MANAGING CLIMATE CHANGE

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The debate

Many scientists retired hurt after 'Climategate'. **Clive Cookson** finds them starting to speak out again

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Accord in danger of disintegration

Chaos in Copenhagen: last year's UN negotiations were hijacked by a handful of small countries Getty

Fiona Harvey reports on the prospects for UN negotiations aimed at building on last year's chaotic Copenhagen pact

World leaders will be thin on the ground at this year's climate change conference in Cancun, Mexico.

After last year's global summit in Copenhagen, attended by most of the world's heads of state and government, this year's meeting will be a rather drab affair.

Little is expected to be settled, with even the United Nations admitting that a global pact is out of reach this year, though it hopes that one may still be possible before 2012, when the current provisions of the Kyoto protocol expire.

Yvo de Boer, the chief UN official on climate change at Copenhagen and now adviser on the subject at KPMG, says that an agreement at Cancun would be "a bridge too far".

For environment ministers, success will be measured in negative terms. If countries can avoid outright confrontation and acrimonious dissent, that will be something. If they can retain the agreements made at Copenhagen, even without moving beyond those commitments, that will be counted a victory.

The Copenhagen Accord, reached amid scenes of chaos as the UN process was hijacked by a handful of small countries, was derided by many non-governmental organisations as a failure, and recent research from the UN Environment Programme has established that the commitments on greenhouse gas emissions made in the Danish capital will be insufficient.

Nevertheless, the accord marked the first time that developed countries and important developing ones signed up to curbs on their greenhouse gas emissions. The US, which never ratified the 1997 Kyoto protocol, agreed to cut its emissions by 17 per cent by 2020, and China, India and Brazil, as well as other emerging economies, agreed for the first time in an international forum to reduce the rate of growth of their emissions.

Mr de Boer says the accord "captured a good deal of commitment on the part of the international community to rise to the climate challenge". He believes Cancun could be an important staging point on the way to a new treaty. "In my view, we go to Cancun with a more robust international foundation than many think.

"Indeed, Copenhagen's focus on setting targets and defining action plans suggests we can look optimistically to Cancun to deliver a business and financial focus. This is hugely significant, as private sector involvement can multiply the effect governments can realise on their own."

But in the year since Copenhagen, the fragile accord has been in danger of disintegration. Rows between the US and China, in particular over how emissions should be monitored, have marred the intervening meetings.

> One of the most serious setbacks has been Obama's failure to push forward his environmental agenda

Developing countries want rich nations to go further in cutting emissions and providing finance to help the poor world. Meanwhile, the European Union has been caught up in internal disagreements over whether to toughen its emissions-reduction target from 20 per cent by 2020 to 30 per cent cuts by the same date.

One of the most serious setbacks to proponents of the talks has been the failure of President Barack Obama to push forward his environmental agenda. When he took office, Mr Obama promised action on a cap-and-trade system for controlling carbon dioxide emissions in the US. That proposed legislation is now effectively dead, as the Republican party is hostile to action on emissions.

With the Republican victory in the mid-term elections, the White House is severely limited in what it can negotiate on the international stage. Although negotiators will continue to try to press for an agreement, the credibility of the US within the UN negotiations has been damaged.

Other countries remember the situation surrounding the Kyoto protocol, when the White House signed up to the pact but never joined it because it failed to bring the agreement before a Congress that was opposed to it.

Finally, the outlook remains clouded by the chaos that accompanied the end of the Copenhagen summit. In the final hours, although the main building blocks of a deal had been hammered out, a handful of countries – chiefly Venezuela, Bolivia and Sudan – held out on passing the decision.

This meant the accord never attained full legal status, and instead had to be adopted by a back-door route. The way in which such a small number of leaders was able to hold the rest of the summit to ransom, as well as the acrimonious mood, and the trading of insults, threatened to discredit the whole UN negotiating process.

Some senior negotiators from the developed economies privately suggested that the UN

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High stakes in low-carbon investments

Financing

Officials at a UN meeting face hard work on carbon trading, writes **Fiona Harvey**

Expectations are low for this year's UN climate meeting in Cancun, Mexico, as governments have deferred to next year their deadline for signing a new treaty.

