

The **Manchester Report**

A search for the world's most
promising solutions to climate change

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The Manchester Report

Foreword by **Dan Reicher** Director of climate change and energy initiatives at **Google**



Working on climate change can at times feel like the ultimate test of optimism. Even the most upbeat among us can't help but occasionally feel worn down by the drip-feed of scientific reports, each of which seems to predict impacts sooner and more alarming than we previously expected. Although we urgently need to keep abreast of the science and be realistic in our assessments of what's coming, it's even more important that we don't allow pessimism to lessen our determination to solve the climate problem. If we act fast, we still have the chance to avoid disastrous global warming, but we'll need to fully exploit that most precious of renewable resources: human ingenuity.

The whole Manchester Report project encapsulates this spirit of innovation and positive thinking, so it was with great pleasure that I accepted the invitation to be on the panel. To come up with this report, myself and the other panellists - chaired by Lord Bingham - sat for two days of fascinating "hearings" in Manchester Town Hall, a remarkable feat of neo-gothic architecture that speaks volumes of what humans are capable of when armed with determination and self-belief.

The ideas discussed in Manchester couldn't have ranged more widely but all the presentations were authoritative and fascinating. Together they conveyed strongly the message that we have the tools and imagination needed to tackle climate change. We hope this conclusion - and this report - will help foster the other essential pieces of the puzzle: public engagement and political will.





About the **Manchester Report**

The Manchester Report is a unique search for the most promising solutions to climate change. An open submissions process invited applications from advocates of all kinds of approaches, including clean-energy technologies, geoengineering schemes, finance mechanisms and ways to bring about greener behaviour. Twenty applicants were shortlisted and given the chance to present their solution to a high-calibre panel of experts during a two-day public event in Manchester Town Hall.

The panel, in consultation with eminent scientist John Schellnhuber, selected the 10 schemes they felt were particularly worthy of attention. However, all the presentations were well received, and all 20 are written up briefly in this document.

The Manchester Report was commissioned jointly by the Guardian and the Manchester International Festival. We are grateful to Ed Miliband, the UK's secretary of state for energy and climate change, for attending and speaking at the event.

The panel



Chair: Lord Bingham
Senior Lord of Appeal in Ordinary until 2008. Previously Lord Chief Justice (the most senior judge in England and Wales), Master of the Rolls and a QC.



Dan Reicher
Director of climate change and energy initiatives at Google. Previously member of President Obama's Transition Team and assistant energy secretary under President Clinton.



Chris Goodall
Energy expert, business consultant and editor of carboncommentary.com. Author of books including the Green Guide for Business and Ten Technologies to Save the Planet.



Bryony Worthington
Climate change policy expert who has worked for government, NGOs and businesses. Founder of sandbag.org and a member of the team that drafted the UK's Climate Change bill.

Scientific adviser



Prof John Schellnhuber
Physicist, climate scientist and founder of the Potsdam Institute for Climate Impact Research. IPCC member and previously chief climate advisor to the German G8-EU twin presidency.

Team

Editor and writer Duncan Clark • **Concept** Ian Katz & Alex Poots • **Event production** Christine Gettins & Dafydd Launder • **Art Director** Daniel Coupe • **Graphics** Paul Scruton



THE TOP 10 IDEAS

The following ten ideas were selected by the panel as the most promising. They are presented in no particular order

1

CSP in the deserts

Creating colossal amounts of energy using solar thermal power stations in desert regions

Concentrating solar power (CSP) involves using arrays of mirrors to focus large amounts of sunlight on to a small area. This creates extremely high levels of heat, which can be converted into electricity using a steam turbine or Stirling engine - or stored in tanks of molten salt for use at night or on cloudy days. The mirrors can be parabolic troughs or giant dishes. Alternatively, a large number of sun-tracking flat mirrors can direct sunlight to the top of a so-called "power tower".

According to advocate Gerry Wolff, coordinator of the British wing of the Desertec project, the world could slash emissions and improve energy security by putting large CSP plants in the Sahara and other desert regions. Wolff estimates that less than 1% of the world's deserts would provide enough space to produce as much electricity as the world currently consumes. An area of just 139km by 139km could match current EU power consumption. As a bonus, the waste heat from the electricity generation could be used to provide desalinated water to dry regions, and the shade of the mirrors could facilitate horticulture in areas usually too hot to support it.

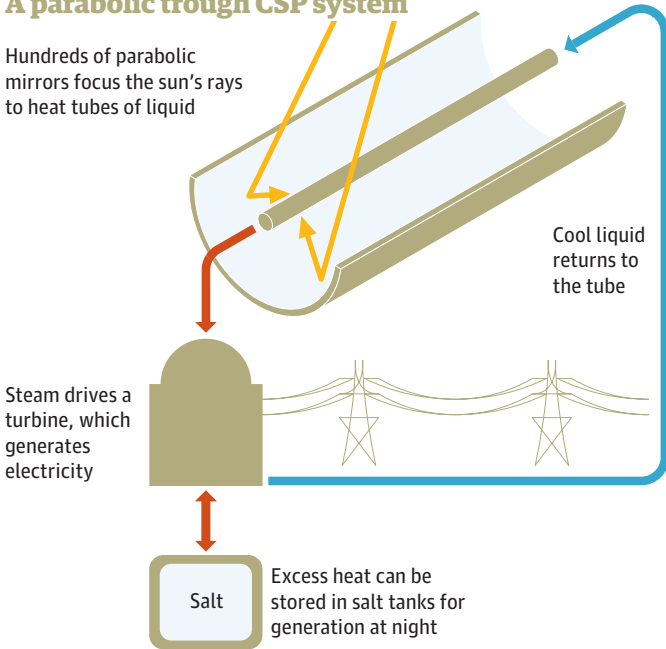
Electricity from the deserts could be transferred to population centres thousands of miles away using high-voltage direct-current cables. Similar cables could connect existing grids to large wind farms, hydroelectric

VERDICT

The panel consider desert-based CSP to be among the most promising sources for abundant low-carbon electricity. The technology is already proven - not just the generators themselves but the salt-based heat storage systems and the long-distance DC cables that can carry the electricity from the deserts to where it is required. Focusing too much of the world's power generation in just a handful of desert countries would raise geopolitical issues, of course, but the panel believe these are outweighed by the potential benefits.

A parabolic trough CSP system

Hundreds of parabolic mirrors focus the sun's rays to heat tubes of liquid



stations and geothermal plants, creating continent-sized “supergrids” that would provide copious quantities of renewable electricity as inexpensively and reliably as possible from a mixture of solar, geothermal, offshore wind and hydroelectric sources.

