SPECIAL REPORT

CLIMATE CHANGE: PROBLEM SOLVED

It's not too late to save the planet: **Alistair Welch** and **Max Mueller** investigate the technologies that could make the biggest difference

TOWARDS THE END of 2014, the Intergovernmental Panel On Climate Change (IPCC) released its latest report, produced by over 800 scientists. It said the impact of climate change is far-reaching, both on the environment and on us. Changes linked to human activity include increases in extreme temperatures, high sea levels and heavy rain.

According to the IPCC, if climate change is left unchecked, global warming could be irreversible by the time the 21st Century comes to a close.

But there is still hope. The IPCC says we can tackle the problem by cutting our emissions and investing in environmentally sound technologies, energy supplies and infrastructures. This, then, is *Focus* magazine's very own guide to the ideas and technology that could do just that. Read on to find out how we'll save our planet.

PHOTO: KYOCERA. ILLUSTRATOR: STEVEN BONNER

"THE OPPORTUNITY OFFERED BY FLOATING SOLAR IS ESPECIALLY APPEALING IN COUNTRIES WHERE LAND IS AT A PREMIUM"

SET UP SOLAR FARMS AT SEA

THERE HAS BEEN a recent drive to site solar farms in more adventurous locations to make the most of the formidable clean energy resource that is offered to us by the Sun's rays.

Such is the pull of solar power that in September 2014 the heirs to the Rockefeller fortune announced that they were to sell investments in fossil fuels. They want to reinvest in clean technology – solar photovoltaics in particular. It's an interesting departure, considering that the family made its fortune in the American oil industry.

Solar panels started on the rooftops and then moved into fields, but now developers are experimenting with constructing them on water. In September 2014, the UK's first floating solar array was built on a reservoir located on a Berkshire farm. The 200kW solar panel system will reduce the farm's energy bills as well as slash its carbon emissions.

In the UK, floating solar is attractive because deploying it avoids the criticism levelled at land-based projects that they waste valuable agricultural real estate. The opportunity offered by floating solar is especially appealing in countries where land availability is at a premium. Indeed, Japanese electronics manufacturer Kyocera recently announced plans to build the world's largest floating solar power plant. The installation is to include 11,000 PV panels over two lakes in Japan's Kato City. The sites would be capable of generating 2.9MW of electricity – enough to serve the requirements of nearly 1,000 homes.

Kyocera's proposed solar power plant would contain 11,000 PV panels

PHOTO: ALTAEROS, MAKANI ENERGY

The high-flying Buoyant Airborne Turbine captures more wind than traditional turbines

"NOW THE LAND AND SEA HAVE BEEN CONQUERED, SCIENTISTS AND ENGINEERS ARE LOOKING TO TACKLE THE SKIES"

BUILD WIND FARMS IN THE SKY

WIND ENERGY IS taking off. Onshore wind farms are now a common sight, while a number of new offshore sites are in the planning stages. Take, for example, the proposed Dogger Bank offshore wind farm, which is awaiting planning approval. The site will be 125km (78 miles) from shore at its nearest point and, when completed, will have a capacity of 7.2GW. To put this into context, its capacity would eclipse the installed capacity of all the UK's onshore wind farms put together.

Now the land and sea have been conquered, US scientists and engineers are looking to tackle the skies. Altaeros Energies, which is a spinout from the Massachusetts Institute of Technology, is currently developing a device that will generate energy from the strong, steady winds hundreds of metres above the Earth's surface.

The company hopes that its concept, the Buoyant Airborne Turbine (BAT), will be the world's first commercial aerial wind turbine. The device incorporates a three-blade horizontal axis wind turbine – the conventional configuration we are used to seeing in onshore and offshore turbines – held within an inflatable shell. When filled with helium, it floats into the air where it is held in place by tethers at a maximum height of 600m (2,000 feet).

At this altitude, the wind power density is three times that found at 120 metres, which is the typical height of an onshore wind turbine. The BAT features an autonomous control system that adjusts the device's direction and altitude to maximise its energy output. Electricity generated is transferred to a ground station by a connection in the tether. From here, it can be introduced to the grid or used to power equipment on site.

