

E&T

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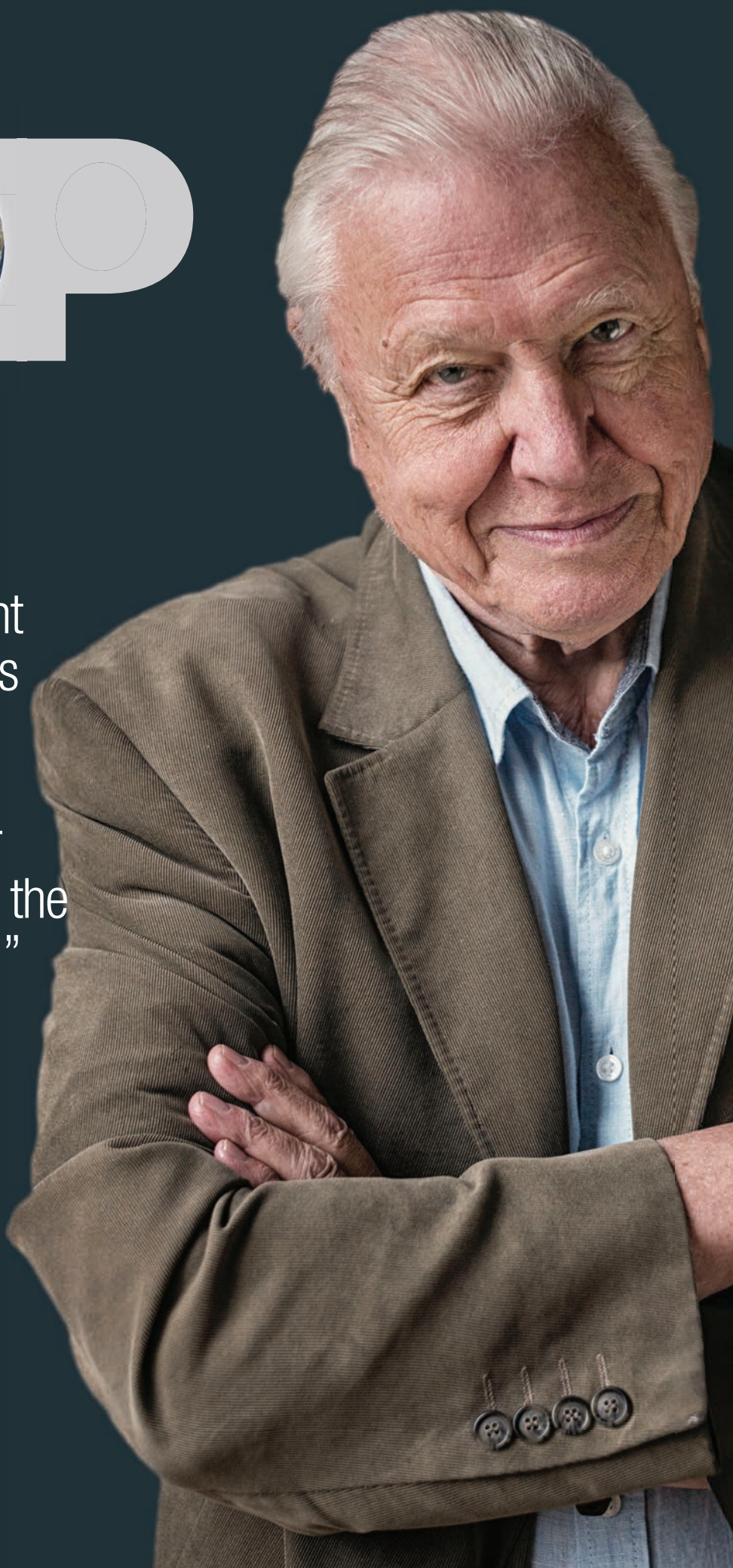
COP26



“Just imagine what might be possible... Tomorrow’s world could be *more* diverse, *more* stable, *more* wild. It’s within our power if we start making the right choices from today.”

Sir David Attenborough

Last chance for carbon trading
Falling renewables subsidies
What’s on the menu in Glasgow?
And more hard choices for COP26



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Volume 16 issue 10

COVER SARAH LEE / EYEVINE

NOV
2021

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COP26 runs from 31 October to 12 November, with a great weight of expectation on its global delegates. *EST* looks at the issues.

Editor's Letter

by Dickon Ross



HONOURS

BSME Talent Awards 2021

Winner: Ben Heubl, Best Innovation

TABIE Awards 2020

Gold Award, Special Section: 'Warm Reception for a Green Recovery', November 2020, Gold Award, Technical Article: 'Keep it Cool', Siobhan Doyle, November 2020, Gold Award, Front Cover, Digital Imagery: 'Sonic Boom!' (February 2020), John Rooney, Gold Award, Front Cover, Photograph: 'New Look Prosthetics' (January 2020), John Rooney, Silver Award, Best Department: Reviews section, Bronze Award, Best b2b Website, Bronze Award, How-To Article: 'Lockdown Challenge', Tim Fryer, Crispin Andrews and Neil Downie, Honourable Mention, Best Feature Article: 'How America's Oil Drilling Boom Threatens the World', Ben Heubl, December 2020, Honourable Mention, Best Covid-19 Coverage.

BSME Awards 2020

Winner: Ben Heubl, Columnist of the Year (B2B)

Shortlisted: Dickon Ross, Editor of the Year (trade and professional); John Rooney, Art Director of the Year (B2B); Cover of the Year (B2B) Hillary Lamb, Columnist of the Year (B2B)

ASW Awards 2020

Ben Heubl, Steve Connor Award for Investigative Journalism

For a full list go to www.eandtmagazine.com/about-us

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Engineering & Technology November 2021 www.EandTmagazine.com

CAN OUR leaders save the world? Put like that, it doesn't sound very likely, does it? But as they gather in Glasgow this month for COP26 – the Conference of Parties 26th meeting – that's what we're all hoping. It feels almost like the planet's last chance.

The mess we're in certainly demands a global response, because while everyone can make a difference, no one can do it alone. However, some populations and even some individuals can make a bigger difference than others.

As the Earth's environment worsens, it's becoming clearer we are not going to reverse global warming without drastic action and some ingenious moves. COP26 must agree more concerted, coordinated action and get on with it. We need global agreements and national policies to cut consumption and to support technologies that mean we can produce in different ways. And that's all about engineering.

This month's cover features a quote from the national treasure that is Sir David Attenborough. It's a more optimistic tone than usual for Sir David because it's from the first of the BBC series introducing the finalists in the Earthshot Prize, looking for ideas that can literally help save the planet.

Prince William said Earthshot was inspired by Moonshot – an achievement for political will and engineering effort. Earthshot isn't all about cutting-edge high tech; in fact there are more innovative grass-roots schemes among the finalists (p8). But they all need worldwide support. As Sir

David says, that means making the right choices today, and COP26 is the forum for those, but negotiations will be fraught (p18).

Should the subsidy levels for renewables be falling? They are still much less than fossil-fuels subsidies but declining levels may be a sign that renewables are becoming more economic. Chris Edwards assesses where governments should put our money in the coming decade (p28).

COP26 could be the last chance to get a coordinated, workable carbon-trading market (p24). Different regions use different schemes. How can they be integrated?

Insulate Britain, the protest movement that sounds more like a nationalist than an environmental pressure group, is blocking roads around London. Its focus is social housing, but getting owner-occupiers to invest in insulation would make a bigger difference. It's just one of the ways to make future homes greener (p40), from easier EV charging to more flexible housing that lasts longer. Homes will also have to cope with the effects of climate change. Many world cities are joining a new race to resilience (p54).

Technology isn't the whole answer but it's most definitely a crucial part and engineers can do more than most people to reverse and mitigate climate change. We're short of engineers and we're short of the right skills. We look at what needs to be done to retool, reskill and retrain for net zero (p58).

Another hard choice in Glasgow faces the delegates as they sit down to dinner: what to eat? Check out the best menu options on p44.

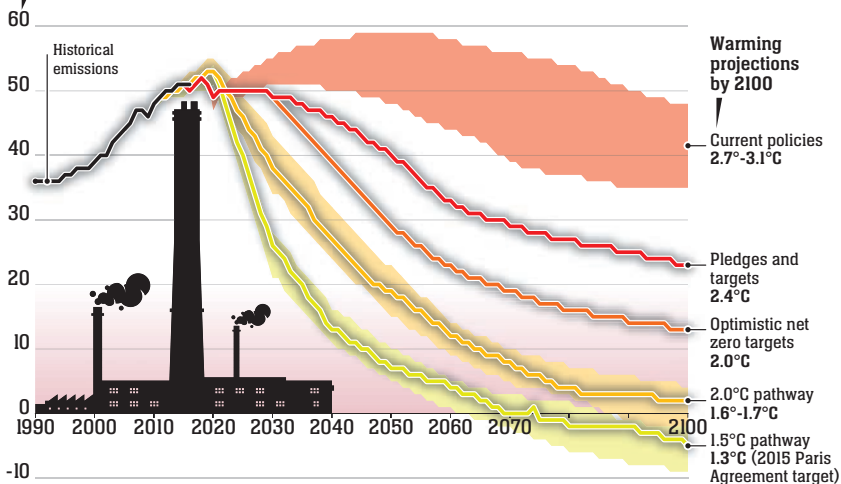
Did you know?...

...COP26: Projected global emissions

The conference aims to address man-made global warming to avert a climate catastrophe. If current practices are not radically altered soon, global temperatures could reach as much as 3.1°C above pre-industrial levels by 2100.

EMISSIONS AND EXPECTED WARMING BASED ON PLEDGES AND CURRENT POLICIES

Global greenhouse gas emissions – GtCO₂e/year (Gigatonnes of CO₂ equivalent)



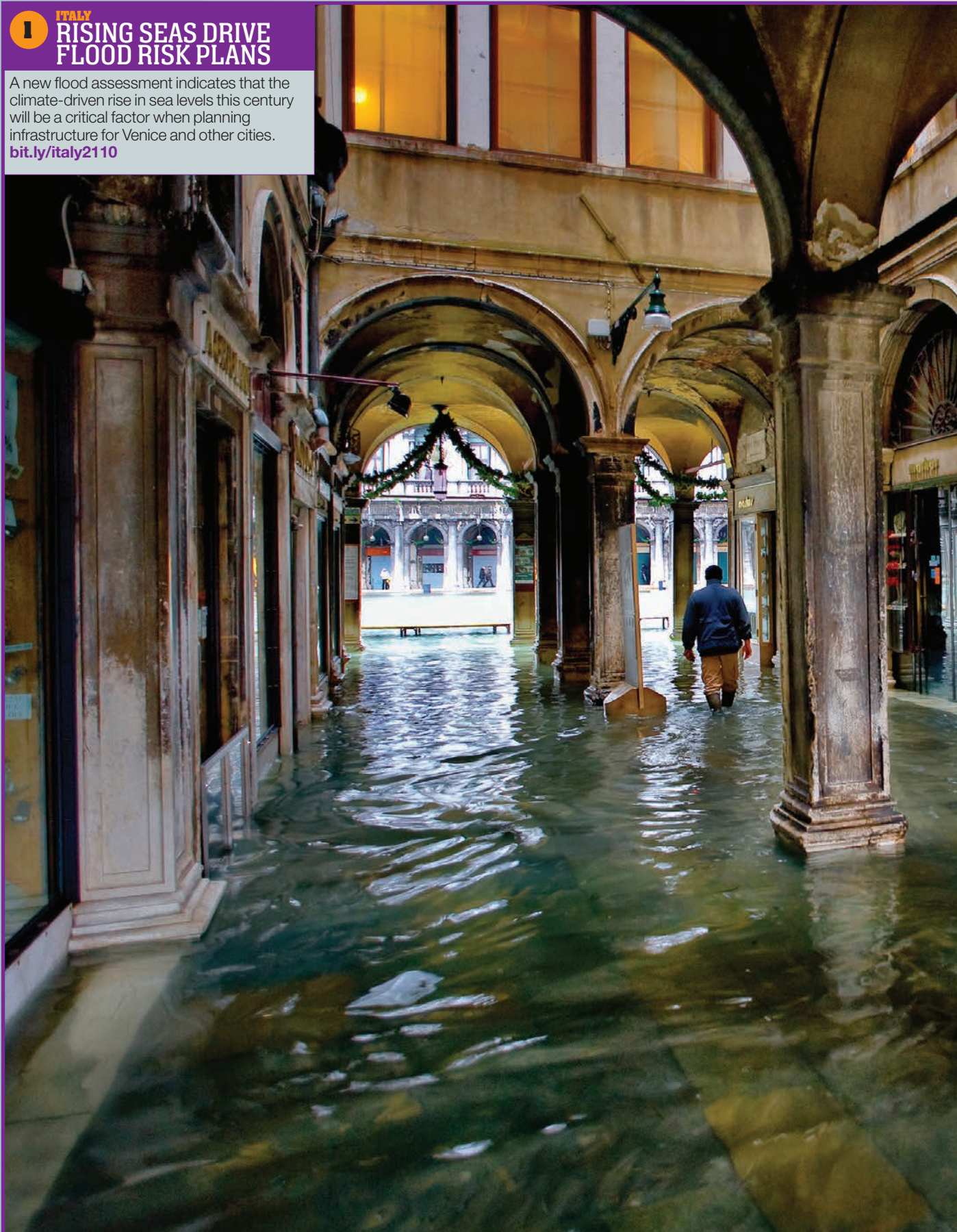
WorldNews

EandTmagazine.com/news

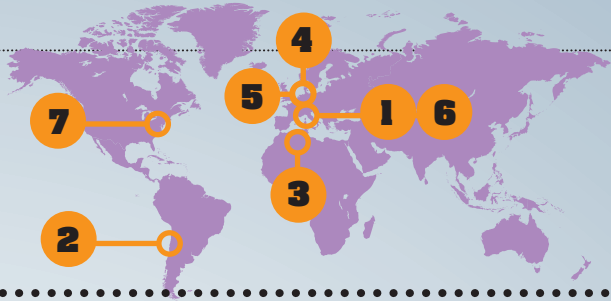
1 ITALY RISING SEAS DRIVE FLOOD RISK PLANS

A new flood assessment indicates that the climate-driven rise in sea levels this century will be a critical factor when planning infrastructure for Venice and other cities.

bit.ly/italy2110



GETTY IMAGES, ALAMY, DREAMTIME



2 CHILE DRONES SPOT FRESH WATER AMID BRINE

Researchers have successfully used drones to find sources of fresh water rising on the shorelines of remote Easter Island, where drinking water is scarce.
bit.ly/chile2110

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3 ALGERIA LAST NATION GIVES UP LEADED PETROL

The UN Environment Programme announced that the last country to use leaded petrol, Algeria, has now stopped producing it. Lead pollution causes a range of serious health problems.

bit.ly/algeria2110



4 GERMANY TOILET-TRAINED COWS GO TO 'MOOLOO'

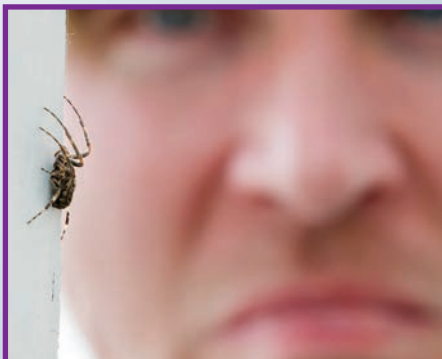
Researchers in Germany and New Zealand have demonstrated that calves can be taught to urinate and defecate in a latrine, enabling waste to be collected and treated.

bit.ly/germany2110



5 NETHERLANDS SHELL RAMPS UP CLEAN JET FUEL

Royal Dutch Shell has announced its intention to produce two million tonnes of sustainable aviation fuel by 2025, marking a tenfold increase from current global output.
bit.ly/netherlands2110



6 SWITZERLAND AR SPIDERS HELP FIGHT THE PHOBIA

The University of Basel has developed an augmented reality (AR) app to help people reduce their fear of spiders. It has been shown to be effective in a clinical trial.

bit.ly/switzerland2110



7 USA BIDEN AIMS FOR BIG GROWTH IN SOLAR

The US government has released a report demonstrating it is feasible for the country to meet 40 per cent of its electricity needs from solar by 2035, given the right incentives.

bit.ly/us2110

The Earthshot Prize, designed to incentivise change and help repair our planet over the next 10 years, has announced this year's 15 finalists that are hoping to win the prestigious award for their environmental efforts.
By **Rebecca Northfield**



THE EARTHSHOT PRIZE: THE FINAL 15

LAUNCHED by Prince William, Duke of Cambridge, back in 2020, The Earthshot Prize is a £50m effort to fund solutions for managing environmental challenges over the next decade. Every year between 2021 and 2030, £1m will go to each of the winning green projects in five categories.

The winners will receive a global platform, with their stories being 'showcased' over 10 years – the Prize's ambition is that the winning solutions lead to mass adoption, replication, and scaling.

This year saw 750 nominations, from which 15 finalists were chosen by an expert panel, including Sir David Attenborough and actress Cate Blanchett. All 15 shortlisted will receive tailored support to help scale their solutions, with the winners being announced at a ceremony on 17 October.

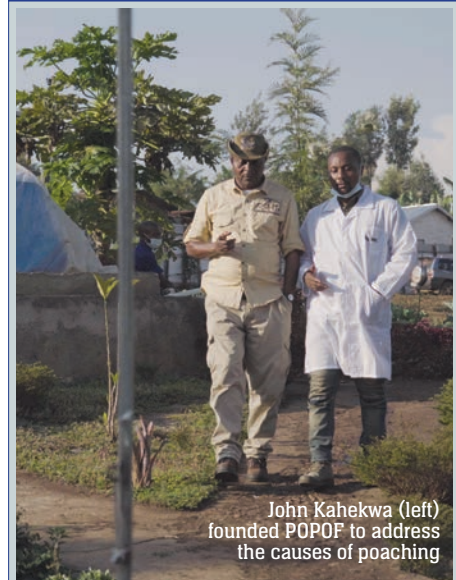
'The Earthshot Prize: Repairing our Planet' series is available on BBC iPlayer.



BBC/STUDIO SILVERBACK/TORY STRONG

From 750 nominations, 15 finalists were chosen by an expert panel, including Sir David Attenborough

RESTORE AND PROTECT OUR NATURE POLE POLE FOUNDATION (POPOF)



John Kahekwa (left) founded POPOF to address the causes of poaching

Based in the Democratic Republic of Congo, the POPOF runs farming projects that grow low-cost, nutritious foods to alleviate poverty and hunger in the hopes of preventing bushmeat poaching.

Founder John Kahekwa, a ranger and expert tracker in Kahuzi-Biega National Park, founded POPOF in 1992 after asking a poacher why he poached. The man replied, "empty stomachs have no ears". This led Kahekwa to find the root causes of deforestation and bushmeat poaching – poverty and hunger.

POPOF helps former poachers gain new skills, teaches importance of conservation, and provides support to park rangers. Four million trees have also been planted.

The Foundation believes winning The Earthshot Prize would help expand their work and secure purchasing agreements with the Global North to develop new products that help protect gorillas.

www.polepolefoundation.org

RESTORE AND PROTECT OUR NATURE

THE REPUBLIC OF COSTA RICA

Back in the 1990s, the vast forests of Costa Rica were devastated to half their former size.

To combat this, the country's Ministry for Environment created programmes that paid citizens to protect forests, plant trees, and restore ecosystems.

The forests doubled in size and, in turn, boosted ecotourism, contributing \$4bn to the economy.

The Costa Rican government, which believes 30 per cent of the Earth's land and oceans could also be protected this way, is now taking the approach to urban areas. Winning the Prize "would help it share knowledge and practices globally, especially in the Global South".

minae.go.cr

Costa Rica's Environment and Energy Minister, Andrea Meza's department has supported citizen projects



Tom Crowther (right) demonstrates Restor

RESTORE AND PROTECT OUR NATURE

RESTOR

Like a 'Google Maps for nature', Restor is a free online platform for the restoration movement, which connects activists, funders, experts and the public with major scientific datasets, meaning local knowledge can help 'fuel global change'.

Dr Thomas Crowther, founder of Restor, believes only a fraction of nature restoration projects have lasting impact, and small-scale efforts can feel futile in the face of global ecological crises.

Yet since launching this year, Restor has connected more than 50,000 restoration sites worldwide. Winning will help the platform "transform how we protect and repair the planet", and local actions can "become a global movement".

www.restor.eco

CLEAN OUR AIR

BLUE MAP

Blue Map is China's first public environmental database, which allows users to check local air and water quality and report polluters in real time.

Tens of thousands of micro-reports have been filed by Blue Map users (10 million downloads) against polluting factories – some of the largest emitters in China have been motivated to openly address their violation records. Because of Blue Map, Beijing is making efforts to no longer be part of the 200 most-polluted cities in the world.

By demonstrating the power of transparency and accountability, the ambition for Blue Map is to "empower synergised air pollution and carbon emission reduction in China and then globally".

www.ipe.org.cn

CLEAN OUR AIR

VINISHA UMASHANKAR

Vinisha Umashankar of Tiruvannamalai, Tamil Nadu, has developed a solar-powered ironing cart, which is a clean alternative to charcoal-powered street irons that cater to millions of Indians daily.

After seeing that iron vendors dispose of their charcoal straight into the garbage, 14-year-old Vinisha began researching the impact of charcoal on humans and deforestation, which led to the creation of the solar-powered cart. Five hours of sun powers the iron for six hours, and extra mobility means vendors can sell on doorsteps and the roadside, as well as offer phone charging points for extra income.

Vinisha plans to manufacture the solar ironing cart in India, sell it at an affordable price, and export it to Asia, Africa and "wherever the sun shines throughout the year".

Takachar's process converts crop residues into sellable products



CLEAN OUR AIR

TAKACHAR

This Indian start-up offers portable technology to convert agricultural waste into bioproducts.

Globally, \$120bn of agricultural waste is generated every year, and farmers often burn what they can't sell. Burning agricultural waste causes air pollution and can reduce life expectancy by a decade. In New Dehli, from where Takachar founder Vidyut Mohan hails, this waste burning occurs every year.

To combat this, Takachar developed a cheap, small-scale, portable technology that attaches to tractors in remote farms. The machine converts crop residues into sellable bio-products like fuel and fertiliser and reduces smoke emissions by up to 98 per cent.

If scaled, it could cut a billion tonnes of carbon dioxide a year.

www.takachar.com



Coral Vita grows farmed coral to restore degraded reefs

REVIVE OUR OCEANS **CORAL VITA**

Hailing from the Bahamas, Coral Vita grows coral on land up to 50 times faster than traditional methods to replant in oceans.

Ocean warming and acidification are set to destroy over 90 per cent of reefs by 2050, meaning death for a quarter of marine life, and disaster for a billion humans who depend on the reef's benefits.

Coral Vita also works with local communities, public officials, and private companies to improve education, job prospects, and "build a model to inject more funding into environmental protection".

A single farm could supply coral for an entire nation, and if it wins the Earthshot Prize, Coral Vita envisions a network of such farms in every nation with reefs.

www.coralvita.co

REVIVE OUR OCEANS **PRISTINE SEAS**

In 2008, Dr Enric Sala, National Geographic's Explorer in Residence, founded the Pristine Seas global ocean conservation programme.

With the aim to protect 30 per cent of oceans by 2030, US-based Pristine Seas has helped establish 24 marine reserves across an area twice the size of India. Winning would scale its conservation mission, "help educate a new generation of leaders, and transform economies".

www.nationalgeographic.org/projects/pristine-seas

REVIVE OUR OCEANS **LIVING SEAWALLS**

Living Seawalls, a flagship programme of the Sydney Institute of Marine Science, has developed habitat panels to mimic natural formations and support marine species.

After two years, Living Seawalls (which are placed in four Australian cities and shorelines in Wales, Gibraltar, and Singapore) have 36 per cent more marine species than flat walls.

Living Seawalls says the Earthshot Prize would support new research, educational programmes and sites across the globe.

www.livingseawalls.com.au

BUILD A WASTE-FREE WORLD **THE CITY OF MILAN'S FOOD WASTE HUBS**

Launched in 2019 with the aim of halving waste by 2030, each Food Waste hub recovers food from supermarkets and companies' canteens and gives it to NGOs who distribute it to the "neediest citizens".

Milan is the first major city to enforce a food-waste policy and has three Food Waste Hubs, each recovering about 130 tonnes of food per year. Milan has "created a blueprint that can be scaled throughout the world" with help from the Earthshot Prize.

foodpolicymilano.org

BUILD A WASTE-FREE WORLD **SANERGY**

Kenya-based Sanergy has developed locally built, cost-effective dry toilets that offer a clean and affordable alternative to sewers.

Sanergy removes 20,000 tonnes of waste per year and its organic fertiliser and insect protein for animal feed boosts farming volumes by up to 30 per cent. Over the next five years, the founders want to repurpose five million further tonnes of waste.

www.sanergy.com

BUILD A WASTE-FREE WORLD **WOTA BOX**

This start-up aims to improve water security by helping people reuse wastewater.

The WOTA BOX is the only solution of its kind, turning more than 98 per cent of water waste into clean, fresh water. It can be delivered at scale and installation requires no existing infrastructure.

Winning would help expand operations across the world, while lowering costs.

wota.co.jp/en

FIX OUR CLIMATE **ENAPTER**

Enapter's AEM Electrolyser technology turns renewable electricity into emission-free hydrogen gas and already fuels cars and planes, powers industry, and heats homes.

Funding from The Earthshot Prize would help scale mass production (planned for 2022), while growing the team faster. By 2050, Enapter wishes to account for 10 per cent of the world's hydrogen generation.

www.enapter.com

FIX OUR CLIMATE **REEDDI CAPSULES**

Nigerian company Reeddi Capsules offers affordable solar-powered lithium batteries for households to rent for \$0.50 a day, cutting energy costs by 30 per cent.

Monthly, the company already provides clean electricity to over 600 combined households and businesses. Funding from the Prize would help it reach 12,000 households per month in 2022.

www.reeddi.com

FIX OUR CLIMATE **SOLSHARE**

Bangladesh-based SOLshare's SOLbazaar is the first peer-to-peer energy exchange network. Homes with a solar panel sell excess electricity into a microgrid network.

SOLshare's 72 grids have helped 7,500 people in remote communities, and energy trading has boosted some incomes by 25 per cent. The Earthshot Prize would help expand its reach and business line.

me-solshare.com

THE EARTHSHOT PRIZE REPAIRING OUR PLANET

Greenhouse gas emissions are still rising, and it seems that even in more sceptical nations most people believe we face impending doom. World leaders will meet at COP26 to agree new measures to avert a climate crisis.

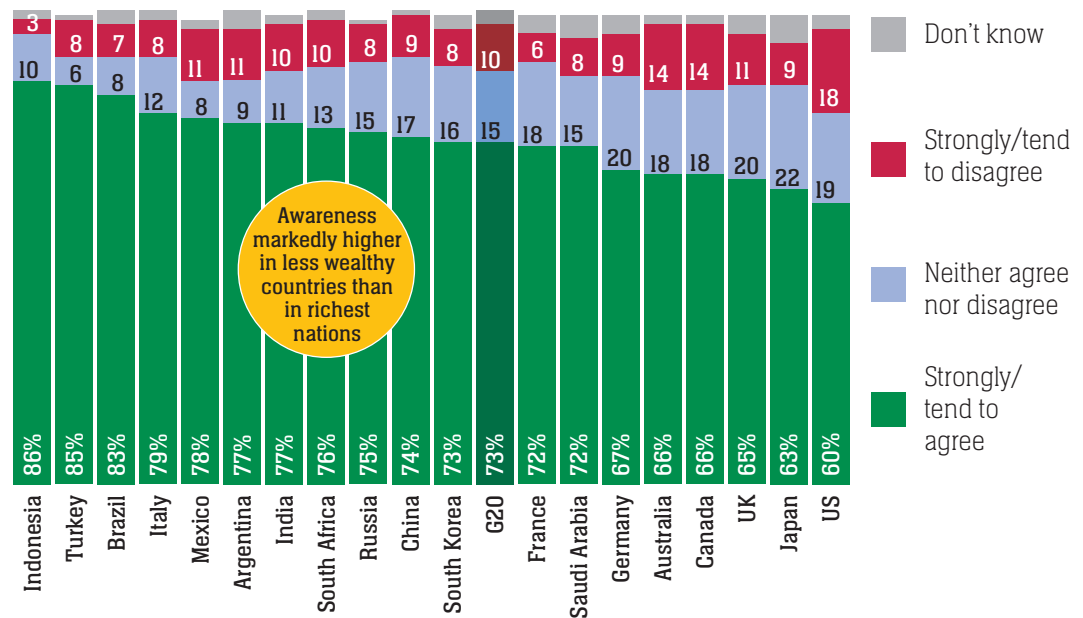
The Graphic

Greenhouse gases

Is Earth nearing 'tipping point'?

Asked whether Earth's climate is close to abrupt and irreversible 'tipping points' due to human activity, three in four people agreed strongly, in a global survey of the world's wealthiest nations.

