with friends and family, and sharing information online.

4. They value the environment over financial gain and want a bigger say on issues relating to sustainability.

Top 4 forces for fostering green technology

48% A society that values the environment over wealth and financial gain

42% A good education system, including world class universities

38% Climate change directly affecting our way of life

37% Public demand for change



5. They believe there is progress in areas such as recycling, reducing energy consumption and using public transport.

6. Most Gen Zs (83%) also agree that governments need to listen more to young people on the subject of sustainability.

7. Global youth believe they are doing more to help the environment than other generations.

8. Young people are prepared to use their consumer power to reward or punish companies over their sustainability records.

9. Solar and wind are strongly favoured as future energy sources.

10. Environmental NGOs (ENGOS) are viewed as leading the debate globally, with 42% of respondents ranking them near or at the top.

11. Key enablers of green tech, according to Gen Z, include social change, public demand for change and world-class education/universities.

MOBILE TECHNOLOGY CASE STUDY

DEWA Run Mobile Application for Kids

Two Canadian University Dubai students, Pedram Parvaz – a member of the university's innovation community, Lighten Up – and Bezhn Odinaev, have designed an award-winning mobile application that encourages children to adopt an attitude that encourages water saving and proper waste disposal.

The app, called DEWA Run, is a mobile edutainment app that was launched in collaboration with the Dubai Electricity and Water Authority (DEWA) as part of its 2015 DEWA App Master Competition.

Upon opening the introductory screen, a message pops up encouraging players to help keep their city clean and save the world. Users play with the character below, making him run as fast as he can while collecting water drops, picking up trash and dodging obstacles.



SIX TEENS WORKING IN SUSTAINABILITY ON THE FORBES 2018 30-UNDER-30 LIST

Annie Ostojic, 16

Inventor (30 Under 30: Energy)

This high school student has invented a better microwave oven and a system to collect 'solar' power from indoor lighting and use it to charge batteries.

Peyton Robertson, 17

Inventor (30 Under 30: Youngest)

He held five patents for inventions by age 16, including a sandbag to combat seawater flooding and a bike with retractable training wheels. He's published a paper in the *Journal of Tropical Diseases*, founded a non-profit for STEM education, and is the youngest winner of both the National STEM Education Award and the Discovery Education 3M Young Scientist Challenge.

Hannah Herbst, 18

Inventor (30 Under 30: Energy)

She invented a device to capture energy from ocean waves. She intends to deploy the system, called BEACON (Bringing Electricity Access to Countries through Ocean Energy), in developing countries where it can power water purification and medical equipment.

Ethan Novek, 19

Founder, Innovator (30 Under 30: Energy)

Ethan, a chemical engineering student at Yale, has 12 patents for CO2 technologies that promise to capture more than half of the carbon dioxide from power-plant emissions at the cost of less than \$8 per ton.

Amber Yang, 19

Founder, SEER Tracking (30 Under 30: Science)

Yang wants to solve an ever-growing problem: space junk. For three years, she worked to improve the way space junk is tracked so that spacecraft and satellites can avoid it.

Elvis Zhang, 20

Founder, Oxy2 (30 Under 30: Social Entrepreneurs)

Elvis was only 13 when he moved from Asia to the US and began pursuing research on combatting pollution. That research laid the groundwork for Oxy2, which he chose to pursue instead of university in 2018, to help design cleaner cities.

As seen on www.forbes.com.

EXISTING INITIATIVES THAT SUPPORT AND ENGAGE WITH THE YOUTH

The UAE's Vision 2021 stresses sustainability, setting targets for improving air quality, reducing landfill waste, increasing the share of low-carbon energy and reducing water overconsumption.

Climate Innovation Exchange (CLIX) is a key element of the Youth 4 Sustainability Hub, a unique marketplace connecting entrepreneurs and investors to enable partnerships that will power sustainable climate-change solutions through knowledge, innovation and funding.