Initially, the company plans to develop a 30kW system with plans to scale up to 100 and 200kW devices. An array of ten 200kW BATs would thus have a similar capacity to a typical onshore wind turbine. And at a height of around 600m, it is unlikely to disrupt anyone's view of the landscape.

Altaeros is not the only player in the high altitude wind game – a range of competitors with various ingenious technologies are also attempting to get their concepts off the ground.

Makani, which was acquired by Google in May 2013, is developing an 'Energy Kite' in an effort to capitalise on the wind resource at altitudes beyond the reach of conventional turbines. The kite is a tethered aerofoil that makes huge loops through the sky. As the wind rushes across the kite it rotates four mounted turbines. Meanwhile, Netherlands-based Ampyx Power is developing an auto-piloted glider that generates electricity as the tether fastening it to the ground station is extended.

The Makani kite flies at altitudes of up to 305 metres

"ENERGY STORAGE IS A CRUCIAL ASPECT OF A SECURE ENERGY FUTURE"

SUPERSIZE BATTERIES

THE ENERGY NETWORKS of the future will contain a higher proportion of energy from renewable sources than we have at present. But renewable energy resources are intermittent: a turbine can only generate power when the wind blows, a solar PV panel when the Sun shines. This intermittency means that energy storage is a crucial aspect of ensuring a secure energy future.

In university laboratories across the world, scientists are working on developing more efficient batteries with larger capacities and higher power densities. However, the battery is not the only energy storage solution. UK company Isentropic has developed an innovative Pumped Heat Energy Storage (PHES) system.

The PHES system operates as both an engine and a heat pump. Fundamentally, electrical energy is stored as the temperature difference between hot and cold rocks. When the 'battery' needs to be charged, spare energy can be used to compress argon gas until it reaches 500°C. This hot gas is then used to heat up rocks, transferring the energy and storing it temporarily. The gas emerges from the rocks at atmospheric pressure (1 bar) and a temperature of -160°C.

To release the energy that is stored in the rock, the process is reversed. The argon gas flows in the opposite direction; this causes the gas to heat up so that it can be used to generate electricity through a mechanical engine.

The company is currently rolling out small (up to 1.5MW) and medium-scale (up to 50MW) PHES systems for businesses, but has plans to develop large scale (100MW+) systems for the electricity grid.

Isentropic's Pumped Heat Energy Storage System acts like a giant battery and could be developed to feed energy into the National Grid

By smartening up the power grid, we could use energy much more efficiently

MAKE THE GRID SMARTER

NO SINGLE TECHNOLOGY can hope to solve our energy needs. But some could make a big difference. One idea is called the 'smart grid'. The grid is the network of cables, transformers and substations that deliver electricity to your home from a power station. The smart grid is all about building intelligence into the network to make the most efficient use of energy.

It could do a lot to mitigate the impact of climate change. A US report entitled *Machine-To-Machine Technologies: Unlocking The Potential Of A $1 Trillion Industry* was published in 2013 by the dramatically titled US body Carbon War Room. The report estimated that smart grids could slash global greenhouse gas emissions by a fifth by 2020.

The smart grid would work by balancing the demand for energy. In future, we'll have variety of renewable energy sources, as well as innovative energy storage systems such as PHES (see left).

Take electric vehicles, for instance, which would help to reduce carbon emissions. The vehicles will need to be charged, placing a burden on the electricity network. A smart grid would help to balance this extra pressure. Imagine returning home from work and plugging in your car. With a smart grid, the vehicle would not start charging instantly; instead, it would wait until the middle of the night when wind turbines are rotating but there is lower demand for energy.

To take this further, electric vehicles aggregated across a residential street or a company fleet could provide a useful energy storage resource. The batteries could be charged at periods of low demand, therefore making use of generation that would otherwise be surplus. At peak periods, they could return energy into the grid with the owner receiving a payment for electricity fed back in. Behind the scenes, computers will be managing demand.