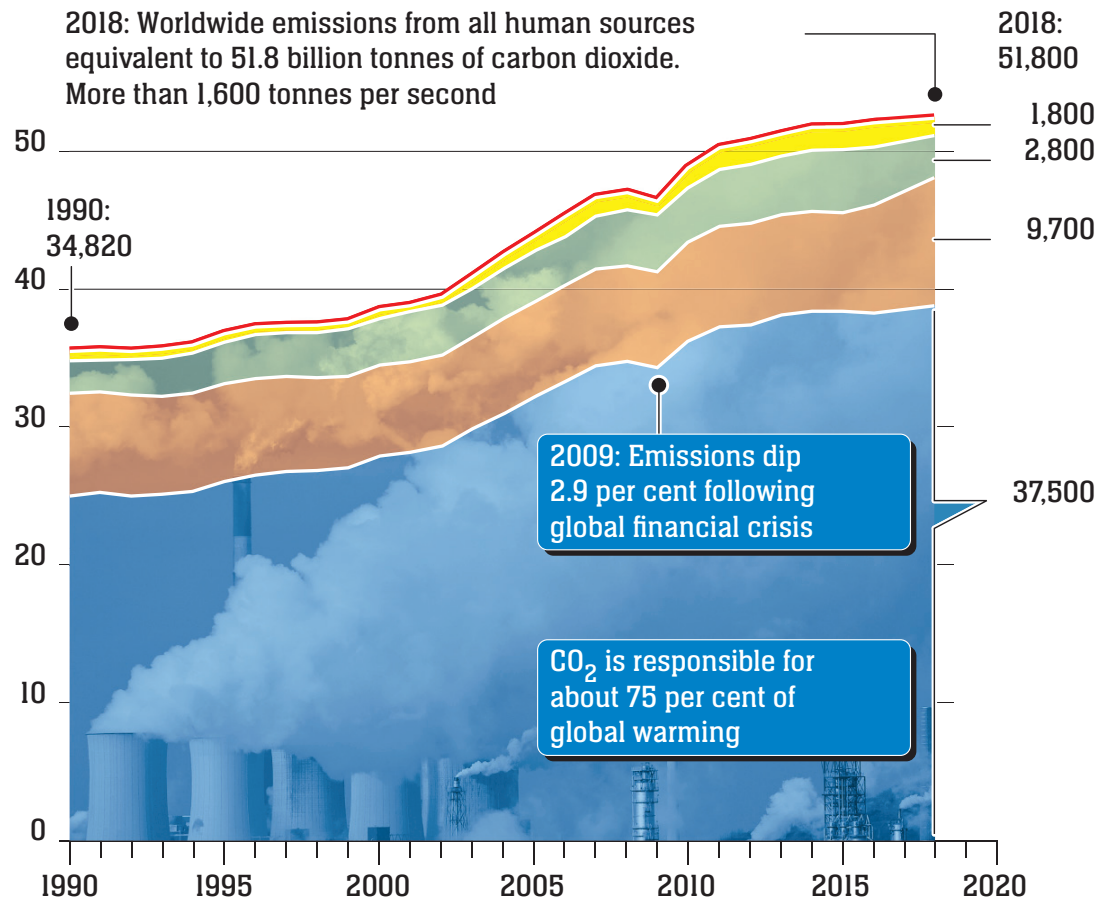
IPSOS I-OMNIBUS ONLINE PANEL SURVEY OF 19,735 ADULTS AGED 16-75 ACROSS 19 G20 COUNTRIES (AROUND 1,000 INTERVIEWS PER COUNTRY) BETWEEN 27 APR AND 14 MAY 2021
SOURCE: GLOBAL COMMONS ALLIANCE / IPSOS MORI



Greenhouse gas emissions

Carbon dioxide (CO₂) is the main greenhouse gas heating the planet. Six other gases are much more powerful, but less abundant. In 2018, greenhouse gas emissions reached 51.8 billion tonnes

Greenhouse gas emissions
(billion tonnes, carbon dioxide equivalent)



GRAPHIC NEWS
SOURCES: NETHERLANDS ENVIRONMENTAL ASSESSMENT AGENCY, GATESNOTES

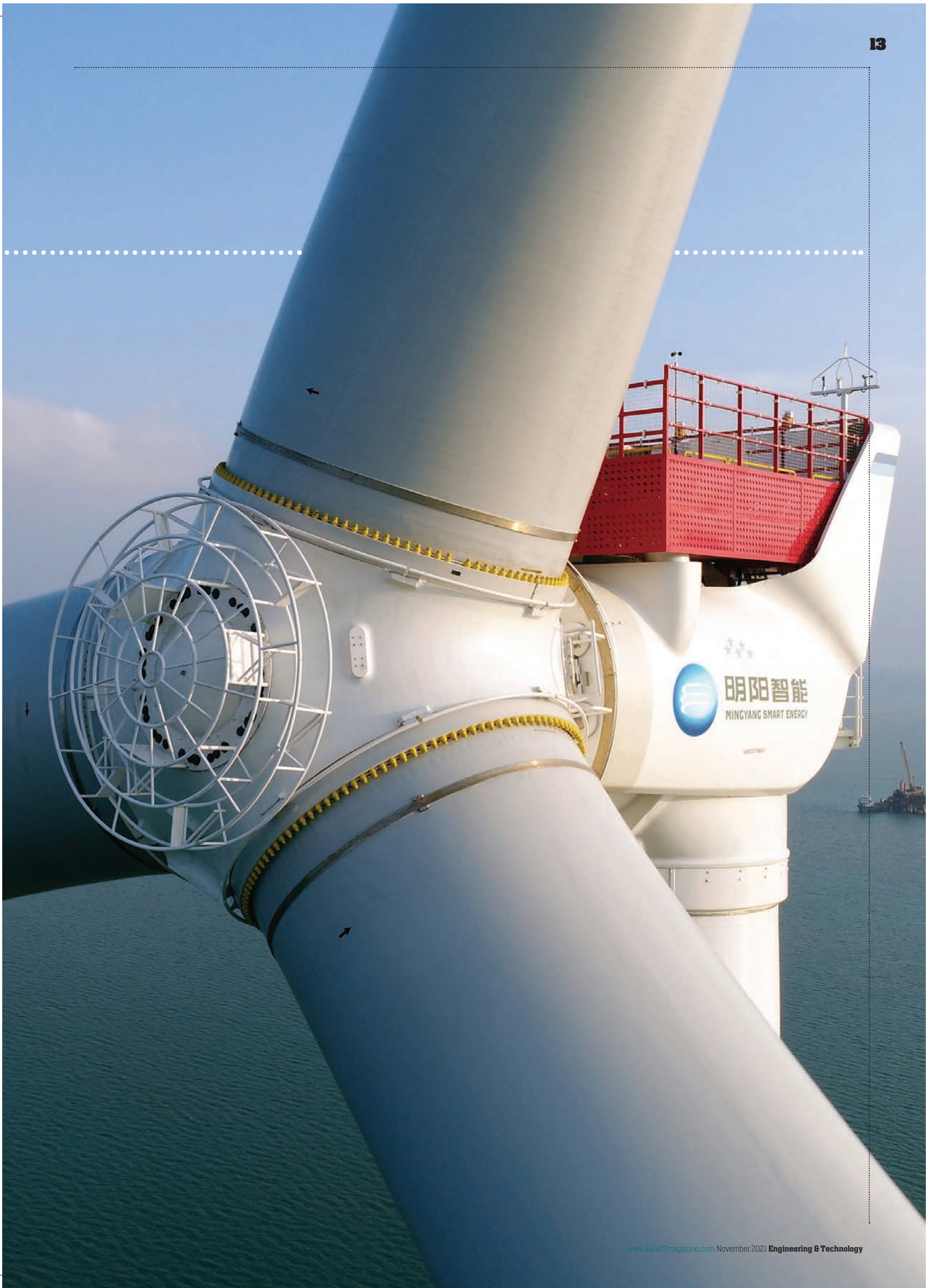
The Bigger Picture

Largest offshore wind turbine

A Chinese firm has revealed its design for the world's largest offshore wind turbine. The MySE 16.0-242 by MingYang Smart Energy is a 16MW, 242m-tall turbine capable of powering 20,000 homes per unit (80GWh per year) over a 25-year life. Three propelling 118m blades will cover a 46,000m² swept area. It will generate 45 per cent more energy than its predecessor, the MySE 11.0-203.

The new hybrid-drive turbine model is designed for high-wind sites and will be capable of withstanding typhoon-class weather conditions. It has been certified by DNV and China General Certification Centre for design, and MingYang aims to install a prototype in 2023 and roll out commercial production in the first half of 2024.

MingYang already offers a number of lightweight offshore turbine models – ranging from 5.5MW to 11MW; the new product sets the stage for a 15MW+ turbine platform that will eventually offer different versions fit for different offshore settings around the world, the manufacturer says.



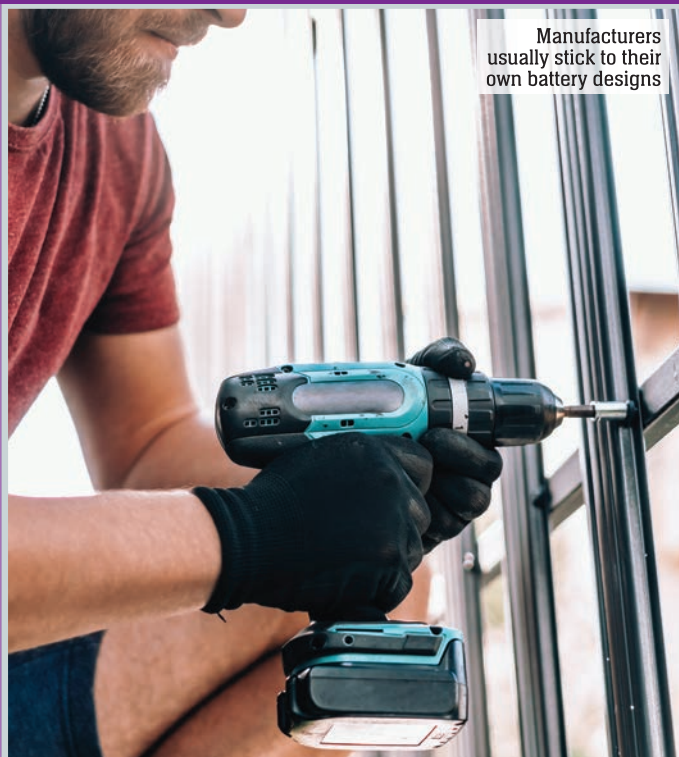
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Your Letters

engtechletters@theiet.org

CONSUMER TECHNOLOGY

WHO BENEFITS FROM INCOMPATIBLE BATTERIES?



Manufacturers usually stick to their own battery designs

Following a recent house move, I purchased a number of cordless tools, most of which use 18V battery packs. These are functionally identical, of similar capacity, shape and size, and use very similar cells inside, yet are totally incompatible between manufacturers. As not every manufacturer makes every type of tool, this means I have five different batteries and chargers for five tools, which is not only inconvenient and expensive, but hardly environmentally friendly.

I am unlikely to use a drill, a lawnmower and a vacuum cleaner at the same time, so the ability to share batteries between tools would be extremely useful; three batteries and a single multi-charger would be plenty for my needs, saving money and the environment while leaving me with more spare batteries for each tool than I have now.

Why on earth can't we have a standard 18V battery pack that fits everything? The double-A battery and its cousins solved this problem for most gadgets

years ago, yet with the modern trend for proprietary or (worse) built-in batteries we seem to have gone backwards. A handful of cross-brand 18V batteries exist, but are not widely supported.

I can't see any valid reason for manufacturers to insist on their own proprietary batteries and chargers, except that it's a nice little earner. A universal 18V rechargeable battery could power almost any 18V tool, reducing emissions during battery manufacture and at end of life, preventing old tools from becoming landfill due to unobtainable batteries, and the standard could be easily extended for more demanding applications. Manufacturers could still differentiate their batteries by offering USB charging or Bluetooth, and adaptors could even be made to upgrade existing tools to the new standard. Win-win for consumers and the environment.

Andrew Howlett CEng MIET
By email

POWER CUT DILEMMA

Last year I explored the installation of solar panels and batteries for my home but rejected the offer. Payback exceeded my life expectancy, an export tariff can only be obtained via a smart meter, which my electricity company said they couldn't fit, and in the event of a mains failure the solar panel/battery combination would also be switched off.

This year I can swallow the first of these to polish my green credentials; and my supplier has installed a smart meter. However, the third objection remains problematic. Power disconnects are not uncommon in the rural area where I live, and with the looming hiatus in energy supplies generally I expect they will become more frequent and prolonged. It seems daft that I could generate my own electricity but be unable to use it in the one circumstance where it would really be needed.

I understand that the system controller supplies the house from solar when available, reverting to mains automatically when it isn't. I was told that the way the system works means that if the mains supply failed I would end up trying to power the whole of Suffolk from my batteries, which is why they are disconnected. I should have thought a simple mains-energised contactor could sort that. I guess the other problem may be that the solar inverter needs a mains feed to synchronise its output with the incoming supply so if the latter fails the inverter loses the will to live.

Not being a power engineer, I wonder if readers could shed any light on this issue and maybe propose a solution?

Peter Finch CEng FIET
Bury St Edmunds

TACKLING EV INACCURACIES

I've noticed a common theme in letters in E&T raising concerns about the move to electric vehicles, and often find myself irritated by significant inaccuracies that are cited to make the point. I would be called an early adopter, as I bought a Vauxhall Ampera EV in 2013. At that time options were

essentially a Nissan Leaf with real-world range of about 70 miles, or the Ampera with its range-extending petrol generator. This vehicle is now over eight years old and has covered 85,000 miles.

The common observation that batteries have only an eight-year useful life is not true. Our vehicle now has a 'battery-only' range of 50 miles. This was a deliberate choice by the development engineers whose research confirmed that it covers the vast majority of people's daily use – very rarely does our vehicle need to move into range-extended mode and actually run the petrol generator, often going months and months without starting it.

Virtually all manufacturers have active battery management that ensures longevity greater than that of the rest of the vehicle. The Nissan Leaf is admittedly one exception where there is no active thermal management and it does suffer battery degradation, but newer models have corrected this.

Do electric cars take hours to recharge? Again, no. We might know of the Tesla superchargers' rapid pace, but they are high-end vehicles. At the other end of the spectrum, the humble Vauxhall Corsa-e can be bought new for £23,000-25,000. It has a range of more than 200 miles and can charge at a pace that means it can go from 10 per cent charge to 80 per cent in 30 minutes. In other words, even the humblest of electric vehicles won't need to be parked at the motorway service station any longer than its ICE sibling. It's not refuelling the vehicle that sets the down time, it's refuelling the driver.

Steve Price CEng MIET
Maidstone

EV 'PURE ENJOYMENT'

I was surprised to read about the dissatisfaction felt by Andy Leslie (Letters, August 2021) with his Kia e-Niro. I have avidly followed the progress made by the manufacturers of electric cars over the last 22 years since the Toyota Prius was launched, with a view to one day making my own electric car purchasing decision when the price, range and battery warranty all ticked the right boxes. That moment



Quote of the month

"We can do for our entire energy production by 2035 what we're doing with internal combustion engine vehicles by 2030"

UK Prime Minister **Boris Johnson** sets a target for all the country's electricity to come from clean sources

arrived a few weeks ago, with the purchase of a Kia e-Soul.

Having spent a period of my working life testing batteries, I have always had reservations about the reliability aspects of these very expensive parts of electric cars. However, I have been pleasantly surprised by the apparent excellent reliability achieved by the manufacturers of these items. There will nevertheless always be the odd failure and Mr Leslie unfortunately got one of them.

As an electrical engineer, I felt bound to take a close personal and professional interest in the installation of my home 7kW charger, and experienced no problems. I have to say that my experience to date with my Kia e-Soul has been nothing but pure enjoyment – I exhort Andy Leslie to hang in there!

John Adams MIET
Knebworth

THE CASE FOR HEAT PUMPS

I believe JR Ball's figures about heat pump performance (Letters, August 2021) are unduly pessimistic. For a typical heat pump to operate at a COP of 1.8, its delta T (the difference between output and source) would have to be in excess of 60°C. In a well-designed system

with a flow temperature of 40°C this would only occur when the outside temperature is below -20°C – not impossible but very unusual in most of the UK. Or it could occur in a system with an excessively high flow temperature and outside temperatures of around 0°C. A more typical seasonal average COP for a reasonably well-designed system would be approaching 3 if air source or 4 if ground source.

The only current gas-turbine-powered generators with efficiencies of 35 per cent are open-cycle. These are rarely used and peaks in demand are normally met by combined-cycle units with an efficiency approaching 65 per cent, plus pumped storage.

When I recently looked at manufacturers' data for condensing boilers, many were quoting efficiencies of about 90 per cent, so 95 per cent is perhaps restricted to a small number? However, a study by the Energy Saving Trust a few years ago found that, in practice, most condensing boilers don't achieve these figures as they are set too hot to operate properly in condensing mode. The average was between 82 per cent and 85 per cent, with combis returning

73 per cent in hot water mode. These figures don't include electricity usage, which varied from 100kWh to over 750kWh per year.

Looking at these figures, a heat pump operating at an easily achievable COP in excess of 2 will result in lower emissions than a gas condensing boiler. And let's not forget that the grid is getting cleaner all the time, so the case for heat pumps will get even stronger.

Rob Cannell MIET
Stafford

JR Ball presents an interesting calculation about the relative carbon dioxide emissions of heat pumps and conventional gas heating for homes. I am no expert in this field, but from my limited personal experience staying in a house where the rooms and water are heated by a ground-source heat pump I suspect one of the assumptions may be incorrect. In the house where I

stay, the heat pump runs continuously, the radiators are just slightly warm at all times and the room temperature remains pleasant all year round.

By my understanding, the electricity demand of the heat pump is more or less continuous. However I would agree that the annual electricity consumed by the heat pump costs around half the annual cost of gas heating. As the demand is continuous, the electricity for the heat pump should be supplied from renewable sources, including, no doubt, a contribution from solar panels on the property itself, as is the case with the house I stay in.

It is the 'peaky' demand of fast space heating in the morning and evening that would have to come from gas turbines. This is why few homes rely on electric fires or radiators to heat them when required, but use either electric storage heaters, or gas/oil burnt locally.

The use of heat pumps instead of gas/oil heating, and the use of electric car charging points instead of petrol stations, will inevitably require a considerable increase in electricity generation and distribution capacity in the future. I hope the necessary investment is being made.

Bob Barnard CEng FIET
By email

CORRECTION

The photo accompanying the 'From the IET Archives' column in the October 2021 issue of *E&T* showed a rebuilt Bombe electromechanical decryption device on display at the National Museum of Computing, not a Colossus computer at Bletchley Park as stated in the caption.

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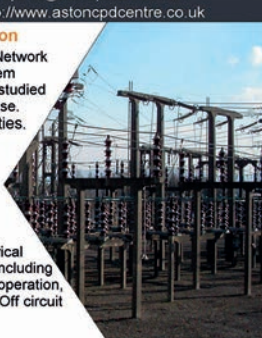
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Legislation requiring manufacturers to maintain support for their products and make it easier to repair them will reduce their environmental impact, but doesn't go far enough.

By **Antony Bourne**

Comment



Extending the lifespan of consumer tech would make a significant dent in carbon emissions



DESIGN

Lengthen the life, strengthen the relationship

THE UK GOVERNMENT'S recent 'right to repair' law may be a step in the right direction for consumers and for the environment, but should the legislation have been wider reaching in order to further incentivise the transition to circularity and servitisation? To require manufacturers to become providers not only of products, but of outcomes, experiences and ongoing services too?

The regulations, which cover domestic white goods, TVs and some non-consumer products including electric motors and commercial refrigerators, mandate that manufacturers must provide spare parts in order to extend a product's lifespan for up to ten years. Parts deemed 'simple and safe' to replace are to be made available direct to consumers, with spares for more specialist repairs supplied to qualified technicians.

There are fears that this will fuel price rises, and concerns over the cost of the parts and the repair work, both of which will be out of the control of the government and the consumer. However, such a stand against 'built-in obsolescence' – goods designed to need replacing after a relatively short period – should be applauded if only for the reduction in non-recyclable waste. Yet comparatively few products are subject to the new laws and it is those not covered that

could have turned a baby step into a major stride forward.

We have come to accept, if reluctantly, the forced replacement of computers, laptops and smartphones, sometimes every two or three years. It is here the legislation could have had a more meaningful impact. While major software players, for example, have long eschewed box-selling in favour of subscription models, tech hardware manufacturers rely heavily on their ability to sell their newest, shiniest, most advanced offerings, clearing a revenue path for new releases by ensuring lack of support, upgrades and parts for previous models.

A 2019 report by the European Environmental Bureau revealed that extending the life of smartphones and other electronics by one year would save the EU the equivalent in carbon emissions to taking two million cars off the roads annually.

Apple is among manufacturers that remain opponents of right to repair, citing security and safety risks to consumers. The tech giant has built a worldwide service infrastructure and offers a recycling scheme, but its core sales model still revolves around relatively short product lifecycles. Apple enjoys unparalleled brand loyalty and clamour to purchase new models, but this is not typical. Many devices end up in landfill

simply because they are no longer fashionable, or are beyond repair.

Widening the scope of right to repair to include such technology would accelerate a growing trend among forward-thinking manufacturers towards servitisation. This is the transition from delivering a single transaction to providing outcomes and ongoing services to customers and, in doing so, cultivating consumer relationships.

The need for such evolution has been accelerated by the supply chain challenges posed firstly by Brexit and then Covid-19. A recent IFS study suggested that 90 per cent of companies have either undergone or initiated a reengineering of their business models in the past year to reflect the need to 'design for service', driven by difficult trading conditions and the expectations of consumers whose behaviours have changed. Amazon in particular has helped to normalise consumers' expectations in terms of rapid delivery and streamlined aftersales.

Servicing of high-tech products tends to be outsourced to third parties and expensive for the consumer. While many brands do offer in-house repairs, this is rarely more than an add-on in terms of marketing and customer relations. Extended warranties are typically viewed more as insurance schemes.

Bringing all elements of the customer journey together means offering a long-term solution to customer needs, encompassing planned and understandable after-sales and service, and pathways to future-proofing investments in the products. Manufacturers need to move away from the linearity of short product lifecycles and the downsides of increased environmental waste, poor value and short-term customer relations.

Adding service to a product, offering repairs and upgrades, longer warranties, subscription or leasing models and, critically, keeping all this under one roof, would better align with today's consumer demands while providing manufacturers with better long-term stability and new, consistent revenue streams.

This requires gaining a more detailed knowledge of the full lifecycle costs of producing, using and maintaining a product. This often means investment in the right technical foundations to underpin this new business model is needed, but the advantages – financial and reputational – significantly outweigh any capital expenditure.

By providing such moments of service and adopting a more circular resources model, manufacturers can more than mitigate loss of revenues previously driven by planned obsolescence with longer-term, outcome-based customer relationships. The 'right to repair' movement, and the legislation we've recently seen, are significant steps in turning back some of the damage to our environment and transitioning to a circular economy, but more can and should be done. **Antony Bourne is SVP of industries at enterprise software firm IFS.**



COP26: TIME TO WALK THE WALK

The UK presidency is being encouraged to make COP26 the event where ambition turns into action to achieve real progress on climate change.

By **Caroline Hayes**

GLASGOW IS about to host the first five-year review of the 2015 Paris Agreement on climate change, and countries are expected to announce updates to their plans for reducing emissions, but many commentators are frustrated that new targets simply point to ambitions for, and not action on, climate change.

The UK's president designate for COP26, Alok Sharma, has outlined four goals for the climate change agenda. Principally, he wants to align every nationally determined contribution (NDC) with a goal of lowering the current 2°C global warming limit to 1.5°C. Countries are being asked to announce ambitious emissions reduction targets ahead of meeting in Glasgow. The other three goals are to help countries adapt to climate change and minimise losses caused by flooding and other weather-related events, to increase and to mobilise climate finance, and lastly, to enhance international collaboration.

Carlos Pacual, senior vice president for global energy at the analyst IHS Markit, says: "Countries are looking at COP26 as the foundational point that will help translate [net-zero] aspirations into action."

Laurence Tubiana, CEO, European Climate Foundation, told a CERAWEEK

energy forum hosted by IHS Markit: "COP26 has to capitalise on the short-term actions consistent with the net-zero goals that more than 115 countries have adopted, and with an element of credibility."

Closing the gap

For Professor Michael Jacobs, a research fellow at the Sheffield Political Economy Research Institute at the University of Sheffield, COP26 has to address the 'emissions gap' – the shortfall between the goal to which countries have committed and the actual commitments they have made to cut their own emissions.

Scientific opinion is that to be on a trajectory to limit global warming to 1.5°C above pre-industrial levels, global emissions in 2030 will need to be 25Gt of CO₂e (carbon dioxide equivalent). Based on commitments made to date, Jacobs says, emissions are currently expected to be 53-56Gt by 2030.

Plans for reducing emissions include accelerating the phase-out of coal, encouraging investment in renewable energies, limiting deforestation, and quickening the pace to switch from petrol and diesel to electric vehicles within the next 10 years. ➤

Speaking at the UN in late September, Boris Johnson described COP26 as a 'turning point for humanity'



◀ Internationally, there is a marked shift away from fossil fuels. Aurora Energy Research's 2021 'Global Energy Markets' report finds that economic growth will lead to global energy demand rising by 25 per cent over the next 30 years, but the share of fossil fuels will decline by 15 percentage points to 71 per cent as renewable energy production increases. Energy market modelling shows global emissions will peak around 2030 followed by a decline.

"Based on current and stated policies, we expect greenhouse gas emissions to peak around 2030, with oil demand also peaking around the same time, due to faster growth in electric vehicles," says Aurora research director Richard Howard.

China's post-Covid-19 economic recovery has seen the reopening of over 40 coal mines and 10GW of new coal-fired power stations in 2020. Its attendance at COP26 has not yet been confirmed but the country has said it will aim for carbon neutrality in 2060 (a decade after the Paris Agreement's deadline) and it is also aiming to get a quarter of its total energy from nuclear and renewable sources by 2030.

Uniting the world

One of President Joe Biden's first acts was to bring the USA back into the Paris Agreement. The country is one of the world's largest CO₂ emitters and has pledged a target of 50-52 per cent reductions from 2005's emission levels in 2030. The EU has adopted an ambitious law which commits the bloc of 27 countries to net zero by 2050. It is on course to meet its target of 40 per cent reduction in emissions from 1990 levels by 2030, and has revised its target to 55 per cent, although this will be using emissions trading incentives. Individually, Germany proposes it will reach net zero by 2045 and France introduced legislation to decrease emissions by 40 per cent by 2030 compared with 1990 levels. Saudi Arabia, Russia, Australia and China are among the 12 G20 countries yet to announce revised targets ahead of COP26.

The UK's role at COP26 will be to lead diplomatic efforts for governments to jointly set a target for removing public finance from fossil fuels and to support renewable energy. It has taken the lead when in April it set a target of 78 per cent emissions reduction by 2035, compared to 1990 levels. Importantly, the target includes international aviation and shipping emissions in the calculation for the first time.

The EU has announced plans to have 25 per cent of all agricultural areas farmed organically, to plant three billion trees, restore 25,000km of rivers and reverse the decrease in bee and wasp populations. Detractors including scientists at the Karlsruhe Institute of Technology argue that the plans may result in the EU outsourcing environmental damage by increasing imports of agricultural products and that the EU's CO₂ footprint should factor in emissions created by production abroad.

All revised targets look to achieve net-zero emissions but Ric Casale, co-founder and trustee of the climate charity Carbon Copy,

CONSEQUENCES CLIMATE CHANGE – SO WHAT?

Changing weather patterns are leading to an increase in forest fires



According to the IPCC, the last five years have been the hottest on record, accompanied by a rise in sea levels. Its August report, 'Climate Change: The Physical Science Basis', is described as a "code red for humanity" by UN Secretary-General Antonio Guterres. "The alarm bells are deafening, and the evidence is irrefutable," he says.

In recent years, phenomenal weather events have become more frequent, with another year of record high temperatures in Europe and the west coast of North America, with accompanying wild fires, as well as fatal flooding in Germany, New York and China. There was also the sight of deep snow falling in late August in the Atacama desert in Chile, said to be the driest place on Earth, when the effects of climate change meant that rising temperatures led to more water evaporating to fall as snow in sub-zero desert temperatures at night.

Ice sheets in the Antarctic and Greenland are melting and they will continue to melt

regardless of the emission scenario, says Professor Michael Norton, environment programme director for the European Academies Science Advisory Council. "All we can do now is to try and reduce the rate at which their melt is accelerating and delay the rate of the sea levels rising," he declares.

The Amazon could also change "from a rainforest to a savannah of grassland and sparse woodland", says Norton. The transition could occur within 50 years, beginning at the edges and gradually spreading inland. "The most recent data shows that it has already become a net source of carbon and is no longer supplying that incredibly valuable ecosystem service of sucking CO₂ out of the atmosphere, he observes.

Research published in the *Proceedings of the National Academy of Sciences* projects that without mitigation a 3°C rise in mean annual temperatures would expose up to three billion people to conditions that today exist only in places like the Sahara desert.

says the world should be focusing on zero-carbon policies. There is, he says, a gap between the rhetoric and the reality, and that success should not necessarily be a set of specific targets but deliverables that are realised in 12 months' time. He believes a 12-month review would be a good way to measure the national and international goals that have been achieved.

Local action

Casale also wants action to be mandated at a local level, with finances allocated to and managed by local authorities and "into the hands of people responsible for implementing policies". He says the UK, and Glasgow in particular, is a good location for COP26. Awarded Global Green City in 2020 by the Global Forum on Human Settlements, the city is committed to achieving carbon neutrality by 2030.

Echoing Casale's call for local action rather than international ambition, Martin Baxter, director of policy and external

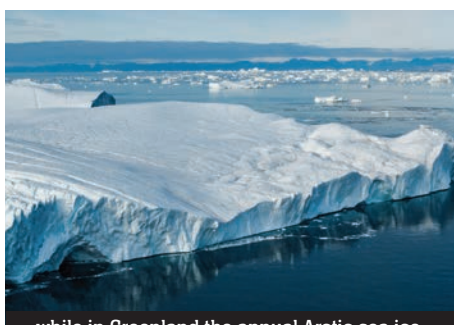
affairs at the Institute of Environmental Management and Assessment, a professional body for environmental practitioners, says that there is a detectable shift in the UK to more corporate action. He praises the government's procurement policy, which will take into account the net-zero ambitions and performance of companies when awarding public contracts over £5m.

He believes incentives and "the right signals" are driving improvements in technologies. For example, the semiconductor industry is investing in ways to reduce waste water in semiconductor production and to improve energy efficiency in data centre operation. Companies are also encouraged to look at their supply chains to understand how they can influence their carbon footprint through supply choices and product design.

Another target, to increase and mobilise finance, may be a significant milestone for COP26. At the 2009 COP in Copenhagen, developed countries agreed to transfer >



China's Henan Province suffered severe rainstorms in August...



... while in Greenland the annual Arctic sea ice limit continues to retreat

< \$100bn each year to developing countries to help them build renewable energy markets. The latest figures from the Organisation for Economic Co-operation and Development (OECD) show only \$79.8bn was transferred in 2018. In addition to delivering the agreed finance, COP26 could be the platform for international financial institutions to work towards releasing private and public sector finance.

The agreed finance is needed, among other things, for early warning systems and flood defences, as well as protecting and restoring habitats that are themselves natural storm and flood defences.

Oil Change International's global industry campaign manager, David Tong, says banks should use financial tools like prudential regulation, credit guidance and public statements to regulate or make it more costly to lend towards fossil-fuel production.

At COP26 all countries will be asked to produce an Adaption Communication with details of actions and plans to adapt to the impact of climate change with a view to sharing best practice around the world. This will build on the Adaptation Action Coalition developed by the UK, Egypt, Bangladesh, Malawi, the Netherlands, Saint Lucia and the UN Development Programme.

The success of COP26 will be based on more than finalising the Paris Rulebook (the rules needed to implement the Paris Agreement). The call for action rather than more rhetoric is getting louder. As the host nation, the UK will have to bridge international differences to progress the phasing-out of coal (if not oil and gas), lower the 2°C temperature cap, and raise accountability for financial contributions. Changes at national, local and individual levels may result from the media attention COP26 attracts, before anything governments can put into place. *

JARGON DECODING COP

There are lots of acronyms and phrases peculiar to climate change meetings. Here is a COP glossary:

COP – Conference of the Parties which signed the 1994 United Nations Framework Convention on Climate Change (UNFCCC).

Paris Agreement – negotiated at COP21 in 2015, 197 countries or states agreed to reduce the impact of climate change by limiting the rise in the mean global temperature to 2.0°C and to strive for 1.5°C above pre-industrial levels. The Agreement called for emissions to be reduced to net zero by 2050.

The Paris Rulebook – will set the Agreement in motion by defining the tools and processes for a full, fair and effective implementation. A focus for COP26 will be to finalise the Rulebook.

Article 6 Paris Agreement – This relates to carbon markets and covers emissions trading schemes, the international transfer of carbon credits between countries, and the application of taxes to discourage emissions.

Critics say carbon trading is a way for developed countries to continue producing emissions and places the responsibility on developing countries without reducing poverty.

NDCs – Nationally Determined Contributions.