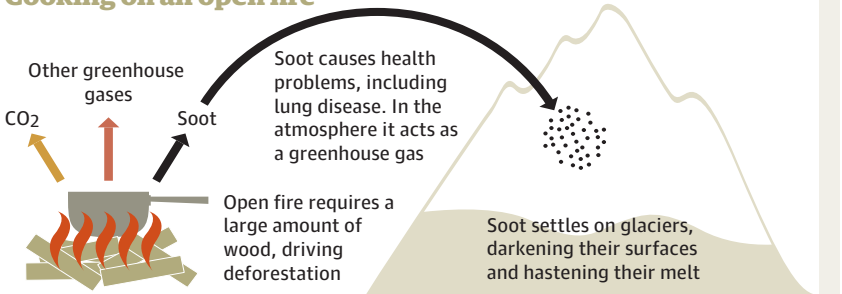
CSP is a proven technology, with plants up and running in the US, Spain and elsewhere.

2 Super-efficient stoves

Using efficient stoves to slash emissions, save forests and improve air quality

Approximately half of the world's population relies upon biomass fuels - such as wood, dung and agricultural waste - for everyday tasks such as cooking, drying crops and purifying water. Although biomass fuel has the potential to be virtually carbon neutral, the demand for cooking wood is driving deforestation in some parts of the world. Moreover, if the biomass is burned in an open fire or a typical inefficient stove, the combustion produces not only releases CO₂ but relatively large quantities of soot, as well as powerful greenhouse gases such as methane and nitrous oxide. All of these particles and gases contribute to global warming and some are dangerous air pollutants that can lead to respiratory disease. Soot has a further effect, too: it settles on glaciers and other areas of ice,

Cooking on an open fire



darkening their surface and increasing the rate at which they melt.

Simple but super-efficient “rocket” stoves, of the type advocated in Manchester by Peter Scott, help tackle all of these problems. They significantly reduce the amount of wood required, taking pressure off forests. They slash emissions of soot and greenhouse gases, reducing the climate change impact by more than 50%, and they avoid local air pollution. As a bonus, efficient stoves can reduce the time families need to spend gathering wood.

An efficient rocket stove can be produced for as little as £4 (\$7) and can save the equivalent of between one and three tonnes of CO₂ per year. This makes it one of the least expensive ways to tackle global warming, even before you consider the social benefits.

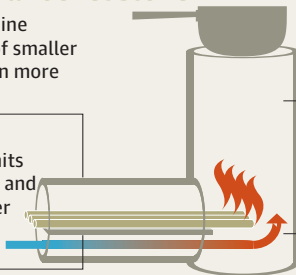
VERDICT

Of all the climate change solutions considered, this one is perhaps the most cost-effective. If a household rocket stove lasts for ten years, then it could reduce emissions at a cost as low as 20p(36¢) per tonne of CO₂ equivalent. This would make stoves an extremely good area for investment even were it not for the very considerable social and ecosystems benefits they provide.

Cooking on a rocket stove

Small fuel magazine encourages use of smaller sticks, which burn more efficiently

Internal shelf limits inflow of cool air and allows air to enter chamber under the sticks



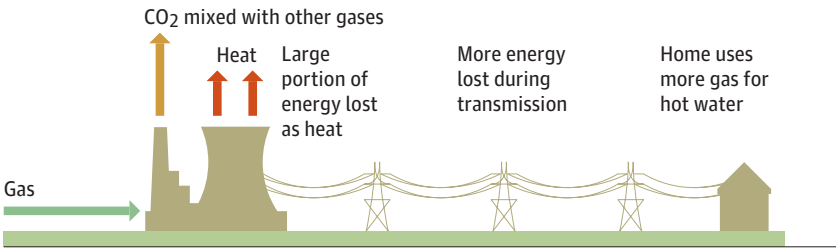
Rocket chimney increases draft. Smoke is drawn through flame and combusts, greatly reducing soot

Air passing under shelf is preheated. Cooler air would lower the temperature in the combustion chamber and decrease efficiency

3 Fuel cells for buildings

Mini power stations producing electricity and heat in the home - from gas or other fuels

Traditional power generation



Conventional electricity generation is

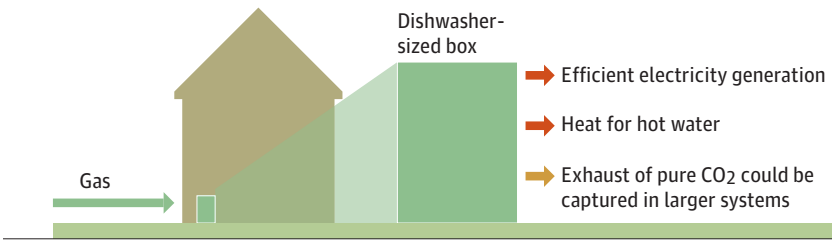
inherently wasteful. Between one- and two-thirds of the energy content of the fuel escapes from the power station's cooling tower as waste heat. In addition, more than 5% of the electricity generated is lost in transmission from power plant to end user. An alternative approach is to generate electricity within buildings using a device called a fuel cell - essentially a large battery with a replenishable fuel source. This way, because the generation happens at the point of consumption, transmission losses can be minimised and any heat created can be captured and used for hot water and heating, displacing other fuel use.

In Manchester, Mike Mason advocated solid-oxide fuel cells that can run on natural gas, renewable bioethanol or even the gas produced during biochar production (see idea 7). Mason described existing

VERDICT

Solid-oxide fuel cells are a very promising technology with a number of apparent benefits: low cost, high efficiency, and emissions savings that can be significant in the short term (if using natural gas as fuel), and even more substantial in the longer term (if a renewable fuel is substituted). If consumers could be incentivised to adopt these kinds of devices widely, the impact could be very substantial.

Domestic fuel cell system



dishwasher-sized devices, produced in Australia by Ceramic Fuel Cells, that hold the potential to produce electricity less expensively than even the best modern large-scale power stations.

Mason estimates that a typical British home with such a device would save 2.8 tonnes of CO₂ each year - a reduction of 35% compared to getting electricity from a modern gas plant and hot water from a gas boiler. Compared to electricity from a US coal plant, the device could save as much as 12 tonnes of CO₂ per home.

An extra benefit of the solid-oxide technology is that any CO₂ produced emerges from the cell mixed only with water vapour. This makes it easy and inexpensive to separate out pure CO₂ - which could potentially be captured and stored in large-scale commercial installations.

4 Enhanced geothermal systems

Fracturing 'hot dry rocks' under the ground to produce power and heat

Traditional geothermal plants exploit natural systems in which water seeps down into porous rocks in the ground and emerges back at the surface at a high temperature. This can work well, but only a limited number of countries, such as Iceland and New Zealand, have suitable geology. Enhanced geothermal systems - also known as EGS or "hot dry rock" geothermal plants - are a newer approach that could be rolled out more widely.