Masdar City's sustainable urban development in Abu Dhabi, which is leading the way in terms of creating a green-print for cities of the future.

The UAE's **Future Skills 2030** initiative will take students and young professionals through a comprehensive journey to explore the future of education, industry, business and jobs in the context of sustainable development. Future Skills 2030 will also demonstrate how the UAE's national agenda, specifically the National Advanced Sciences Agenda 2031, is enabling the country to remain at the forefront of the changing global landscape by empowering youth to advance high-priority areas.

The **Zayed Future Energy Prize** empowers global efforts by recognising and awarding exceptional solutions in renewable energy and sustainability.

The **Global Green Growth** Institute promotes environmentally friendly economic growth across a number of frontier, emerging and developed countries.

The UAE leadership's visible role in launching sustainable initiatives, such as hosting the **International Renewable Energy Agency (IRENA)** and launching the successful **Mohammed bin Rashid Al Maktoum Solar Park**.

AN EXISTING EDUCATION YOUTH INITIATIVE

The Student Exclusive Ambassadors Programme at ADSW

As part of its Student Exclusive programme, Abu Dhabi Sustainability Week invites young men and women from diverse backgrounds to become student ambassadors and support its sustainability initiatives and events. This year-round programme encourages young people to:

- Think critically
- Embrace change
- Be innovative
- Become communicators
- Lead

“With Generation Z willing to lead the way – and the renewable energy industry poised at a tipping point – we must empower our youth to realise a more sustainable future.”

Mohamed Jameel Al Ramahi
Chief Executive Officer, Masdar



CONCLUSION AND FUTURE AGENDA

ENERGY TRANSITION - defined on the International Renewable Agency's (IRENA) website as "a pathway toward the transformation of the global energy sector, from fossil-based to zero-carbon, by the second half of this century" - is undoubtedly underway. But to limit the average global temperature rise to well below 2°C in the present century, and scale renewable energy up at least six times for the world to start meeting the goals set out in the Paris Agreement on climate change, an acceleration in the development of technological and other sustainable innovations needs to happen immediately.

According to the IRENA report, *Global Energy Transformation: A Roadmap to 2050*, "Keeping the global temperature rise below 2°C is technically feasible, and would also be more economically, socially and environmentally beneficial than the path resulting from current plans and policies. However, the global energy system must undergo a profound transformation, from one largely based on fossil fuels to one that enhances efficiency and is based on renewable energy. Such a global energy transformation - seen as the culmination of the 'energy transition' that is already happening in many countries - can create a world that is more prosperous and inclusive."

At the heart of this change is the need to reduce energy-related CO₂ emissions to limit climate change. Decarbonisation of the energy sector requires urgent action on a global scale, with movement needed to reduce carbon emissions and mitigate the effects of climate change. With this in mind, renewable energy and energy-efficiency measures can potentially achieve 90% of the required carbon reductions. According to IRENA's June 2017 working paper, *Accelerating the Energy Transition Through Innovation*, even with economically viable and scalable renewable-based solutions available for around two-thirds of the world's energy supply, population growth and rising energy demand could outpace energy decarbonisation without urgent investments in research and development (R&D).

Successful innovation should encompass the complete technology lifecycle. The policy framework for innovation, similarly, must provide balanced support, addressing technologies and factors beyond technology, including systems operations, market design and regulations, and the enabling infrastructure to scale up renewables.

In short, improved processes, Research, Development and Deployment (RD&D) systems and cooperation networks are essential to overcoming barriers to reaching a zero-carbon energy sector. The UN's Sustainable Development Goal 13 (SDG13) aims to "take urgent action to combat climate change and its impact" acknowledging that the United Nations Framework Convention on Climate Change (UNFCCC) is the primary international, intergovernmental forum for negotiating the global response to the problem.