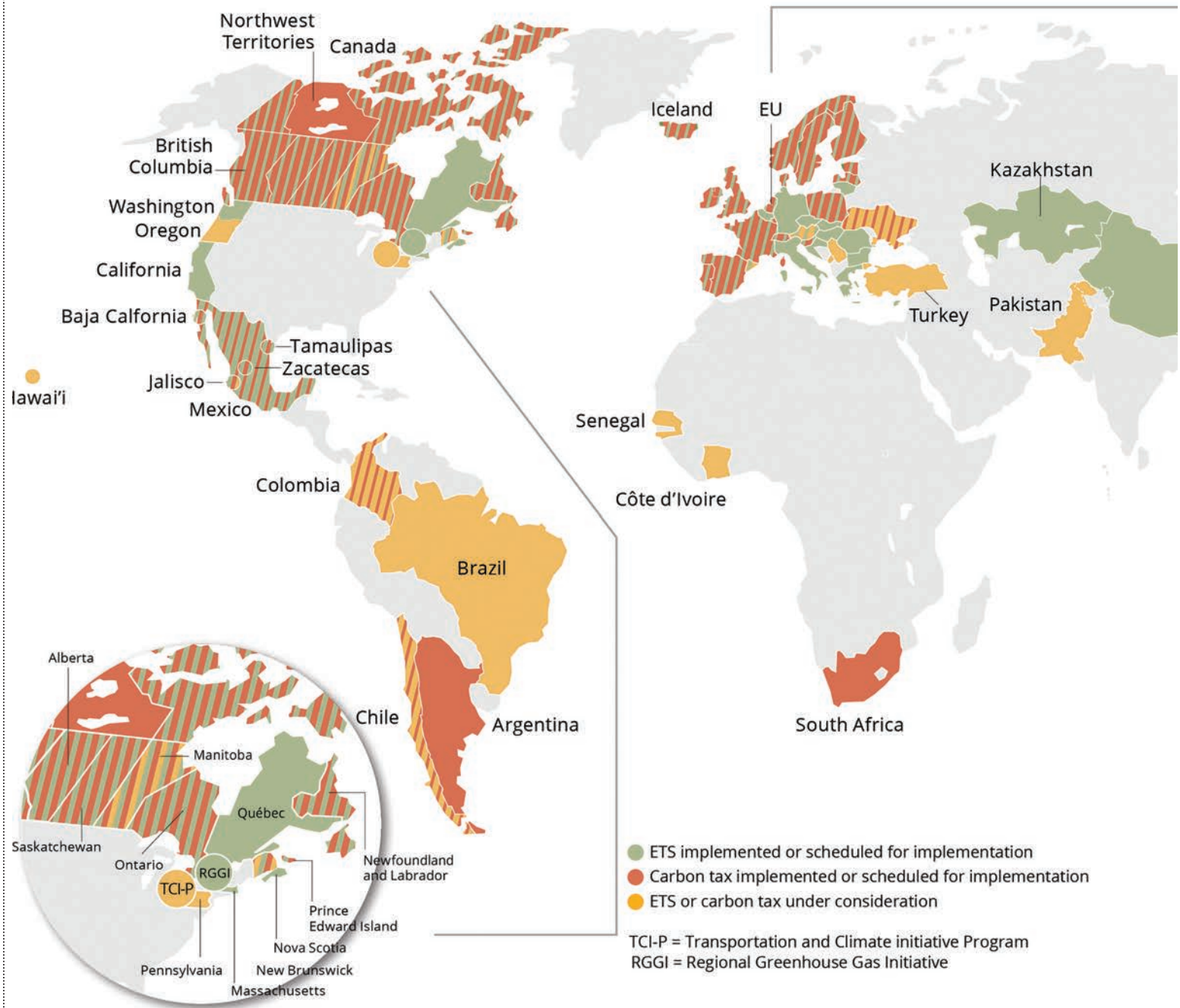
An expression of how a country feels it can reduce emissions to reach the overall aim of halting global temperature rises. The UN says they “embody efforts by each country to reduce national emissions and adapt to the impacts of climate change”. NDCs are submitted every five years to the UNFCCC secretariat and must represent a progression compared to the previous NDC.

Net zero (also called carbon neutral) – the state when the emissions produced (by coal- and gas-fired power stations, for example) and the reduction of those already in the atmosphere (via reforestation and trees absorbing CO₂) are equal.

Zero carbon – using only renewable energy rather than offsetting emissions from fossil fuels to reduce carbon emissions to zero.

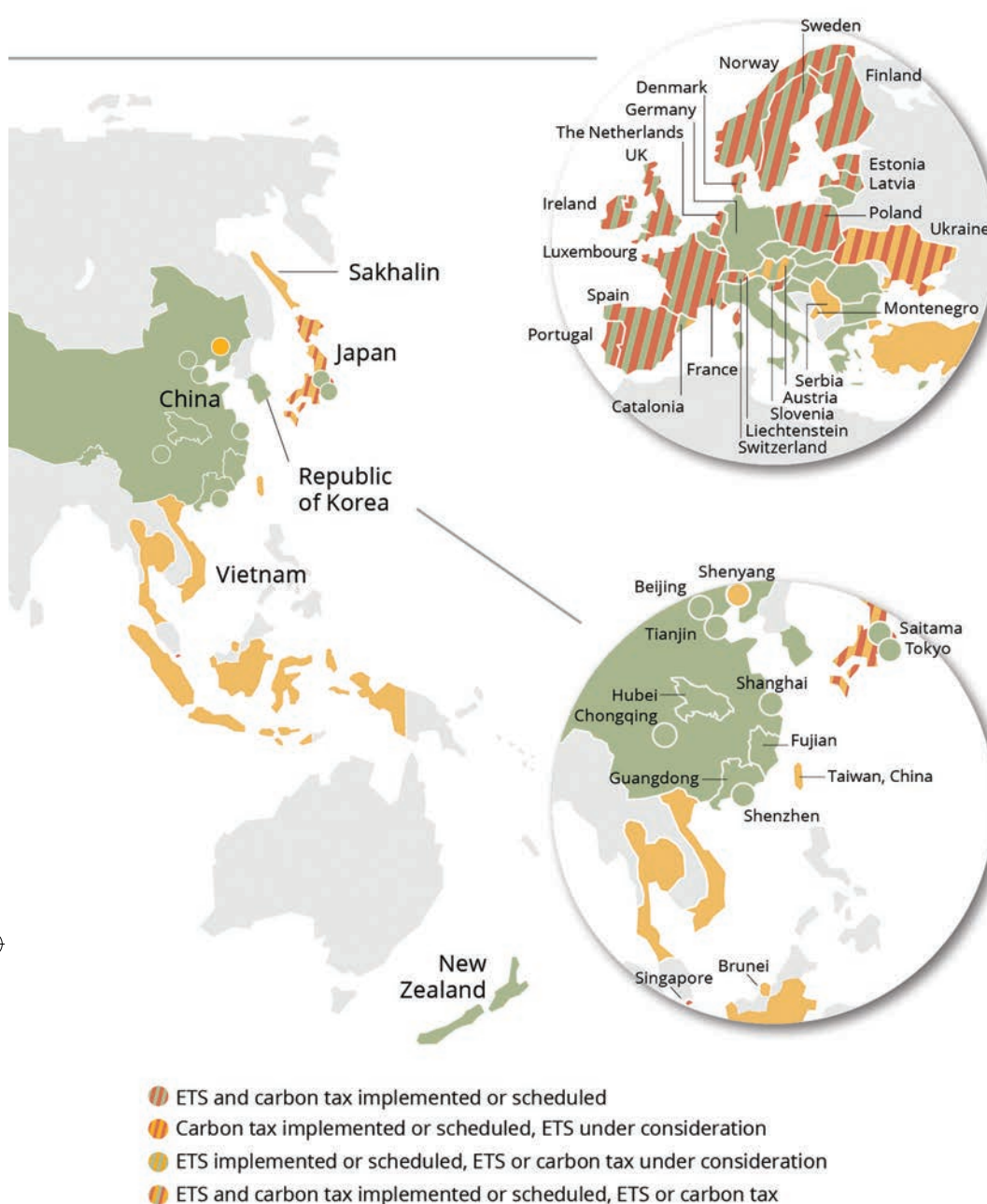
Glasgow's SEC will host COP26 and, hopefully, set the global climate change agenda





Leaders at the COP26 climate conference will consider how to create a framework for global cooperation on carbon markets, which could be a key breakthrough for climate change mitigation. By **Heidi Vella**

LAST CHANCE FOR CARBON TRADING?



A Carbon Pricing Map from the World Bank, 2021. The large circles represent cooperation initiatives on carbon pricing between subnational jurisdictions. The small circles represent carbon pricing initiatives in cities. ETS = Emissions Trading Scheme

carbon. In this way, the EU ETS was, in large part, successful in making gas-fired profits better than coal-powered ones. But for almost everything else, carbon markets have failed to reach this equilibrium, with weak pricing, poor market design, and liberally distributed exemptions meaning current mechanisms have barely dented emissions.

For example, four-fifths of global emissions remain unpriced, and the global average price is only \$3 (£2.16) per ton, with countries too scared to impose taxes on their industries for fear of driving up prices too steeply. Only 3.76 per cent of emissions are covered by a carbon price above \$40 (£29)/tCO_{2e} – yet experts believe it should be double this to spur change.

What's more, cap and trade systems like the EU's – where a cap on future emissions is decided and permits sold accordingly – are often rendered ineffective by economic downturns, and indeed pandemics, which have lowered consumer demand and seen emissions fall without big polluters needing to do anything. For example, as coronavirus spread last year, the price of carbon fell 30 per cent in the three months to March.

Carbon leakage has also been a key factor holding back domestic carbon pricing. When big polluting industries such as the steel sector start incurring increased taxation they might be motivated to move offshore. This wouldn't remove the emissions from the atmosphere but simply shift them elsewhere.

This is partly why in Europe free allowances are given to most energy-intensive industries, which Carbon Market Watch says has led to companies profiting from the market by up to €50bn (£36bn) between 2008 and 2019.

"This is one of the reasons why the European system has been very focused on the power sector, because you can't offshore your power by trading electricity with China or the US," explains Seb Henbest, BloombergNEF chief economist and lead author of the recently published New Energy Outlook (NEO) report.

Is global carbon pricing the solution?

In theory, a global carbon pricing mechanism could mitigate the carbon leakage risk, while also raising the standards of manufacturing and the speed of clean energy adoption across the globe.

"The more countries joined together under the same carbon price regime, the harder industry can be pushed, which will then drive innovation and solutions and create competition between manufacturers to get their carbon emissions down," explains Henbest.

Countries that struggle to meet their nationally determined contributions under the Paris Agreement could purchase emissions from other nations that are overachieving on their pledges. Such cooperation under Article 6 has potential cost savings of \$250bn (£180bn) per year in 2030, according to the International Emissions Trading Association.

To develop such a system is fraught with challenges, however. To start, leaders will >

CARBON PRICING mechanisms have long been considered an effective way to galvanise clean technology adoption and global emissions reductions, yet current schemes have been lacklustre. The imminent COP26 conference in Glasgow could change this.

In 2005, the European Union (EU) established the world's first international emissions trading system (ETS). Since then, similar mechanisms have proliferated, and today the World Bank records 64 carbon pricing arrangements in operation, up by six from the previous year. Most significantly, this year China launched its domestic ETS, which covers 30 per cent of its national greenhouse gas (GHG) emissions and is the world's largest.

Under Article 6 of the Paris Climate Change Agreement, brokered in 2015, leaders are tasked with negotiating a framework from which these domestic carbon markets could be connected to each other to, in effect, create the foundations for a global emissions

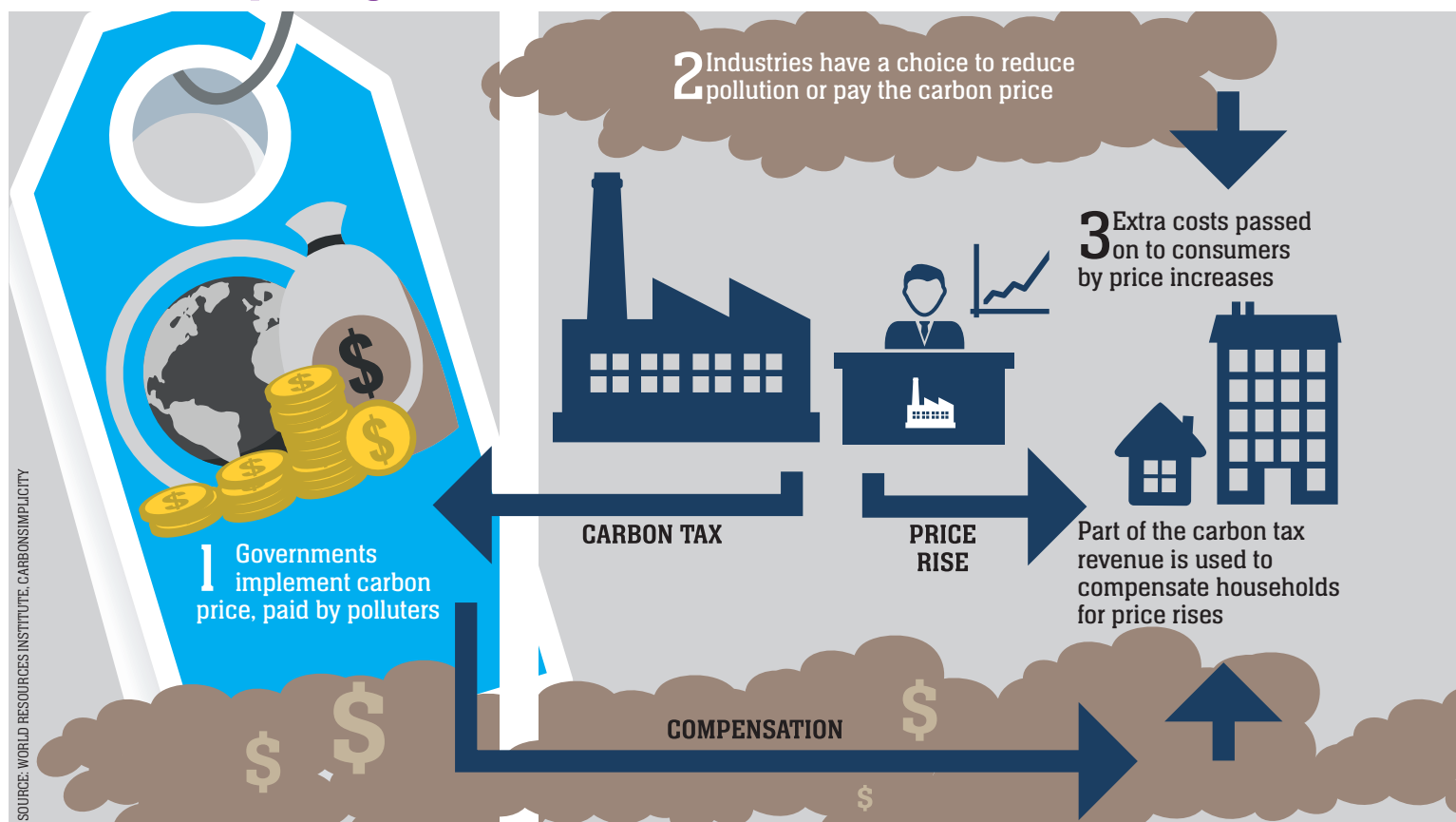
trading system. In theory, this would help nations decarbonise faster by supporting investment from one country to the next and by reducing the cost of emission reductions by trading carbon at the most efficient price.

Yet, with competing domestic responsibilities, finding common ground on what is at its core a new cost for business has proved one of the most difficult components of the Paris Climate Accord and the planned discussions at COP26 are widely seen as a 'now or never' moment for global carbon pricing and trading.

Creating a market that works

In theory, carbon pricing mechanisms incentivise big polluters to reduce their emissions by making them pay for the carbon they emit, therefore encouraging them to invest in abating measures, such as more efficient processes and/or cleaner fuels. To work, the costs of the emission-reduction action must be cheaper than the price of the

How carbon pricing works



◀ need to make sure two trading countries can't claim the same mitigation credit.

"It needs to deliver a global reduction in GHG emissions, rather than just shifting forms of CO₂ around. It also needs to deliver sustainable development benefits on the ground, and make provisions for stakeholder consultations and grievance mechanisms," says Sam Van den plas, a policy director at Carbon Market Watch.

Linked carbon markets tend to see price equalisation, with the lower system taking on the higher system's price. This is likely to be unpalatable for emerging markets that are trying to grow their economies and standard of living in line with that in the West.

"Often governments don't want to damage their economic growth, or improvements in living standards, so there's a really big difference in what's considered an acceptable carbon price between countries," says Mark Johnson, technical director for energy and carbon regulation at engineering and environmental consultancy Ricardo. "That's why the EU can link with Switzerland, which

has a similar economy, but not Argentina, who's got a \$5 (£3.60) price," he adds.

Agreeing on a globally accepted carbon price floor could be a positive outcome if a trading framework cannot be achieved.

"From a regulatory perspective, it might be easier to navigate a carbon tax, rather than a market," says Joshua Firestone, principal petroleum economist at energy consultancy Wood Mackenzie. "But no one's interested in passing carbon taxes on a massive scale."

In this respect, the International Monetary Fund has proposed the creation of an international carbon price floor arrangement that would start with the biggest emitters and the G7 and gradually expands to other countries. It suggests two or three different price levels that vary according to accepted measures of a country's development. As an example, it outlines a three-tier price floor among just six participants (Canada, China, EU, India, UK, US) with prices of \$75 (£54), \$50 (£36), and \$25 (£18) for advanced-, high- and low-income

emerging markets respectively. In addition to current policies, this could help achieve a 23 per cent reduction in global emissions below baseline by 2030, it notes.

Many support such an idea. The Net-Zero Asset Owner Alliance, which is convened by the UN and whose 43 members include some of the world's biggest pension schemes and insurers, has said a coordinated global price on carbon would give certainty to investors and provide stable and reliable incentives for stakeholders to adopt or develop low- or zero-emission technology. Others such as British economist Dieter Helm in his book 'Net Zero: How We Stop Climate Change' believe a carbon price is better than a trading system because "...having an auction over a continuous period of time is wide open to lobbying and political manipulation", as has been seen with EU ETS.

No silver bullet

Though carbon pricing is expected to be an efficient and effective mechanism for reducing emissions, experts say that on its

EUROPE

THE EU'S CARBON BORDER ADJUSTMENT TAX

When it comes to carbon taxes, the EU has an ace up its sleeve... the carbon border adjustment mechanism (CBAM). Part of a package of climate measures announced in mid-July, CBAM would impose the equivalent of tariffs on imports from countries where producers pay a carbon price below that of the EU's, set either directly or through an ETS. It would work by importers buying CBAM certificates (reflecting carbon content) that cost what

the EU's ETS permits do on domestic producers, thus effectively imposing the EU's carbon price on importing countries. The adjustment tax will at first only apply to electricity, iron, steel, cement, aluminium and some fertilisers, but could be extended to other products.

The hope is that it will end carbon leakage and the need to handout free credits for the EU ETS.

"CBAM effectively levels the

playing field between EU-based companies subject to the ETS and those exporting steel from China, for example," explains Joshua Firestone, principal petroleum economist at Wood Mackenzie. "It sort of creates a global tax scheme, and if other big players like the US followed suit it would effectively set an international carbon rate, but I don't see the appetite for that."

The proposal is controversial, with many countries getting upset

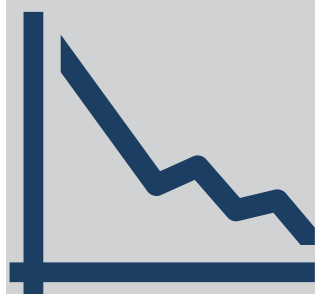
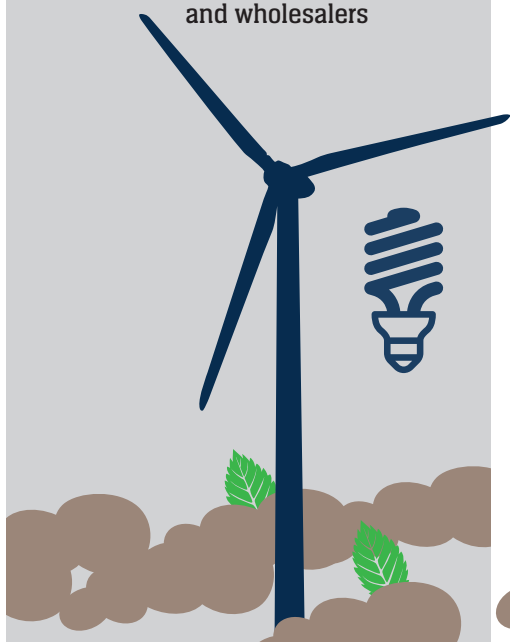
about it, largely because it does move away from the voluntary spirit of the Paris Climate Change agreement. "Once you have carbon borders, you make it competitive, even adversarial," says Neil Hirst, senior policy fellow for energy and mitigation at the Grantham Institute. "Suddenly the climate effort goes from being a cooperative global one to something the West is trying to enforce on the developing world." Sam Van den plas, a policy

4 Small businesses and households have a price incentive to save energy and buy less pollution-intensive goods and services, eg. energy retailers, manufacturers and wholesalers

5 As demand rises for clean energy and energy efficiency, products and investment becomes more attractive and affordable

6 Carbon-intensive industries shift toward lower emissions. There is growth in cleaner energy and carbon sequestering technology.

7 Emissions fall



own it will not be a silver bullet.

"The EU is taking revenues from selling cars and putting them into an innovation fund to support new R&D activities to develop demonstration activities, so clearly, all the EU economists don't think the ETS carbon price is going to deliver the innovation needed," explains Johnson. "Investment in early-stage research and development and other types of support mechanisms are also important."

Neil Hirst, senior policy fellow for energy and mitigation at the Imperial College London's Grantham Institute, agrees. "It's only easy to shift from one technology if others are available. In the UK, carbon taxes were successful in helping run down the coal industry because it could be easily and cost-comparatively replaced with gas and subsidised renewables. The opposite has proved true for gas," he says.

Yet Helm, who advocates for everything people consume to be subject to a carbon tax, not just the most polluting sectors as currently happens, is unequivocal about the

'Pursuing a global carbon price requires many countries with very different geopolitical, commercial and economic interests to agree – there's no sign that can be achieved.'

Seb Henbest
BloombergNEF

necessity: "If there is not an appropriate carbon price, then decarbonisation at scale will almost certainly not happen." Because to not have a carbon tax is to pretend that decarbonisation doesn't cost anything extra, which it does, he goes on to say.

Of course, one of the draws of carbon taxes or emissions trading schemes is that they can provide the capital needed to make the big investments in R&D and pilot projects or to support the poorest nations to decarbonise.

Yet, the fact remains that finding a consensus on a global tax mechanism will be tough, and the experts aren't hopeful it can be done. "Pursuing a global carbon price requires many countries with very different geopolitical, commercial and economic interests to agree – there's no sign that can be achieved," says Henbest. Summing up the general sentiment, he adds: "There's definitely a real sense that carbon taxes may miss their moment or never really materialise into the solution promised." *

director at Carbon Market Watch, believes the policy could work if the EU recycled some of the revenues back to developing countries to help them decarbonise. "If there are unfair impacts on countries which are highly dependent on specific exports to the EU, they should look at ways to avoid that."

However, it has already sparked an international response in the direction the EU wants. Mark Johnson, technical

director for energy and carbon regulation at Ricardo, who works with governments, including the EU Commission, to design carbon markets and taxes, says countries such as Russia and (so it is rumoured) China, started to look at developing their own national carbon tax systems because they'd rather collect the revenue themselves.

"Countries are definitely taking notice of what Europe's doing and they're trying to plan

accordingly," he says.

However, the International Monetary Fund does not support CBAM, saying that, from a global climate perspective, "border carbon adjustments are insufficient instruments, as carbon embodied in trade flows is typically less than 10 per cent of a country's total emissions".

But Johnson says it is being done in a measured way and people shouldn't panic. "The headlines seem more dramatic

than it actually is, but CBAM covers a relatively narrow set of sectors and they're doing it in a very gradual way," he explains.

Although the proposal is likely to be difficult to implement in practice, with the EU needing to find ways in which to rigorously monitor, track and trace carbon footprints, Johnson believes it will go ahead. "There's a lot of political commitment and capital invested in taking the proposal forward, so they will," he predicts.



Green subsidies are getting trimmed but might outlast those for fossil fuels in the end.

By **Chris Edwards**

AS NATIONAL leaders meet to thrash out what they are prepared to do to promote the growth of renewable energy ahead of fossil fuels, the reality is they have largely decided market forces will be used for delivery. Governments have been reining in the subsidies that have been used to encourage investment in renewables such as wind and solar as their operational costs begin to approach those of existing fossil fuels.

The good news for renewables is that subsidies for the competition look to be on the way down as well. Even excluding the externalities – the environmental costs – of fossil fuels that are rarely included in calculations, direct government subsidies to fossil fuels have long outweighed any others. A recent report compiled by the International Renewable Energy Agency (IRENA) estimated more than two-thirds of the \$634bn (£458bn) spent on energy subsidies went into fossil fuels in 2017.

A quarter of the total energy subsidies worldwide were used for renewables; the remainder were for nuclear. By 2030, IRENA expects fossil-fuel subsidies to have dropped to 35 per cent of the total, but that is not because it expects renewables subsidies to surge. Instead, overall subsidy spending could drop below \$500bn (£362bn), with renewables subsidies by governments rising just 15 per cent to around \$200bn (£145bn). According to IRENA, the situation could stay like that up to 2050, with fossil-fuel support still accounting for almost 30 per cent.

Today's reality

Why has fossil fuel support been so sticky in an environment where governments are less than keen to turn on the money taps for cleaner energies? A closer look reveals the spending is not evenly distributed around the world. The country with the largest fossil fuel subsidy in 2020, according to the International Energy Agency's figures, was Iran: spending close to 5 per cent of its GDP to keep fossil fuels cheap. China and India spend less as a proportion of GDP but each accounted for more than \$20bn (£14.4bn). The stated reason for the subsidies in most of these countries is to help the poor, though a number of economists have questioned whether they are as effective for this as they are for helping richer business owners.

The growth in subsidies for renewables that these projections show are also misleading, experts claim. IRENA predicts Japan will be the only country where subsidies for renewables generation will grow. For practically all other nations, the subsidies are being redirected away from financing the installation of solar panels and wind turbines for grid generation. Instead, they support a transition to electrification in transport and industry. These are more difficult to decarbonise compared to electricity generation for domestic and >

ALAMY, IRENA, IEA

IRENA'S RENEWABLE ENERGY ROADMAP ANALYSIS

ENERGY SUBSIDIES AND THEIR EVOLUTION TO 2050 (EXCLUDING CLIMATE AND HEALTH COSTS)



Insulate Britain is a new campaign group that is calling on the government to put in place policies and funding for a national home insulation programme starting with all social housing

THE COLOUR OF MONEY

ECONOMY

ECONOMIC VALUE OF GLOBAL FOSSIL-FUEL CONSUMPTION SUBSIDIES
BY ENERGY SOURCE, 2010-2018

< office users. According to IRENA, around half of the industrial subsidies are being aimed at iron and steelmaking, with a third directed at cement production.

An end of an era?

Instead of subsidies for renewables for power generation, the incentives now look to be shifting strongly towards carbon pricing while direct funding gets trimmed. There are two main reasons for this shift. One is that, arguably, the job of subsidies is now done. Unlike the fossil fuel subsidies that were ostensibly kept in place to support consumers, the payments for renewables were more about kickstarting an industry and getting it into a situation where it can compete directly with fossil fuels.

In principle, once the cost of generation using solar and wind, and perhaps later wave energy, falls below that of natural gas or coal, the thinking is that investment in renewables is the obvious choice. Carbon pricing should nudge this process along, something that is helped by the operating costs of solar and wind. Though they are relatively expensive to install, once they are active they cost far less than natural gas or coal. The resource you need to operate them does not need to be mined, it just turns up as long as the weather is favourable. In this environment, many governments are keen not to be seen giving money to businesses who are going to be making money anyway because their marginal costs are so low. Even with that in

mind, is it really time to abandon subsidies? A lot depends on how fast governments want to move on decarbonising energy.

A greener future?

Measuring the effect of subsidies is hard, not least because every country has a different approach. One way to look at the effects is to see what happens when they are removed. The IEA's latest outlook for renewables around the world points to the reduction of subsidies as being a major influence on investment in several territories, especially China, where the government is changing its approach to green energy, though with a stated continued commitment to hit net-zero emissions by 2060. The IEA expects growth to weaken in the wake of these changes.

Support in Europe has ebbed and flowed, as has the pace of installation, over the past 30 years. The German and UK governments were the first in the region to try what have become the main instruments for implementing subsidies. Germany opted for the commonly used feed-in tariff and the UK a green certificate in the form of the Renewable Non-Fossil Fuel Obligation. Since then, Germany and other countries have tweaked their incentive schemes multiple times. The Renewable Energy Sources Act of 2014 saw the feed-in tariff move aside in favour of auctions for long-term contracts for many renewables technologies, an approach the government said would control costs more effectively in addition to making it

easier to tune how the deployment would proceed. In this case, it was designed to both promote wind-based generation in areas with good prospects for efficient generation as well as giving more parts of the country opportunities for hosting renewables.

According to a 2017 review performed by Marcella Nicolini of the University of Pavia and colleagues, payments in Germany alone had risen from less than €1bn (£853m) in 2000 to over €20bn (£17bn) in 2010. The UK lagged far behind how much it paid, barely rising beyond the equivalent of €1bn in any year during the same period. The UK had adopted a more stringent policy that kept tariffs below €0.05/kWh. They reached as high as €0.15/kWh in other European countries. By 2008, close to 20 years into its programmes, Germany had built up approximately twice as much renewables generation as a proportion of total capacity as the UK. In 2012, Germany hosted around 30 per cent of the photovoltaics for power generation installed worldwide.

In later research, Claudia Hitaj of the US Department of Agriculture and Andreas Löschel of the University of Münster concluded that the level of feed-in tariffs does help increase capacity. Their model estimated that adding just one cent per kilowatt-hour, on top of the average 15 cents, would have increased renewables capacity by close to 800MW per year up to 2010. Though capacity additions surged in 2009 through 2012 to more than 7GW, the average annual >

< increase before then was around 1.5GW. However, the type of subsidy does also matter according to the Pavia team. Their model indicated that green certificates, even adjusted for the amount of subsidy, result in less of an incentive compared to feed-in tariffs.

In any subsidy environment, there are ever-present subtleties that distort how investments are made. One issue with the original model in Germany that Hitaj and Löschel found was that companies building the plants had to bear the cost of upgrading local grid transmission to support additional capacity. That in turn led to them being built in areas with good existing transmission infrastructure. When the German government shifted more of the cost to the grid operators, the generating companies started to look more widely for sites.

Investing in renewables

Another unintended consequence of the long-term nature of traditional subsidies can be seen in the German home-generation sector. Industry group Solar Power Europe expects significant growth in home battery storage in the coming years as prosumers who had been on generous 20-year feed-in tariffs retrofit their systems to store the electricity for later consumption rather than supply at market prices.

Will carbon pricing alone lead to continued strong investment in renewables? In an analysis of the carbon-pricing policies implemented in the past decade, Johan Lilliestam from the Potsdam Institute for Advanced Sustainability Studies and co-workers concluded that carbon pricing does help reduce emissions but that this tends to take place by swapping existing sources of energy for others rather than stimulating larger-scale technological changes. For those changes to take place, more active intervention such as subsidies for specific technologies may be unavoidable even with falling costs.

Professor Charles Donovan and colleagues at Imperial College, London warn that governments may be too optimistic about the willingness of private investors to finance further expansion of renewables simply on the basis of the average daily cost compared to gas or coal. Too much may be made of the averaged numbers, which do look good, when it is the vagaries of energy markets that influence the initial go/no-go decisions.