In an EGS system, a borehole is drilled down through the Earth's crust to a depth of a few kilometres and water is pumped down at high pressure. This fractures the rock, creating "enhanced natural permeability" and exposing a large surface area of hot rock. More bore holes are then drilled into the fractured rock, enabling the water being added in one hole to flow through the fractures in the rock and emerge from the other in the form of steam at a temperature of 150-300C. The steam can be used to generate electricity as well as hot water, with excess hot water being pumped to nearby buildings where suitable.

The case for EGS was made in Manchester by Roy Baria, a leading expert on geothermal energy and technical director of EGS Energy, the company planning the UK's first hot dry rock power plant: an installation in Cornwall that will provide power and heat to the Eden Project. Baria argued that EGS could provide

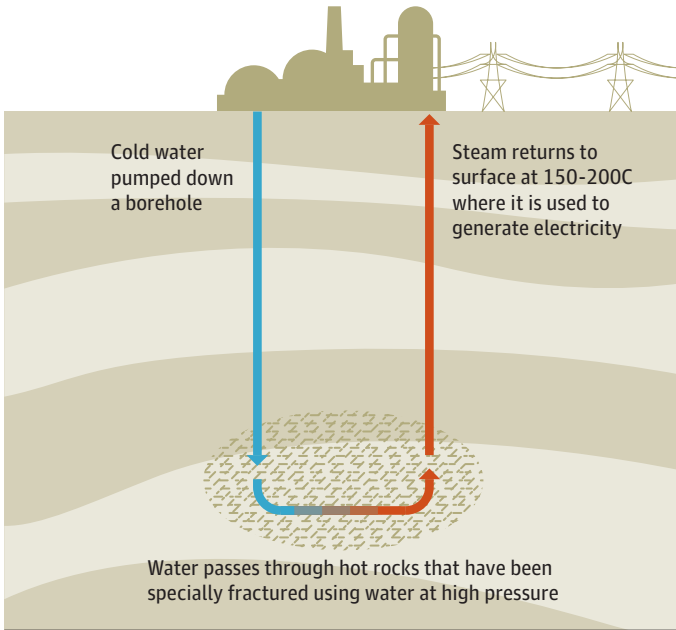
VERDICT

The heat stored in dry underground rocks is a truly vast energy resource that to date has been only minimally exploited. Although some questions remain about the feasibility of large-scale systems, the panel were impressed by Baria's advocacy and felt that EGS deserves to be taken seriously by governments and energy companies alike - especially in those the countries with the hottest accessible rocks, Turkey, the US and Australia being three examples.

* In the name of transparency, Dan Reicher put it on record in Manchester that Google has made some investments in EGS.

up to 35% of Europe's electricity and make huge contributions in China, the US, Australia and elsewhere. Unlike most renewables, geothermal power has the advantage of operating 24 hours a day. Moreover, it requires only a small amount of space at the surface.

A commercial EGS plant is already in operation in Landau, Germany, with larger-scale projects planned for the US and elsewhere.



5 Regenerative grassland management

Turning dryland soils into a giant carbon pump

Planting forests as carbon sinks is a familiar idea. Less discussed - but potentially even more significant - is the possibility of locking vast quantities of carbon into the soils of the world's dry grasslands. This could be achieved by changing the way we graze cattle and by adding more grazing animals in regions that currently have none, according to advocates Tony Lovell and Bruce Ward.

In naturally functioning grasslands - the Serengeti being a rare surviving example - huge herds of grazing animals such as wildebeest move constantly and remain closely packed together as a defence against predators. When a herd grazes an area, the grasses get shortened and shed parts of their carbon-rich roots into the soils. But the herd quickly moves on, giving the grass a chance to grow back and pulling

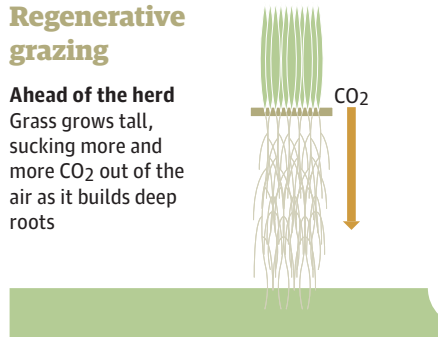
Conventional grazing

Spread-out herd crops same grass over and over, never allowing it to grow deep roots



Regenerative grazing

Ahead of the herd
Grass grows tall, sucking more and more CO₂ out of the air as it builds deep roots



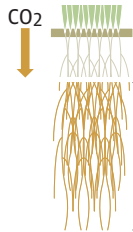
CO₂ from the air. The result is a giant biological pump that takes carbon from the atmosphere and moves it safely to the soil, where it adds to productivity and increases biodiversity.

In contrast, most domesticated cattle are kept in small herds that are stocked for long periods in the same place - a practice that doesn't encourage healthy grasses. If farmers switch to grazing practices that mimic the movements of wild herds, this can increase the proportion of carbon stored in dry soils from 1% to 2%, according to Lovell and Ward. This is sufficient to remove 100 tonnes of CO₂ (equivalent to the annual carbon footprint of ten Europeans) from the atmosphere for each hectare of land. Rolled out over billions of hectares, such a change would massively reduce the amount of greenhouse gas in the air.

VERDICT

The panel were hugely impressed with this presentation - in particular Lovell's figures showing the massive volume of CO₂ that could be sequestered from the air if this scheme could be made to work on a large scale. Soil carbon is increasingly recognised as a pivotal area in mitigating climate change, and more research and funding for regenerative grassland management are urgently needed.

Large bunched-up herd crops the grass short and then moves on to fresh pasture, allowing the grass to regrow



Behind the herd

Deep roots are discarded by newly cropped grass

A large amount of carbon remains trapped in the soil as new roots grow

6 Marine energy

Tidal turbines and other methods of extracting energy from the oceans

A huge amount of energy is stored in, on and above the oceans. Strong sea winds can be exploited by offshore windfarms, while waves can be converted into electricity using articulated snake-like generators. Scientists are also exploring how to create electricity from the salinity difference between rivers and oceans and the temperature difference between the sea surface and the colder waters below.

One of the most promising marine energy technologies is the tidal turbine, which was advocated in Manchester by Peter Fraenkel of Marine Current Turbines (MCT). These devices act like underwater windmills, with blades that rotate as the tide flows through them in each direction. Tidal turbines could create large amounts of power in those countries with very fast-flowing tidal streams - such as the UK and Canada - and similar devices could be used to extract energy from deep ocean currents such as the Kuroshio in the north-west Pacific.