But officials at the talks will have plenty of work to do – one of their hardest tasks will be to work out how an agreement on climate change can be financed.

Yvo de Boer, who was the UN's chief climate change official at last year's Copenhagen summit and is now and adviser to the consultancy KPMG, agrees.

"I think Cancun will succeed if it mobilises business and finance across both the developed and developing worlds to take co-ordinated action on global climate change work.

"Specifically, if it moves forward the thinking about how market-based mechanisms [such as carbon trading] can tie into government policy delivery on the ground," he says.

Finance was one of the main sticking points at last year's Copenhagen climate summit. Developing countries want the rich world to assist them in investing in the infrastructure needed to cut their greenhouse gas emissions, and to adapt to the probable impacts of global warming.

At Copenhagen, rich country governments agreed to provide $30bn in "fast start" financing within the next two years – though, to the anger of environmental campaigners, much of this will come from their existing overseas aid budgets. More importantly, governments agreed that the flows of funds to poor countries should amount to at least $100bn a year by 2020.

Rich countries insist their taxpayers will not be asked to foot the bill, and the bulk of the financing must come from the private sector. But bringing the private sector to bear on the problem is a difficult task.

This month, a working group of government officials and economists convened by the UN published a report setting out how finance might be provided.

The group concluded that a tax levied on international aviation and shipping, both of which are carbon-intensive, could generate $10bn a year, and a tax on banking transactions a similar amount, while redirecting the subsidies rich countries currently give to the fossil fuel industry would also contribute.

A third, or more, of the $100bn a year needed could be provided by the carbon markets, the group said.

However, the future of the trade in greenhouse gas emissions is uncertain. The market in greenhouse gas emissions was created under the Kyoto protocol, which was signed in 1997 but took effect only in 2005.

Under the UN-backed system, called the clean development mechanism (CDM), projects in developing countries that reduce carbon dioxide – such as wind farms or solar power plants – are awarded carbon credits. These can be bought by rich countries to count towards the greenhouse gas emissions reductions they agreed at Kyoto.

> 'The EU emissions trading system has also not worked as well as its architects had hoped'

The European Union also operates its own carbon trading system, related to the UN mechanism. Under this scheme, businesses are awarded or must buy a quota of carbon permits to cover the emissions they produce. The amount of permits awarded is gradually reduced, forcing companies to buy more, which they can do through the CDM.

The future of the CDM is in doubt, however. The provisions of the Kyoto protocol expire in 2012 and, if no new agreement is reached before then, the system looks in doubt.

The EU's emissions trading system has also not worked as well as its architects hoped, as an over-allocation of free permits has kept the price of permits stubbornly low, so that it does not act, as intended, as a spur to the adoption of low-carbon technology.

The world's existing carbon markets are also limited in scope, because the biggest potential player – the US – is now effectively out of the game.

Barack Obama, on taking the US presidency, promised to bring forward a system of cap-and-trade for US businesses similar to that in operation in the EU. Vociferous opposition from the Republican party, however, and from some Democrats, has put paid to a US carbon market.

Existing carbon markets "would survive", even if the UN talks do not produce an agreement, says Richard Gledhill, global leader on climate change and carbon market services at PwC, the consultancy.

He says: "The European Union is still committed to emissions trading, and the CDM will probably limp on. But the prospects for rapid growth in finance through the carbon markets would look very uncertain."

If the talks on a new global agreement fail at Cancun or at next year's crunch meeting in South Africa, then businesses will carry on investing in ways to tackle climate change, but at a slower rate, Mr Gledhill predicts.

"Low carbon investment would continue, but with greater policy uncertainty and higher transaction costs," he warns. "The UN process brings consistency and integrity, which are crucial to rapid scaling up of low-carbon investment."

Technology starts to take hold

Energy use

But innovation and upgrades are going to be expensive, says **Sylvia Pfeifer**

A new supermarket in Crayford, Kent, in the UK hides an interesting secret. Extending 200m beneath shoppers' feet is a network of pipes that is heating the building by capturing the natural warmth in the earth's crust.

The technology uses a series of closed loop boreholes drilled to gain access to natural heat from the earth. The store's heating system consists of 15 pipes filled with a fluid of vegetable-based glycol and water.