Energy storage is predicted to play a critical role in sustainability's future, too. While hydroelectric and other renewable sources can generate power 24/7, solar and wind energies aren't as reliable, making energy storage vital to future sustainable energy. According to a 2018 article in *Forbes*, "recent energy storage innovations have included advancements in traditional battery technology as well as battery alternatives such as liquid air storage".

Projections from Wood Mackenzie Power and Renewables and the Energy Storage Association state that the energy storage market is expected to grow 17 times between 2017 and 2023. This projection accounts for private and commercial deployment of storage capacity, including impacts from government policies like California's solar panel mandate. During the same interval, the energy storage market is expected to grow 14 times in dollar value. Critically, electrolysis-generated hydrogen may also provide a solution to fluctuations in renewable-sourced energy, according to National Renewable Energy Laboratory (NREL) research, although additional studies and development are required in this area. With added storage, the sharing economy – which many countries have adopted through ventures like Uber, Careem and Airbnb – is likely to grow, allowing consumers to take advantage of other users who produce more energy than they need, with users selling excess power for profit.

Sweeping changes aside, energy transformation isn't up to large corporates and governments alone. The UN's ActNow.bot has been designed with this in mind, fuelling climate change understanding and urging advocates to take personal action via its Facebook Messenger platform. Created with support from Facebook and advertising company Grey, the new social media tool harnesses advances in Artificial Intelligence (AI) to engage people in the growing movement to take action on climate change. Launched by David Attenborough at the UN Climate Change Conference in Katowice, Poland, it is a fully interactive and responsive chatbot that suggests everyday actions, determined by users' interactions, that can be taken to preserve the environment. These are then shared via the social media platform to encourage collective action.

In the water sector, it is thought that, by 2030, global demand for water is expected to grow by 50%. That's according to the UN-Habitat 2016 *World Cities Report*. With global consumption of water doubling every 20 years, and at more than twice the rate of the world's population growth, securing clean water is a serious issue for major cities. Climate change will also contribute to water scarcity. For each degree of global warming, approximately 7% of the global population is projected to be exposed to a decrease of renewable water resources of at least 20%. Efficient water use, new techniques to maximise the reuse of wastewater, and innovative water-desalination technologies could significantly reduce water and energy needs. With this in mind, the United Nations (UN) has created a Sustainable Development Goal to "ensure the availability and sustainable management of water and sanitation for all" as part of the UN's Sustainable Development Agenda.

In response to the UN's call to action, countries are attempting to help solve global water shortage through a variety of demand-side and supply-side solutions, the latter including desalination of brackish water and seawater.

The Masdar Renewable Energy Water Desalination Programme, launched in 2013, aims to develop and demonstrate seawater desalination technologies that are more efficient, can be powered by renewable energy sources, are cost competitive, and have a minimal environmental impact.

According to a 2017 *Eco-Business* article, examples of future solutions in the wastewater sector include Anammox, a process that uses special bacteria to remove pollutants from water using less energy, oxygen and chemicals than similar water-treatment solutions. Another low-cost example is BioGill, a solution from Australia that can clean up wastewater that is too dirty or oily for other systems to process.

In mobility, emerging technologies – such as autonomous cars, zero-emissions vehicles and the Hyperloop – will make transport easier, faster and safer, with smart city transit technologies leading the way to sustainable transportation overall. There are several competing companies vying to make the breakthrough on Hyperloop technology around the world. Some observers have questioned the overall economic and commercial viability of this innovation, but in terms of promising, clean mass-transport systems, it has generated much excitement and media attention. In the UAE, Hyperloop Transportation Technologies (HTT) has signed an agreement with Aldar Properties, the developer behind Yas Island, to begin construction of a Hyperloop system for Abu Dhabi. In theory, Hyperloop technology could cut travel time between Abu Dhabi and Dubai to just 12 minutes, compared to an hour and a half otherwise. That could save an estimated \$800 million in lost working hours. Funding smart transit projects could be one of the biggest barriers to mobility innovation, however.