Compared to wind and solar energy, tidal generation has the advantage of predictability. Being driven by the gravitational pull of the moon and sun, as opposed to the weather, the timing and strength of the tides is known in advance to a high level of certainty. A further advantage is the high energy density of tidal streams. With as much as a thousand tonnes of water passing through a turbine's blades in a single second, a relatively small device can

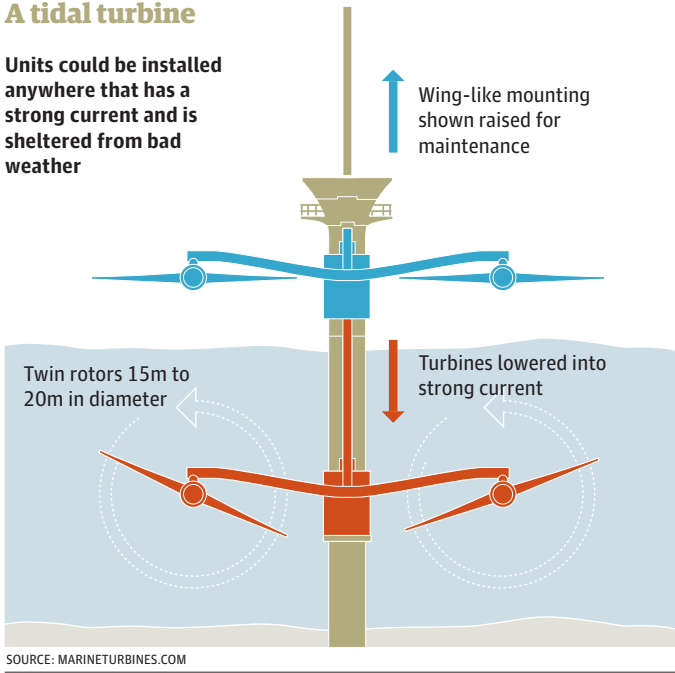
VERDICT

Despite its significant potential, marine energy research has been severely underfunded for decades. MCT's tidal-stream turbines are an example of an impressive and proven system. In some countries, devices such as these have the potential to contribute a large amount of electricity that is not only clean but also predictable - a particularly useful attribute for grids that will in the future need to absorb a large amount of wind power.

create a large amount of electricity. Producing devices robust enough to withstand these forces is a formidable engineering challenge, but MCT's flagship device - the SeaGen - has already been proven to work on a commercial scale. Positioned in Strangford Lough, Northern Ireland, the first SeaGen turbine recently generated its first 100MW hours of electricity.

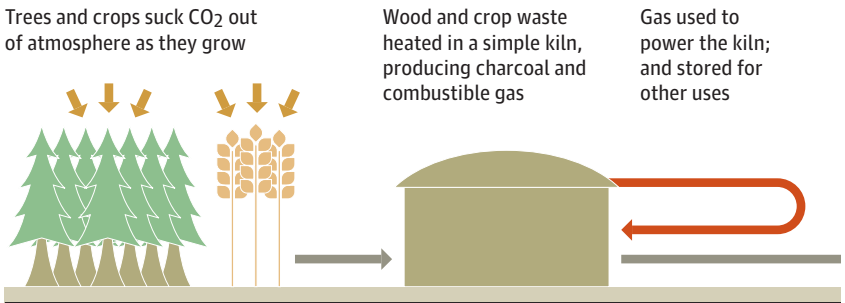
A tidal turbine

Units could be installed anywhere that has a strong current and is sheltered from bad weather



7 Biochar

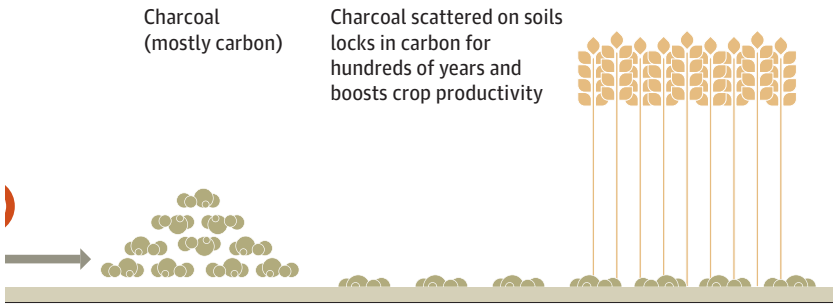
Using charcoal to lock away carbon and fertilise soils



Biochar is a type of charcoal produced by heating crop wastes, wood or other biomass in a simple kiln designed to limit the presence of oxygen. This process, known as pyrolysis, creates rather than consumes energy, as more combustible gases are released than are needed to heat up the kiln.

Biochar is made largely of carbon, which the crops or trees sucked out of the air in the form of CO₂ as they grew. Unlike crop wastes and wood, biochar is an extremely stable substance, which if mixed into soil will safely lock up its carbon content for hundreds or even thousands of years - a biological form of carbon capture and storage.

If biochar is mixed with poor-quality tropical soils, it has an important added benefit: it can significantly boost crop productivity, reduce nitrous oxide and methane emissions and improve soil structures. These effects are the



result of biochar's structure, which is full of microscopic pores that can harbour useful bacteria and fungi.

Biochar advocate Laurens Rademakers arrived in Manchester directly from Cameroon, where his experiments have demonstrated quite how effectively biochar can increase crop yields. In his photos, maize grown with biochar-enriched soils is almost twice as tall as - and much more productive than - the same maize grown in the adjacent plot without biochar.

Rademakers and others believe that it would be possible to produce enough biochar to reduce atmospheric CO₂ concentration to a safe level. At the same time, food production could be significantly boosted in the tropics - the very region where agriculture is likely to be hardest hit by climate change.

VERDICT

Rademaker's presentation was very persuasive, in particular his evidence of biochar's fertilisation effect. The panel believe that small-scale biochar projects deserve serious consideration by policymakers and the development community alike. However, they felt that any incentive scheme for biochar production should be very carefully managed to ensure that wood from ecologically important old-growth forests is not used as the source material.

8

CCS with biomass cofiring Carbon negative energy using coal, wood and CO₂ capture

Carbon capture and storage (CCS) is the practice of capturing the CO₂ emitted by a power station or other industrial facility and piping it to an underground storage site - such as a disused oil well or saline aquifer. Scientists believe that these geological formations are capable of storing virtually all the CO₂ injected into them for millions of years.

CCS has various disadvantages: the infrastructure is expensive to build; the separation and compression of the CO₂ takes large amounts of energy; and there will always be a small risk of leakage from storage sites. Nonetheless, with so many existing and planned coal-fired power stations in the world, a growing number of experts believe that only with the help of CCS will it be possible to reduce greenhouse emissions to a safe level.