Heat from the earth is absorbed by the fluid which then flows into an exchange unit, from where it is pushed around the store by a network of ceiling fans.

The supermarket's greener approach has paid off: its energy use is down by 30 per cent and the new system has also helped reduce the electricity bill by 60 per cent.

It may be a remarkable approach to energy use today, but if governments around the world are to meet their green energy targets, then other companies will have to adopt similar innovative methods.

We will all have to make big changes to the way in which we use energy over the next few decades if the world is to move to a low-carbon future.

It will take time. Renewable energies are growing rapidly, helped by government support, but most forecasts agree that, 20 years from now, the bulk of global energy demand will still be provided by fossil fuels.

The International Energy Agency's recent World Energy Outlook forecast that renewables-based generation will treble between 2008 and 2035, while the share of renewables in global electricity generation will increase from 19 per cent in 2008 to almost a third. The increase comes primarily from wind and hydropower.

China, which this summer overtook the US to become the world's largest energy user, is already feeling the strain in its rush to save energy and meet its energy savings target by the end of this year – a 20 per cent reduction in energy use per unit of gross domestic product.

It will not be cheap. According to the IEA, the scale of government support is set to expand as the contribution of renewables to the global energy mix increases. The agency estimates that total support will top $200bn (in 2009 dollars), or 0.17 per cent of global GDP, by 2035.

In the UK, for example, where the government has gone further than other western countries and committed itself to cutting carbon dioxide emissions by 34 per cent by 2020, regulators have begun to estimate the cost of the challenge.

Ofgen, the energy regulator, has estimated that £200bn of investment will be required in the energy sector alone to meet these targets and connect new sources such as wind and solar to the national grid.

Of that £200bn, £32bn will be needed to upgrade the UK's ageing energy infrastructure, a 75 per cent rise from the past 10 years, Ofgem said last month.

Consumers also face higher prices.

Alistair Buchanan, Ofgem's chief executive, said at the time that gas and electricity charges would have to rise by an average of £6 per household a year over the next 10 years to help pay for the extra investment in new pipelines and wires.

There are other challenges. Lord Turner, chairman of the Committee on Climate Change, warned the government in September that drastic new measures needed to be implemented if it wanted to meet its targets.

These included an overhaul of planning, so that companies face fewer obstacles to building renewable energy infrastructure, as well as finalising regulatory arrangements for building transmission lines from offshore wind farms.

Households will also have to change their approach. Using renewable energy for heating rather than for electricity is a particular challenge. Wood-fired boilers and heat pumps are two possible technologies that are available, but are used by only a tiny number of households.

Wood-fired boilers and heat pumps are used by few households

Energy efficiency is also becoming more important. The development of "smart grids" – grids that are equipped with communications technology that allows the amount of power to be delivered to be balanced to meet the demand – is an important step forward.

Smart meters, which show consumers how much energy they are using and also allow flexible pricing, are also being rolled out.

Other advanced technology could also allow companies to control household equipment in order to manage demand – for example, turning down refrigerators during peaks.

But all these sources of investment will require the right regulatory framework – if not in the form of direct funding by government, then to provide the right kind of conditions to incentivise the private sector to invest.

In the US, for instance, the government has awarded more than $3.4bn in grants for the development of smart grids.

In the UK, meanwhile, a lot of investment will depend on the government's forthcoming consultation on the reform of the electricity market – the biggest shake-up for two decades.

Chris Huhne, the energy secretary, recently called the planned reforms "a seismic shift".

The government knows the stakes are high.

World focus 'needs to fall on agriculture'

Water

The farming industry is responsible for 70 per cent of all withdrawals, writes **Charis Gresser**

It has been a while coming, but the threat of water shortages has shot up the corporate agenda. Multinationals are increasingly joining the ranks of academics, consultants, public officials and development experts in trying to define both the size of the problem and the range of the solutions. This is a vast undertaking, for several reasons.

First of all, water is an intractably local problem. Future water shortages, as measured globally, do not take into account how much worse it will be (or already is) for some countries and regions. A study by consultancy McKinsey, the International Finance Corporation, the commercial arm of the World Bank, and a number of multinationals, estimates there will be a 40 per cent gap between current water supply levels and water demand in 2030, assuming demand is unconstrained.