The Imperial work underlines a problem with renewables that more often crops up as an issue of energy security and the vagaries of the weather. In a particular region, if you are having a good day generation, it is likely so is everyone else around you. During these times, wholesale prices can drop sharply during phases of 'price cannibalisation'. Conversely, when prices are high, this could easily be because the weather is unfavourable and there is no energy to supply.

A gas-fired plant on the other hand can, in economists' terms, respond to market price signals. If prices drop it simply stops running and when prices rise, the plant

FINANCE SUBSIDY OPTIONS

There are plenty of variations in how subsidies are put together but they fall into three major classes, with most of those being used now designed to react to market prices.

Traditionally, the feed-in tariff was the most common option. In general, the feed-in tariff gives users with generating capacity guaranteed access to the grid over a number of years and pays for the electricity at a level that is also guaranteed. Generally, there is a fixed premium payment made for each kilowatt-hour combined with a pricing that is set at a certain level over the regular electricity spot price. The feed-in premium variant just offers a premium on top of the spot-market price, making it less predictable for operators when determining their break-even level for investment but one that makes renewables more favourable to investors.

Another technique is the green certificate, an approach used in the UK for some years. With this, a government sets targets for the amount of energy that needs to be generated from renewables and agrees to pay operators if they fulfil the conditions of their certificate. One advantage of the green-certificate

system is that it generally works out cheaper for a government to implement but also acts as less of an incentive than feed-in tariffs.

One technique that may prove to be more popular in the future is the Contract for Difference (CfD). Much like the futures contracts developed for crop and livestock farmers, these contracts give the operators a more secure base on which to base investment decisions and have already become part of the policy instruments used by the UK to promote some types of renewable. This need not be a full subsidy: much depends on the price. Its main aim is to provide pricing stability and, in turn, make it easier to estimate the break-even cost of an installation over many years.

The early CfDs employed in the UK were awarded for more than £100m/kWh, which at the time was more than double the wholesale price of electricity. However, governments with an eye on expenditure will likely look to much lower levels and use the CfD to overcome problems caused by oversupply when all the renewables in a region are active and demand is low.

'The Imperial work underlines a problem with renewables – the vagaries of the weather. If you are having a good day, it is likely so is everyone else around you. During these times, wholesale prices can drop sharply.'

ramps up its output and fuel consumption. The net effect is that the weighted average price for wind or for solar can easily drop well below the apparent average.

Importance of storage

There is a longer cycle that the Imperial team sees as also having a major influence: the supply and demand for fossil fuels tend to fluctuate widely over long periods. The oil price, for example, fell from more than \$100 (£72) per barrel to less than \$30 (£22) in a matter of months in 2016, a crash that pushed many shale-oil producers out of the market. The price returned to around \$60-70 (£43-50), though even that was punctuated by a few days in April 2020 when futures contracts for oil turned negative for the first time because refineries were sitting on full tanks for which they had no orders. As the balance between fossil fuels and other energy sources continues to shift, similar peaks and troughs are likely to form in the coming years. Though direct subsidies would help, one

option for risk reduction is to use financial instruments such as contracts for difference, as these can iron out short-term fluctuations in price.

One developing sector that could change the viability of investments in the face of fluctuating energy prices is storage. If the problem lies in either being forced to sell electricity at a loss or even into curtailment by the grid operator, one answer is to move the supply closer to peak demand by storing the energy temporarily. So far, however, subsidies for storage have focused mainly on grid stability, which calls for short-term storage based primarily on batteries, or on the domestic batteries now used widely in Germany.

In their analysis of storage in Germany, Andreas Coester of the Vrije Universiteit Amsterdam and co-workers forecast the widespread deployment of batteries in what they call a "green maximum" policy could force fossil-fuel generation out of the German market they took as an example, albeit with a price tag of some €350bn (£300bn). Other, cheaper policies down to full free-market operation lead to slower rollout speeds for renewable energy and in full free-market scenarios to highly cyclical phases of building followed by decommissioning when installations turn out to be long-term unprofitable, a problem that historically has not been a big issue with renewable energy. As the proportion given to renewables increases, the question of long-term profitability could lead to the transition seeming to stall or go backward. Though governments will try to lean on the market more to make changes happen, they may have to keep an eye on contracts to avoid heading in the wrong direction when it comes to low-carbon power. *



To help mitigate the effects of climate change on a global scale, there are projects in place to promote the transfer of climate technologies in developing countries. So why aren't they working?
By **Jocelyn Timperley**

TECHNOLOGY is clearly crucial to tackling the climate crisis. From solar panels and smart grids to electric vehicles and green steel, much of the policy plans relies heavily on innovation and new technologies. But since the development and implementation of these technologies is dominated by the richer, developed countries, the UN climate negotiations include a key idea known as 'technology transfer'.

This compels wealthier countries to support developing ones in accessing climate technology, a notion found in the original 1992 treaty that began the climate talks and later repeated in the Paris Agreement. This fits into a wider pillar of UN climate negotiations, which recognises that richer developed countries must take the lead in reducing their emissions and in supporting poorer countries to do so as well.

In their climate plans, submitted to the UN in 2015, some 67 countries said they have a need for technology support. Thirty years after the promise was made, however, technology transfer can hardly be described as a pillar of support and collaboration on climate change.

"There's a failure to set in place mechanisms to enable developing countries and least-developed countries to properly acquire clean technologies at scale," says Matthew Rimmer, a professor of intellectual property and innovation at Queensland University of Technology. "If you want to

have a transition to a low-carbon economy, it seems like an important issue to deal with."

Rich countries have not allowed climate technologies to be made available to developing countries to reduce their emissions and become resilient to rising climate impacts, says Harjeet Singh, senior advisor at Climate Action Network International, a conglomerate of green non-profits. "They have only focused on guarding the interest of their private corporations so that they can continue to make profits," he says.

Transferring climate technology

"There are huge inequities in terms of the development and implementation of clean technologies. Just look at the distribution of ownership of clean-tech patents. This is dominated by certain key countries in the EU, some Nordic countries, the US, Japan, and South Korea," says Rimmer. "China over the last decade has [also] really risen in terms of patent filings."

After much discussion, the UN Framework Convention on Climate Change (UNFCCC) established a Technology Mechanism in 2010 consisting of two bodies: the Technology Executive Committee and the Climate Technology Centre and Network (CTCN).

But many say progress has been slow. "There is a real gap between the original ambitions and aspiration for that

mechanism and what it is actually doing in practice," says Rimmer. "It was meant to facilitate technology transfer but really is only providing technical information. It was meant to be driving research and development and deployment of new technologies but, really, it's only done that in a marginal way."

Singh says that rich countries, particularly the US, Australia and Japan, have blocked progress at the UNFCCC. "The nexus between large private corporations and governments of rich countries is not leading to any meaningful progress on technology transfer and development in developing countries," he says.

Suggestions have been made by developing countries to buy patents through the Green Climate Fund, or by developed countries to directly reward innovation and make it available for mass production, he says, but these have been brushed aside.

It is actually the bigger developing countries such as China, India, Brazil, Mexico and South Africa which are leading the way on tech transfer, says Neth Daño, Asia director at the non-profit ETC Group.

"These countries produced technologies that are more appropriate and accessible to communities in other developing countries, such as low-cost solar panels," she says. "The technology is accessible, replicable and not constrained by intellectual property rights, so that smaller companies in other

GREEN TECH TRANSFER IS TOO SLOW



GETTY IMAGES

developing countries get to copy and produce them for the local markets.”

Intellectual property

The most contentious source of conflict on clean technology transfer is intellectual property rights. The debate has much in common with the ongoing discussion about waiving intellectual property protections for Covid-19 vaccines. “Developed countries have been unwilling to find ways to provide a waiver to development of technologies that are vital to dealing with the climate crisis,” says Singh.

The question centres on how intellectual property holders should be encouraged to share their technologies or enable them to be deployed and used elsewhere, says Rimmer. He adds that debates around intellectual property of clean technologies have intensified in recent years due to a rise in litigation such as battles over patterns and trademarks.

Even if many consider it too little, the establishment of the Technology Mechanism is the biggest shift that has been seen in the UNFCCC on technology transfer.

The CTCN acts as both a matchmaker between developed countries that have technology and developing countries that need it, and a repository of knowledge about technologies in different countries, says Rose Mwebaza, director of the UN CTCN.

Developing countries can come to the

CTCN with requests about certain technologies and be linked up with companies in other countries that have these technologies, allowing the faster spread of clean technologies.

The CTCN also works with developing countries on laws and policies to provide security of investments, incentives, and frameworks to support the roll-out of climate technologies. “We have facilitated over 300 technologies to over 100 countries,” says Mwebaza.

Most of the requests are currently focused on the energy sector and renewables such as solar and wind, since many developing countries still have power challenges, says Mwebaza. But a wide variety of projects are covered, from technologies to reduce emissions in dairy farms in Uruguay, to developing energy-efficiency regulations in Nigeria, to the introduction of electric buses in Jakarta.

The CTCN is also working with the World Intellectual Property Organization, another UN entity, to create a framework which incentivises bigger companies with transformational technologies to release them on scale so they can be used in poorer countries, says Mwebaza.

With an operating budget of \$10m (£7.2m) per year, the CTCN’s funding is a fraction of the UN disbursement bodies for climate finance such as the Green Climate Fund, and many argue it is not enough. Daño notes that

the scale of technical assistance is too small and goes mostly to consultants, while the advice provided by networks mainly from the Global North is too limited.

“Overall, the Technology Mechanism has failed to scale-up production and distribution of climate technologies in developing countries that could have helped in urgently bringing down greenhouse emissions and enhancing resilience to climate impacts,” says Singh. “The finance that is being offered under the mechanism by developed countries is largely to facilitate the deals between their private corporations and developing countries to sell those technologies.”

The failure on technology transfer fits into a wider picture of discontent in the lead-up to COP26 this November. Developing countries are frustrated with the failure of developed countries to reach a \$100bn (£72bn) per year climate finance goal, and there are concerns about the accessibility of the conference to those from vulnerable countries who have not been vaccinated.

The negotiations will include some discussions on technology, says Singh. But he is not too optimistic about progress. “Such processes have not proven to be more than a lip-service or a delaying tactic to avoid actual technology transfer from the Global North or providing genuine support to poor countries in developing the technologies for climate action.”



Kenya's Olkaria Geothermal Project in Hell's Gate National Park, Olkaria, uses the labyrinth of tubes to push steam past turbines to create clean energy

A BUOYANT FUTURE FOR OFFSHORE WIND

IDEAL BY JON HERBY/WIND CATCHING SYSTEMS



Floating wind systems are on the cusp of a huge transformation as they transition from pilot projects to commercial-sized wind farms.

By **Louise Murray**

Floatgen is a 2MW floating wind turbine demonstrator installed off the coast of Le Croisic, France, on the offshore experimentation site of the Ecole Centrale de Nantes (SEM-REV).

OFFSHORE wind farms are becoming a familiar site in prime shallow-water locations around the world, from South Korea to the North Sea. Most of these are anchored in the seabed, but winds are stronger and more consistent further offshore, so energy companies are turning their attention to deeper waters unsuitable for anchored turbines.

The final 9.5MW turbine was towed into position in what is currently the world's largest floating offshore wind farm in August 2021, and the Kincardine Offshore Wind Farm was completed. The array of six Vestas turbines (five at 9.5MW and one 2MW) sits 15km off the coast of Aberdeen, Scotland – Europe's windiest country – in a location with a water depth of 60-80m. The larger turbines have a rotor diameter of 164m, and each blade weighs 35 tonnes.

The 50MW site will not hold the world title for long, as recent Scottish and Celtic Sea seabed auctions attracted multiple bids for gigawatt-scale operations from consortia including Shell/Scottish Power and Norway's Equinor. Floating offshore wind (FOW) costs are currently considerably higher than offshore fixed bottom systems, but costs have already dropped by 30 per cent in the last four years for fixed systems, and as the floating sector begins to scale up similar economies of scale are expected.

If wind power is to deliver its contribution to a zero-carbon future, floating offshore wind must become a reality. The tough deep water environment presents the industry with a set of technical challenges that must be overcome before commercialisation. Much of the technical groundwork has been done in the oil and gas sector but installation, monitoring, and the ongoing essential maintenance of multiple individually low-value sites (turbines in an array) comes with a quite different basket of economics from a single high-value constantly producing asset like an oil rig.

According to the International Energy Agency, the world's offshore wind resource is capable of meeting estimated global electricity needs in 2040 by a factor of 11. Harnessing that energy will be a key component in meeting global net-zero carbon emissions targets by 2050. Eighty per cent of the windiest parts of the ocean's real estate is too deep to install farms that have their foundations in the seabed. The solution is to float the giant turbines and tether them to the sea floor, which will extend wind power generation capability to countries with deeper coastal waters, or where the seabed is unsuitable for fixed structures. Norway, France, Spain, South Korea, Japan and much of the US coast will benefit.

Structure is key

Floating offshore structures are in constant motion, exposed to vibrations and shocks from waves up to 15m in height; 365 days a year, for their whole lifetime – estimated at 30-35 years. The job of designing structures to permit the tall, top-heavy windmills to float upright is largely done. Borrowing heavily from deep-water oil and gas >

Norwegian company Wind Catching Systems is developing a floating offshore wind power generator that it says could produce renewable energy for 80,000 homes at prices comparable to traditional fossil fuels. Named the Windcatcher, the structure would contain more than a hundred rotors stacked vertically within a 300m-high framework.

< experience, the most common design is a semi-submersible triangular frame that holds water-ballasted vertical tanks at two corners counter-balancing the third point, which holds the windmill itself. Seawater can be moved around the semi-submersible structure to maintain stability.

Other approaches to keeping the turbines upright and relatively stable include the spar design developed by Equinor, which puts the turbine into a long, deep ballasted tube like a flower in a vase. Norwegian BW Ideol's Damping Pool is a concrete or steel barge-like structure like a picture frame, where sloshing water movement inside the floating frame stabilises the movement of the turbine above. This design has already survived three typhoons in trials off Japan.

The final basic design type is a tension-leg platform. These are anchored to the seabed via adjustable mooring cables. Sensors identify incoming wind and swell activity and adjust the cable lengths in real time, to give the gigantic turbine platform a smooth ride on rough offshore waves. General Electric in the US is pursuing this strategy.

Floating substations will also need to be developed, because the voltage losses along a long cable taking the energy to shore would be unacceptable. Small subsea transformers already exist to service oil and gas installations but are too limited in capacity for floating offshore wind.

Operational substations

César Saiz, head of innovations and solutions for renewables at Hitachi ABB Power Grids, is planning for the next generation of FOW, fields of 250MW and above planned for completion in 2025/6. He explains: "We expect to have operational floating substations by the middle of the decade. The technology is already developed. But building these floating substations will require a whole new supply chain and close collaboration and coordination with both the energy companies and the platform designers."

Hitachi has a long history in FOW, having manufactured an early proof of concept for the 2013 Fukushima Floating Offshore Wind demonstration project. The new generation of floating substations will be modular, assembled, and mounted on a substructure in port, then towed to their final positions. "Anything out in deep water for up to 35 years will be subject to constant day-to-day environmental stress, in perpetual motion from the action of waves and currents. The movements generated by each different platform design will need to be accommodated in any final substation design. We are working closely with the turbine manufacturers on these aspects," he says.

With the intended lifespan, maximum reliability with minimal on-site intervention will be key to economic operations. In common with the turbines, substations will have multiple sensors to monitor performance constantly, and AI and machine learning will be used to give early warning of fatigue that might lead to costly downtime.

STATISTICS WIND POWER IN NUMBERS

180GW is the annual rate that the world must build new wind installations in order to meet IPCC targets for limited global warming by 2050

93GW commissioned in 2020, of which **6.1GW** was offshore

743GW global total wind power in 2020

35GW total offshore wind capacity

74MW is floating offshore (2021)

244.5MW coming online 2022/23

Source: GWEC 2021

Saiz added that looking much further out, into the next decade, hybrid underwater and floating solutions might be in use.

If the offshore structures and substations are areas where companies are confident that solutions are in place for the near future, there are other technologies that lag farther behind. The Carbon Trust is an international consultancy working to accelerate the delivery of a sustainable, low-carbon future.

Sam Strivens is a maritime technologist and head of floating wind at the Carbon Trust. He explains: "Carbon Trust has been active in offshore wind for over 13 years, and in 2016 set up the Floating Wind Joint Industry Project to focus collaborative research between offshore wind developers. Our aim is to help de-risk commercial-scale floating offshore wind, identifying and removing the barriers to development by encouraging cooperative research."

Early on, the CT identified dynamic export cables as key to supporting 500MW-plus operations and is helping five cable manufacturers to accelerate cable design to that stage. The cables have not been manufactured yet, but the designs are there and ready for deployment.

In other areas, there's still more to do. "Heavy-lift offshore operations for key component exchange like blades or gearboxes currently do not exist, and a cost-effective solution for ongoing monitoring and inspection of components, especially subsea still has to be found," Strivens adds.

A big approach

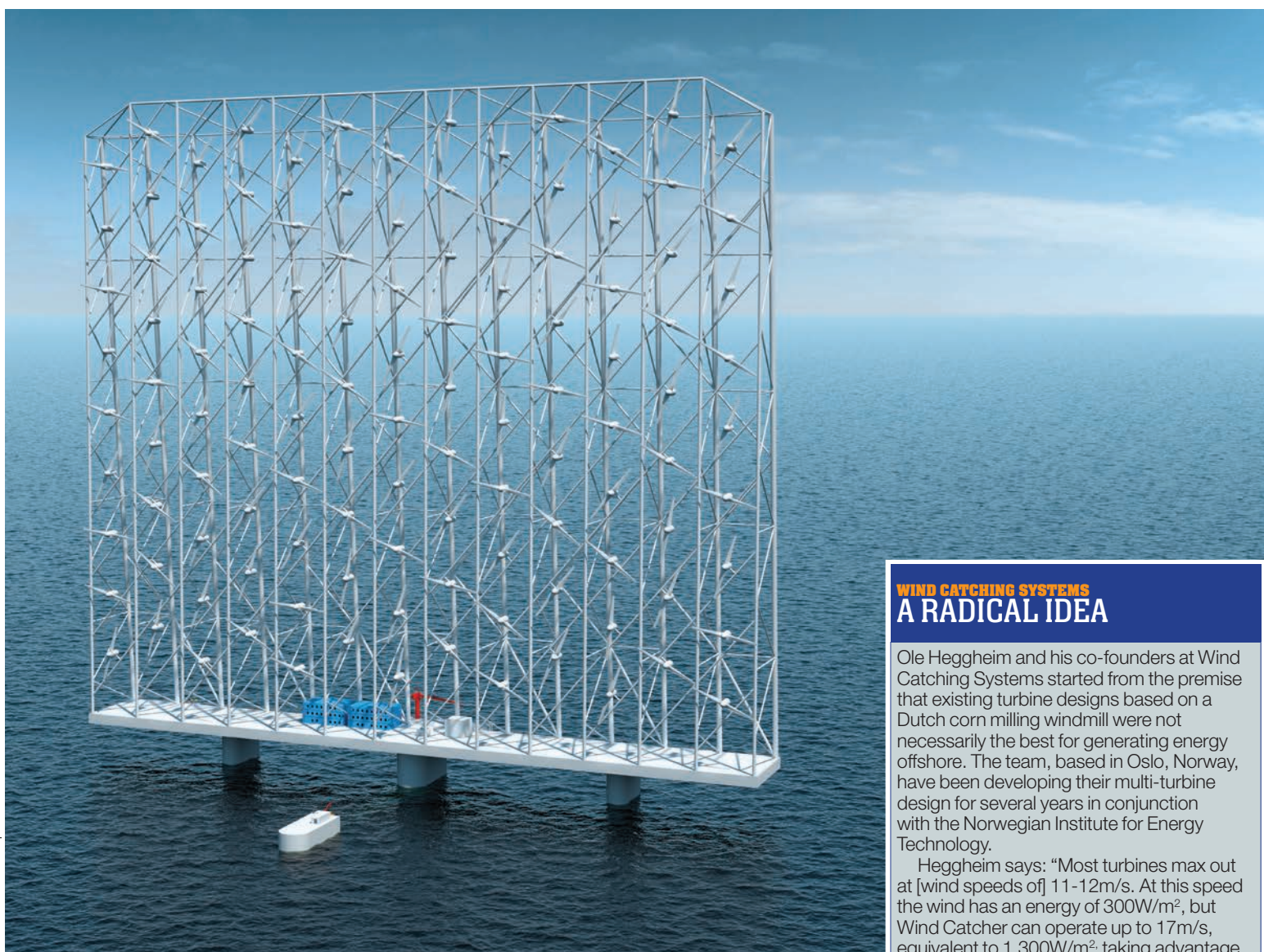
When it comes to wind, bigger is always better. Turbine size is increasing rapidly, with 13-15MW turbines expected to be on the market by 2025. Bigger turbines are more efficient, but the current batch of windmill designs are reaching the limit of the capability of existing vessel-mounted cranes to reach up, maintain them, and replace key heavy components such as blades and turbines. Move these giants offshore and float them, and you have a compounded difficulty: one floating, moving object trying to service another.

The industry is taking two approaches to this very real future problem. Tow to port means disconnecting the turbine from its moorings and export cables, then slowly towing the whole thing into a nearby port for required maintenance. The disadvantage of

this is twofold: excessive downtime detracts from the economics of floating offshore wind, and effective disconnect/reconnect couplings for power and mooring cables will need to be devised. There are also concerns among some of the energy companies that the towing process itself could induce metal fatigue and shorten the working life of the asset. Moreover, ports with the infrastructure and water depth suitable to handle the turbines are few and far between.

The second approach is to deal with operations and maintenance on site, in deep water and with harsh wind and sea conditions. Some heavy-lift crane vessels might have the required reach, but will be unable to meet the horizontal accuracy to avoid damaging either the crane tip or the turbine due to their relative movements at sea. Novel cranes will be needed for major maintenance of the next generation of turbines.

Joop de Fouw is technical director at Conbit, a Dutch engineering consultancy with 20 years of experience in oil and gas and offshore wind. "No current solution exists for the coming 15MW turbines," he explains. "Our concept is to install a temporary lifting device in the nacelle, using pre-installed light winches to run up the tower and start building a crane in situ. But that will need standardised attachment points and needs the cooperation of the OEMs, perhaps driven by the field developers." Conbit is looking for



‘Our aim is to help de-risk commercial-scale floating offshore wind, identifying, and removing the barriers to development, by encouraging cooperative research.’

Sam Strivens Carbon Trust

a partner to take that design to a fabricated prototype stage. “At a certain point, field developers will insist that there is a solution to this problem. There just has to be if the industry is to progress,” de Fouw adds.

There are no quick-fix solutions to monitoring and inspection of assets, but there are techniques in development. The use of the digital-twin approach is likely, but handling and analysis of the data flow from the very many sensors required above and below the waterline will definitely require some new ideas.

Global subsurface surveying and monitoring business Fugro has a keen interest in the potential for FOW. Dan Jones, Fugro’s service line director of inspection, repair and maintenance for Europe and Africa, says the company is planning to introduce a fleet of uncrewed surface vessels that can launch underwater remotely operated vehicles. “We will be testing a 12-metre vessel close to Aberdeen in the coming months at an offshore wind farm,” he

says. “It’s clear to us that there will be a huge requirement for ongoing monitoring of floating wind because of the high-energy environment, and the sheer numbers of turbines and cables.”

In the near future, remotely operated vehicles will upload data from asset-mounted sensors and scan the moorings, inter-array cables and subsurface structures with laser scanners – the digital equivalent of callipers – to measure thinning, corrosion, wear, and fatigue of metal parts at the sub-millimetre level. Further out, these uncrewed vehicles could dock within the wind farm to recharge and upload data for processing. Fugro is also developing machine-learning algorithms to take the heavy lifting out of the sheer volume of data processing that will be required. “It’s a rapidly evolving space,” says Jones.

Floating offshore wind is an industry in its infancy with enormous potential, but the prize is great – access to an energy resource that is more consistent than nearshore wind and delivers up to 50 per cent more energy. *

WIND CATCHING SYSTEMS A RADICAL IDEA

Ole Heggheim and his co-founders at Wind Catching Systems started from the premise that existing turbine designs based on a Dutch corn milling windmill were not necessarily the best for generating energy offshore. The team, based in Oslo, Norway, have been developing their multi-turbine design for several years in conjunction with the Norwegian Institute for Energy Technology.

Heggheim says: “Most turbines max out at [wind speeds of] 11-12m/s. At this speed the wind has an energy of 300W/m², but Wind Catcher can operate up to 17m/s, equivalent to 1,300W/m² taking advantage of the exponential energy levels at higher wind speeds.” At the pre-pilot stage now, Abiel have been contracted to design and engineer the Wind Catcher.

Wind Catching Systems claims that its design is five times more efficient than conventional turbines because it can combine operation at higher wind speeds, with the larger swept area of its multi-turbine design. In tests the company has also demonstrated a synergistic multi-rotor effect that more than compensates for any drag effect of the novel design.

The Wind Catcher is a 300m by 350m framework holding 117 dual-blade 1MW turbines above a deck sitting near sea level which accommodates crew and component exchange areas. The deck is big enough to house a substation to export the energy from the field to shore. Wind Catcher sits atop a hybrid subsurface structure that is a cross between a trimaran hull and a semi-submersible rig. It all rotates naturally and faces into wind. Necessary maintenance and inspections crews will take elevators up the vertical struts of the framework to work. There are also seabed usage benefits to the design, which occupies 20 per cent of the space of a floating turbine farm for the equivalent energy output.

“In addition, an ease of maintenance which does not require large vessels or cranes should make our system competitive in the future,” Heggheim adds.



We all know the climate is changing, and so must our homes and how we build them. By **Steve Johnson**

THE GREEN HOUSE EFFECT

THE UK'S HOUSEBUILDERS will have to consider much more than bricks and mortar if they are to do their bit for climate change. Every new home must now be designed and constructed for maximum energy efficiency. Simplistically, things appear to be on course, but remain work-in-progress. Across the industry, drums are being banged with little dissent about the why, what, and how, albeit with some variations in tune and tempo according to individual agendas. Perhaps not surprisingly, more clarity, less uncertainty and, inevitably, more tangible government support would be welcomed.

The big number is the government target to build 300,000+ new homes annually by the mid-2020s (In 2020, the National House Building Council registered 123,000 homes, and 160,000 in 2019, pre-Covid). In context, a spokesman for the UK Climate Change Committee (CCC) said: "New builds play a

critical part in the UK commitment to reach net-zero by 2050 – around 20 per cent of buildings in the UK housing stock in 2050 have not yet been built." It's clearly an opportunity with a goal at the end of it.

In terms of progress, it's reckoned that homes are using 20 per cent less energy now than 20 years ago, alongside growing domestic consumption. Insulation is better; heating and appliances are more efficient. Smart meters are helping consumers to understand energy cost and usage.

In 2019, the Royal Institute of British Architects set up its 2030 Climate Challenge initiative, encouraging architects to design buildings with net-zero lifecycle emissions by 2030. To date, the take-up rate has been small, with a reported 230 of the UK's 4,000 firms signed up – indicating that architects may be preferring a more independent approach. Whether COP26 will act as a

catalyst to swell support, time will tell – the conference will have a full day dedicated to the 'built environment'.

In January 2021, the government issued its response to the Future Homes Standard (FHS) consultation. Setting out the stall for building regulations changes in England, views had been sought on conservation, power and ventilation. The FHS is to ensure that all homes built from 2025 will produce 75-80 per cent less carbon than those completed under current regulations, with a commitment that new homes will not require any refurbishment to reach zero-carbon as the grid continues to decarbonise, and no new home built under the FHS will rely on fossil fuels. An interim uplift to building regulations will ensure that homes built from 2022 will produce 31 per cent less CO₂ than under current standards, ahead of full FHS implementation in 2025.

Future new-build houses are likely to have charging points for electric vehicles



LONG-LIFE BUILDINGS

CHOOSE REFURBISHMENT OVER DEMOLITION

It is still relatively common for industrial and commercial developments to start with demolition – not a good thing when dealing with climate change.

There are two main issues – the first is the construction of short-lived buildings. Current legislation works on life-cycle analyses that assume a building lasts 60 years. So, developers build buildings that will only last 60 years. “We need to think more long-term,” says Dr James Campbell from the Department of Architecture at Cambridge University. “Our students are already designing projects where the carcass will last for centuries and the interior can be refitted.”

Second, under the current tax regime new-build is VAT-free (or lower rate), but conversions are charged at the full rate – so it is often cheaper to demolish and rebuild. “We need a tax regime that encourages good practices, not incentivises bad ones. Upgrading most existing buildings to meet modern standards of insulation and air-tightness is difficult, but far from insurmountable,” says Campbell.

a home that doesn’t have adequate ventilation to match the performance of the home. A lack of quality control is causing new homeowners to see the effects of under-ventilated properties such as mould and overheating, but these often get pinned on airtightness.”

Passivhaus

Passivhaus, arguably the de facto standard for home energy-efficiency, is growing in significance. Local authority developers such as Exeter City Living (ECL) are building more Passivhaus housing – airtight performance means both energy efficiency and air quality is up to 90 per cent better using heat-recovering ventilation and filtration systems.

“Our work has helped reduce the cost premium of building to Passivhaus standard to less than 5 per cent,” says ECL managing director Emma Osmundsen. She makes the point that Passivhaus should not limit design creativity, but be an objective from the outset. “Building to Passivhaus standard can add some challenges, but our experience and understanding continues to grow with every development,” Osmundsen continues. “Essentially, we adopt a ‘fabric first’ approach to maximise component and material performance. One particular material is Porotherm blocks for their thermal performance, and when used with wet plaster, improved airtightness is achieved more simply than with other methods.” Triple glazing is also a key factor to achieving the necessary thermal performance, along with careful detailing to avoid cold bridging. The increased air tightness requires a mechanical ventilation system with heat recovery (MVHR), which improves air quality and reduces heat loss. ➤

Why has the wake-up call taken so long? Dr James Campbell, head of the Department of Architecture at the University of Cambridge, says: “Having talked about this for over 50 years, developers and the government finally seem to be demanding that the industry moves in this direction. Climate change has been the driver and there is a genuine political appetite for change. Now, we see clients asking for zero-energy, zero-carbon buildings. Younger architects used to get jobs because they knew about computers; the next generation will get jobs because of the need to understand Passivhaus (see below) and how to use energy software.”

A number of tools and technologies are primed and ready. Giving a steer, the CCC says: “The technology exists to deliver homes which have high levels of thermal efficiency – staying warm in winter, cool in summer, while being moisture-safe and with excellent

indoor air quality. By 2025 latest, we recommend that (1) all new builds need to rely on low-carbon heat (e.g. heat pumps/low-carbon heat networks) and be off the gas grid and (2) to have ultra-high energy-efficiency – space heat demand of 15-20kWh/m²/year.”

One of the key elements is airtightness. The situation is improving, but slowly, i.e. homes are becoming less leaky. Data collected by the Building Compliance Testers’ Association (BCTA) backs this up. Barry Cope, scheme director at the BCTA, says: “With homes improving by around 0.1m³/h/m² @ 50Pa per annum, it will take another 30 years at least for us to achieve levels of airtightness linked to net-zero homes. However, upcoming changes to building regulations look to reduce the maximum air leakage homes are allowed to leak through gaps and cracks. There is no such thing as a home being too airtight, only

◀ According to the CCC, there is a real need to focus on reducing the whole-life carbon impact of new homes, including embodied (material production) and sequestered (stored) carbon. Using wood in construction to displace high-carbon materials such as cement and steel is one of the most effective ways to use limited biomass resources to mitigate climate change. Every 1kg of timber removes 1.8kg CO₂ from the atmosphere. “Increasing [the number of] new homes built in the UK using timber frame construction systems to 270,000 annually could triple the amount of carbon stored in UK homes to three million tonnes a year,” says a CCC spokesperson. Factor in insulation alternatives such as hemp lime, hemp fibre and sheep’s wool and more beneficial savings will result.