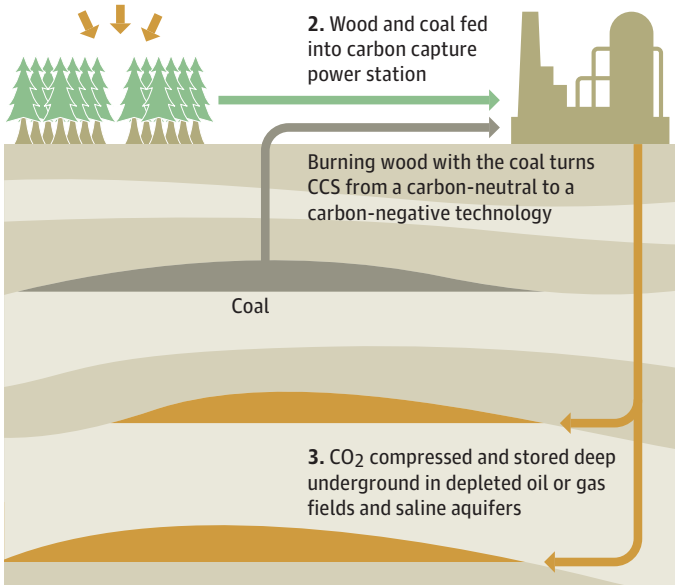
In Manchester, Staffan Gortz made the case for CCS on behalf of Vattenfall, the Swedish energy giant that has built a pioneering carbon-capture power station in Schwarze Pumpe, Germany. This pilot-scale plant uses the so-called oxyfuel approach to capturing carbon. Nitrogen is removed from the air, enabling the fuel to burn in pure oxygen. This results in a waste stream of virtually pure CO₂, ready for capture and storage. Vattenfall and other companies are also investigating two other CCS technologies, known as pre-combustion and post-combustion.

VERDICT

Though some questions about cost, safety and feasibility remain to be answered, the panel believe that carbon capture is highly likely to become a key tool for mitigating climate change. Certainly governments would be foolish not to generously fund research into this technology - even if only as a safety net. The idea of combining CCS with biomass cofiring to produce carbon-negative electricity is particularly exciting and deserves more widespread consideration.

One crucial but less-discuss aspect of CCS is the possibility of producing “carbon-negative” energy. This could be achieved if sustainably harvested wood (which is largely made of carbon sucked out of the air) was mixed with the coal being burned in a CCS power station - a process known as biomass cofiring.

1. Trees suck CO₂ out of the atmosphere as they grow

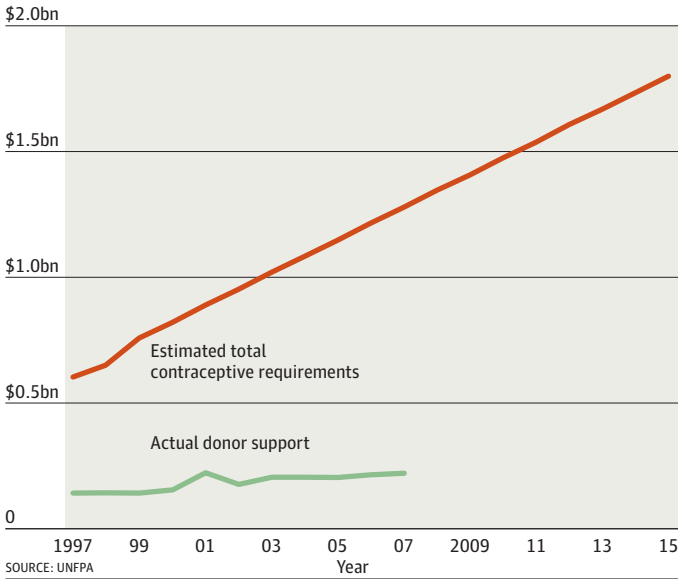


9

Universal family planning access

Easing emissions by limiting unwanted pregnancies

Family planning support



Demographic factors will play a significant role in determining future emissions. The most obvious such factor is the global population, which is expected to rise to around nine billion by 2050. Although the fastest population growth is happening in countries with relatively low emissions per person, the addition of two or three billion people



will inevitably make it even more difficult to reduce global emissions to a sustainable level – especially in the context of other demographic trends such as urbanisation and ageing.

Rising population is significant not only as a driver of emissions but also in determining the vulnerability of developing countries to the impacts of global warming. In almost all of the climate change adaptation plans submitted to the United Nations by least-developed countries, rapid population growth is mentioned as something that exacerbates vulnerability or impedes adaptation.

Ensuring universal access to family planning services and investing in female education is a pivotal climate change solution, Louise Carver of the Population and Sustainability Network (PSN) told the the Manchester panel. According to Carver, 200 million women wish to delay or prevent their next pregnancy but lack access to contraception. Despite this fact, and the sharp projected growth rate in potential contraception users, global investment in family planning has not risen significantly since the 1990s. In addition to being a relatively inexpensive way to tackle emissions and climate vulnerability, family planning services can help improve maternal and infant health and offer expanded opportunities for women’s employment and social participation.

VERDICT

Population tends to be a divisive issue in the climate change debate – so much so that the uncontroversial but important issues of family planning access and female education often get lost in the noise. Although the precise impact on future emissions of these approaches is difficult to predict with certainty, the panel believe there is a very strong climate change argument – as well as an overwhelming social one – for spending money to help women around the world avoid unwanted pregnancies.



10

Thorium nuclear energy

Nuclear power from a different fuel

The uranium that makes conventional nuclear power possible has a number disadvantages. For one thing, uranium reactors generate large quantities of waste - some of which remains dangerous for millenia and a small proportion of which can be used to make nuclear weapons. A second issue is that uranium is a comparatively scarce material, which exists in significant quantities in a small number of countries.

For both of these reasons, a growing number of scientists and energy experts believe that the world should investigate the possibility of switching from uranium to thorium as its main nuclear fuel. Compared to uranium, thorium is far more abundant as well as much more energy-dense - a person's lifetime energy needs could be held in one hand. In addition, the waste products generated by thorium are virtually impossible to turn into the plutonium needed for nuclear weapons production - and they remain dangerous for hundred of years rather than thousands.