Space is one of the most exciting sectors in terms of sustainable future development. In a 2018 article for the Abu Dhabi Sustainability Week (ADSW) website, H.E. Dr Ahmad bin Abdullah Humaid Belhoul Al Falasi, Minister of State for Higher Education and Advanced Skills and Chairman of the UAE Space Agency, writes, "Some may wonder why a space agency, which focuses on furthering human knowledge of the universe, is concerning itself with environmental protection. One of the biggest differences we can make – whether on an individual or

a global scale – is to improve efficiency in the way we use resources. By reducing the amount we consume, we decrease both our net waste and emissions. Here, we have already learned a great deal from space exploration, which requires highly efficient processes as a result of strict weight limits applied during launches."

According to a 2017 article in *The Ethicalist*, the space technologies industry is estimated to be worth around \$300 billion globally and is growing by around 8% annually. The UAE's investments in space technologies have already exceeded AED20 billion (\$5.4 billion), with players including Al Yah Satellite Communications Company, Thuraya Satellite Telecommunications, and Earth-mapping and observation systems DubaiSat-1 and DubaiSat-2.

The UAE, and other countries, also have their sights set on Mars. In 2017, His Highness Sheikh Mohammed bin Rashid Al Maktoum, Dubai Ruler and Vice President and Prime Minister of the UAE, announced plans to construct a Martian city in the desert. The project is part of the UAE Mars 2117 Project, which sees the nation aiming to establish the first human settlement on the Red Planet by 2117. In order for the UAE's Mars 2117 Strategy to work, scientists and planners will also need data from the Red Planet. That's where the Emirates Mars Mission comes into play. The UAE developed the Hope space-exploration probe mission to Mars, and it is set for launch in 2020. The nation hopes that the probe will reach Mars in 2021, the UAE's 50th anniversary.

MeznSat is another UAE space project in the pipeline. According to the MeznSat website, UAE university students are primarily involved in developing 3U CubeSat, which is being built and tested chiefly to detect Greenhouse Gas (GHG) concentrations. The project aims to offer the UAE space-industry qualified, well-trained graduates who have gained hands-on experience through projects like this. In addition, the CubeSat project opens windows for advanced space-oriented research relevant to the UAE.

In terms of sending people into space, the ambitious UAE Space Agency aims to have the first Emirati astronaut visit the International Space Station in 2019.

Biotechnology and technology for good are growing leaps and bounds in terms of sustainable innovations, with startups, educational facilities, and governments developing groundbreaking innovations across sectors, from medical to manufacturing. Artificial Intelligence (AI) and 3D printers are playing starring roles in sustainability across multiple sectors. The former is already proving valuable, capturing Earth-related data from space and contributing to genetic engineering innovations, while the latter is currently able to 'build' houses, manufacture industrial parts and print animal-free meat. Future 3D developments may allow the technology to produce human organs.

Smart technology, improved networks, data analytics and storage, and sustainable blockchain are key to managing energy and sustainability across sectors, with the Internet of Things (IoT) an important enabler of continued environmentally-friendly practices and the monitoring thereof. Governments have put programmes and initiatives into place to encourage further smart adoption.

The 2020 Smart City Outlook will see predominantly wealthy urban centres with significant levels of autonomous governance having learnt from their pilot projects and partnerships, implementing sensor networks to collect data on mobility and other industries. The 2030 Smart City Outlook, meanwhile, is set to see data collected from smart cities and used to create dynamic electric bus routes, smart parking systems and intelligent traffic control in the mobility sector.

Of course, the world needs people to put all of the above into action. Fortunately – according to Masdar's Gen Z Global Sustainability Survey – young people are keen to take on more responsibilities to find solutions to climate change both today and in the future. They view their behaviour as particularly important when it comes to supporting clean technology, with half (50%) believing that getting individuals to change their behaviour is one

of the main barriers to investing in renewable and clean technology. According to Masdar's research, today's youth value the environment over financial gain and see social change, public demand for change, and a good education – including world-class universities – as enablers for green technology.