PHOTO: ISENTROPIC, CORBIS

“IF WE’RE AGONISING OVER WHETHER WE USE PAPER OR PLASTIC, WE MIGHT MISS INCREDIBLE POSSIBILITIES”

THINKING ABOUT ‘GOING GREEN’?

Dr Michael Maniates explains why saving the planet one purchase at a time won’t cut it

Can energy-saving light bulbs save the planet?

This idea that you save the world one small purchase at a time is quite entrenched. Some environmental groups have been operating off this ‘escalator’ effect. They think that if they can get us to buy an energy efficient light bulb today, it might prime us to be more politically active on energy issues tomorrow. It would be great if that theory were true. But most of the evidence suggests that small acts of consumption aren’t as politically activating as we’d hope. It makes sense that people would think that you could save the world one purchase at a time, but unfortunately it’s probably not a complete solution.

But it must help?

It does. Buying energy-saving light bulbs, using bags for life and riding your bike to work are the correct choices. They’re the *right* thing to do and it’s what we should be doing, but we can’t imagine it’s going to solve the problem. It’s important to walk little old ladies across the road but it’s not going to solve global conflict.

There is this idea that if *everyone* switched to energy saving light bulbs we could cut out something like 16 coal-powered power stations, but this idea propagates a theory of social change that says “to get anything done socially or politically, everyone has to get on board”, which simply isn’t true.

Is there any harm to it?

The danger is that you end up being drawn into a politics of guilt. So you’re doing your own little thing, but then you’ve got to convince everybody else to do the same to get anywhere. This is why we [environmentalists] never get invited to parties. Because we’re going to show up and the host is going to get criticism for using paper plates or something. I don’t think there’s a conspiracy to defang the environmental movement, but if there was, then this is what they would have us do.

What should we do?

One of the challenges is that we may have confused theology with good strategy. We want to bring everyone to the ‘church of Gaia’, but good strategy may mean just getting a few of us together to rejig these harmful systems. I think there are incredible possibilities out there and if we’re sitting at the checkout agonising over whether we use paper or plastic, we might miss them. It only takes a small number of people working together to start shifting these systems. Just get you and eight of your friends together and you can start affecting the system in interesting ways.

Farmers’ markets in the US have been a great example. The first few markets initially emerged not because of some outcry of consumer demand, but because a few people came together and made it happen. Then it became natural, and more and more opened across the US. Soon, shopping at markets rather than the superstores became the most natural thing to do for many people.

So is there hope?

In the US, about 20 per cent of the population are committed green consumers. Most people in this group see that figure and think it’s awful – they can’t believe it. But from another perspective, 20 per cent is fantastic; Gandhi would have killed for those numbers. I think that’s what a lot of this comes down to: the sense of the possible and the faith in human nature to do some amazing things. If your path to a better world says that you’ve got to convince 80 per cent of people to do the same thing as you, you’re going to miss the possibility of what smaller groups can do. And of course, if you take this idea further and look at the advances in the world of science and technology, these really underscore the ability of small groups of people to make a big change.

MICHAEL MANIATES heads up the environmental studies programme at Yale-NUS College in Singapore

MAKE CARBON VALUABLE

IS IT POSSIBLE to ‘clean’ emissions from traditional carbon-emitting forms of energy generation so that the waste carbon dioxide never actually reaches the atmosphere? Carbon Capture and Storage (CCS) aims to do just that. Despite the various renewable energy technologies in operation or development, some carbon-emitting forms of energy generation, such as the burning of fossil fuels, will undoubtedly remain part of our energy mix.

Carbon Capture and Storage (CCS) removes CO_2 at the point of generation – at power plants and factories, for example. The industry has been around for a little while, with the first commercial CCS demonstration taking place in 2000. Nevertheless, the tech involved is becoming increasingly sophisticated.

A CCS system involves a host of technologies linked together in a chain: the capture of carbon dioxide at source, its transportation through a pipeline, and then its sequestration (safe storage). Efforts to improve the efficiency of capture, therefore eliminating a higher proportion of carbon dioxide from emissions, are ongoing.