But, as Giulio Boccaletti, associate principal at McKinsey, says: "That gap, at a local level, can reach 50, 60 or even 80 per cent. Population growth, urbanisation, economic growth, especially where it leads to increased meat consumption, are all drivers of demand.

Second, water is slippery to measure. There is no equivalent, yet, of the greenhouse gas protocol for water. "The major difference between water and carbon is that you need to understand the context in which water is used. It's not just about the volume of water but where it comes from. Is it from a watershed where water is abundant or scarce? Is it from a renewable source or from an aquifer that might take thousands of years to replenish? It is also about the quality of the water – the levels of pollutants in it – both before and after it is used," says Marcus Norton, head of water disclosure at the Carbon Disclosure Project, a UK-based non-governmental organisation.

The third problem is an institutional one: who is responsible for tackling water shortages, who pays, who has rights to water and how will all the stakeholders – multinationals, smallholder farmers, governments, public utilities, international organisations – agree on what to do?

Many believe that, to address water shortages, the world's focus has to be on agriculture. Not only does it account for roughly 70 per cent of all water withdrawals, it is also the hardest to regulate, unlike domestic and industrial consumption, which can be managed via pricing, permits and licences.

Historically, water used in agriculture has been relatively inefficient. "Where it is subsidised by governments, the risk is there is no stewardship of water. That leads to inefficient practices, such as the entire flooding of fields for irrigation, instead of drip irrigation," says John Temple, R&D sustainability director at Unilever.

The company has estimated the environmental impact of 30,000 of its products. In trials looking at the use of drip irrigation for tomatoes, Unilever reckons water use could be reduced by 30 per cent, while maintaining or even increasing crop yields.

These technologies and practices exist. The challenge is an institutional and an economic one. Governments and the private sector have to assess which crops should continue to be produced and how to incentivise farmers and companies to use water more carefully. That is hard.

Water wheels: more efficient irrigation could reduce water use by 30 per cent while maintaining yields Alamy

Claudia Ringler, senior research fellow at the International Food Policy Research Institute, says: "Water is scarce in some countries and yet very few are saying they won't irrigate staple crops such as wheat or maize or export crops such as cotton, even though these can be water guzzlers. It's a difficult subject because it raises issues of food security and foreign exchange. But if you want to affect water scarcity, you have to tackle irrigation." McKinsey says that changing agricultural practices could be among the more cost-effective tools, in some places, to tackle that 40 per cent global gap. Certainly, the changes will have to be radical for, on McKinsey's estimates, the current rate of efficiency improvements even when coupled with new water supplies via dams, for instance, will not be sufficient.

> 'Very few are saying they won't irrigate staple crops, even though these can be big water guzzlers'

If governments in water-scarce countries are acutely aware of the problem, multinationals, too, are becoming increasingly sensitive. A United Nations Global Compact-Accenture report found, in its study of top chief executives, that 26 per cent pinpointed water as one of the most critical factors to address for the success of their business.

Of course, there have already been big improvements in the water intensity of the manufacturing process. The report quotes Dow Chemical, for instance, as generating savings by reusing treated wastewater in its manufacturing plants. What many companies are grappling with is how to measure the impact of water use throughout the value chain of their products, from suppliers to consumers.

Peter Lacy, managing director of sustainability services for Europe, Africa and Latin America at Accenture, says: "We are starting to see large global companies create water maps of their supply chain to include in longer-term business plans. Some are working in partnerships with local farmers, NGOs and UN agencies to look at sustainable agriculture."

This could be one of the most complex exercises in public-private partnerships these companies have ever undertaken.

Alliances that lead to creative industrial symbiosis

Resources

One company's waste may turn out to be suitable fuel for another, says **Sarah Murray**

It is not often that a global chemicals company goes into partnership with a small-scale vegetable farmer. However, John Baarda, a Yorkshire tomato grower, has expanded rapidly because of a fruitful working relationship with Terra Nitrogen, a global nitrogen producer, by recovering and reusing the nitrogen company's steam heat and 12,500 tonnes of its carbon dioxide.

The partnership means that Terra Nitrogen can cut its carbon footprint substantially, while John Baarda pumps the carbon dioxide into its greenhouses to boost plant growth.