Housebuilder Barratt Developments acquired Oregon Timber Frame in 2019 in pursuit of its objective to extend the company’s use of modern methods of construction (MMC). Oliver Novakovic, group technical and innovation director, says: “We set a target of delivering 25 per cent of homes using MMC by 2025, particularly featuring timber frame. In acquiring Oregon, the business is responding to the opportunities that timber materials can provide for both productivity and environmental performance.”

Electrifying your home

Returning to some of the ‘new’, or not so new ascendant technologies, more and more solar panels are being installed on properties up and down the land. “I see solar photovoltaic (PV) moving from often token amounts to satisfy planning requirements,” says Stephen Barratt, managing director of energy specialists Solar Sense. “Modern thinking is to have roof power from earliest to latest – covering east and west roofs achieves that. The cost of PV panels has reduced from £3 per watt to 20p per watt in ten years, so cheaper than other sources and with batteries coming down in price to give night power as well.”

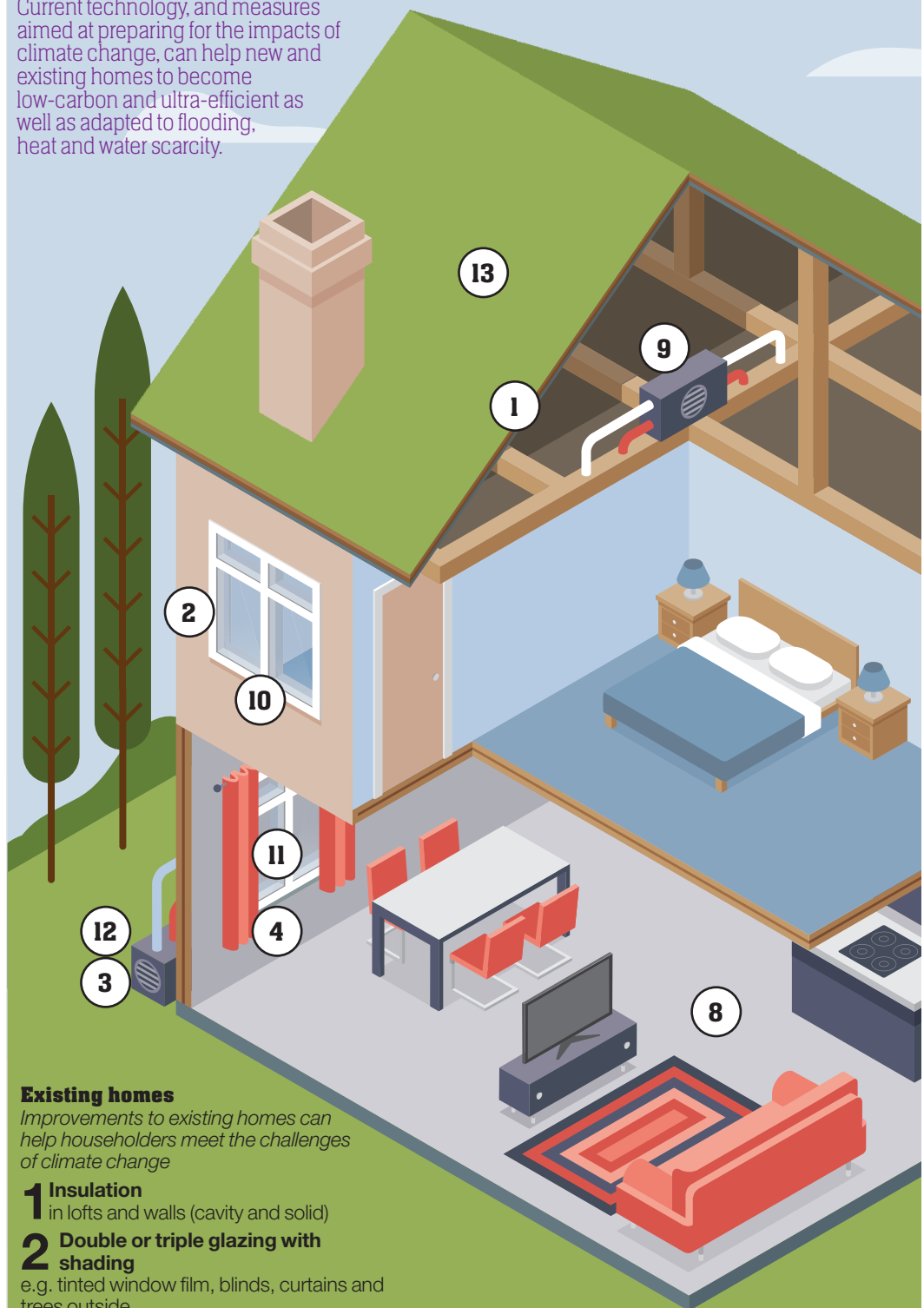
To make a real difference, solar technology needs to be rolled out far more widely across the UK – a big ask, especially as most PV panels are made in China, so rising demand could put pressure on supplies.

Alongside the need to save energy, the growing popularity of electric cars is surely a compelling event driving up demand for home-grown electricity. Most chargers are now smart and can be switched to use free surplus PV power. Paul Lawler, head of communications at Bellway Homes, explains that the company’s policy now is to install an untethered 32A 7.4kW ‘smart’ Ethernet or Wi-Fi and metered electric vehicle charge point (EVCP) on all developments where charging is required.

Is there a need to see a robust national strategy for new builds to have EVCPs as standard – more rule than exception? Perhaps all in good time. Taking a broader view on electricity supply, another housebuilder, Wates Group, is exploring grid management technology. “This will allow

What does a low-carbon, sustainable home look like?

Current technology, and measures aimed at preparing for the impacts of climate change, can help new and existing homes to become low-carbon and ultra-efficient as well as adapted to flooding, heat and water scarcity.



Existing homes

Improvements to existing homes can help householders meet the challenges of climate change

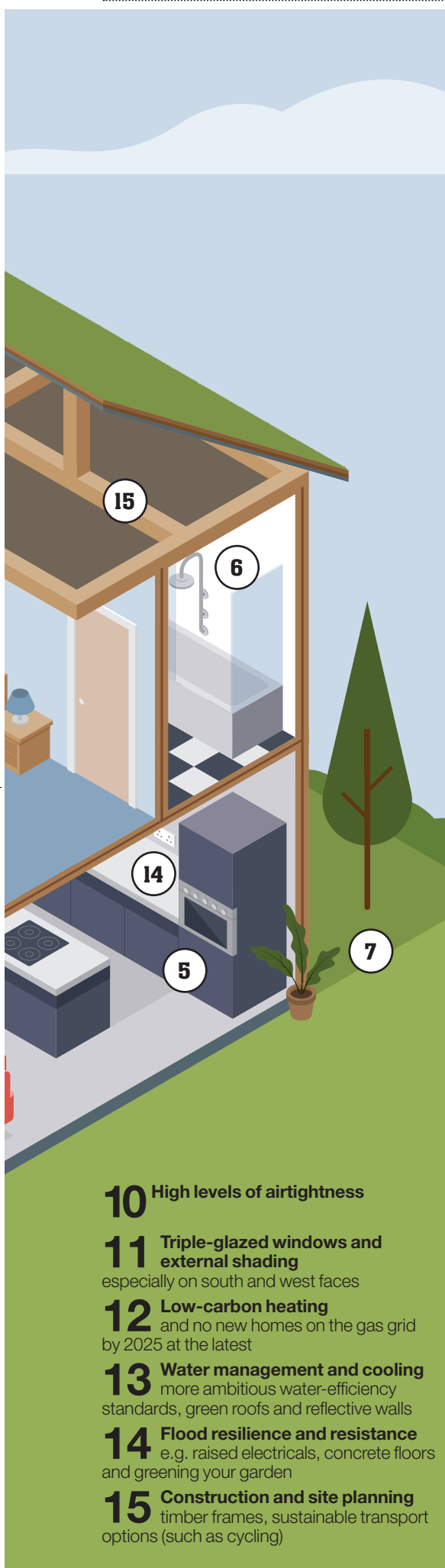
- 1 Insulation** in lofts and walls (cavity and solid)
- 2 Double or triple glazing with shading** e.g. tinted window film, blinds, curtains and trees outside
- 3 Low-carbon heating** with heat pumps or connections to district heat networks
- 4 Draughtproofing** of floors, windows and doors
- 5 Highly energy-efficient appliances** e.g. A++ and A+++ rating
- 6 Highly water-efficient devices** with low-flow showers and taps, insulated tanks and hot water thermostats
- 7 Green space (e.g. gardens and trees)** to help reduce the risks and impacts of flooding and overheating

- 8 Flood resilience and resistance** with removable air brick covers, relocated appliances (e.g. installing washing machines upstairs), treated wooden floors

New-build homes

New-build homes can and should meet even more ambitious standards in some areas

- 9 More fresh air** with mechanical ventilation and heat recovery, and passive cooling measures such as openable windows



10 High levels of airtightness

11 Triple-glazed windows and external shading
especially on south and west faces

12 Low-carbon heating
and no new homes on the gas grid by 2025 at the latest

13 Water management and cooling
more ambitious water-efficiency standards, green roofs and reflective walls

14 Flood resilience and resistance
e.g. raised electricals, concrete floors and greening your garden

15 Construction and site planning
timber frames, sustainable transport options (such as cycling)

energy to be imported and exported to the grid at optimum times,” explains principal design manager Stuart Jones. This will not only reduce people’s energy bills and carbon use, but at the same time smooth peaks and troughs in the grid demand and generation profile, he elaborates.

Are heat pumps the only answer?

“Heat pumps are progressing and proving highly reliable without the servicing and risks of gas while saving carbon,” Solar Sense’s Barratt explains. “Switching all gas boilers to heat pumps is a tall order; in towns, flats and smaller houses should probably go to stand-alone electric heaters as home insulation improves. Larger and rural homes, together with anyone with oil-fired boilers, should opt for heat pumps.”

Despite the challenges and uncertainties, the boundaries of what can be done are being stretched to meet climate change demands. Some of the leading builders are creating new opportunities and engaging with the tools at their disposal – there’s a lot of learning and knowledge to acquire.

Bellway Homes is constructing ‘exemplar’ plots to assess the impact of low-carbon/ electrical space and water heating on customers’ energy bills. Designed around government information released so far, the aim is to assess fabric and heating options alongside technology such as solar PV with battery storage, waste-water heat recovery and mechanical ventilation with heat recovery.

Wates has worked with Cardiff Council for the installation of heat pumps, solar PV panels, batteries and EV charging points for 1,700 new homes as part of the Cardiff Living Project. “The homes will be to a fabric standard 17 per cent better than current building regulations, using MMC,” Jones explains, “including sites being built to Passivhaus standards to reduce homes’ energy output and carbon footprint.”

Barratt Developments says that all its new homes will be ‘zero-carbon-ready’ from 2030, but to get there the company understands the need to innovate, test new technology and develop new talent. “We’re starting work on a prototype zero-carbon, wildlife-friendly home that will surpass the 2025 FHS and can be built at pace and scale. We’ll trial innovative construction, as well as a range of smart and sustainable technologies. Some may not succeed, but all will move us forward,” says Novakovic.

There are considerations that might collectively make the business of building more energy-efficient homes more commercially attractive. Economies of scale should see costs of technology and innovations fall. In parallel, construction costs may rise as building regulations become more demanding. Inevitably, some burden of cost will fall upon home buyers, who will also need to be convinced of the benefits and understand how to use the new technology. Therefore, there may be mortgage offer considerations. Wates is currently working with Sero Energy and Monmouthshire Building Society to pilot a

WHAT THE EXPERTS SAY

EXISTING HOUSING: ‘THE ELEPHANT IN THE ROOM’

“One of the biggest challenges is our existing stock. At least 19 million homes in the UK need to be retrofitted to become low carbon. To achieve the government’s net-zero targets by 2050, three homes every minute will need to be retrofitted with energy-efficient improvements. We are delivering a zero-carbon retrofitting service for social housing landlords to include a feasibility service, installing pilot properties, large-scale installations and monitoring.” *Stuart Jones, principal design manager, Wates Group*

“Zero-carbon homes are an essential part of the puzzle, but will not in themselves deliver the UK’s climate goals. We must improve the footprint of the existing housing stock. This must involve collaboration and bold long-term government decisions. As a nation we must not shy away from raising awareness among homeowners.” *Bukky Bird, Barratt Developments*

“Improving existing builds will significantly reduce the strain on energy suppliers – homes can be kept warmer for longer using less electricity and gas. Existing homes need to be assessed for air leakage, insulation and ventilation, but must be improved together. Tests can even tell which rooms to target to gain massive performance. Large-scale roll-out of heat pumps will build supply chains to enable deployment of retrofits.” *Barry Cope, Building Compliance Testers’ Association*

“The owner-occupied sector is the biggest, yet worst-performing tenure group. The RICS is investing significant resources and expertise to address the challenges facing the private sector, working in collaboration with government and property stakeholders to create long-term solutions.” *Matthew Collins, RICS*

green mortgage product that will factor reduced energy costs into the affordability calculation for a property.

A design and potential cost factor that has arisen since the pandemic is the increase in home working. Unless there’s a big swing back to the office, more and more of us want workspace in our homes – not just somewhere for a desk, but with the right light and ventilation provisions.

However, building 300,000-plus homes a year will need a sizeable, experienced, and increasingly qualified workforce. In a Construction Industry Training Board survey, 78 per cent of respondents said there was a skills gap for decarbonisation in their occupation or profession. CITB concluded that a rapid increase in skills is needed, with large-scale re-skilling and key issues addressed, including build quality, sector reputation and training readiness.

Building energy-efficient homes may be today’s headline grabber. But ultimately, the key is to ensure that all efficiencies and savings deliver on the promise. *



Experts hope delegates at COP26 will be more environmentally conscious about what they eat and drink at this year's conference in Glasgow.

By **Helena Pozniak**

WHAT'S FOOD GOT TO DO WITH IT?

Restaurant The Gannet is part of the 'Plate up for Glasgow' campaign, scheduled to coincide with COP26. The initiative aims to embed sustainable and circular practices to reduce waste in Glasgow's food and drink sector.





The hemp used to make these smoothies is one of the fastest-growing plants, renewing up to three times per year, and requires smaller fields, generating high yields. This makes it more sustainable than other methods.

WHEN DELEGATES AT COP26 sit down to eat, they'd better choose carefully. Back in Poland in 2018, some 30,000 attendees munched their way through a meat- and dairy-laden menu. Every plate of fried beef, pork and burgers consumed in Katowice at COP24 helped contribute several thousand tonnes of greenhouse gases over the 12-day conference, campaigners say.

Food production accounts for a third of global emissions today, and we're running out of water, land, and time. Business as usual in the Glasgow food courts won't help the world meet the 1.5°C target. Campaigners and food and farming groups all have an opinion about what international delegates should be eating. "We'll only achieve net zero if we fundamentally transform food systems," say campaigners Nourish Scotland in a joint letter.

Food tech has a role to play as the population grows and the planet warms – it's transforming the sector, boosting efficiency, cutting packaging, limiting waste.

What should be on the menu?

Think like a vegan. Wild mushroom pie or scrambled tofu, anyone? If everyone were to become a vegan, it would be possible to slash emissions and produce enough food for all by 2050 when the global population is forecast to swell to 10 billion – it's the biggest action delegates could take for the environment, says campaigning charity Viva. They'll be in good company.

By 2025, vegans and vegetarians are forecast to make up a quarter of the UK population. Biofortified crops – already on supermarket shelves – are predicted to become mainstream this decade and could boost global health.

Should all food be local?

Not everything we eat must be produced nearby, says Sofie Quist at Nourish Scotland.

"But food trade should be redesigned to protect local food systems rather than generating international profit. We shouldn't be transporting food around in a way that's carbon intensive," she says. Shipping bananas that ripen is more sustainable, for instance, than flying frozen produce, and heating greenhouses to grow tomatoes locally can be more carbon intensive than transporting them. In the future, 3D printing might prove feasible – Nasa has looked into saving on delivery costs by 'printing' a pizza, and tech companies are experimenting with growing food onboard spacecraft.

Is local meat acceptable?

You won't find many rare mountain hares on the menu today, although Scotch beef and lamb have high sustainability credentials. But rich nations eat far more meat than is healthy for them or the planet. Livestock farming accounts for 14.8 per cent of global greenhouse gas emissions, while 70 per cent of deforestation takes place to make way for crops to feed animals. For delegates sniffy at the taste and texture of processed plant-based protein meat substitutes, then cultured meat – grown in a lab from animal cells – might be more palatable. Of the 80 companies racing to 'grow' meat, none can yet mass-produce it, though it's inching closer to supermarket shelves.

"Making meat from plants and cultivating it from cells can reduce emissions by up to 92 per cent and use 95 per cent less land," says Seren Kell, science and technology manager at the Good Food Institute Europe.

Jellyfish fingers?

A warmer planet means more jellyfish, and a report commissioned by Sainsbury's predicts we will have turned to these for our fishy protein by 2050 – they're rich in some vitamins and low in calories, if a little chewy. Lab-grown shrimp meat could make an

appearance in the future, grown in the same way as meat. But this year delegates could tuck into Isle of Skye langoustines and west coast crab – if fished sustainably. Line-caught mackerel with horseradish ice cream, buttermilk, dashi (meat free broth) and dill, or sustainably farmed halibut from the Hebridean Isle of Gigha, may tempt attendees, says Peter McKenna, owner and chef of The Gannet, one of Glasgow's finest restaurants. "Our menu is based upon what's local and sustainable," he says.

Microgreens from vertical farms

Enticing salads, herbs and soft fruit are grown year-round at Scotland's first vertical farm in Aberdeenshire, which now sells its technology around the world. Rainwater harvesting and renewable energy systems allow agritech specialists Intelligent Growth Solutions to grow crops stacked in airlocked towers under optimised LEDs. IGS says its farm uses 50 per cent less power and 96 per cent less water than traditional methods.

Algae are responsible for half of all oxygen production on Earth, can be rich in protein and even a potential meat replacement. Seaweed is a neglected superfood, and can be responsibly foraged from Scottish shores – laver seaweed is rich in vitamin C and iodine. Scotland even has seaweed farms – edible seaweed cultivation could be a game changer in the food system.

Hemp smoothies

Hemp – a strain of the cannabis sativa plant without the psychoactive components – removes CO₂ from the air more effectively than any other crop. Every hectare grown could remove 66 tonnes a year. "It's time we understood better how to use it in food rather than demonising it," says Peter Miles, chief executive of eHempHouse, whose business helps organisations offset carbon and has been invited to showcase innovation at COP26. From biodegradable hemp cutlery to hemp smoothies, wines, granola and more, food made using hemp seeds and hearts is nutritious and tasty enough to tempt world leaders, he promises.

Ice cream and dairy

Beyond soya milk, there's now a tastier choice of nut and plant milks and yoghurts and even a potato milk launched in Sweden this summer – but delegates might soon be able to put the real thing in their coffee without guilt.

Biotech entrepreneurs are focusing on making milk – it's actually simpler than meat to make, say academics, because fermentation is already an accepted method of food production. While cultured meat begins with animal cells, a process called precision fermentation gives microorganisms the genetic instructions to produce complex organic molecules – the milk proteins found in curd. Ice cream is currently the only dairy product on the market made in this way, but several companies are trying to make cheese. *



THE GALLERY

OUR THREATENED BUT WONDERFUL WORLD

To coincide with COP26, 26 of the world's leading photographers have come together to provide eye-witness accounts of nature under threat. By **Tim Fryer**

As part of the build up to COP26, the Earth Project, in collaboration with Nature Picture Library, has organised a photography competition to raise awareness of the huge challenges faced by nature, as well as the impacts of climate change on global ecosystems.

The competition links to one of the main goals of COP26: to help protect and restore ecosystems in countries adversely affected by climate change. The full gallery of 72 stunning pictures, along with the environmental stories they tell, is available online at theearthproject.world/cop-26-gallery. The competition winner will be announced at COP26.

TONY WU ROY MANGERSNES, JO-ANNE MCARTHUR / WE ANIMALS MEDIA / ANIMALS AUSTRALIA, NEIL ALDRIDGE, YASHPAL RATHORE, ASHLEY COOPER, NATUREPL.COM

In Botswana's Makgadikgadi Pans a Zu/'hoasi bushman finds the carcass of a zebra



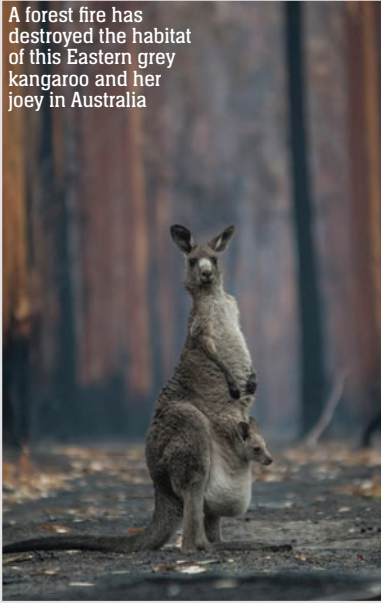
With the monsoon approaching behind, this endangered Bengal tiger walks through the Kanha National Park, Central India



Dump trucks queue to load tar sand in front of a toxic wasteland created by the Syncrude mine, Alberta, Canada



A forest fire has destroyed the habitat of this Eastern grey kangaroo and her joey in Australia



A female olive ridley turtle caught in a ghost fishing net in the Indian Ocean

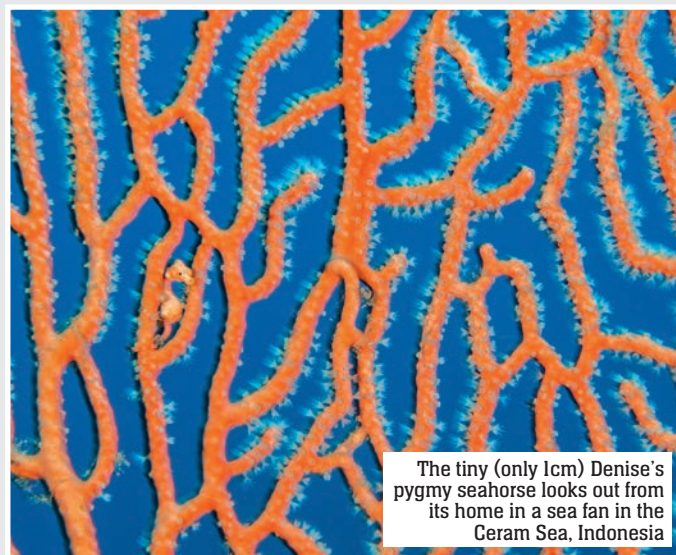


A waterfall runs off the melting Austfonna glacier, eastern Svalbard, in the Arctic Ocean

Two little blue penguins captured in front of Melbourne's city lights



This song thrush feeds the family it has found a home for in this old car in Sweden



The tiny (only 1cm) Denise's pygmy seahorse looks out from its home in a sea fan in the Ceram Sea, Indonesia

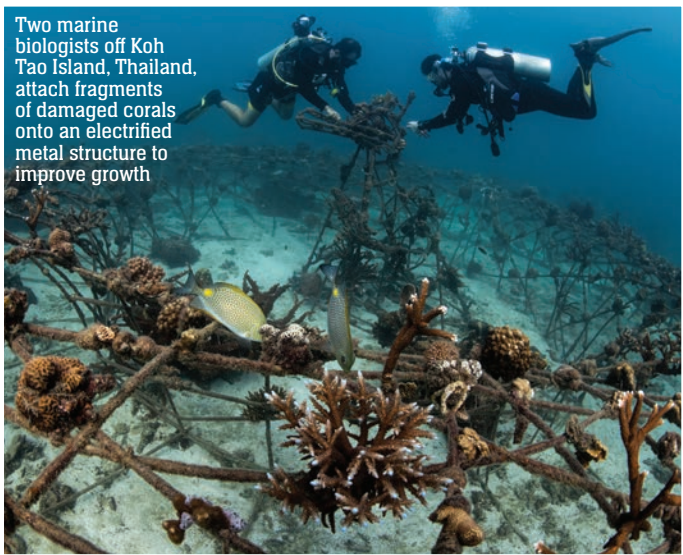
PAL HERMANSEN JEN GUYTON, DOUG GIMESY, ALEX MUSTARD, JACK DYKINGA, SIRACHAI ARUNRUGSTICHAI, NATUREPL.COM



Mozambican vet Mercia Angela on her daily walk with Boogli, a female Cape pangolin confiscated as an infant by Gorongosa's law-enforcement team



Giant cactus in the Sonoran Desert, Arizona, at sunset after a spring storm



Two marine biologists off Koh Tao Island, Thailand, attach fragments of damaged corals onto an electrified metal structure to improve growth



As extreme weather events from heatwaves to hurricanes increasingly dominate the headlines, scientists are getting better at linking them to climate change. **Isabella Kaminski** explores the growing field of attribution science.

IS CLIMATE CHANGE TO BLAME?



IN JULY, the world watched as record levels of rain fell on parts of Germany and Belgium, causing widespread flooding. More than 200 people died after rivers burst their banks, many homes and livelihoods were destroyed, and the long-term economic impacts are expected to run into many billions of euros.

As well as its devastation, the event was notable because local officials were quick to blame the extreme weather on global warming. During a visit to one of the worst-affected areas, the premier of North Rhine-Westphalia, Armin Laschet, said the region would be “faced with such events over and over, and that means we need to speed up climate-protection measures”.

Just two months later his strong words were vindicated. A team of 39 scientists at international network World Weather Attribution produced a ‘rapid attribution study’ showing that climate change had increased the risk of the heavy rain by between 1.2 and 9 times and made the rain itself between 3 and 9 per cent stronger than it would otherwise have been.

Studies such as these are becoming more common because scientists can now calculate the extent to which a specific

extreme weather event was made more likely or worse by climate change. It is part of a flourishing field called attribution science, which links meteorology, atmospheric physics, and statistics.

The first attribution study was published in *Nature* in 2004, a year after record-breaking temperatures across much of Europe caused more than 70,000 deaths.

The paper’s authors said it was “an ill-posed question” whether the heatwave was caused by a modification of the external influences on climate – for example, increasing concentrations of greenhouse gases in the atmosphere – “because almost any such weather event might have occurred by chance in an unmodified climate”.

Instead, inspired by the idea of one author, Professor Myles Allen, head of the climate dynamics group at the University of Oxford’s atmospheric, oceanic and planetary physics department, they decided to take a probabilistic approach. Armed with the latest climate model called HadCM3 and the best set of real-life temperature records anywhere in the world, they sought to calculate how much more likely such an extreme heatwave had been made by human activity.

The authors ran the model from the middle of the 19th century – when coal, oil and gas began being burned in industrial quantities – until the present day, both with and without the additional greenhouse gases generated by those fossil fuels. This enabled them to compare human influence on the climate and see what potential variations in summer temperatures it might have caused in Europe.

They also ran the model from 1,000 years in the past with no greenhouse gas emissions. “That was important because we could see how [temperatures] vary from year to year to work out the one-in-1,000-year temperature extreme and see whether the model captures that,” says lead author Professor Peter Stott, science fellow in climate attribution at the UK’s Met Office.

It was a novel approach. “As a climate scientist I had to do some rapid learning on extreme value statistics,” says Stott. The authors ultimately concluded that climate change had “at least doubled” the risk of such an extreme heatwave.

The paper opened the floodgates and hundreds of other attribution studies have since been published.

These showed, among other things, that >



In August, thousands of residents had to flee the Greek island of Evia after wildfires hit. Such fires are predicted to become more common.



Mud cracks at Thirlmere reservoir in the Lake District, UK. Climate change is expected to make long dry spells more intense in some areas due to lower regional rainfall, increased evaporation, and a reduction in snowpack during warm winters.

◀ climate change tripled the risk of extreme heat in a record-breaking hot period over north-west China in July 2015, boosted rainfall during Hurricane Harvey in Texas and Louisiana in 2017 by a factor of 3.5, and increased the chance of devastating bushfires in Australia in 2019 and 2020 by at least 30 per cent. They even found that the Siberian heatwave of 2020 would never have happened without climate change.

Not all studies find a connection between particular extreme events and global warming. One by the Dutch national weather institute KNMI could not conclude climate change was to blame for heavy summer rains that flooded central Europe in 2013.

Yet overall, the papers show a clear pattern. Earlier this year, experts producing the Intergovernmental Panel on Climate Change's (IPCC) sixth assessment report (AR6) analysed hundreds of attribution studies to conclude that anthropogenic greenhouse gas emissions have "led to an increased frequency and/or intensity of some weather and climate extremes".

Scientific credibility

Dr Friederike Otto, associate director of the Environmental Change Institute at the University of Oxford and co-lead of World Weather Attribution, says its inclusion in AR6 had made attribution science much more credible in the eyes of the public and the wider scientific community. "They are now seen as a really important part of the scientific literature," she says. "Not something new or special but something that you assess alongside observation studies and projections to understand what does climate change mean with respect to extreme events in every region of the world."

The field has matured considerably since Stott's original study.

For one thing, climate models have become much more advanced and there are more of them, developed in academic centres across the world from the US to China. While HadCM3 could simulate how the ocean and clouds interact and respond to rising temperatures and map rainfall patterns and

temperatures over broad regions, modern models such as CMIP6 can simulate what happens in much smaller areas with greater accuracy by taking into account land surface, hydrology and ocean dynamics. "We can represent the particularities of weather much better now," says Stott.

All these models use common information such as observational temperature records but diverge in other ways. For example, they might represent clouds differently or the dynamics of how the ocean and atmosphere interact. "I think it's important that you have a diversity of models to represent those different choices," says Stott. "If the range of answers are all very definitively showing a significant effect due to human activities, then we can be very confident of it."

Power of citizen scientists

Computer power has also hugely grown, with supercomputers becoming increasingly accessible to crunch the vast amount of data needed to run complex long-term climate models.

Alternatively, climateprediction.net at the Oxford e-Research Centre relies on the processing power of thousands of citizen scientists to run computer simulations of many different possible versions of the climate system, each with very slight variations, to see what extreme events might happen under different scenarios. "It's like SETI@home – the search for extra-terrestrial life – in that we use idle time on their computers to run climate model simulations," says programme co-ordinator Sarah Sparrow.

Benefitting from cooperation between scientists in different countries and institutions, as well as well-established methodologies, individual studies can now be produced more quickly. In the case of the recent German floods, a team at World Weather Attribution published its results before they had been peer reviewed to capitalise on interest in the event before media attention drifted away.

"The evidence from those studies is that when they are repeated slowly you get the

same answers, so they seem to be pretty robust," says Stott, who has been involved in World Weather Attribution. "But having said that, we've got to have careful protocols in place to check whether you can do it well."

However, as the field has grown, it has also led to a divergence of approaches. Most attribution studies, modelled on that pioneered by Stott, seek to put figures on the increased likelihood of an extreme event due to climate change or how much more intense it has become (or both), although they can do this with different models and methodologies that try to take account of the uncertainties involved.