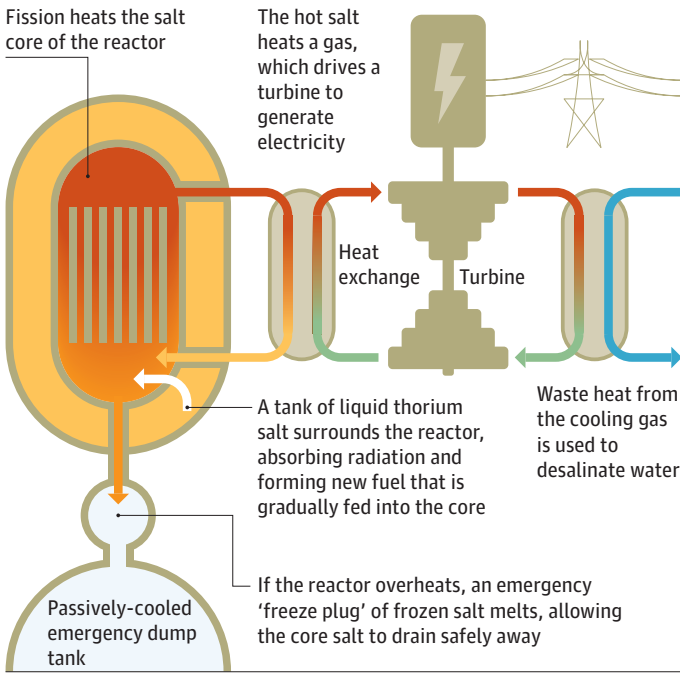
There are a number of different ways to use thorium to produce electricity. In Manchester, Kirk Sorensen made the case for liquid-fluoride reactors. This technology was developed by the US military in the 1950s and 1960s and was shown to have many benefits. For example, reactors of this type can be both small and

VERDICT

Although the panel are not in a position to assess the feasibility of liquid-fluoride thorium reactors, Sorensen's articulate and knowledgeable advocacy made a persuasive case that this electricity generation technology deserves renewed investigation. Other ways of extracting energy from thorium should also be explored - both to reduce emissions and to help limit the production of the most dangerous nuclear waste.

massively productive. Despite its early promise, research into liquid-fluoride thorium reactors was abandoned - the most likely reason being that the technology offered no potential for producing nuclear weapons.

Liquid-fluoride thorium reactor



The other ten shortlisted ideas - in no particular order

11 Carbon conversations

Many of the lowest-hanging fruit for reducing emissions relate to energy efficiency in homes and lifestyle decisions about travel, diet and shopping. But convincing people to give their home a green makeover or make changes to the way they live is extremely difficult.

The psychotherapist Rosemary Randall observed that even among people who fully understand the risks of climate change, few have taken steps to reduce their carbon footprint. To get around this kind of inertia, Randall developed Carbon Conversations, a series of six meetings in which participants address climate change in a different way - focusing on values, emotions, lifestyle and identity in addition to the usual facts. Instead of just discussing energy use in the home, for example, the meetings explore notions such as what it is that makes a home a home.

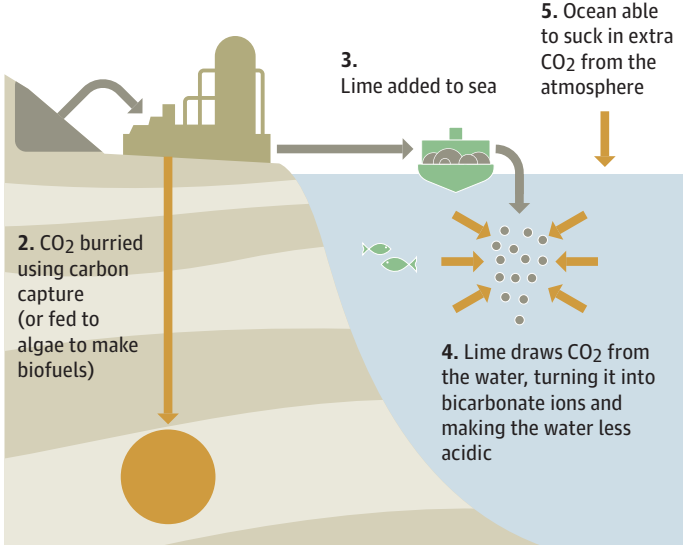
Carbon Conversations have proved effective among the 360 people who have taken part to date. A typical participant makes an immediate saving of a tonne of CO₂ a year and develops plans to reduce emissions by 50% in five years.

VERDICT

Randall made a very persuasive case for the importance of psychology in motivating low-carbon behaviour. Her scheme has already delivered impressive results. If carbon savings of this type can be achieved on a large scale - and locked in for the long-term - then this kind of approach could become an extremely significant and cost-effective way to reduce emissions.

Cquestrate

1. Limestone quarried and converted to lime and CO₂



SOURCE: TIM KRUGER

12 Cquestrate: using lime to tackle CO₂ and ocean acidity

About one-third of the CO₂ released into the atmosphere by humans each year is absorbed by the oceans. This helps slow the rate of global warming but also increases ocean acidity, posing a serious threat to marine life. Cquestrate, advocated in Manchester by Tim Kruger, is a plan designed to tackle global warming and ocean acidity simultaneously.

The first step is to convert limestone into lime - a process similar to those used in the cement industry. This releases large amount of CO₂, though in theory this gas could be

VERDICT

This is perhaps the only large-scale climate change scheme designed specifically to tackle ocean acidity as well as atmospheric CO₂. For that reason alone it warrants serious consideration, though carrying out lime production on a sufficient scale - with carbon capture - would present an extraordinary technical and practical challenge.

captured and stored. The next step is to add the lime to the ocean, where it reacts with CO₂ dissolved in the water, converting it into bicarbonate ions. This decreases the acidity of the water and enable it to absorb more CO₂ from the air, thereby helping to reduce planetary warming.

The basic chemistry looks good, but two key questions of feasibility remain: whether a sufficient volume of limestone could be mined; and whether it will ever be affordable to capture and store the CO₂ generated during the lime production.

13 Cloudseeding ships

Clouds play an important role in the global climate system. Some types, such as marine stratocumulus clouds, can have a significant cooling effect thanks to their ability to reflect sunlight back out to space before it ever reaches the surface of the planet.

Professor Stephen Salter of the University of Edinburgh has a plan to expand the size and whiteness of these clouds using a fleet of remote-controlled, energy-self-sufficient ships. The ships use energy from the wind to propel themselves around and spray minuscule droplets of sea water into the air. These droplets become the nuclei, or “seeds”, around which reflective stratocumulus clouds can form. Salter believes that if 50 of these ships were built each year the fleet would be capable of increasing the reflectivity of the planet sufficiently to cancel out the temperature rise caused by man-made climate change. This wouldn't solve the CO₂ problem, nor will it