It also diverts Terra Nitrogen's steam to heat 38 acres of greenhouses in which 300,000 tomato plants are cultivated throughout the year.

This alliance is one of many being fostered by the National Industrial Symbiosis Programme (NISP), a UK government-funded organisation that helps companies to discover how their waste, energy and by-products can be turned into valuable resources and sold to others.

The list includes everything from carbon dioxide and steam to materials such as packaging wood, which is turned into fuel pellets, and used oils from the cosmetics industry, which can be transformed into a raw material for biodiesel. "When one company's waste becomes another company's resource, it is fascinating," says Dax Lovegrove, head of business and industry at the WWF.

The WWF has included NISP in its "green game-changers" initiative, a collection of case studies of innovative sustainable ways of doing business.

To foster these partnerships, NISP brings together companies and industries around the country. In free workshops, companies working in seemingly unrelated businesses learn how to maximise the use of resources by joining forces.

In addition, a database stores and matches resources entered by NISP staff and those of its member organisations.

"We run cross-sector industry workshops," says Peter Laybourn, chief executive of International Synergies and NISP programme director and founder. He adds: "Most people are trying to do something within their company, whether on waste or carbon, but not many people have time to look outside their company boundary."

In the workshops, executives from different sectors can learn about what their counterparts in different businesses or sectors do, and where opportunities might lie for the productive exchange of energy, water or waste materials.

"We're trying to break down barriers to cross-sector activity," explains Mr Laybourn. For Mr Laybourn, the key to finding these opportunities is the sharing of knowledge.

"We don't know what we don't know," he says. "And it's incredible when we bring the brains together from different sectors, because it's so creative."

'If companies can make use of waste, it will be a big benefit' - Dax Lovegrove

Take John Pointon & Sons, a large West Midlands animal renderer. After working with NISP, the company found that its meat and bone meal – a byproduct that was once sent to landfill – could be a viable alternative fuel for the kilns of cement companies.

In the East Midlands, NISP helped CTO Holdings, one of the UK's largest snacks producers, to generate £11,000 in additional sales to Jayplas, the UK's largest plastics recycler.

Jayplas is now buying the company's plastic waste – the polypropylene plastic sacking used to package potato powder and the small plastic trays used to package the finished products – to reprocess and sell on.

Through these and other partnerships, NISP claims to have reduced UK carbon emissions by more than 30m tonnes and saved 48m tonnes of virgin material being used across the country.

Industrial symbiosis also saves companies money. "Whatever companies can do to avoid landfill costs and make use of their waste is going to be a big business benefit," says Mr Dax. "And there's so much opportunity to partner with others in this."

At the same time, industrial symbiosis has the potential to create a new industry of "middlemen". Because waste materials do not always emerge in the appropriate form for companies to use right away, secondary processing or treatment is often needed to turn by-products into materials that are suitable for use.

"Once you can highlight an issue, there are entrepreneurs and solution providers out there for that kind of business," says Mr Laybourn. He also argues that, when it comes to combating climate change, industrial symbiosis is extremely cost-effective compared with other initiatives such as carbon trading.

NISP estimates a cost of about 62p for every tonne of carbon dioxide saved through its programmes.

"The transaction costs of carbon reduction commitments are incredibly high," says Mr Laybourn. "The monitoring, audits, registration and trading all add costs. This has virtually zero transaction costs. It doesn't need international agreements or trading mechanisms, and we can scale it up."

Academics climb back into the ring of debate

Science

Researchers are restating the need for action, after retreating in the wake of last year's scandals, says **Clive Cookson**

Mainstream climate scientists have come under unprecedented assault during the past year from politicians and commentators – particularly those on the right of the political spectrum – who challenge the causal link between human activity and global warming or claim researchers have exaggerated the impact of mankind on climate in order to attract more funding for their work.

In the first part of 2010, in the wake of the failed Copenhagen summit and the "Climategate" scandal at the University of East Anglia, many scientists retired hurt from the public arena.

In an interview with the journal Nature to mark the anniversary of the release of hacked e-mails from UEA's Climatic Research Unit in November 2009, its head, Phil Jones, said: "I was getting lots of messages of support from my fellow scientists, and I did wonder why they didn't go to the media and say the same things they were saying to me."