Another way of considering extreme events, championed by Ted Shepherd, Grantham Professor of Climate Science at the University of Reading, is called the 'storyline' approach. Instead of looking at the likelihood that climate change caused a particular event, it takes a specific event and analyses how climate change affected it from a physical point of view.

Shepherd, whose background is in atmospheric dynamics, is sceptical that even the best models can accurately represent whether climate change influenced a particular weather event, because the system is so chaotic. "The nice thing about the probabilistic event is they give a 'yes or no' answer. Yet while I don't think that any of the claims that this was climate change are somehow wrong, the idea of a number is a false precision to me."

Robert Vautard, director of the Institut Pierre-Simon Laplace in France and a member of the World Weather Attribution group, came to attribution science with a background in statistics. He says these are open questions in the field, and there is always a degree of uncertainty, but remains confident in the numbers.

"We try to use several approaches, observations, models, so we try to cover all the possibilities and then average them. So quantitatively speaking it's more reliable."

Otto says most modern studies include an element of both approaches. "I think, and I think most of the rest of the community is very much with me on that, that it is useful to provide the numbers, but of course that's not the whole story."

Shepherd is also critical of the way in which attribution studies must define particular extreme events, describing these as too rigid since individual events unfold in very particular ways. It certainly is not a precise science. Sparrow says there are many ways to describe an extreme event, depending on the specific question you are trying to answer, such as whether the meteorology or atmospheric circulation were extreme or whether the event had serious impacts on humans – and deciding how to do it often requires expert judgment.

What all agree on is there is room for improvement.

For a start, not every country has datasets as good as those in Europe. Particularly Africa, which lacks a good set of observational records. Even in areas with better records, there are limits. For the

'What makes an extreme event or disaster is, to a very large degree, driven by vulnerability and exposure... We need to find a way to communicate more of this within these studies.'

Dr Friederike Otto *World Weather Attribution*

German floods, for example, there simply was not enough historical data about the specific affected region, so World Weather Attribution had to combine data from different river catchments in other areas.

Climate models also still struggle to accurately simulate details in such small areas. "The tension is always between the resolution of the model you can get, how fine a scale, how many physical processes you can include, and how many ensemble members you can get," says Sparrow. "You can't run these really big models on your standard laptop – you really need a supercomputer to run it and then it becomes very resource-hungry and financially hungry."

"We can't necessarily robustly do attribution studies for everything right now," warns Stott. "So, we've got to be a bit careful that we can't necessarily answer all the questions that people have."

Climate change fatalities

However, attribution science does have plenty of real-world applications, from public communication of climate science and the actual impacts of global warming to the premiums offered by insurance companies.

Studies are also increasingly going beyond the likelihood that an event will happen and how extreme it is, to looking at its societal impacts. A 2016 study into the 2003 Paris heatwave, for example, concluded that most of its fatalities were a result of climate change.

They can also be used to examine economic impacts. Climateprediction.net recently held a workshop for early-career scientists in Brazil following devastating floods in Minas Gerais state in early 2020. "We were able to get access to their disaster database so we are really able to catalogue the impacts of this particular event, and then start to say how much we think of those impacts could be attributed to climate change. So, when you're seeing financial losses or people displaced from their houses, you know how much worse that was because of climate change."

Attribution science can also support the burgeoning legal field of climate litigation. A recent paper published in *Nature Climate Change* concludes that better use of the latest

CHALLENGES

TRACING THE CAUSE OF EXTREME EVENTS

Climate change is already affecting every inhabited region across the globe, with human influence contributing to many observed changes in weather and climate extremes, but some types of event are easier to connect than others.



Heatwaves

The easiest extreme weather event to connect with climate change because they are much more directly connected to the increase in global median temperatures. There have already

been clear observed changes in hot extremes across the world, and a recent study found there would be much more intense heatwaves in the next few decades.

Wildfires

These are predicted to become more common as global temperatures rise and spring comes earlier, increasing the number of months in the year where fires are likely. They are also likely to be more intense as climate change induces periods of drought and stronger winds. However, wildfires also depend on a variety of other factors such as land use, so predicting them becomes more complicated.



Rainfall

In general, climate change will lead to more extreme rainfall in some places. The hotter it is, the more water the atmosphere can hold, increasing the risk of heavy

downpours. However, there is a lot of local variability, which makes it difficult to predict which areas will be affected. Flooding is even more challenging as it is affected by local river catchments and hydrological systems, soil type and land use.



Hurricanes

Hurricanes are tricky to analyse because they are so rare, variable, and depend on complex interactions between ocean and atmospheric conditions. We do

know that the development of tropical cyclones is fuelled by rising ocean temperatures so climate change could affect intensity and path, although researchers disagree on whether they will become more frequent. One study suggested climate change would substantially increase the incidence of storms that intensify rapidly just before landfall, making them even more difficult to predict.



Drought

This is particularly difficult to define because it is the cumulation of a lack of rain over an extended period and affects wildlife and people at different points.

However, climate change is expected to make these long dry spells more intense in some areas due to lower regional rainfall, increased evaporation, and a reduction in snowpack during warm winters.

studies could improve the chances of lawsuits seeking compensation for climate-related losses, regulatory action, and emission cuts. It could also help lawyers decide when a case is weak and not worth pursuing.

Increasingly, attribution science is being used to calculate the risk of extreme events that have not yet happened.

The future becomes less certain because there are no observational records to check the models against, and there is uncertainty about what level of emissions the world will end up producing over the next few decades. But mathematically, says Vautard, the method is the same. "The numbers we give actually allow us to calculate risks for today. Once we have trust in the models, then we can apply the same statistics, and give numbers for the present as well as calculating future risk."

These approaches could help identify critical areas at risk, like 'breadbasket' regions, which feed millions of people but

are vulnerable to drought.

They can also help communities prepare for extreme weather events. A US city, for example, might benefit from knowing if there is an increased likelihood of a hurricane hitting it and how much more intense it might be – and allocate funds to help it plan and adapt. At present, those risk assessments tend to examine a particular country or region, but there is potential for them to go into more specific detail over smaller areas.

Otto would like to see more emphasis in future on the real risks an extreme event poses. "What makes an extreme event or disaster is, to a very large degree, driven by vulnerability and exposure and has nothing to do with the hazard. We need to find a way to communicate more of this within these attribution studies."

"Attribution science in a sense has a practical outcome," concludes Vautard, "which is to emphasise the need of urgent adaptation – not in the future, but today." *



The race to resilience

While the 'Cities Race to Resilience' campaign aims to accelerate action against climate change and ensure commitment to achieving specific goals, many resilience initiatives are already under way in cities all around the world.
By **Amanda Saint**

A NEW GLOBAL campaign from the United Nations, launched ahead of COP26, is highlighting the urgent need to focus on climate resilience action. Cities Race to Resilience launched in July 2021 and is all about the importance of prioritising people and nature as cities all over the world strive to become resilient in the face of increasing climate extremes. One of the campaign's goals is to get 1,000 cities involved; the first that signed up to the race was Makati in the Philippines, an urban centre in the Metro Manila region.

This campaign is running alongside the Race to Zero initiative, which launched in January 2021 and has 733 cities currently signed up. The hope is that the two campaigns working together will ensure the greater resilience of approximately four billion people and ensure emissions reduction goals are met by 2030.

So, what does competing in the race actually look like when cities will have to take very different approaches to meeting the goals of the campaign? Rather than competing against each other, the race is really against time and temperature rise, so that cities remain on track for meeting the goals they need to if they're to limit the impacts of climate change.

Depending on elements such as their local climate, population demographics, and whether they're primarily focused on manufacturing, agriculture, services or tourism, cities will need to aim for very different goals.



Dublin, Republic of Ireland

In a €10m (£8.6m) project funded by the EU, Dublin is serving as a Coastal City Living Lab as part of a project called Smart Control of the Climate Resilience in European Coastal Cities. The city is a testbed for climate resilience solutions focused on coastal cities, and measures for managing rising sea levels, coastal erosion and extreme weather events are being developed and tested there.

The project launched in July 2021 and is working with 28 partners to find solutions to the issues Dublin faces, many of which are due to flooding. Keeping transport systems running is a major focus, as currently one of the main train lines, which runs along the coast, is regularly flooded. A big element of this project is to develop and test smart technologies and hybrid nature-based solutions (NBS), particularly around early warning systems and prevention, and also to explore the potential for these technologies to be deployed in other parts of Europe.



Glasgow, Scotland

Climate Ready Clyde (CRC) is Glasgow City Region's programme for developing resilience. CRC has developed a 'Theory of Change', setting out a long-term vision for the city, what steps will be needed to deliver on the vision, and principles to guide them as they set about achieving the goals.

Flooding is an issue for Glasgow too, and one of CRC's main projects is Clyde Rebuilt, which brings together community groups, local councils, universities, businesses, and government agencies to develop resilience tools and processes that will help limit damage to homes, commercial and public buildings, roads and railways, and stresses to hospitals and emergency services caused by more extreme weather.

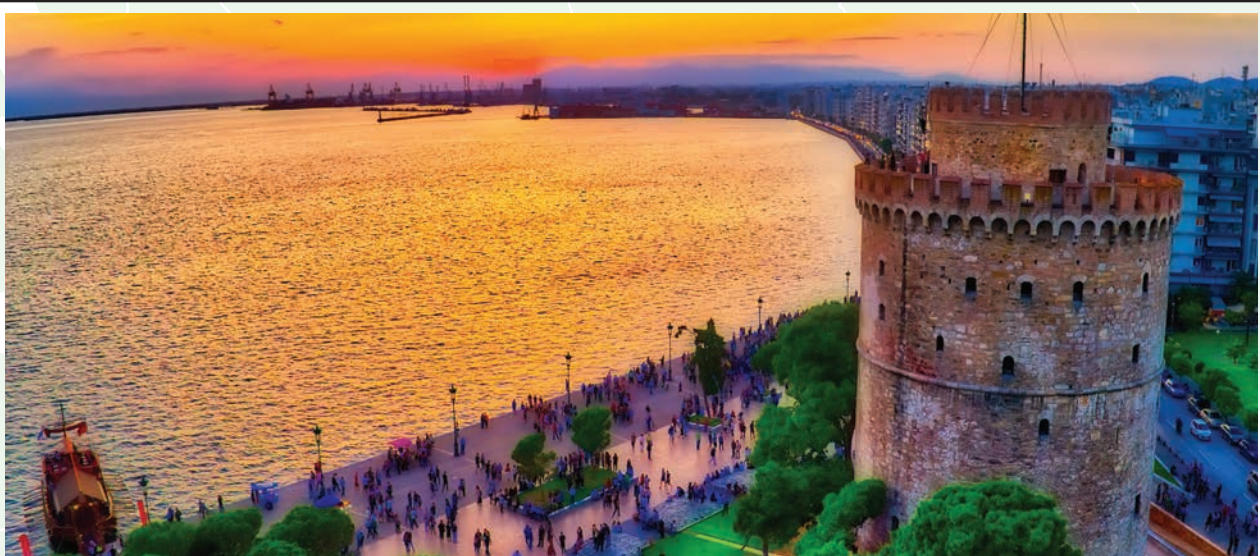


Ulaanbaatar, Mongolia

The capital city of Ulaanbaatar is building 10,000 affordable green homes, which will cut carbon emissions by 200,000 tonnes a year, improve air quality and provide better housing for 35,000 city

residents. The homes will all have rooftop solar panels, better insulation, and improved connectivity to the central energy grid, water supply and sanitation services. The homes will be sited within a new, resilient eco district.

Ulaanbaatar,
Mongolia



Thessaloniki, Greece

Thessaloniki is an important metropolitan region with an active port, a respected university, and a robust tourist industry. But the economic and political crises that have hit Greece in recent years mean the city has suffered from high unemployment due to a shrinking manufacturing sector, and this lack of opportunities

for young people has increased social needs, while resources to provide services have decreased. The city has a dense urban structure with very little open or green space, although it does have a 7km waterfront.

New projects are being implemented to upgrade infrastructure to make the city more climate resilient and drive economic recovery.

Community members are being involved in planning processes so that they can work collectively to share responsibility, resources, opportunities and results and feel that they are a part of their city's recovery.

Thessaloniki is also using this approach to build response plans for natural disasters, climate crises and resilience planning.



Atlanta, USA

This cosmopolitan city has a diverse cultural population, high levels of education, and the third-largest concentration of Fortune 500 companies in the US. But it also has a failing transportation system, which causes traffic congestion, poor air quality and barriers to social cohesion. A lack of affordable public transport is leading to growing inequality,

and stops the city's poorest communities accessing food centres and economic opportunities.

The city's dependence on highways and vehicle ownership makes infrastructure a primary concern. A disaster affecting a major highway or bridge could prevent emergency responders from reaching areas affected by electrical outages or flooding. The city is working to mitigate the potential

impact of resilience shocks such as infrastructure failure through the creation of an Emergency Preparedness and Management group. It's also transforming public transport with an investment of \$173bn (£125bn) over the next 30 years, which will see the development of a light railway, bus lanes and additional routes, cycle lanes and incentives to get the city's residents carpooling.

SAMOA



INTERNATIONAL EFFORT RACE TO RESILIENCE COMMITMENTS

- **Integrating climate change adaptation and resilience** in all aspects of urban planning and carrying out a community-wide climate risk and vulnerability assessment that specifically addresses the needs of the most vulnerable communities.
- **Using available climate-change knowledge and scientific evidence** in decision-making and creating interim targets and milestones as part of a long-term commitment for citywide climate action.
- **Taking immediate action in one of the resilience areas specified by COP26:** Buildings, Digitalisation, Energy, Food Systems, Governance and Community Engagement, Nature-Based Solutions, Risk and Vulnerability Planning, Social Equity, Urban-Rural Linkages, Waste, and Water.
- **Reporting initial commitments** in the above categories by COP26, and making annual progress reports on achievements.



Samoa

This small island nation is dependent on international marine trade through its harbour, but its port operations are constrained by seasonal wave patterns. What's more, the current breakwater can't stand up to rising sea levels and worsening storms, so a project is under way to strengthen it using local materials, and new

stormwater drainage will decrease vulnerability to flooding.

In addition, a new terminal is being built to increase the number of boats that can dock. This, together with a multi-hazard preparedness plan, aims to improve economic resilience and mitigate disruption to port operations in the aftermath of natural disasters.

ATLANTA,
USA



Buenos Aires, Argentina

Buenos Aires faces significant and growing challenges from social and economic inequality. The city's informal settlements now house over 250,000 residents and changing weather patterns are resulting in increased heavy rainfall and flooding, which cause significant physical and economic loss. Flooding also puts pressure on the urban infrastructure,

which causes power, water and telephone outages that, in turn, hamper recovery.

So the city has developed a new Hydraulic Planning Master Plan, with significant investments in the urban drainage system, while a Hydrometeorological Monitoring Network aims to increase preparedness and reduce emergency response times.

Buenos Aires,
Argentina

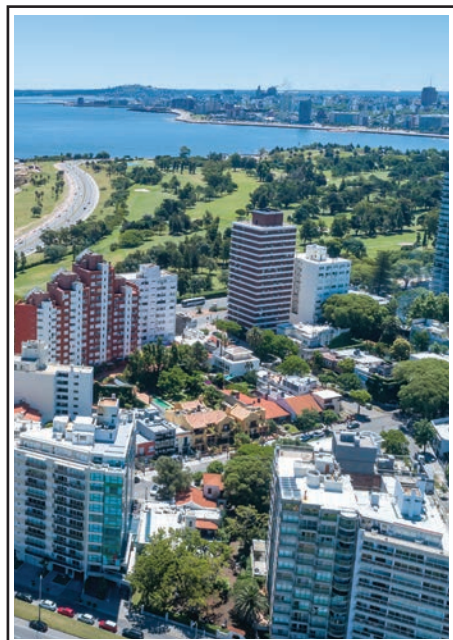
Montevideo,
Uruguay

RESOURCES

RESILIENCE PARTNERS

A wide range of expert knowledge and resilience planning resources is available from the following campaign partners.

- C40 Cities
- Global Covenant of Mayors for Climate & Energy (GCoM)
- Making Cities Resilient 2030 (MCR2030)
- Resilient Cities Network
- World Resources Institute (WRI)
- World Wide Fund for Nature (WWF)



Montevideo, Uruguay

Uruguay's capital city, Montevideo, joined the 100 Resilient Cities Network in 2016 and has since started work on a long-term transformation project for one of its most vulnerable neighbourhoods, the Pantanos basin, which previously had little access to public transport and suffered from high levels of air pollution, environmental degradation, and social deprivation. Pantanos has now been converted into a 'Resilience Laboratory' to help its residents attain a better standard of living and enable the area's communities to manage the environment and prepare for a changing climate.

The plan for the Pantanos basin includes development of wetlands to minimise flooding, building of new housing away from the flood plains, new transport links to help build social mobility, and an intervention plan to engage local residents and get them involved in environmental improvement projects.

While the Race to Resilience is a way to focus resilience mobilisation and hopefully speed it up, cities the world over are well aware of the challenges they face and are already stepping up to meet them head on.



PLUG THE GAP: RETRAIN FOR NET ZERO

GETTY IMAGES/THE IET

Workers at all levels need new skills for the green economy. Government and employers must act now to build a coherent strategy and invest in training.
By **Helena Pozniak**

THERE ARE JUST 29 years to net zero – a commitment enshrined in UK law. A steady drumbeat of disasters caused by extreme weather has highlighted the peril we are in, from deadly floods to blazing landscapes to rising seas.

But amid all the talk of urgency and an impending ‘green industrial revolution’, many people in the engineering and tech sectors are asking what they can do. From renewables to domestic heating to electrification, specialist knowledge will be in demand.

When thousands of engineers and technologists first trained, ‘green’ careers weren’t really an option. Even now as the clock is ticking, there’s been a dearth of guidance and training for professionals who want to leapfrog into the green economy and direct their skills to combat climate change.

There’s a pressing need for engineers and technologists in both new green technologies and also to clean up traditional dirty industries. “We don’t yet have a coherent strategy for skills for net zero,” says Thomas Gunter, education policy adviser at the Royal Academy of Engineering. Skills reforms in the pipeline will help change this, he says – a government-convened Green Jobs Taskforce published its report in July, which will inform an official net-zero strategy due later this year.

Opportunities lie in the UK’s strengths – in electric vehicles, offshore wind and emerging renewables, hydrogen technologies, carbon capture and more. Carbon-cutting renovations will require buildings to be retrofitted. And there will be roles to help decarbonise industrial giants such as aviation, agriculture, steel, manufacturing, and construction. Today, just the 12 most carbon-intensive industries make up 62 per cent of all UK carbon emissions and 21 per cent of current UK jobs, according to Onward Research.

But start searching for opportunities – or funding – to retrain and there’s currently a bewildering array of pricey postgraduate courses, and only the larger companies have the resources or clout to reskill employees in a structured way. And for a mid-career professional in a secure role, a change in direction can be a financial risk – much of the guidance targets those starting out in their careers.

Importance of skills

While half of engineering employers say they have a sustainability strategy, according to the IET’s 2020 Skills for Net Zero survey, fewer than one in ten say they have all the skills they need to reach their goals. Six in ten say they’ll help train their employees and 38 per cent say they plan to hire new skills. “Engineering employers understand their responsibility to tackle climate change and are taking steps to improve sustainability,” the report says, but they’re held back by a series of challenges. Four in ten (41 per cent) of employers say time is the greatest barrier to engaging with education.

Pressure to cut costs is another blocker, while 57 per cent of employers say financial

incentives for new greener technologies would encourage them to do more to lower their environmental impact. Long-term government support in these skills is essential, says the IET. “Industry must have the confidence to invest in infrastructure and skills in order to work on major projects.”

Part of the problem, says Gunter, is that there’s currently no national coordinated career structure for professionals working in science, technology and engineering. “That’s not to say there aren’t opportunities when you look for them, but we’d like to see a more strategic approach,” he says. “What’s lacking is a bigger picture – a kind of ‘this is how you do it’ advice,” he says – help to navigate different courses and to understand what kind of roles might be emerging.

The Green Jobs Taskforce recommended that education, business, and government work together to help create skilled roles for the road to net zero, with the ambition to support 250,000 highly skilled green UK jobs by 2030. These include some 60,000 jobs in offshore wind, 40,000 in zero-emission vehicles and 50,000 in decarbonising UK buildings. There’s a need for green careers advice and clear routes in to “good” green jobs, the taskforce reported.

For the entrepreneurially minded, now is a good time to get involved. Investment is forecast to flow towards companies that fight climate change rather than cause it, particularly after one of the world’s most influential economists, Mark Carney, flagged reaching net zero as “the greatest commercial opportunity of our time”.

Tech-focused agenda

There is also a rise in climate tech initiatives – this July saw the launch of an international non-profit accelerator to combat climate change. This is Subak – named after an ancient Indonesian irrigation system – which aims to harness the power of data to help cut carbon emissions. As a network, Subak unites individuals from technology, business, policy, and environment.

Founding member companies include Open Climate Fix, which helps use weather data better to predict how much solar electricity will be created each day, potentially cutting generation from fossil fuels. Transport research group New AutoMotive tracks how electric cars are used around the UK – data that can help local authorities plan charging stations and services to boost take-up.

Founders of Subak – whose first group of start-ups have already raised £8.5m in funding – include environmental pioneer Baroness Bryony Worthington, author of the Climate Change Act, and tech veterans and entrepreneurs. They hope some 500 members will join its international network in the next five years.

For Chris Ballard, who’s worked in data science and artificial intelligence (AI) for more than two decades, climate tech has become a natural home. “I’ve become increasingly concerned about the climate crisis and I’ve seen at first hand the impact of flooding in India and the UK. I decided >

In June, Solar Energy UK and the Mayor of London launched a project called ‘Solar Skill London’ to provide training and support for people who want to pursue a career in the solar industry

Strategies to achieve sustainability

Half of engineering employers have a **sustainability strategy**.



Eight in ten employers are doing activities to **lower their environmental impact**.

Using new, greener technologies

43%



Adapting existing technologies

33%

Financial incentives to adapt/purchase technologies would **motivate over half of employers** to lower their impact.



Less than one in ten employers have **all the skills** their strategy needs.

60%

will **upskill** employees.



38%

will **hire** for skills.

Costs are the **main barrier** to lowering environmental impact.



Increased operating costs

31%

Initial investment costs

30%

Top three workforce impacts from environmentally friendly challenges:

Changes to general business practices

41%

Changes to flexible working

34%

Changes to benefits

31%



Reaching sustainability

One in five have **not introduced** any technological change to **lower their environmental impact** over the past five years.



Flexible working is the most **common area** of organisational change to lower environmental impacts.

28%

will **improve** flexible working arrangements.

27%

will **introduce** flexible working.

A quarter do not engage with **schools, colleges or universities**.



A third will **train staff** in **efficiency skills** to help **lower environmental impacts**.

Efficiency skills

34%

Management skills

29%

Innovation skills

25%

Delivery skills

24%

Most employers think key priorities for the UK education system are:

60%



58%

More opportunities for young people to acquire relevant **work experience**.

Increased **engagement** with businesses.

41% say that **time** is the **biggest barrier** to encourage greater **engagement with education**.



Some of the findings from the IET's 2020 survey on 'skills for net-zero and a green recovery'.
bit.ly/IETskills2020

< this year was the right time to make a move." He's now chief technical officer at early stage start-up Climate Policy Radar, a Subak founding member.

Climate Policy Radar uses machine learning and AI to analyse climate policies around the world in a bid to support more informed decisions and investment. "It's been exciting to see how much my data science and technical skills have been directly transferable," he says. "I've a lot to learn about climate change and climate policy decisions, but the chance to develop is exciting."

An optimist, he believes tech can help do things better and faster. "The obvious application of technology is to replace the systems we already have in place," he says. "Such as building net-zero energy and transport systems, creating solutions to reduce the impacts of extreme weather events, and enhancing food production. But it can do more than that – it can help us make better decisions... we can now model worldwide emissions, track deforestation and understand which policy decisions work." But these insights must then be communicated to people in power, he adds.

Increasing opportunities

Professional groups and bodies are mulling how they can support members who want to make the leap. The government's 2020 'Ten Point Plan For A Green Industrial Revolution' gives a broad overview of jobs but doesn't go far enough, say campaigners and industry groups. There's a wider lack of awareness of career opportunities, says the CBI (Confederation of British Industry), and individual businesses need guarantees of longer-term support and strategies from government before committing.

Then, as industries make the transition, employees will need help to retrain. For some the switch will be relatively simple, with skills slotting neatly across sectors. "Moving across from construction to renewable energy was fairly easy as many of my skills were transferable," recalls Tom Ransley who's moved back to the UK from Austria. "It's just the nuts and bolts that are different." He now works at renewable energy firm SunGift Solar in Devon; having worked on trams in Vienna, he didn't fancy a return to roadworks – "not a good fit for my principles... if it's something you want enough and your ethics are aligned it's easier to secure a job than by just having the right qualification. If you want to make the jump enough, you'll make it happen."

While the Royal Academy of Engineering is pushing for better training and investment in skills, the construction sector is working hard behind the scenes to identify the technical skills required for net zero, and plans to launch an energy transition leadership scheme later this year for the up and coming.

The ECITB (Engineering Construction Industry Training Board), which is part of the government's Green Jobs Taskforce, has published a list of available training for individuals and companies in areas such as

'Engineering employers understand their responsibility to tackle climate change and are taking steps to improve sustainability.'

The IET

hydrogen, offshore and renewable energy, as well as energy transition leadership. Innovation champion Nesta calls for a series of clear jobs labels to help clarify which roles will be hit by the climate crisis, as well as funding to help individuals switch out of 'brown' jobs.

There are thousands of people working collaboratively to address world challenges including climate change at the moment, says Fran McIntyre, director of the Knowledge Transfer Network, which links individuals from business, industry and research to work on projects aiming to have a positive impact. Some of these include innovation in battery technology, applications for hydrogen, low-carbon jet fuel, electric vehicles and their infrastructure, and negative emissions technologies that remove carbon from the atmosphere. And then there's work to decarbonise traditional industry too, she says. "There are live projects to improve hubs where carbon emissions are high, such as industrial clusters, harbours and ports in developing countries."

Training, training, training

Of all potential sectors, energy offers some of the best opportunities to retrain and it's where there will be plenty of vacancies, says Claire Scott, employment law legal director at Pinsent Masons. "There are many industry-led events, and a number of universities are looking at energy transition qualifications," she says.

Schemes such as STEM Returners – which help employers to recruit and qualified people to re-start their career – could also help find roles linked to decarbonisation and sustainability, if an individual requests it.

This June saw the launch of the Tech Zero task force to rally support for climate action across the UK tech sector. With members ranging from Starling Bank to Olio, the task force aims to have 1,000 members by the start of COP26. The initiative has produced a toolkit to "demystify climate jargon" and help companies set and meet net-zero targets.

There are hundreds of specialist Master's degrees targeting different sectors from energy through to sustainability – and traditional management postgraduate degrees now incorporate skills for net zero.

Gunter, though, sees a need for more accessible, shorter, and cheaper 'micro-credentials', supported by a local further education college and over in a matter of weeks, which would be suitable for mid-career individuals who don't want the

COURSES TRAIN UP

■ Online learning platform FutureLearn offers short courses suitable for professionals – with some 100 Nature & Environment courses and 200 Science Engineering & Maths Courses.

■ The 'Systems Thinking for Sustainability: Complex Systems Analysis' ExpertTrack is designed specifically with career-minded learners, to help them gain new skills for the sector.

■ The Open University also has two micro-credentials, 'Climate Change and the Polar Regions: Tools for the Climate Crisis' and 'Tackling the Climate Crisis: Innovation from Cuba', also designed to give professionals flexible, accredited and bite-sized learning.

■ Samsung's recently launched 'Designing for a Sustainable Future' course is specifically targeted at those in or looking to get into the tech sector.

■ 'Green Travel and Climate Change: An Introduction to Low Carbon Road Transport' course by Cenex.

expense of a postgraduate route. "The training and upskilling landscape needs simplification," he says. Further education – once a natural hub for adult retraining – has seen a 20 per cent fall in funding over the last decade, but the government is hoping to revitalise skills training with a series of reforms.

In May this year, the Prime Minister's Lifetime Skills Guarantee was a central part of the government's 'levelling up' agenda. And the Skills and Post-16 Education Bill aims to make it easier for adults to get into higher education by offering finance and creating shorter courses in engineering. In England, new Institutes of Technology, run as partnerships between further and higher education and employers, have begun offering short modular courses with an aim to boost local technical skills, though these don't overtly focus on net zero.

And of course there are the open online courses offered by FutureLearn and Coursera, which allow users to dip their toes into green sectors (see box). Many are designed for professionals and last a matter of weeks.

Employers could do more to keep their staff up to date, says Gunter, and retrain rather than hire new staff to meet skills shortages. Could they offer digital, modular training tailored for those in their mid to late career stage? He calls for investment and better anticipation of what skills will be in demand and when.

"There are hundreds of jobs in these fields, available right now," says McIntyre, "and we're just scratching the surface. The planet is in desperate need of technical experts and engineers to help fight climate change, so now is most definitely the time to make the jump if you're already thinking about it." *

In celebration of **IET@150** we look at feats of engineering from around the world. Here, we explore an astronomical observatory built in the middle of the desert.

150
1871 - 2021

ENGINEERING PLACES **ATACAMA LARGE MILLIMETRE ARRAY (ALMA)**

By **Siobhan Doyle**

AT THE HEART of the Chajnantor plateau in Chile lies the Atacama Large Millimetre/sub-millimetre Array (ALMA). It is the most complex astronomical observatory ever built on Earth and is used to observe light from space at millimetric and submillimetric wavelengths.

The facility can study cosmic light that straddles the boundary between radio and infrared – most objects in the universe emit this kind of energy, so the ability to detect it has been a driver for astronomers for decades.

ALMA uses a system called an ‘interferometer’ that arrays many small antennas across a wide area and links them together to operate as one huge telescope. By combining 54 parabolic antennas with 12m diameters and 12 parabolic antennas with diameters of 7m, it creates one huge radio telescope comprising 66 antennas in total.

The astronomy facility is the brainchild of an international partnership between the European Southern Observatory (ESO), the National Science Foundation (NSF) of the US, and the National Institutes of Natural Sciences of Japan in collaboration with the Republic of Chile.

The construction of the observatory dates to 2004. However, two decades prior to this, the global scientific community had already identified the need for a radio telescope with the characteristics of ALMA.

In 1983, eminent radio astronomers in the US met to discuss priorities for an array of millimetre-wavelength telescopes. By 1990, the National Radio Astronomy Observatory in the US proposed a project called Millimetre Array (MMA), which considered the construction of 40 antennas with 8m diameters, reaching an atmospheric window of 30 to



350GHz to receive millimetre wavelengths. The NSF approved further MMA planning for this in 1994.

In parallel to this, ESO planned the Large Southern Array, a proposal that considered the installation of 50 antennas with 16m diameters, operating with frequencies below 350GHz and receiving millimetre wavelengths.

Yet it wasn't until April 2001 when the National Astronomical Observatory of Japan proposed the construction of a Large millimetre/Sub-millimetre Array, which considered the same number of antennas as ESO, but with a 10m diameter, and unlike the others, was also planned to receive sub-millimetre wavelengths.

However, it soon became clear that such ambitious projects could not be developed by a single community, so all three parties joined forces. After its design, the team had to establish a location for this type of radio-astronomy project. So why did the team choose Chile?