Prof Peter Eisenberger, a researcher at Columbia University in the US, is taking things a stage further and hopes to build a machine that could suck carbon dioxide out of the atmosphere. His company, Global Thermostat, has installed a demonstrator of its air capture machine in Silicon Valley. Fans within a rectangular tower draw in air over surfaces called ‘contractors’. Each contractor comprises 640 cubes containing a capture agent called amine sorbent that strips CO_2 from ambient air.

The main obstacle, as is so often the case, is money. CCS systems involve huge capital investment, so aren’t necessarily that appealing to the owners of power stations. “New research and development will lead to better and lower cost solutions,” says Dr Ward Goldthorpe, programme manager for CCS at The Crown Estate in the UK. “However, the real issue is the financial challenge. Currently, there is no market to dispose of carbon dioxide because society does not put a realistic price on the cost of carbon pollution.”

If governments introduced schemes whereby companies were offered £50 per tonne of carbon, for example, they might be encouraged to extract CO_2 from the environment.

Carbon Engineering is another company that thinks it is possible to ‘scrub’ CO_2 from the air. This is an artist’s impression of its technology

“THERE IS NO MARKET TO DISPOSE OF CO_2 BECAUSE SOCIETY DOES NOT PUT A PRICE ON CARBON’S COST”

PHOTO: YALE UNIVERSITY, ALAMY, CARBON ENGINEERING

FERTILISE THE OCEAN

GEOENGINEERING describes ways to reduce global warming by removing carbon dioxide from the atmosphere or managing solar radiation. Taking the emphasis away from reducing greenhouse gas emissions has caused controversy, but some researchers say it's far too late to disregard the approach.

In 1988, the late oceanographer John Martin quipped, "Give me a half tanker of iron and I will give you another Ice Age". He said that a huge amount of iron dumped into the ocean would act as a fertiliser and cause plankton growth to increase. During photosynthesis, plankton draws CO_2 from the atmosphere – more plankton would mean more CO_2 absorbed, therefore slowing global warming. His idea caused enough of a storm to bring about a research effort.

"The scientific community hasn't done enough research yet to evaluate iron fertilisation as an effective carbon sequestration option," says Dr Kenneth Coale from Moss Landings Marine Laboratories, California State University. "Whether the carbon would be bound by the plankton for long periods of time remains one of the big open questions." Coale is adamant that it would need to be part of a wider strategy for CO_2 reduction and removal. "Reversing the trend would need a reduction in CO_2 emissions and a variety of mitigation measures, including geological sequestration. If effective, iron fertilisation could be part of a larger geoengineering portfolio," he concludes.

Plankton blooms, such as these in the Barents Sea, could lock up CO_2 from the atmosphere

"GIVE ME A HALF TANKER OF IRON AND I WILL GIVE YOU ANOTHER ICE AGE"

PHOTO: NASA, MINDEN PICTURES/FLPA, JOHN MACNEILL

CONTROL THE RAIN

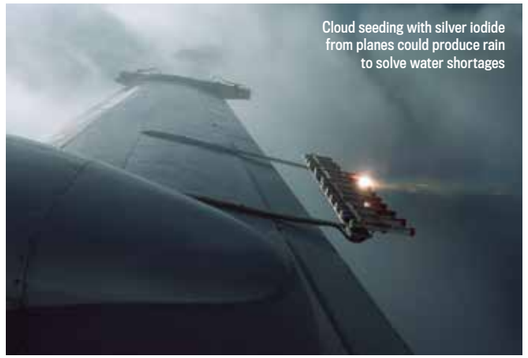
DROUGHT AFFECTS EVER larger areas of the planet. Most of the Arab world now falls under the classification of 'extreme water scarcity', as defined by the United Nations. North Africa and the Middle East are also facing rapid population growth – Yemen's population, for example, is expected to more than double by 2050, making large-scale water wars a real possibility.