But in recent months, climate scientists and their representative bodies have become more vocal in restating what they see as the urgent need for action to reduce emissions of carbon dioxide and other greenhouse gases.

Individual researchers, such as Simon Lewis at the University of Leeds and Michael Mann at Pennsylvania State University, have written strong appeals to confront the sceptics. "My fellow scientists and I must be ready to stand up to blatant abuse from politicians who seek to mislead and distract the public," Prof Mann wrote last month in the Washington Post. "They are hurting American science. And their failure to accept the reality of climate change will hurt our children and grandchildren too."

At the institutional level, for example, the American Geophysical Union is launching a Climate Q&A service to "provide accurate scientific answers to questions from journalists about climate change".

The Geological Society of London has put out a statement entitled "Stop pulling the carbon trigger". It says that, regardless of analysis of recent temperature and satellite data, the geological evidence makes an irresistible case for the way natural carbon dioxide emissions have caused global warming.

Evidence for climate change is preserved in a wide variety of geological settings, including marine and lake sediments, ice sheets, fossil corals, stalagmites and ancient tree rings.

One of the latest and more bizarre sources of data is fossilised urine and faeces of hyraxes – small African mammals that have used the same "middens" in rock crevices as communal toilets for 30,000 years. These preserve a record of climate through the animals' diet in deserts where there is little other evidence.

But some of the recent excitement in palaeoclimatology concerns a period in the much more distant past, about 55m years ago, when the world was as hot as it has been for at least 100m years. At this point, the so-called Palaeocene-Eocene Thermal Maximum, a gigantic amount of carbon – an estimated 2,000bn tonnes – was released, probably through a combination of volcanic activity with the breakdown of methane hydrates beneath the ocean floor. Temperatures rose 3°-6°C globally and more than twice as much at the poles.

Sea sediment: evidence for climate change is preserved in a variety of settings, including marine and lake deposits AP

What happened to the world's flora and fauna during this event? There was an extinction of many marine species, but a paper published in the journal Science by the Smithsonian Tropical Research Institute in Panama suggests rainforests thrived.

Analysis of pollen in rock cores from Colombia and Venezuela shows forest biodiversity increased rapidly during the event, because new plant species evolved much faster than old ones became extinct. The fact that the regional climate remained wet probably helped plant life to proliferate.

"It is remarkable that there is so much concern about the effects of greenhouse conditions on tropical forests," says Klaus Winter, a Smithsonian scientist. "However, these horror scenarios probably have some validity if increased temperatures lead to more frequent or more severe drought, as some current predictions for similar scenarios suggest."

Matthew Huber, a palaeoclimatologist at Purdue University in the US, has introduced a new ingredient into the "horror scenario". His simulations suggest the temperatures in the hottest parts of the world would have been too warm for mammals to survive.

Whether this tropical "heat death" scenario could conceivably occur in the future as a result of man-made global warming depends on the sensitivity of the Earth's temperature to increasing carbon dioxide levels.

"The whole climate change enterprise depends on knowing the carbon sensitivity of the climate – and all the palaeoclimate evidence shows that the carbon sensitivity of the models used to predict future climate is too low," says Prof Huber. In other words, the world will heat up more quickly than the mainstream predictions used by bodies such as the Intergovernmental Panel on Climate Change suggest.

It should become clearer over the coming decade whether climate sceptics or climate pessimists such as Prof Huber have a more realistic view of the future.

People power employed to detect patterns

Fresh approaches

Fiona Harvey reports on a 21st century mass observation scheme

Do you want to be a climate change researcher? All you need to do is turn on your computer.

A group of academics is hoping to enrol millions of computer users in the fight against global warming, by using the power of their PCs to perform complex calculations on climate data.

They are hoping that millions of desktop computers will provide processing power similar to that of a supercomputer, enabling them to detect patterns in the vast volumes of data gathered by research stations across the world and reach new conclusions on climate science.

The system was inspired by SETI, the search for extraterrestrial intelligence, a system by which computer users leave their machines switched on overnight and their chips are used to try to find patterns in radio transmissions from space that may indicate the presence of intelligent life.