Low-frequency waves are better received at high altitudes and in dry climates, as this reduces the amount of noise. In addition, the surface area should be large and flat enough for distribution of the antennas.

Several areas in New Mexico, Hawaii (Mauna-Kea), France (Plateau de Bure) and northern Africa were explored. However, none of these sites measured up to the conditions in an arid plateau between the Andes and the Chilean Coast mountains.

In 1995, the three partners ran tests in the Chilean plains, with positive results. In 1999, Europe and North America signed a Memorandum of Understanding, and two years later in Tokyo a resolution was signed to support the joint intent to construct ALMA between Europe, the US, and Japan. By the end of 2003, after a series of tests, the first stone was placed at the site high up in the Atacama Desert, in what was to become the most ambitious radio observatory on Earth.

Indeed, ALMA is still used to this day, and has helped to discover the most spectacular sightings within our universe. In 2019, astronomers using the ALMA Observatory found counter-rotating discs of gas around a supermassive black hole, with observations providing an unprecedented close-up view of a swirling disc of cold interstellar gas rotating around a black hole.

Meanwhile, in the same year, astronomers witnessed 3D

motions of gas in a planet-forming disc using ALMA for the first time. At three locations in the disc around a young star called HD 163296, gas was seen flowing like a waterfall into gaps that are believed to be caused by planets in formation.

The overall scientific goals of ALMA include observations of star formation, molecular clouds, and signs of our early universe – and the facility has already produced a series of unique images and data that achieve this. It has provided images of proto-planetary discs such as HL Tauri, which transformed the previously accepted theories about the planetary formation.

When the HL Tauri image was released in 2014, it was the sharpest picture ever made at submillimetre wavelengths, and could only be achieved with ALMA's long baseline capabilities. Tim de Zeeuw, then director general of ESO, said at the time that such high-resolution images started “a new era in our exploration of the formation of stars and planets”.

ALMA has also detected complex organic molecules – carbon-based, pre-biotic structures, necessary for building life – in distant proto-planetary discs, confirming that our solar system is not unique in potentially fostering life. Scientific results from ALMA are helping exoplanet researchers determine the types and locations of systems that could support habitable planets. It has also provided valuable information about worlds closer to home, including Saturn's moon, Titan.

According to ESO, ALMA is “the most powerful telescope for observing the cool Universe – molecular gas and dust”. Its detailed images of the birth of stars and planetary systems let scientists address “some of the deepest questions about our cosmic origins”.

ALMA is the most complex astronomical observatory ever built on Earth



TIMELINE ALMA

1997 National Radio Astronomy Observatory and the European Southern Observatory (ESO) agree to a common project that would merge the Millimetre Array of the US, and the Large Southern Array of Europe.

1999 Europe and North America sign a Memorandum of Understanding on the project.

April 2001 A resolution is signed between Europe, North America and Japan.

14 Sept 2004 Japan officially joins consortium.

17 Nov 2009 ALMA makes first measurements using just two of its antennas.

4 Jan 2010 Three antennas work in unison.

Sept 2011 Early Science observation starts with 16 antennas.

3 Oct 2011 ALMA opens for astronomers – using the partially constructed antenna array.

13 March 2013 ALMA is inaugurated in an official ceremony marking the completion of all the major systems of the giant telescope.

13 June 2014 The 66th ALMA antenna is transported to the Array Operations Site. The 12m-diameter dish is the 25th European antenna.

March 2015 ALMA combines its collecting area and sensitivity with that of the APEX (Atacama Pathfinder Experiment) Telescope to create a single instrument through a process known as VLBI, where data from two telescopes are combined to form a virtual telescope, yielding magnifying power.

July 2015 ALMA successfully opens on another frequency range after obtaining the first fringes with a Band 5 receiver, specifically designed to detect water in our universe.

4 Nov 2015 A new instrument is attached to the 12m APEX telescope at 5,000m above sea level. The Swedish-ESO Pi receiver for APEX detects faint signals from water and other molecules within the Milky Way, other nearby galaxies, and the early universe.

12 July 2018 To maintain the leading-edge capabilities of the observatory, the ALMA Board designates a Working Group to prioritise recommendations from the ALMA Science Advisory Committee on developments for the observatory until 2030.

Department for Transport chief scientific adviser, **Professor Sarah Sharples** admits that her constant questioning of how she could design things better drives her family nuts, but she will find it useful in guiding the UK government to deliver a more environmentally friendly transport policy.

WHEN IT COMES to the UK's transport system, "we've got some really big and important decisions to make", says Professor Sarah Sharples. "Some of those decisions might be about which of the number of alternative solutions that are out there are the best to help us on the path to decarbonisation – a path I think we are all aware that we need to progress through."

Sharples, who is chief scientific adviser (CSA) for the UK's Department for Transport, is referring to the recently published plan for transport decarbonisation, a term that Secretary of State for Transport Grant Shapps has gone on record as saying is "a dull way of describing something much more exciting". If Shapps's choice of vocabulary is perhaps unfortunate, Sharples is nothing but upbeat: "It is the articulation of where we need to get to if we are to meet our transport decarbonisation challenges that are extremely important to us in our fight against climate change." Looking at the issue from the perspective of CSA, Sharples is clear that "what's needed is the right research that answers the right questions at the right time".

She pauses to give an example relating to zero-emission vehicles, saying the questions currently in the air centre on "how we make this happen on a national scale. We know that it is possible to purchase zero-emission

Words and portrait by Nick Smith

vehicles. We know that the charging technology is available. What we need to understand is how this plays out in practice within the vast range of settings we see in the UK. What we really need to address is to make sure that we have the answers to the more difficult questions about how we can move from a proven technology – that still needs to develop – into the practical reality that makes it viable for the UK's population."

Staying with the topic of decarbonisation, Sharples says "we know that there are also challenges in terms of rail electrification. We know that it costs a lot to electrify railways, but we also know that in order to modernise and decarbonise our railways, the right solution is to move away from a reliance on diesel."

She explains that part of the role of the CSA is to frame questions in such a way that "they are at the right scale and level of detail that will allow research communities – very often a combination of industrial and academic partners who might take things forward to innovation – to respond. It's important that we get those questions right so we enable the people out there with

brilliant ideas to be able to test them. A lot of the work that the department funds is competitions and design challenges or opportunities to test. But we don't say: 'this is what we want, and you must deliver it'. It's not a service delivery. Instead, we say: 'this is our challenge, and we'd like to hear what you as technical and academic experts come back with that helps us to make decisions'."

While CSAs are in place to assist government with tackling hard questions, they are also finding themselves under greater public scrutiny as their roles become more visible. The proliferation of televised press conferences laying out the UK government's response to the Covid-19 public health crisis over the past 18 months has meant that scientists such as government CSA Sir Patrick Vallance have moved out of the relative anonymity of their profession and into the media spotlight.

Sharples sees this as a positive outcome for roles that exist in part effectively to provide checks and balances. "One of the things Covid has demonstrated is the important role that science can hold in informing policy. We need to build on that and use that momentum to engage the public in conversations about science. A key challenge here is when the evidence is complex or uncertain. The more we can do to make sure that all understand what evidence means, and how we can use it to inform >



'Covid has demonstrated the important role that science can hold in informing policy'

Sarah Sharples



Sharples accepts that the UK's transport system can be an emotive subject

◀ decisions, the better. The CSAs have an important role in that.”

Based at the University of Nottingham where she is Professor of Human Factors in the Faculty of Engineering, Sharples accepts that the UK's transport system can be an emotive subject. While she becomes almost poetic about the beauty of the coastal landscapes that the road network gives the public access to, as well as the grandeur of the architecture that goes with the expansion of the railways during the reign of Queen Victoria, when it comes to obvious environmental pressure points such as heavily congested motorways, she explains her position in terms of her academic career expertise: human factors. “One of the things I am passionate about is recognising the part people play in the system. We recognise that people will have feelings, behaviours and views that will play out in the choices they make as to how they travel.”

Switching hats, she says that as CSA one of her responsibilities is to make sure that “research isn't blind to the human factors aspect of the way in which we deliver future transport”. I try again to get Sharples to react to my assertion that transport creates ecological stresses by suggesting that if the 18th-century pictorial satirist William Hogarth were alive today, he might not be so much concerned with ‘Gin Lane’ as with ‘Dartford Crossing’.

Most valuable aspects

“It's important to understand what transport is there for and why we travel,” she says. “We usually travel for a purpose rather than for the sake of travel itself. Transport is there as a service to enable us to live our lives in society. It's there from an

economic point of view to deliver the best possible outcomes for the country. And therein lies one of the biggest challenges for the CSA for the Department for Transport, because a lot of the value of transport is seen out in other parts of society.” She goes on to say that one of the “most valuable” aspects of the transport system is that it “allows people to access a healthy way of life, access healthcare, access leisure facilities. It also gives them access to work that gives them a standard of living that enables them to have positive health outcomes. So, you can absolutely think of transport as an enabler.” It is also, she finally admits, “a major contributor to UK carbon emissions”. The figures for this are in the public domain, published in the 216-page government document ‘Decarbonising transport: a better, greener Britain’. That, says Sharples, “is why it is so important we address the different transport solutions that are out there, and think: ‘what do we need to do to influence how, when and why people travel?’”

This last question is central to delivering a sustainable transport model for the UK, and for Sharples one of the key pillars of this is inevitably human factors, a field of engineering in which she is an acknowledged world expert. She is forthright in her defence of human factors (“in the UK the term is interchangeable with ergonomics”) as an aspect of engineering (“our department here at the University of Nottingham is in the Faculty of Engineering”) and disapproves robustly when I suggest that there might be readers out there who think of human factors as a ‘soft’ science or skill. “The way I explain human factors is that people have

capabilities and limitations. Our job as human factors experts is to maximise the impact of these capabilities and minimise the impact of these limitations.” The discipline of ergonomics (the term is derived from the Greek words for ‘work’ and ‘natural law’) has evolved to incorporate this knowledge of capabilities and limitations into the design of systems and technologies. Relatively new, the science was formalised and given its name in 1949 at a meeting of distinguished (“all men”) physiologists and psychologists at The Admiralty.

Plug a gap

According to Sharples, this historic conference went on to become the Chartered Institute of Ergonomics and Human Factors (of which Sharples is a past president). Since that initial meeting, “the world of ergonomics and human factors has evolved significantly, especially over the past 20 years”, to plug a gap that existed somewhere between physiology, psychology, engineering, design, sociology and anthropology. Drawing on experiences of pilots during the Second World War, the new ergonomists could see that there was a need to better understand the way they responded to aircraft cockpit displays, which led to analysis of better designing work situations “to meet the needs of people. One of the philosophies is to think about the whole system that a human works with.”

While the lay person might only associate the term with chair comfort or workspace layout (‘physical ergonomics’), Sharples’ area of expertise within the discipline is cognitive ergonomics, which concerns “how we design information, support decision-making, think about workload”.

With degrees, both from the University of Nottingham where she's been based since 1991, in psychology as well as human factors in manufacturing systems, Sharples has always been well-placed for a career in human factors, and by extension her current role in transport. In the late 1990s her PhD brought her into the world of health-and-safety aspects of virtual-reality technologies. "That was a really interesting opportunity to think about the research we needed to do to inform the guidance on how we implemented virtual-reality technology."

It was at about this time that the UK's rail industry started to focus on human factors: "Network Rail, or Railtrack as it was then, should take a lot of credit for a significant insight into the value human factors could bring to its business." This was highlighted in 1998 by the Ladbroke Grove rail crash. "There were many technologies that were being used in the rail network system to support decision-making," but the cause of the disaster was that a train passed a signal at danger. "The question was, why did that driver make that error? How can we more effectively design the technologies that drivers, signal controllers and so on interact with to help them make safety-critical decisions in the most appropriate way that takes advantage of human capabilities and

manages their limitations?"

The main way in which her experience in the discipline of human factors has influenced Sharples' current role is that "it teaches you to step back and think 'why?' Why has this system worked well? Why has this system not worked well?" She emphasises the importance of analysing positive outcomes because "all too often we focus on when things go wrong, which means that we fail to pay attention to the role people play in making things go right."

It follows that the first and most important impact her human factors expertise has on her role as CSA is simply "that of all the analytical and decision-making skills I have learned over the past 27 years thinking about the subject. It drives my family nuts, but ergonomists tend to indulge themselves continually with everyday questions such as: 'how could I design that coffee machine better?' Second, human factors, as with many other science and engineering disciplines, plays an important role in designing innovation in future transport systems. For example, if you think about air traffic control, we've seen modernisation take place over the past few decades, moving from a system that was heavily based on technologies such as paper, to electronic flight strips. Yet it is the users

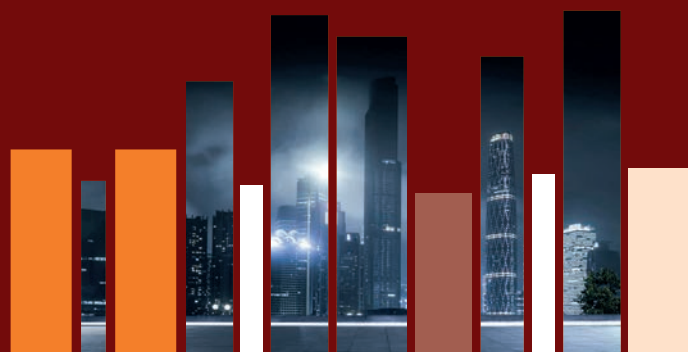
who have played an important part in designing the way these technologies have been implemented."

Sharples won't be drawn on what she thinks of the politics that goes with delivering a transport infrastructure. "My job is to provide advice and my advice needs to be based on evidence, and that evidence sometimes has uncertainty associated with it." At this point she repeats that the role of CSA is to provide advice, pointedly distancing it from policy makers "whose job it is to deliver policy", further to which, decisions are taken by ministers.

When asked if she finds this structural demarcation of responsibilities challenging, especially in the light of the management of the Covid crisis, where at times the advice provided by CSAs has appeared to have been overlooked by politicians, she says: "Actually I don't find it challenging at all because it is clear that we are all different parts of an important system."

"I'm comfortable that there may in future be a situation where my advice is not reflected in a decision that is made. That's because my advice is given from a scientific perspective, while the goal of politicians may be to consider other factors. It's not a difficult situation at all, because everyone understands what everyone's job is."

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**HANDS-ON
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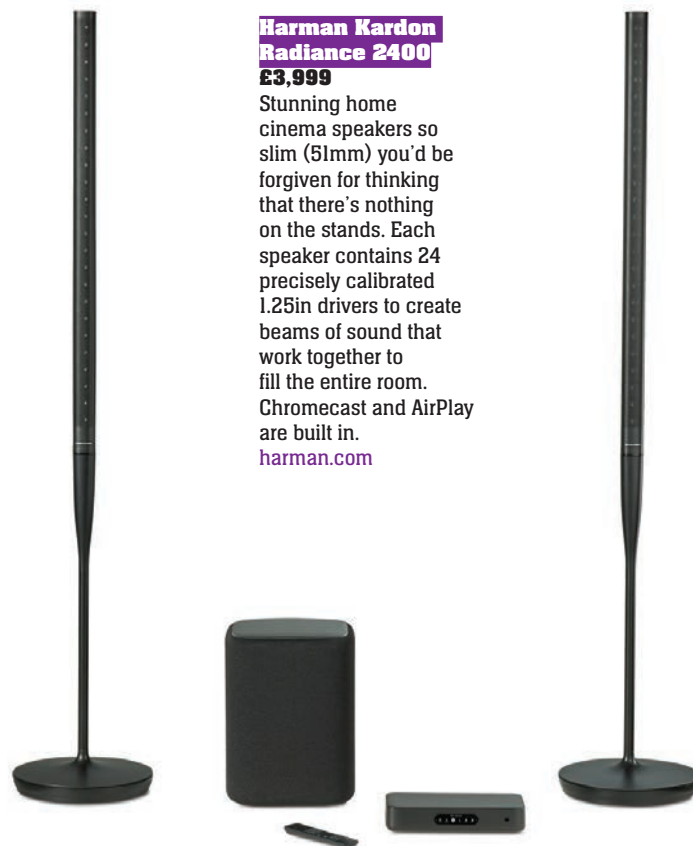




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SLIDEE

£7.99 for three

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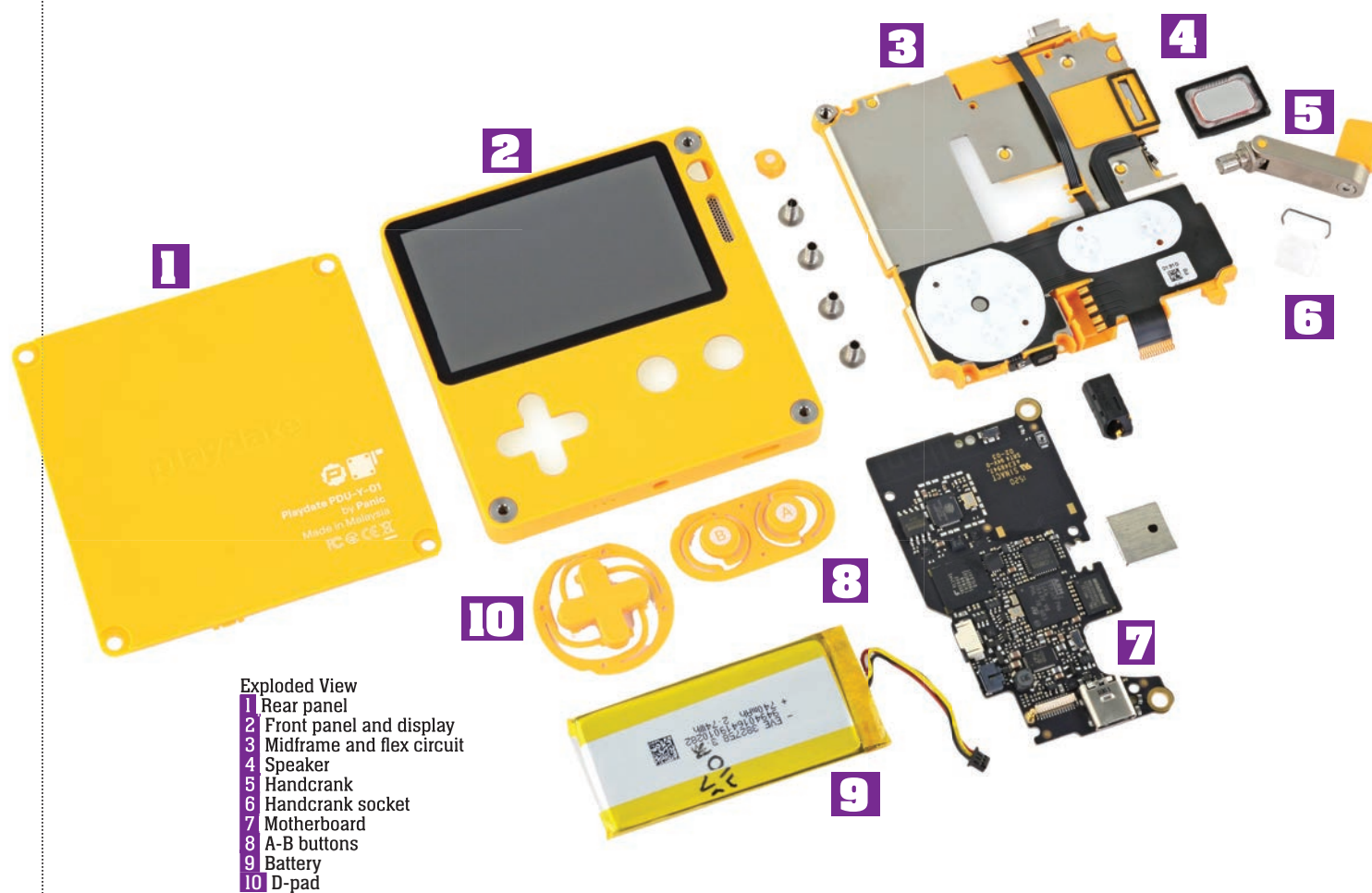
slidee.co.uk

The Raspberry Pi of gaming?

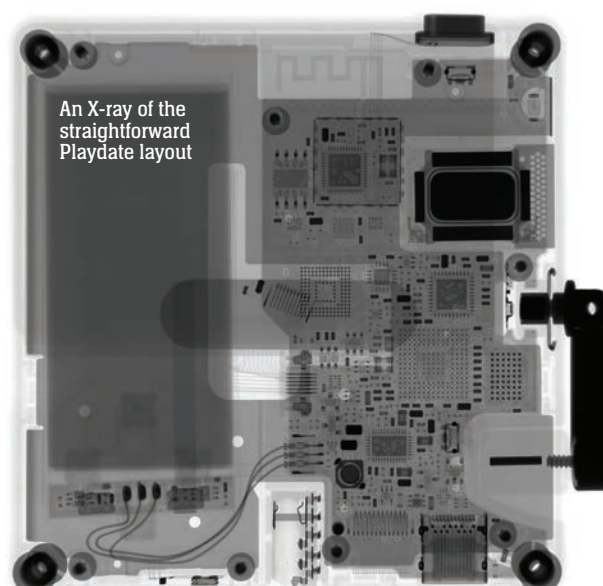
By **Paul Dempsey**

The Teardown

Panic Playdate



The handcrank assembly is simplicity itself



An X-ray of the straightforward Playdate layout

YOU MIGHT HAVE seen a back-up smartphone battery that appears to double as a GameBoy clone. Naughty. The Playdate from software house Panic is not one of those, despite first appearances. It is something a little bit more interesting. With a launch price of \$179 (£129), it needs to be.

For 'fun', Panic is instead seeking to introduce a new open-system gaming platform. Users will be able to sideload their own games and offer them for wider distribution. To do that, a developer kit for Windows, MacOS and Linux is also being released.

But the main attraction will be an official release of two new games every month, included in the price, alongside a dozen that are to be bundled on the handheld console at launch.

Panic has said that, by adopting this approach, it wants Playdate to encourage game creation by women, LGBTx and other minorities that are under-represented in the gaming developer community.

In terms of general inclusiveness, the specifications are deliberately basic. The games play on a 1-bit screen with 400x240pi dimensions at 173ppi resolution using the same black-and-white technology as e-ink (with pixels holding their form in a way that reduces power consumption). The engine room is a 180MHz SoC from STMicroelectronics, leveraging the Arm Cortex-M7 core. Total storage is 4GB of flash memory. Supported programming languages are our old friend C and Lua, which is known for being lightweight and easy-to-use.

Wi-Fi is present to allow the gamer to download new titles. There is also Bluetooth, so that the Playdate can be docked in a charging station peripheral that doubles as a stereo speaker (price TBA), and will also support a radio app (there are a mono speaker and a USB-C charging board built-in). There is a standard 3.5mm headphone socket.

Meanwhile, reflecting Panic's 'fun' approach, the most interesting feature is a handcrank on the side that works



Playdate aims to encourage game creation by minority groups including LGBTx and women, which are both under-represented in the gaming developer community

as an extra controller on some of the titles. It does not act as an emergency charger but instead allows you to control motion (e.g. backwards, forwards, run, walk) rather than stabbing the D-pad or buttons.

The business model is interesting, and in some respects the Playdate feels like a gaming-dedicated play on the Raspberry Pi, providing opportunities for young (and not-so-young) innovators to get some entry-level coding experience in what will always be a hot sector – and put their screen time to more profitable use.

As befits that kind of objective, the design is straightforward yet still compact. It was undertaken for Panic by Swedish consumer electronics group Teenage Engineering, best known for its synthesizers, as used by artists such as Beck, Depeche Mode and Jean-Michel Jarre.

An iFixit teardown found a very tightly packed motherboard. The crank includes a cylindrical magnet that triggers a Hall-effect sensor to dictate response.

"One thing this crank won't do? Drift," notes iFixit. "There's no wiper or spring or sensor surface to wear out. The design is simplicity itself. You might even say there's... no cranky-panky."

The designers also made space for a small MEMS microphone. The battery is rated at 2.74Wh, much smaller than for a smartphone, but several power-efficient features have been included.

The main quibbles were that the high-traffic USB-C port is soldered in place, that all the

controls have been aggregated on a single flex circuit, and that the display is glued down such that replacing it will probably involve replacing the entire front panel. The iFixit repairability score for the Playdate is 6 out of 10.

The console is still at the pre-order stage; the idea has been welcomed even though the quality of the games on board remains unknown. On that vital point, Panic has partnered with some well-known developers. These include Bennett Foddy (QWOP), who has created 'Zipper' for the console, while Chuhai Labs (Carve Snowboarding for the highly specified Oculus VR platform) is providing 'Whitewater Wipeout' – titles that make you think the handcrank is going to get some use from day one.

But for now, the games' full content does remain secret – and Panic will not be saying when each, beyond the initial 12, will make their specific debuts; each is meant to be a surprise. They will be the primary benchmark for Playdate's future. But if the console can also create a new group of developers from outside where talent usually emerges in the gaming world, that will be more than just fun. *

KEY COMPONENTS

PANIC PLAYDATE HANDHELD CONSOLE

Part	Supplier	Comments
SoC	STMicroelectronics	ARM Cortex-M7, 32bit, 180MHz, MPU+FPU
Memory (Flash)	Kioxia	4GB, eMMC, NAND
Memory (Flash)	Winbond	32Mb, serial NOR
Memory (SRAM)	Winbond	128Mb, low power
Display	Sharp	400x240pi (173ppi), 1-bit, 2.7-inch diagonal, Memory LCD
Wireless SoC	Espressif Systems	Wi-Fi, Bluetooth
Sensor	Infineon Technologies	Hall-effect
Sensor controller	Allegro Microelectronics	Hall-effect
Microphone	Knowles	MEMS, SPH1642HT5H-1
Accelerometer/gyroscope	STMicroelectronics	3-axis
Power management	Analog Devices	LTC3576 (formerly Linear Technology)
Audio codec	Cirrus Logic	w/ headphone and speaker amplifiers
Note: the components listed here are not exhaustive but restricted to key parts whose suppliers and function could be identified.		

Source: iFixit

Author **Marco Alverà** says that if we are serious about getting to net zero, we've got to think big. And the biggest idea is to embrace hydrogen.

BookInterview

By Nick Smith



Hydrogen's energy promise

"HYDROGEN IS JUST a means of storing solar energy," says Marco Alverà, "it's as simple as that." It's not as versatile as electricity, probably won't have the same sort of business-to-consumer profile that electricity has, and will certainly be one of those technologies that operates 'behind the curtain'. When it comes to how it will heat our homes, Alverà thinks that "the jury is still out on that". But what he does know is that as the price of solar energy decreases, hydrogen will – or should – play a bigger part in how we power the world with clean energy.

Author of 'The Hydrogen Revolution', Alverà has spent more than two decades in the energy industry and is currently CEO of Snam, one of the world's largest energy infrastructure operators. A leading advocate for hydrogen, he is also author of 'Generation H: Healing the

Climate with Hydrogen'. Both in his new book and in person, Alverà has a talent for expressing vast challenges and complex concepts in simple terms. For him, one of the key reasons for bringing hydrogen into the mix is simply the economics of solar.

"This has been my journey in energy," says Alverà. "When I first started in this field, solar energy cost about €1,000/MWh, with electricity from coal and gas between €60 and €70/MWh. I thought that renewable hydrogen made from solar was beautiful – ideal – but way too expensive." Looking at the present, "we have solar at €10/MWh in sunny places. No technology can compete with it because it is static. We can apply to solar the development path of digitalisation, which enhances the productivity and performance. It has no moving

parts and there are plenty of sunny places."

Germany is so notoriously overcast that in the vocabulary of renewable energy it has its own term for winter – *Dunkelflaute* – which translates literally as 'dark dull'. Critically, Germany also has, according to Alverà, "an ambitious and bold hydrogen strategy". He describes Germany as a "quintessential" manufacturing country: "It's a country that produces steel, cement, plastics, fertilisers and cars. It's also a country that's running on coal, nuclear and diesel. It doesn't have a lot of sun or sea and it's densely populated." These factors, along with a tendency for nimbyism, combine to mean that Germany is, "really struggling to build renewables. And they have the *Dunkelflaute* – long spells with no sun and no wind. In winter they have snow

that settles on the solar panels in the Black Forest, which is called 'black' for a reason."

Finding itself having to "suddenly exit coal, exit nuclear and exit diesel", Germany's hand has effectively been forced, and it will need to import renewable energy. Alverà goes on to explain that according to current statistics, the cost of importing hydrogen via ship could be 5-10 times more than by pipeline. All of which means that in situations such as the one German finds itself in, "a lot needs to happen. But I don't think that we need a lot of politics or subsidies." When it comes to a hydrogen future: "We just need to do what we did for natural gas," which was essentially to connect the source of energy to where it was needed.

Put like that, the policy, technological and economic

'Not many colleagues of mine have ten-euro solar in their mindsets.'

Marco Alverà

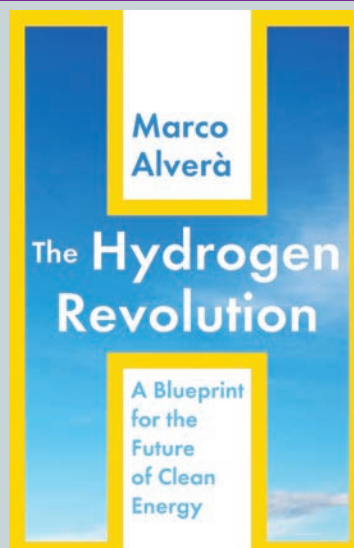


WE READ IT FOR YOU

THE HYDROGEN REVOLUTION

Imagine a time not too far in the future – perhaps in 2050 – when the news headlines declare that the looming shadow of climate change has been banished for good. The planet has stabilised. Rainforest and reef thrive in a world at ecological equilibrium. This may sound like science fiction, but it could be reality, says Marco Alverà in his thought-provoking and incisive 'The Hydrogen Revolution'.

His book explores a pathway to Net-Zero by embracing element H, atomic number 1. Alverà argues that hydrogen is the missing link between today's energy mix and a truly clean future, making the case for it ensuring reliable, green and consistent power to fuel commercial transport, trains and aeroplanes. But we need to act fast, he says, as he lays out his three-point action plan for companies, governments and consumers. Compelling stuff.



of the reaction is water). Existing infrastructure can be repurposed to move it around the world. All we need to do is manage the costs.

But there could be a PR job to do too. In his chapter on safety, Alverà refers to a consumer poll that confirms when people hear the word 'hydrogen' their minds instinctively go to the Hindenburg disaster or the nuclear H-bomb. As you read his footnote that says, "of course the tankful of hydrogen in your car is not going to become an H-bomb", you can't help wondering how many times he's had to remind people of how science works. In fact, there have only been a couple of minor hydrogen-fuel accidents to date in South Korea and Norway. Despite the public's general wariness of hydrogen, another poll reveals that most citizens would travel on a hydrogen-powered bus; a finding Alverà ruefully puts down to people trusting buses more than the fuel that powers them.

Hydrogen, says Alverà, is simply a means of "connecting solar energy from sunny locations to ships, trains, trucks and factories". But its success is

dependent on market economics. For the reader of 'The Hydrogen Revolution' this is neatly summed up in what Alverà describes as "the essence of the book" on page 229, where an innocuous-looking table (taking up no more than a quarter of a page) tabulates forecasts for the descending cost of solar energy. This descent into the realistic range it is in now "has only happened in the past three years", which means that "not many colleagues of mine in this space have ten-euro solar in their mindsets. People haven't realised this, which is why I wrote the book."