A technology that may bring relief is cloud seeding. The use of silver iodide particles to act as tiny kernels for the formation of raindrops goes back a long way: it was pioneered in 1946 at General Electric by Bernard Vonnegut. His brother, Kurt Vonnegut, would later fictionalise the invention as Ice-Nine, a substance capable of instantly freezing all water on Earth.

Far from producing a freezing effect, silver iodide – alongside other substances such as salt or propane – is said to enhance rainfall. Cloud seeding from planes offers large savings over desalination, which costs around 50 to 60 US cents per cubic metre, according to Prof Zev Levin at the Energy, Environment and Water Research Centre of Cyprus. "If you can prove that it works, it's the cheapest solution, at three cents per cubic metre. It also avoids the need for expensive irrigation systems. The disadvantage is that it cannot be guaranteed to work when and where you want it to," the cloud and precipitation expert says.

Despite six decades of research, the jury is still out on cloud seeding. Science demands data, and comparison with unseeded clouds within the same weather system is notoriously difficult. Unperturbed, 37 countries are currently running over 150 weather modification programmes, according to the National Centre for Atmospheric Research in Colorado (NCAR). Scientists at NCAR are hopeful that their extensive statistical analysis will prove whether or not cloud seeding is feasible.

It may prevent wars. The Pacific Institute for Studies in Development, Environment and Security has recorded more than 100 conflict situations over water in the Middle East and North Africa (MENA) region. More than 250 people were killed in clashes over wells and pastoral lands in Somalia and Ethiopia between 2004 and 2006. Then again, countries might perceive cloud seeding as stealing 'their' water if they experience droughts. It may not be the panacea we're hoping for.



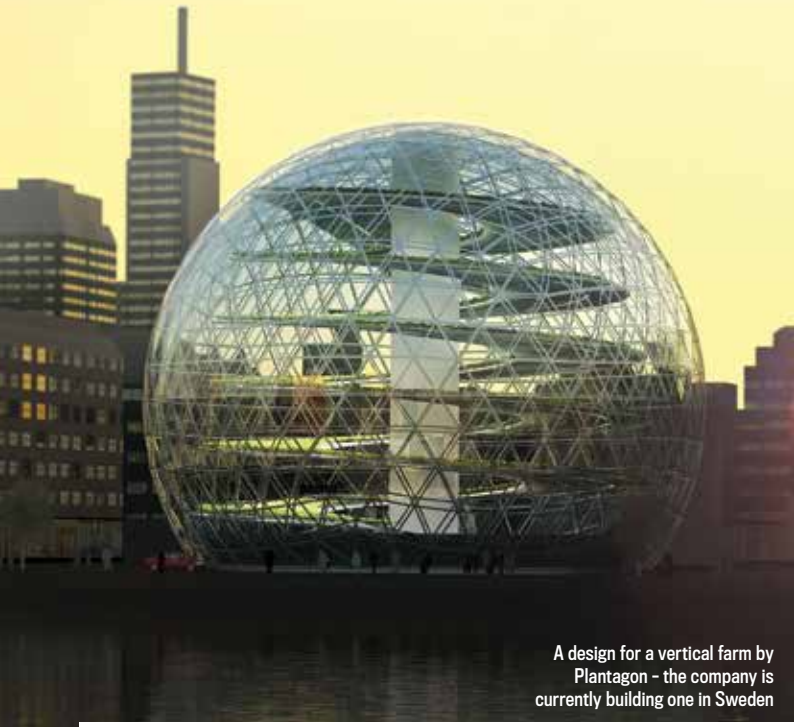
Cloud seeding with silver iodide from planes could produce rain to solve water shortages