A vital part of the project, which is called weatherathome.net, will be to run experiments on regional climate change models, which can be used to predict the weather.

Myles Allen, head of the climate dynamics group at the University of Oxford and one of the world's leading climate change scientists, says: "With the help of the public, we can run the model many more times than we could possibly do, even with a supercomputer, so we can count one-in-100 year weather events to see how climate change is affecting weather risks."

This is not the first time that climate scientists have tapped into the power of home computer users.

The climateprediction.net project has been running for seven years. Some of its results were used in the landmark 2007 report by the Intergovernmental Panel on Climate Change, a body of leading climate scientists convened by the United Nations.

Using these and more conventional systems of research, climate change scientists are building up a more accurate picture than ever of how the world's climate is changing and the extent to which human influence is to blame – primarily through burning fossil fuels and cutting down forests.

One of the problems, however, is that the IPCC reports are issued infrequently. The successor to the 2007 report is not due until 2014 – well after the 2012 deadline when the current provisions of the Kyoto protocol expire, and by which time the UN talks on a global climate change agreement are supposed to have concluded.

While scientists are amassing data for the next report, some important findings are being added. This summer, an important international study concluded that there was clear evidence of human influence on the climate.

Peter Stott, a scientist at the Met Office in the UK, one of the world's leading centres of climate change research, says: "This is a very clear conclusion. We have looked at multiple data sources and they are all pointing clearly in the same direction."

For instance, he points to research showing that temperatures in the stratosphere were falling. While this may seem to detract from the evidence for global warming, it actually confirms climate scientists' conclusions.

He says: "This would be expected as a consequence of a combination of ozone depletion and greenhouse gas increase. This is part of a very distinctive pattern of change associated with human influence on climate systems."

Millions of PCs will be used to perform complex calculations

He concludes: "The evidence is so clear that the chance that there is something we have not thought of [that could be warming the climate, other than greenhouse gases] seems to be getting smaller and smaller."

The study, which also involved the US National Oceanic and Atmospheric Administration, gathered large volumes of data published since the last IPCC report. Although that report was published in 2007, most of the data used in it dated to several years before.

Two pieces of research included in the study found that the first half of this year was the warmest on record, refuting the claims of many climate sceptics who have said that global warming has stopped or reached a plateau in the past 10 years.

But scientists also warn against drawing too many conclusions from a single year's data.

For instance, ice cover in the Arctic reached a record minimum in 2007, and has since recovered slightly. That has been used by sceptics as evidence that global warming is not happening.

However, Mr Stott says it shows that the climate can vary strongly from year to year, so scientists can only detect trends based on decades or more of data.

Pact in danger of falling apart

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might no longer be a suitable forum for such talks, and that a better alternative might be to try to forge agreement within the G8 or G20.

For many observers and participants who want to see a deal, therefore, the priority at Cancun is to stave off the potential collapse of the UN process.

"A complete collapse of the UNFCCC [framework convention on climate change] process would play to the climate sceptics, undermining confidence in climate science and climate action, and would unsettle the carbon markets," warns Richard Gledhill, global leader on climate change at PwC, the consultancy.

"National policies are clearly the key to tackling climate change, but the international process provides the catalyst, and some of the funding, for ambition and action."

Mr de Boer sees hope in the actions of businesses, which he says have become one of the main constituencies pushing for action because they want to see a level playing field and want to safeguard their future.

"Business is more engaged than ever on addressing the long-term issues of soaring energy prices, increasing energy security risks, an exploding global population and a scarcity of raw materials," he says.

"In fact, forward-thinking enterprises recognise that responding robustly will create opportunities to generate a competitive edge."

Some experts are pushing for an entirely different approach – one that would emphasise bilateral or multilateral deals among the main nations rather than requiring every one of the world's governments to agree.

Michael Grubb, chairman of Climate Strategies, a research group based at the University of Cambridge, says: "It is vital that the international community continues to discuss collective action on climate change through the UN. However, if the US cannot move forward for now, the rest of the world should be looking at ways in which co-operation can be enhanced not weakened.

"In the short- to medium-term the emergence of low-carbon coalitions could play an important role in unblocking the negotiations, for example helping to overcome north-south divisions via collaborations on several dimensions of policy, including low carbon technologies and [carbon] pricing structures."