VERDICT

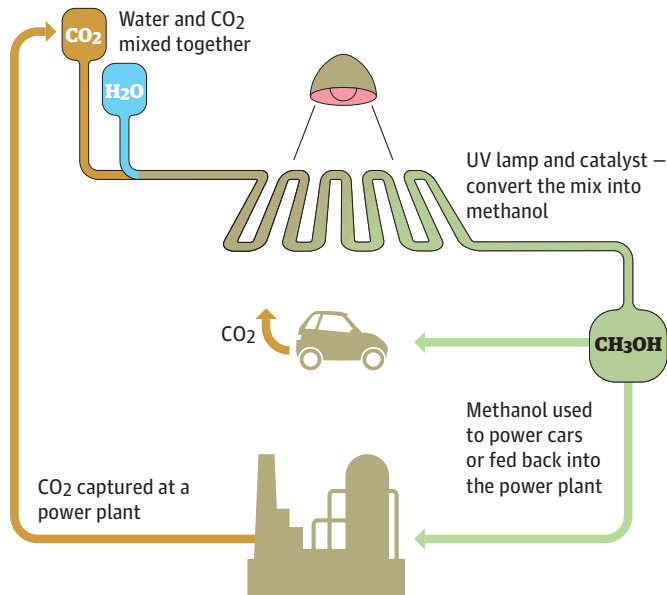
Masking temperature rise without reducing CO₂ emissions is far from ideal for a number of reasons. However, if key climate tipping points are reached, emergency stopgap technologies – such as cloudseeding ships – may have a role to play. The fact that Professor Salter has failed to find any funding at all for his scheme speaks volumes of how hard it can be even for distinguished innovators to develop climate change solutions.

tackle ocean acidity. But the plan could create a window of opportunity in which the global economy could be decarbonised without the earth being pushed over the threshold of runaway global warming.

14 Methanol fuel from CO₂

Permanent underground storage is only one of the options for dealing with CO₂ captured at a power station. One much-discussed alternative is to feed the gas to algae and turn the algae into biofuels. A less familiar approach, advocated by the

Methanol from CO₂



Polish environmentalist Marcin Gerwin, is to convert the CO₂ into methanol fuel using a process called “artificial photosynthesis”.

In this system, the first step is to dissolve the CO₂ in water. The resulting solution is directed into tubes containing a catalyst that is activated by UV light and causes the dissolved CO₂ to react with water (H₂O) to form methanol (CH₃OH). The methanol can then be burned for power generation, displacing coal use, or used as a vehicle fuel instead of oil. The basic conversion process for turning pure CO₂ into methanol is proven, and research is now being carried out to assess the viability of using the technology on unprocessed gas from power-station flues.

VERDICT

Gerwin was unable to reach Manchester due to airport closure. In principle, however, the panel are warm to the idea of converting CO₂ into methanol (an idea supported by chemistry Nobel laureate George Olah, among others). More evidence is needed, but the potential for using this technology to displace transport fuels, in particular, looks promising.

15 Rethinking economic indicators

In a world beset by climate change and financial crisis, a growing number of thinkers are questioning the assumptions that underlie the current economic paradigm. Some believe that climate change can only be solved with negative growth, while others argue that “growth” as it is currently defined is entirely the wrong economic goal.

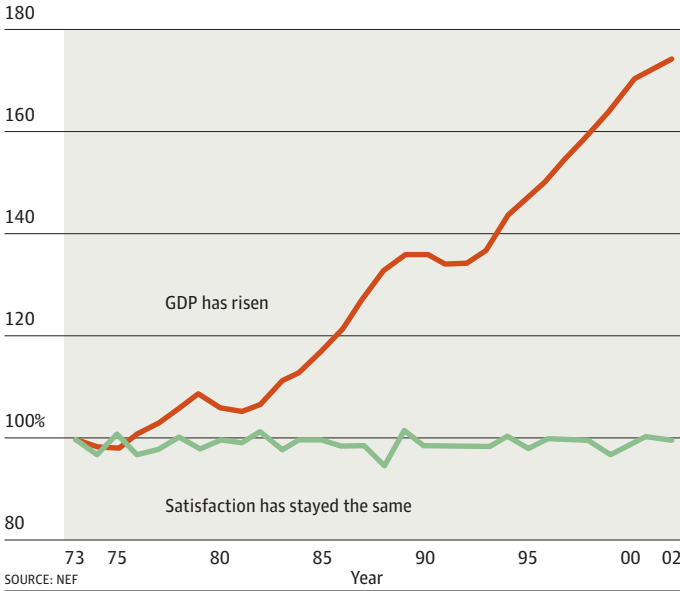
Gross domestic product (GDP) is a simple measure that recognises all economic activity as being of equal value. By this metric, a citizen who commutes 100 miles a day in a 4x4, burning up large volumes of expensive fossil fuels, contributes more to economic health than someone who walks to work. In Manchester, Andrew Simms, Policy Director of the New Economics Foundation and author of Ecological Debt, argued that in

VERDICT

The broad thrust of Simms’s presentation – that current economics often hinders rather than helps sustainability – was convincing. The hard part is coming up with specific policies to get around this problem. A new economic indicator that incorporates environmental impact and life satisfaction would be a useful starting point.

UK life satisfaction index

Life satisfaction against GDP, relative to 1973



order to tackle climate change society needs to ask itself fundamental questions about what its economic systems are designed to achieve. Simms points out that while GDP and carbon footprints have shot up in the past few decades, people are no happier or more satisfied with their lives than they were before.

16 “Carbon mortgages” for eco-renovating homes

One Planet City is a project that seeks to reduce the carbon footprint of Manchester and in the process develop tools and systems for use throughout the wider world. A key

part of the plan is the “carbon mortgage”, a financial mechanism enabling and encouraging individuals and families to increase the energy efficiency of their homes. Investors could pay the up-front costs of an eco-renovation, to be paid back over two or three decades by a mortgage premium that stays with the home rather than the current resident. In practice the financial cost of the premium would be cancelled out for the homeowner by reduced energy bills, so there would be no reason not to sign up.

Utilities would measure future energy savings; mortgage companies would administer the financial elements; and energy service companies would organise the improvement works, upgrading entire blocks or streets at a time.

17 Energy bonds for funding clean power and heat

Although most experts agree that reducing emissions will be cheaper in the long run than not doing so, there’s no avoiding the fact that quickly decarbonising a fossil-fuel-dependent global economy will require massive investments in clean energy. To help raise the money, governments should issue “energy bonds”, according to thinkers such as Tim Helweg-Larsen of the Public Interest Research Centre (PIRC). These bonds would allow individuals and institutional investors alike to make secure long-term investments in renewable energy projects.

Investors would buy the bonds online or in post offices. The money raised would be placed in a trust dedicated to financing renewable

VERDICT

Given that in many developed countries only 1% of the housing stock is newly built each year, it’s absolutely vital to focus on eco-renovations as well as zero-carbon architecture. Renovation schemes that avoid up-front costs to householders are the only way to achieve widespread up-take, and the “carbon mortgage” is an excellent example of how this could work. The UK government is now examining just such a scheme.