Wind-powered yachts could blast seawater into the sky

WHITEN THE CLOUDS

ANOTHER DISCIPLINE OF geoengineering is solar radiation management. Unlike more outlandish proposals such as installing mirrors in space, scientists consider marine cloud brightening a more viable option. Researchers talk about two variants of Cloud Reflectivity Modification: cirrus stripping and marine cloud brightening. Thinning or 'stripping' high cirrus cloud would allow infrared radiation from the Earth to escape into space and result in a cooling effect. In turn, making low clouds more reflective could also reduce temperatures by taking advantage of the Twomey Effect, which is named after the Irish meteorologist Sean Twomey. The phenomenon describes how smaller water droplets lead to a 'whitening' of vapour in the atmosphere, which causes more sunlight to be reflected. Reducing the size of the droplets can be achieved with cloud seeding techniques, such as spraying seawater solutions from ships. Researchers at the Max Planck Institute for Meteorology in Hamburg, Germany are currently evaluating the approach. Dr Hauke Schmidt has been investigating the method's outlook as part of the international Geoengineering Model Intercomparison Project (GeoMIP). "One potential side effect is that we would have to commit to the technology – probably for centuries – otherwise climate change would quickly catch up," the geoengineering specialist says. Despite this, Schmidt thinks that the benefits might just outweigh the risks, and he encourages debate: "We must recognise that these proposals are on the table. The most sensible course of action is to try and fully understand the risks, side effects and positive outcomes such interventions are likely to have."

“IF YOU CAN COOL THE SEA SURFACE, YOU WOULD CALM THE HURRICANES”



A design for a vertical farm by Plantagon – the company is currently building one in Sweden

FARM VERTICALLY

AT PRESENT, THE World Health Organization estimates that half of the world’s inhabitants live in cities. By the year 2050, this will increase to 80 per cent. By 2050, the world’s population will have grown by three billion people and an additional space exceeding the size of Brazil will be required to grow enough food to feed everyone on the planet.

If over three-quarters of the world’s food is to be consumed in urban areas, wouldn’t it make sense to produce some of it in the cities themselves? It’s an idea that prompted Columbia University scientist Prof Dickson Despommier to pioneer the idea of Vertical Farming. The microbiology and public health scientist thinks that in terms of area usage, his concept could outperform conventional farming by a factor of 10.

The key thought behind the technology is to grow food crops across several storeys. There would be rotating access to sunlight or recently improved LED Grow Lights. Buildings would be put to double use, with space for office or living spaces as well as plant cultivation. “There is a duality to this. Yes, we need to produce food and conserve water. But we also need to start repairing damage to the ecosystems,” Despommier explains. “With vertical farming, every indoor acre will allow 10 acres outdoors to be returned to growing what we need to soak up carbon, and that is hardwood forests.”

Many fellow developers agree – Despommier’s idea is being implemented in different guises around the world, most notably at Pasona O2 in Tokyo, Japan. This pesticide-free urban farm is open to the public and occupies the ground and first floors, while a human resource company works across the other storeys.

HIT BACK AT HURRICANES

THE LAST TWO centuries have seen hurricanes claim the lives of over 1.9 million people. They cause various problems, including destruction of infrastructure and the spread of disease. Damage wreaked by 2005’s Hurricane Katrina cost $108 billion to repair. It is likely that increasing global temperature may cause more devastating storms.

A typical Category 3 hurricane can produce energy equivalent to 10,000 nuclear bombs. Confronted with such force, can we really stop them? Billionaire philanthropist Bill Gates and British engineering professor Stephen Salter recently filed a patent with for a system of giant tubes extending 100m deep into the ocean. The system would mix water of different temperatures, therefore keeping the ocean’s surface below 26.5°C – the critical level at which hurricanes form. Gates’s effort is not his first. In 2009 he patented similar technology that relied on barges equipped with pumps and conduits. It was dismissed by some scientists who said the boats couldn’t dredge up enough cold water within the time window offered in hurricane prediction.

This time, Gates and his team are more optimistic. Salter is confident he has fixed any problems, but thinks more funding is required. “If you can cool the sea surface, you would calm the hurricanes,” Salter says. “I estimate you would need about 150-450 of these structures. They would drift around and send out radar signals so that nothing would collide with them.”

Engineering professor Stephen Salter at work in the lab on an earlier project

PHOTO: MURDO MACLEOD, REX

ALISTAIR WELCH and MAX MUELLER are science journalists with particular interests in technology and engineering