You could argue, Alverà continues, that 'The Hydrogen Revolution' is already obsolete. This is because there has already been a solar auction in Saudi Arabia won at \$10.4/MWh, within range of Alverà's forecast for prices a decade into the future. "Why hasn't hydrogen happened before? Why isn't it happening now? It's because the fall in price of solar is just so recent. But it will change everything."

'The Hydrogen Revolution' by Marco Alverà is from Hodder & Stoughton, £20

EXTRACT

INEXHAUSTIBLE MOLECULE

November 2018: I was in my office in Milan almost at the end of a long day. As CEO of Snam, an energy infrastructure company with natural gas pipelines in Europe and the Middle East, part of my job is to think about what the global energy system might look like, and what we might need to build to make it happen. Among my last appointments was the Snam scenarios team with a study that showed how Europe would reduce its CO₂ emissions to zero by 2050. The idea was to look at a host of clean energy sources – solar and wind power, biomass and hydrogen – and how much each might cost to produce, transport, store and use. Armed with this knowledge, a model could figure out the least costly combination of these sources in 2050. As I looked through the study, I noticed there seemed to be a lot of hydrogen in 2050. An awful lot, really, for something that was almost absent from the energy mix and the policy discourse.

I had known about hydrogen for a long time, ever since we'd made it from water in science class at school, using one of those rectangular prism-shaped 9-volt batteries. I'd also encountered the dream of endless hydrogen energy when, at 17, I'd read Jules Verne's 'Mysterious Island'. In the novel, he talks about how "water will one day be employed as fuel", and how the "hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable". Reading Verne was how my slow-burn love affair with humanity's inexhaustible, rewardable molecule started. Yet when I went to my first hydrogen conference in 2004, almost 130 years after 'Mysterious Island' was written, Verne's vision seemed as far away as ever.

Edited extract from 'The Hydrogen Revolution' by Marco Alverà, reproduced with permission.

Hydrogen's long-term success as a mainstream fuel will depend on market economics

arguments for hydrogen from solar are compelling, lucid and conclusive. But there is also a more emotive thread to 'The Hydrogen Revolution' that could have an equal impact on the reading public. Coming from a committed environmentalist – whose great moment of revelation came after witnessing the sheer scale of plastic waste left in Venice's St Mark's Square after a Pink Floyd concert – Alverà's book makes clear that hydrogen presents us with the big idea that provides the answer to our green energy challenges.

'The Hydrogen Revolution' explains how, by doing little more than bottling sunlight, we can find the missing link between ourselves and a clean energy future. The beauty of hydrogen lies in its versatility. You can do almost anything with it: store it, transport it, pipe it and even burn it (and the only by-product

FROM THE IET ARCHIVES

From the Haslett correspondence to the White House

BY ANNE LOCKER

AS THE IET starts to reopen the collections in its Archives to members and researchers, it can also restart some of the cataloguing and research projects that have been on hold over the last 18 months. One such project is the re-cataloguing of the correspondence of Dame Caroline Haslett.

Dame Caroline (1895-1957) was an important figure in the development of electricity supply in the UK, and a notable member of an international group of women in business and the professions who supported each other in their work. In addition to her numerous engineering roles, she became president of the International Federation of Business and Professional Women in 1950.

Her correspondence reflects the breadth of her personal influence. Archives staff have only just started on the files, and

have already found letters from MPs, ambassadors, company directors, embassy staff, authors and society figures.

A regular correspondent in the early 1940s was Margaret Drexel Biddle, the second wife of the US ambassador to Poland, Anthony Drexel Biddle Junior (Biddle would go on to serve as ambassador to Belgium, Czechoslovakia, Greece, Luxembourg, the Netherlands, Norway, and Yugoslavia at the same time). Biddle connected with Haslett when the Biddles were based in London, before they moved to Paris, and in 1942 she presented a radio broadcast that looked at the role of women in UK munitions factories during the Second World War.

Margaret Drexel Biddle interviewed women at a technical training centre and talked with Haslett and two women who were working in the factories: Sheila Leather and Miss Hodgson. Incidentally,



Caroline Haslett's correspondence includes this photograph of Margaret Drexel Biddle with a handwritten message

Leather (who was working as a factory supervisor) would go on to found the engineering company Holmes & Leather with the mechanical engineer Verena Holmes, and became president of the Women's Engineering Society in 1950. Haslett was quick to point out that women were suited not only to specific technical tasks but for roles with more responsibility: "Not only are women working in these highly skilled jobs [in the tool room] but they are acting increasingly in managerial capacities – as supervisors, as managers of whole departments and as inspectors of all kinds."

Margaret and Anthony Biddle separated in 1945. She stayed in Paris and became a well-known figure in American society, even being tipped for an ambassadorial role of her own. She died in 1956 and left her extensive and important collection of gilded (also known as vermeil) tableware to the White House, where it is now on display in the Vermeil Room, which also houses portraits of first ladies of the United States.

More information on the project, and some of the other characters discovered so far, can be found on the IET Archives blog at bit.ly/IET-Archives

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We know of very few 19th-century female engineers, not least because for a woman to 'get on' in the field she needed to be far more than just an engineer. Sarah Guppy was just that.

The Eccentric Engineer

by Justin Pollard



INNOVATION

Brunel-era Bristol woman whose patents ranged from bridges to beds



SARAH GUPPY had the three things that were essential in the early 19th century for a woman to be taken seriously in the very male world of engineering – money, an excellent education, and social contacts. The daughter of a wealthy brass founder and sugar importer, she grew up surrounded by the prosperous new class of Bristol merchant keen not only to flaunt their new wealth, but to 'improve' the lot of the people of Bristol and the country in general.

Having married Samuel Guppy, a builder of agricultural machinery, she immediately immersed herself in his trade, helping to run the business and negotiating contracts but also turning her hand to the practicalities of engineering.

Samuel had fingers in many pies, from nail manufacture to the sale of tea urns, and Sarah seems to have taken an interest in it all. Success came quickly when Samuel's interest in a new method for producing flat-headed nails led to a contract to provide copper versions for attaching anti-fouling copper plates to the

hulls of ships. Sarah took charge of the negotiations, making the Guppys between £20,000 and £40,000 – roughly £2.4m in today's money. Whether she was involved in the manufacturing process itself is less certain, but her practical interest in engineering became very clear in March 1811 when she patented "a new mode of constructing and erecting bridges and rail-roads without arches or sterlings, whereby the danger of their being washed away by floods is avoided".

Her idea was to create a type of suspension bridge whereby a trackway across a river – in this case the unspanned Avon gorge – was suspended on chains held taut between piles driven into each riverbank, thus removing the need for piers in the river which might be washed away.

Not being one to simply create paper designs, she promptly went about raising subscriptions for such a bridge at Hotwells, producing a detailed model to demonstrate the effectiveness of her design. Sadly, despite her own investment in the project, the bridge was never built.

COMPETITION

What's the woman thinking? The wittiest caption emailed to engtechmag@theiet.org by 3 November 2021 wins a pair of books from The MIT Press.

Not one to be disheartened, Sarah threw herself into the new 'improving' atmosphere of the era, dashing off letters to Lord Liverpool, suggesting reform of the Smithfield meat market, and proposing a recycling scheme for piles of manure that lined the turnpike roads. Nor had she given up on invention, taking out a patent for what might be considered the forerunner of the Teasmade – a coffee and tea pot that also steamed the breakfast eggs and kept the toast warm.

Sadly, her own family life proved less than happy. Samuel became estranged from his dynamic wife who was equally at home corresponding with members of the government, discussing plans with the great engineers of the day or working in his metal goods warehouse. Sometime in the 1820s Samuel appears to have left Sarah and wound up his business, dying shortly after.

Having inherited the family house and the residue of Samuel's estate, Sarah went straight back to work, this time patenting a new bed designed to reduce dust collection and improve ventilation. Always keen to improve every aspect of her inventions, this bed also included under-mattress storage and even an exercise machine for those unwilling or unable to rise from her ingenious device.

Nor had she forgotten bridges. She became an enthusiastic proponent of the Clifton Suspension Bridge plan as well as allowing Thomas Telford free use of her patents for safe pile-driving in his construction of the Menai Straits bridge.

Befriending Isambard Kingdom Brunel, she became a shareholder in the Great Western railway, energetically writing to the board with suggestions such as planting trees to consolidate

unstable railway cuttings. Her son Thomas later worked informally with Brunel providing ideas for his great marine projects: the SS Great Western and SS Great Britain.

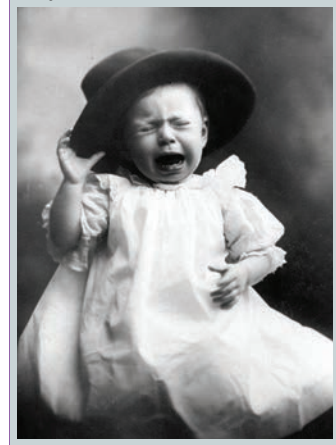
After seven years of widowhood and now aged 67, Sarah married again, this time to one of the partners in the *Bristol Mercury* newspaper. The match was widely commented on at the time, her husband Richard Coote being 28 years her junior. It proved an unfortunate match as Richard was a gambler who soon spent his wife's fortune. However, he did not dissipate her ambition. Even as her once substantial fortune dwindled, she continued to patent new ideas, ranging from the everyday – improved fire hoods and candle holders – to new methods for caulking wooden ships.

She died aged 81 in 1852 with just £200 to her name.*

CAPTION PRIZES BAG A BOOK



This month's competition winner will receive copies of two books from The MIT Press's Essential Knowledge Series (examples above). The winner of our August 2021 caption competition is Andy Green: "The mask was bad enough. Now they want me to wear a hat!"



Urgent medical supplies will soon be delivered rapidly across the US thanks to a German company that specialises in drone technology.
By **E&T** editorial staff

The Measure Of

Wingcopter 198



144 km/h
Maximum cruise speed

100 km/h
Default cruise speed



2x

Li-Ion battery // 814Wh each



Air medical service provider Air Methods has partnered with German drone manufacturer Wingcopter to create a drone-based network that can fly medical supplies across the USA.

The new network, dubbed Spright, will help ease shortages of blood products, medicines, diagnostics, or small medical devices, Air Methods says. It will achieve this by deploying fleets of Wingcopter's new flagship delivery drone, the Wingcopter 198.

With the proven technology and production capacity to create a nationwide network built around Air Methods' existing infrastructure of over 300 bases, Wingcopter says Spright can serve hundreds of hospitals across 48 states in predominantly rural areas.

An initial pilot project using Wingcopter's delivery drones will launch this year and will provide a proof of concept of how this venture can provide needed relief and certainty for

medical resources in rural America, according to Air Methods.

The Wingcopter 198 is an autonomous eVTOL delivery drone that enables reliable, fast, and bi-directional medical deliveries, according to its developers. The company's tilt-rotor technology allows for vertical take-off and landing, while also enabling efficient forward flight over long ranges, thus removing the need for additional infrastructure.

5,000_m
Altitude (ceiling)

110_{km}
Range without payload
75km with 5kg payload



15_{min}

Maximum flight time in multicopter mode, 90 mins in fixed-wing mode



10_{kg}

mass when empty, incl.
Triple Drop delivery System

20_{kg}
with batteries

25_{kg}
max take-off weight

6_{kg}

Total payload,
max 5kg with triple drop

15_{m/s}
Average wind resistance

20_{m/s}
Wind resistance (gusts)

1.98_m
Wingspan

3_m

Auto-landing accuracy



0-45°C

Operating temperature



8x

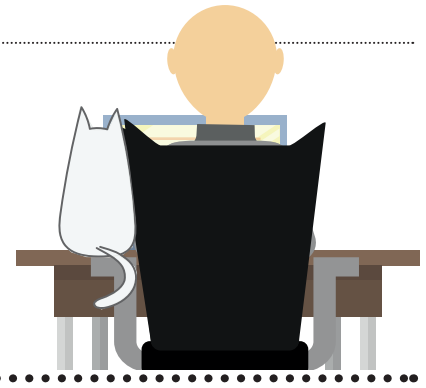
rotors for redundancy
during multicopter flight

4x

of which tiltable for redundancy
during fixed-wing flight

The Evil Engineer turns their attention to a booming area of villainy: water theft.
As reported by **Hilary Lamb**

Dear Evil Engineer



QUESTION

Could I steal a lake to top up my shark-infested moat?



The water might be there for the stealing, but moving it won't be cheap

Dear Evil Engineer, Earlier this year I bought a derelict castle. I've been busy with upkeep, dealing with a bat infestation (the previous owner had chased them out) and fixing the dungeon (it had been converted into a yoga and wellness studio). The final addition will be a shark-filled moat.

I have dug out a deep moat around my castle and now I just need to fill it. However, my water is metered, so I hesitate simply to get out the hosepipe. Could you suggest how I could empty a nearby lake in the dead of night and use the stolen water to fill my moat?

If you also have any time for transporting sharks (I can't be certain it is impossible to send them whooshing down a

pipeline, but I've never tried), that would be much appreciated.

Yours,
An aquatic villain

Dear villain, Water theft, "a crime as old as time", as we say, is enjoying a steady revival in the villainy sector. I even included it in last year's listicle, Top 10 Troublemaking Trends for the 2020s, in *Evil & Treachery Magazine*. It is poorly policed, making it a great strategic area of growth for thieves, and the sector is booming; according to Interpol, between 30 and 50 per cent of Earth's water supply is stolen every year.

Large-scale operations tend to involve tapping water supply infrastructure and redirecting it towards farming of enjoyable

plants or other water-intensive industries, including many with the appearance of legitimacy.

In your case, unless you have a nearby lake with convenient geography that would allow you to divert outflow to your moat, you will need to pump the donor lake. As you want to finish the job overnight, you will need to set up portable equipment between lake and moat.

The first thing to say is that you must ensure you have access to an industrial drainage pump, as consumer pumps are very unlikely to cut the mustard. For a moat the shape of a tinned pineapple slice, its volume is $\pi d(R^2 - r^2)$, where d is depth, R is outer radius, and r is inner radius. I don't know the size of your moat, but to get a grasp of magnitude, let's stick in some figures: for $d=10\text{m}$, $R=50\text{m}$, $r=45\text{m}$, you'll need $15,000\text{m}^3$ of water. An industrial pump, such as an Andritz wastewater and sewage drainage pump, which looks more mobile than most and pumps $10,000\text{m}^3/\text{hour}$ at 16 bar, would certainly shift enough water overnight even for a much larger moat. However, if you are stuck with consumer pumps, such as an impressive Makita model that pumps $14.4\text{m}^3/\text{hour}$, you would not be able to steal a moat's worth of water overnight (unless your moat is the size of a child's swimming pool).

Next, to the matter of transporting thousands or tens of thousands of tonnes of water between lake and moat. Although HGVs are sometimes deployed to provide water during emergencies, I would not recommend driving tanks of water back and forth between lake and moat, even if the distance is minimal. In the UK, a six-axle vehicle is not recommended to carry more than 44 tonnes, requiring hundreds of trips. So – unless there is existing pipeline infrastructure handy for hijacking – a temporary pipeline it is. Set up a temporary flexible pipeline of the sort used in the oil industry for rapid deployment: a flexible lay-flat hose of knitted nylon and polyurethane running between the lake and moat. You can purchase lay-flat hose up to

around 30cm in diameter, which can withstand around 12 bar.

Next, regarding the transport of sharks. Unless the sharks are very small (and, really, why bother?) the limited diameter of mass-produced lay-flat hose alone is a barrier to sending them whooshing o'er hill and vale into your moat. Thankfully, captive sharks are frequently carried from one place to the next, meaning there is a standard procedure to follow. This involves lowering a huge canvas shark-sized stretcher into the pool, sea, or other shark-infested body of water of your choice, forklifting the shark from the water, and immediately transferring it to a large fibreglass water tank.

Some species are content to sulk in the bottom of their tank while others, such as the great white, require constant movement and hence a tank large enough to swim in continuous loops during transit while minimising collisions with the walls. For a longer journey, consider using circulating pumps, oxygenators, skimmers, and monitoring equipment, to ensure your shark does not pass away before the night does.

Keep in mind that most species of shark cannot tolerate freshwater (river sharks and bull sharks are among the species that can) and will die if released into a lake. But I'm the Evil Engineer, not your mother, so if you want to kill some sharks, go ahead and kill some sharks. You could even get some soup out of it.

If this heist is well planned and executed, it could be completed in a single night using an HGV with a forklift to drive one big loop. Drive from castle to lake, laying hose as you go; set up pump at lake; pick up sharks using forklift and stash in back of HGV during pumping; return to lake and uninstall pump once enough time has passed to fill moat; drive back to castle rolling up hose as you go; release sharks into moat using forklift.

Good luck!

Yours,
The Evil Engineer

PS: Alternatively, you could look for an unmetered water tariff.

What's up, friends? Once again, I've managed to find a few interesting – and weird – pieces of tech for you ('tech' being a loose term for one of them). Have a nice time!

BizarreTech

By Rebecca Northfield



Engineering baby book

The quest for world domination starts at infancy

So, computers are made up of on and off signals, and this book claims to show some ways that computers combine on/off signals to do interesting things.

It's a simple board book, which is apparently designed to keep your baby engaged while they learn about the 'stuff' computers are made from. The maker of the book also recommends it to people who "skipped CE150" – whatever that is.

Maybe I need the book?

According to Chase Roberts, the gadget's creator, 'Computer Engineering for Babies' (I'm sure he could condense the title a little, right? Perhaps an acronym? CEB?) has two buttons and an LED. The book explores basic computer logic gates, including NOT, OR, AND, XOR and a Latch. It uses light sensors to detect which page is open and change the operands accordingly. So the baby is learning basic computer engineering.

Just imagine, though. You've looked at the baby monitor, and your sweet angel is missing from their bed. The sneaky wee thing has crept out, managed to leave their room, without your knowledge. Miffed, because you were enjoying your tot-free time and had just gotten comfortable, you heave your tired body off the sofa and walk up the stairs.

You see the office door is open, and you can hear the tinkering sound of the computer keyboard, as if someone is typing.

You are confused. Your partner isn't home. Oh god, it's an intruder. And where's the baby?!

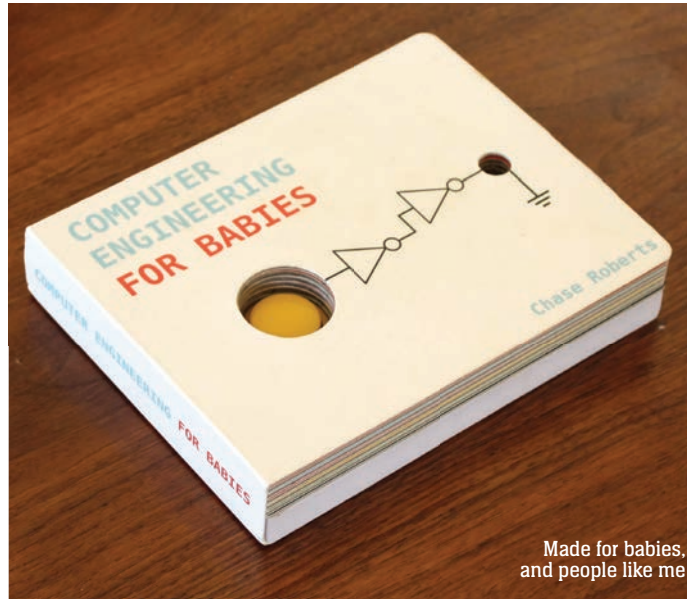
Being careful not to step on the noisy floorboards, you poke your head around the office door.

You do a double take as you see your wee one, who has managed to clamber on the swivel chair, tapping on the keys, staring intently at the screen.

You gasp in shock, and the child turns to look at you. With menace in their eyes, they whisper: "Mother, I crave violence." Then they press the enter key...

Anyway.

According to Roberts, the book is designed to be "quietly



Made for babies, and people like me



Boingy boingy seasickness seat

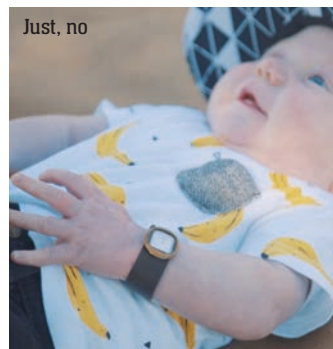
entertaining while helping build basic intuition for simple digital logic concepts". Cool.

The prototype has six pages and each page has a different function; sensors can detect which one you're on so the buttons have different functions.

For example: "When you open the AND page, the LED is only lit when both buttons are pressed," says Roberts. "And when you are open on the NOT page the LED is on as long as the button is NOT being pressed. And each page lights the LED with a different colour." Yep. Simple pimple, am I right? Had to read that through a couple of times.

The book should supposedly last about a year and a half and has a replaceable battery. It's primarily made of 'greyboard', which is 100 per cent recyclable, and will be shipped using no plastics. Wooh.

computerengineeringforbabies.com



Just, no

MOWO furniture

Sea-sickening furniture

Do you want a weird, bendy seat that makes you move and feel a bit out of sorts?

MOWO furniture is apparently anything but an ordinary seat. Well, yeah, it looks like you can't actually relax on it.

I'd be all like "just going to pop a squat on here, oop, no can do, can't do that, it's moving... let me try and switch... no, no, that's moving too. How's about I... oh, nope, can't do that... you know what, I'm just going to stand up."

The company sells stools and mats, and they're not solid. You can apparently feel the shape bend and twist when you sit down. Just what I need after a long day is the inability to stay seated. Every move you make "is mirrored in the structure beneath you" and it turns sitting into a "an active and playful experience".

I'd rather have a seat that, ya know, seats me?

According to the creators, MOWO stools make you move, swing, bounce and wiggle. The mats are springy yet supportive though, so you can relax... ish. There's no backrest, so you'll have to maintain your posture.

MOWO says changing positions regularly when seated can make a positive difference to our bodies and, according to their research, we move on average 53 times per hour when seated. "Simply said, people are 'unstable'." That's 100 per cent me. Fidgety and unstable. MOWO reckons chairs should accommodate body movement.

So how do the stools and mats get so springy, you may ask? Is it magic? Science genius?

Actually, they're made of thin and curved plywood to give its bounciness. SURPRISE.

bit.ly/3umYZG8

Baby watch

Shoot me now

"Finally, a baby accessory specifically for swag."

I literally have no idea why a baby would ever require or want 'swag'. It is a baby.

The person who purchases this for their little'un... I would happily punch them in the face.

What kind of idiot would want this for their baby?! They can't count yet. Also... THEY DON'T EVEN KNOW HOW TO CONTROL THEIR OWN WEE AND BODY MOVEMENTS.

I'm talking about the baby here. Then again, it can apply for whoever decides this would be a good addition to their child's everyday wear.

The adjustable hole sizes mean your baby can wear their watch until they're about four years old. Fantastic.

Winston's Watches are made of leather and wood and come in black, brown and camo. With camo at least you can joke about it being invisible.

Oh yeah, forgot to mention. It's not actually a real watch! It has no battery and is 'set' to the baby's birth date.

Good lord.

You can follow them on Instagram @winstonswatches if you really want to.

bit.ly/3kQ4Wbn

TV presenter Dr Shini Somara talks to **Dr Joanna Sadler**, a BBSRC Discovery Fellow in the School of Biological Sciences at the University of Edinburgh.

BackStory

by Shini Somara



BACK STORY

'We need to stay driven by what motivates us, not by what motivates other people.'



You are working to develop biological methods to recycle plastic sustainably into higher value chemicals. Tell us more.

Most of the research done so far focuses on breaking down or melting down the plastic and reforming it into more forms of plastic – many of which are of a lower grade than the first-generation polymer. Instead, I'd like to turn plastic into a resource by using it as a feedstock for making industrial chemicals. I'm a chemist by training, so I have always been fascinated by the ways in which we can make the chemical industry more sustainable. The chemical industry is responsible for vast amounts of greenhouse gas emissions, so I think finding ways to tackle this while addressing the plastic waste crisis is really interesting.

How did your career develop? Sustainability drives me and I'm

trying to do something to ensure a slightly more sustainable planet for future generations. After my undergraduate degree, I did an industrial PhD at Glaxo-SmithKline in collaboration with Strathclyde University. This gave me the opportunity to work at the interface between industry and academia to see academic breakthroughs have a real-world impact.

What is it like for you being a woman in STEM?

The gender ratio is about 50:50 at undergraduate level in my field, which is very encouraging. But, unfortunately, as you move up the career stages, it drops off. As soon as you get to group leader and professor level, it's very much still weighted towards male dominance.

For me, however, these statistics have been a driver and not a disincentive; it makes me want to help drive change. I want

to be a role model to other young women and say, 'look, this is possible. You can do this. You can still have a life. You can still do and have many other things.' But we just need enough of us to lead by example.

What makes women turn away from a career in STEM?

Quite honestly, I think one of the biggest disincentives is the myth that you can't have a family and be an academic. And that's something which I was told when I was doing my PhD and undergraduate degree – people saying that they left academia to have a family and you can't do both. I found the whole thing so worrying for such a long time.

I think there has also been a real lack of role models and a lack of females in high positions in universities. It is changing, in fact, I've recently been appointed as a Chancellor's Fellow at Edinburgh University. In these

positions, they specifically want to see a 50:50 gender ratio, which I believe is a positive step forward in trying to change this kind of culture for the future. The universities are certainly doing things to address this, but we need to just do more of it.

As a mentor, what advice do you have for your mentees?

The overarching thing is to really follow your gut instinct. We always have a feeling of what the right and wrong thing is. In the end, it's your career, it's your life and you've got ownership over that. We need to stay driven by what motivates us, not by what motivates other people.

What has been the most useful advice you have been given from mentors?

It's the little comments such as 'don't give up' or 'you can do this', that have stuck in my mind or clinched it for me. Although they will not have realised it at the time, those little comments really made the difference and convinced me to follow my dream of becoming an academic.

What makes a good mentor?

Not telling people what to do but being a sounding board and facilitator. Everybody is different and I don't think you can impose your experiences on somebody else's life. Everybody has their own ambitions but working out what that is for each individual and then helping them to facilitate this is key.

What are your views on equality, diversity and inclusion (ED&I)?

Equality and diversity are beneficial for innovation in both academic and industrial environments. There have been long-term studies to prove this. It's important not just on a personal level for the careers and quality of lives of a diverse group of people; it's important for science. The biggest breakthroughs come through diverse teams working on a problem because they bring a wider range of experiences and the collective thinking is more creative. So, I think ED&I is crucial – we don't have a choice, it is something we have to do. *

Continuing his campervanning adventures, our columnist introduces to the readers his fleshless, yet vociferous, techno-travel companions.

AfterAll

by Vitali Vitaliev



TRAVEL

Four voices in a campervan (to say nothing of the bark)



THERE WERE not three, but four of us, in that relationship. To say nothing of the dog...

All four (or five) of us were stuck inside the moving Toyota Alphard (aka Alphie) converted campervan. No wonder the atmosphere inside it was often volatile.

"You are over the speed limit!" George would crackle in his rough ear-grating voice.

"Oh, George, here you go again!" my wife would exclaim. "Don't you see that we are actually standing in a queue?"

"Yes, George, why don't you shut up once and for all?" I would echo from the driver's seat.

"At the roundabout in 800 metres, take the third exit and turn right," Liz would butt in. She spoke with a posh accent, which made her sound permanently annoyed...

Heading for Dumfries, I was driving Alphie through the Scottish Borders, which H V Morton once described as a "queer compromise between fairyland and battlefield". It was our fifth camping journey this year, and by now I could proudly admit that we had learned the basics of campervanning. Gone were the times when it took us over two hours to set up camp. We

came to discover the advantages of a concerted team effort, with me unloading Alphie, setting up a storage tent and starting the fire, my wife turning around the seats inside the salon (easier said than done) to create a comfy Pavarotti-size bed, and Tashi, our fluffy Tibetan terrier, sitting on the grass chewing on a bone and barking half-heartedly at the low-flying birds, or bats (depending on the season). Each of us knew what to do, and we hardly spoke until everything was ready for an unhurried evening feast around the bonfire.

Packing up in the morning was a tad more cumbersome, but not half as tricky as finding our next camping place. For some reason, most campsites are in the middle of nowhere. They are connected to the rest of the world by narrow and often unpaved unnamed paths, consisting almost entirely of bumps and potholes. In Russia, they aptly refer to such locations as 'bears' corners'.

It is here that satnavs, with their dubious ability to make no distinction between a motorway and a permanently deserted country road (because they tend to calculate your route by distance alone, you see), come

into the picture: tired after spending the best part of the morning packing up, you don't want to worry about how to negotiate every road turn and roundabout.

We inherited 'George the SatNav' (that was how my wife monikered him) as part of an outdated sound system that bore more than a passing resemblance to the original Game Boy and was firmly embedded into the dashboard of our Toyota Alphard, made in Japan, yet converted into a campervan in the UK some years later. Operated via a series of buttons and with no touchscreen, the system was clearly antediluvian. With his favourite mantra being the cantankerous and crackling "You are over the speed limit!", often voiced when the car was stationary, George was useless. No wonder that soon we started referring to him as "our SatNag"!

George's other annoying eccentricity was to triumphantly announce "Route recalculation!" at the most inappropriate moments, such as when negotiating a seemingly endless roundabout – an unasked-for intervention that could easily lead to an accident.

Why didn't we get rid of George straight away, you may ask? Well, just like turning around the seats inside our campervan, that was much easier said than done. George proved to be extremely resilient and – like a courageous voice of the determined political opposition in a totalitarian country – utterly irrepressible. Not just ourselves, but a number of experienced audio technicians were unable to silence him completely.

Not quite defeated, George remained grossly unreliable, so we started using a Google Maps satnav from my wife's smartphone instead. 'Liz' was how we christened the pleasant female voice – a direct opposite of George's, best described as the half-hearted drawl of a life-long geezer. Liz was posh, precise and matter-of-fact, her only eccentricity being an unbridled affection for bridleways and semi-abandoned trails where she would send the not-so-tiny Alphie without the slightest hesitation,

as if directing him (it) to a toll-free flyover or an autobahn. As a result, I once had to back down a super-narrow dirt track for about a mile to give way to a farm tractor. On another occasion, we got stuck on top of a small mountain on 'the roof of England', i.e. in the Pennines, and I was only able to retreat after several dozen frantic three-point turns on the edge of a steep drop.

As you see, having two vociferous and mutually incompatible satnavs inside one vehicle, with George's demented "route recalculations" in the middle of Liz's instructions on how to negotiate yet another octopus-like giant roundabout, is not conducive to successful navigation. And here I'd like to urge all members of my Virtual Campervanning Club (see *E&T* June 2021) to be very careful when choosing their satnavs, which (who) – like pets – are not just for Christmas. Whether you want it or not, you end up forming an almost intimate relationship with them, for how can it be otherwise when they become directly responsible for the lives of yourself and your campervan companions? In my dreams, I can see a new generation of satnavs that could be interviewed before you buy them to allow you to decide whether you like their voices, accents, and manners. Ideally, you should be able to take them on a test drive to see if you could work together as a team. Because teamwork, as I have already said in this column, is a guarantee of successful campervanning!

...Well, unlike that of George, Liz's speech has always been formal. Therefore, it came as a surprise when at some point in our trip to Scotland I heard her say: "In 500 metres, turn left towards Devil's Porridge!"

My first thought was that she has somehow – perhaps under George's corruptive influence – learned to swear. But then I spotted a road sign: 'Devil's Porridge'. We followed it and soon arrived to one of many engineering wonders of Dumfries & Galloway. Which wonders? With Liz's and George's help, I will navigate you around them in my next column. *