VERDICT

Done right, either at the micro or macro level, energy bonds have the potential to significantly increase investment in renewable energy. At a community level, a bond scheme – like other local ownership models – can have the significant advantage of creating a sense of ownership over wind turbines and other developments, thereby helping to overcome planning objections.

energy development. The investments would be backed by government, which would guarantee repayment. The precise return for investors would depend on electricity prices and other factors, but Helweg-Larsen estimates that purchasers of energy bonds could expect “high single-digit returns ... somewhere between 5% and 9%”.

18 **Solar photovoltaics with generous feed-in tariffs**

Solar photovoltaic (PV) cells generate electricity from sunlight. They’ve existed for decades, though over time have become less expensive and more efficient, with production accelerating very quickly in the past few years.

Many experts believe PV is still too expensive to warrant substantial government investment as a means of reducing CO₂ emissions, especially in cloudy regions. In Manchester, Jeremy Leggett of Solacentury argued the opposite, making the case for a massive roll-out of PV on domestic and commercial roofs as well as in solar “farms”. According to Leggett, few energy sources offer such good long-term investment opportunities - a case in point being the PV cells produced in the 1960s that are still working at 80% capacity, having paid for themselves many times over. Many solar advocates believe that given appropriate incentives - such as generous “feed-in tariffs” that offer payments to householders for each unit of solar electricity produced - PV power could become as inexpensive as conventional electricity generation within a few years.

VERDICT

In cloudy areas PV is still an expensive way to generate electricity, but it offers some significant advantages. There are no significant planning delays, for example, and people who install PV at home tend to reduce their power consumption as they strive for electrical self-sufficiency. A feed-in tariff is one mechanism to incentivise PV installation and can unlock up-front consumer investment in renewables - though governments should consider making such schemes available only to those households that have already achieved high levels of energy efficiency.

19 **Leased, low-carbon hydrogen cars**

Internal combustion engines generate globe-warming CO₂ as well as local air pollution - a real problem in cities. They're inefficient, too, as a large slice of the energy stored in their fuel is wasted as heat during combustion and braking. Cars driven by electric motors, which can be powered by batteries or fuel cells, look set to play the central role in reducing transport emissions.

In Manchester, the case for alternative vehicles was made by Hugo Spowers of Riversimple, a company that has produced a prototype two-seater city car running on hydrogen gas. Even if the hydrogen is produced using natural gas, the emissions of the car are many times lower than those of a petrol-hybrid model.

The chassis is made from lightweight composite materials rather than steel, which reduces the emissions of manufacture as well as extending the vehicle's range. Instead of being sold, the car will be leased, thereby removing the barrier to entry of a large initial outlay for consumers.

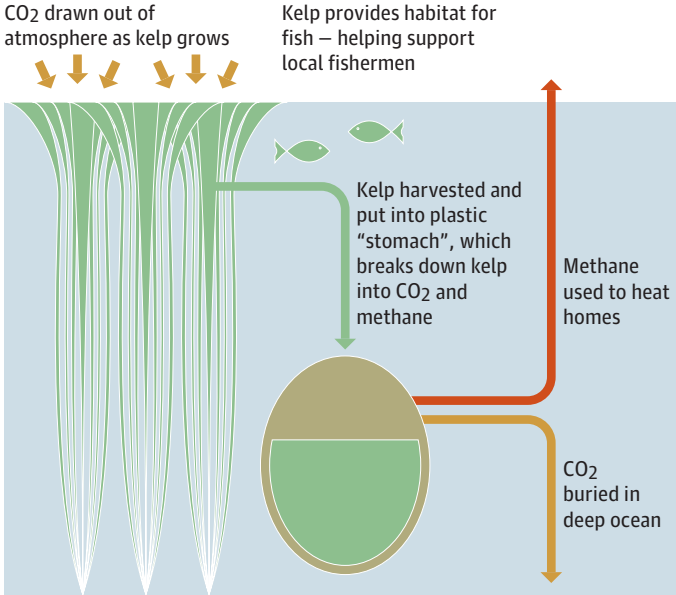
20 **PODenergy: harvesting kelp in giant "stomachs"**

There has been plenty of promising research into using fast-growing algae to produce sustainable biofuels. The marine engineer Mark Capron of PODenergy has a related but different scheme. His plan is to establish giant "forests" of kelp seaweed (a type of algae) at ocean surface. The harvested kelp would be

VERDICT

The panel members believe that battery-powered rather than hydrogen-powered cars are most likely to dominate the future of transport. Nonetheless, they were impressed with many elements of the Riversimple project - including the lightweight materials, the leasing scheme and the innovative way the company is run.

PODenergy



SOURCE: MARK CAPRON

placed into giant "stomachs" - essentially large plastic bags - suspended in the sea. Natural bacteria in the stomachs would digest the kelp, breaking it down into CO₂ and methane. The two gases would be separated, with the CO₂ sent to the deep ocean for permanent storage and the methane piped to the surface for use as a renewable heating and cooking fuel.

Capron claims that his scheme would have the positive side-effect of giving a major boost to fish stocks. He estimates that if kelp forests were established on 4% of the ocean surface, they could remove around 70% of the CO₂ currently emitted by humans.

VERDICT

Various algae-based fuel-production and carbon-capture systems are being developed, and it's perfectly possible that one of them will result in a significant breakthrough. The precise feasibility of PODenergy is hard to assess without evidence from large-scale field trials, but it is certainly an innovative and intriguing approach.

Afterword by **Lord Bingham**, former Senior Law Lord

Manchester holds a unique position in the history of environmental problems and solutions. As the cradle of the Industrial Revolution, the city spearheaded a system of mechanised manufacture and long-distance trade that accelerated fossil-fuel use and ultimately led to climate change. Not coincidentally, Manchester was also the home to some of the world's first environmental campaigners: individuals who fought to clean up the suffocating pollution spewed out by the city's proliferating factories. This history made Manchester a very fitting place to examine solutions to global warming.

It was a remarkable event. As a judge, I have spent my career examining complex and important problems, but few issues are quite so complex - or quite so important - as climate change. Tackling this unique problem will require a wave of innovation no less revolutionary than the industrialisation that swept across Manchester and the wider world more than a century ago. Thankfully, as our hearings in Manchester made clear, the world has no shortage of impressive innovators working on solutions to climate change. I suspect that everyone who attended our event left - as I did - with a renewed sense of optimism about the potential to bring global warming under control.

The aim of this report is to convey that spirit of optimism and - more specifically - to generate widespread interest in a selection of particularly promising solutions. Our list is by no means definitive, and we can't say with any certainty that all of our favoured approaches will work - or work at scale. But all of them look promising, and all of them deserve, at a minimum, to be taken seriously by policymakers and investors alike. We have the ideas. Now we need to research and employ them with the energy and zeal of Manchester's great industrialists.