UAE youth, in particular, view a good education system as most important for fostering green technology (43%), with education contributing to awareness of environmental issues, as well as building the skills required to develop and deploy green technologies and supportive policies. With this in mind, the UAE's Future Skills 2030 initiative will take students and young professionals through a comprehensive journey to explore the future of education, industry, business and jobs in the context of sustainable development. Future Skills 2030 will also demonstrate how the UAE's national agenda, specifically the National Advanced Sciences Agenda 2031, is enabling the country to remain at the forefront of the changing global landscape by empowering youth to advance high-priority areas.

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Thank you.

SOURCES

thenational.ae
abudhabisustainabilityweek.com
government.ae
sustainabledevelopment.un.org
irena.org
IRENA_Report_GET_2018
masdar.ae
moei.gov.ae
un.org
climaterealityproject.org
bloomberg.com
greentechmedia.com
news.mit.edu
qz.com
businessinsider.com
carbonrecycling.is
www.climeworks.com
large.stanford.edu
sciencedaily.com
jwnenergy.com
energy.mit.edu
bigthink.com
youtube.com
www.abc.net.au
fastcompany.com
sustainabledevelopment.un.org
unfccc.int
forbes.com
climate.nasa.gov
gulfnews.com
greentechmedia.com
utilitydive.com
Masdar Report on Renewable Energy
Water Desalination Programme: The
New Frontier of Sustainable Water
Desalination
unwater.org
theguardian.com
eco-business.com
britannica.com
metrovancover.org
iwa-network.org
arabianindustry.com
export.gov
tunza.eco-generation.org
badiafarms.com
aqualonis.com

darsihmad.org
waterseer.org
designindaba.com
designswan.com
unesco.org
esa.un.org
uneplive.unep.org
wssinfo.org
iwa-network.org
washdata.org
PwC, 2012. Water: challenges, drivers
and solutions.
IPCC, 2014. Climate change 2014:
impacts, adaptation and vulnerability.
Chapter 3, freshwater resources.
UN-Habitat, 2016 World Cities
Report.
Environment Agency – Abu Dhabi,
2013, Maximizing Recycled Water Use
in the Emirate of Abu Dhabi
AGEDI, 2016. Final Technical:
Regional Desalination and Climate
Change. LNRCCP. CCRG/IO
Masdar's Report on Technologies for
Future Smart City Transit
Bloomberg New Energy Finance
United Nations Sustainable
Development Goals (SDGs)
vision2021.ae
Hyperloop TT
cnbc.com
khaleejtimes.com
reuters.com
www.gulfbusiness.com
electricvehiclesuae.com
theverge.com
wam.ae
ecouncil.ae
dot.abudhabi.ae
ead.ae
twitter.com
spacenews.com
technologyreview.com
accion-systems.com
vox.com
asia.nikkei.com
nasa.gov

scientificamerican.com
techport.nasa.gov
icelandmonitor.mbl.is
grapevine.is
theethicalist.com
digiitaltrends.com
interestingengineering.com
jpl.nasa.gov
spacex.com
theatlantic.com
ku.ac.ae
hackernoon.com
medium.com
interestingengineering.com
businesstech.co.za
itnewsafrika.com
info.trendwatching.com
newstorycharity.org
digitaltrends.com
tech4goodawards.com
techworld.com
technologyreview.com
dronesforgood.ae
dubaifuture.gov.ae
thefuturescentre.org
transreport.co.uk
oxfordvr.org
ngoadvisor.net
mashable.com
World Economic Forum (WEF) Top 10
Emerging Technologies Report 2018
Masdar's Gen Z Global Sustainability
Survey White Paper
cud.ac.ae
dewa.gov.ae
unenvironment.org
mnn.com
goodnet.org
greenoptimistic.com
momtastic.com
inhabitat.com
businessinsider.com
pinterest.com
ecobnb.com
forestapp.cc
Getty Images