These ideas are still controversial. Smaller developing countries are worried that they will be the losers from any deal struck among the big developed and emerging economies. They are reluctant to cede control from the only international forum that gives them a real voice.

Cancun will be the big test. If countries can succeed in maintaining a semblance of civility, and make progress on drawing up a text for a potential deal to be signed next year, then faith in the UN process may be restored.

If the meeting dissolves into acrimony, the clamour for an alternative process may become overwhelming.

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Finding the formula to make world of difference

Geoengineering

Clive Cookson explains alternative strategies for tackling global warming

In the 1990s, a few scientists suggested that we might be able to fix global warming by engineering the climate to cool it down, for example by reflecting more solar radiation back into space. They were widely regarded as misguided, if not mad.

In 2010, what we now know as geoengineering is a mainstream research subject. The Royal Society, Britain's scientific academy, has published an 80-page report on geoengineering and this month it held a meeting entitled "Geoengineering – taking control of our planet's climate".

But the idea that we might seek to control Earth's climate as an antidote to man-made global warming enrages many environmental campaigners for two reasons. First, they say it distracts from the main battle – to cut carbon emissions – and gives politicians and industry an excuse to go on polluting. Second, some of the proposed geoengineering initiatives risk making things worse through unintended consequences.

"The Royal Society has been very good at standing up for climate science, but it would be terrible for it to blow its reputation by catering to the fantasy of oil companies and climate change deniers that some kind of magic band-aid will make the problem go away," says Alex Ludd, an activist picketing the meeting.

For their part, the meeting's organisers say: "Society seems unable or unwilling to make the drastic reductions in CO_2 emissions necessary to avoid 'dangerous' [unacceptable] climate change." In those circumstances it makes sense to research – though not yet to deploy – geoengineering techniques that might be needed if global warming proceeds faster than scientists are predicting. Geoengineering proposals fall into two main categories: those that cool the planet by reflecting the sun's energy and those that remove carbon dioxide, the greenhouse gas most responsible for global warming, from the atmosphere or oceans.

Carbon removal is generally regarded as preferable in principle, because it reverses the root cause of the problem and should have fewer uncertainties and risks. But all carbon removal techniques proposed so far would only work over a very long timescale and therefore could not be employed in a climate emergency. They include:

- Capturing CO_2 chemically from ambient air and then locking it into permanent (or very long-term) geological storage, as with the CO_2 removed from the emissions of coal-fired power stations. David Keith, a geoengineering expert at the University of Calgary, has set up a company called Carbon Engineering to design a system that would use strong hydroxide solutions to remove CO_2 from air inside forced-draft towers.
- Enhanced weathering, which greatly accelerates the naturally occurring reactions of CO_2 with rocks and minerals. One variation, favoured by Tim Kruger of Oxford University, would turn limestone into lime to be dumped into the oceans, where it would react with CO_2 dissolved in seawater.
- Afforestation. This requires no new technology but its potential is very limited because huge amounts of land would be required to plant enough trees to suck up significant amounts of CO_2.

Solar radiation management techniques range very widely. The most discussed possibilities include:

- Stratospheric aerosols. Spreading tiny droplets or particles of sulphur compounds through the upper atmosphere would imitate the natural cooling effect of a large volcanic eruption. This might be the fastest acting and most cost-effective geoengineering method, but the risk of adverse side-effects is high.
- Space-based methods. Ideas such as shading the planet by putting solar reflectors into space sound like science fiction but the Royal Society's report considered that they could have long-term potential "if the major problems of implementation and maintenance could be solved".
- Making clouds. Fleets of "cloud ships" pumping tiny droplets of seawater into the atmosphere could increase the amount of white clouds over the oceans sufficiently to counteract global warming. But there could be adverse effects on weather patterns and ocean currents.
- Making the Earth's surface more reflective. Many people have proposed ways to make the planet whiter and/or brighter so that more solar energy is reflected back into space. One of the simplest is for the owners of buildings to paint their roofs white – unfortunately calculations show this would not make much difference to global temperatures, though it might still be worthwhile locally to reduce high urban temperatures.

A recent proposal is to plant agricultural crop varieties with more reflective leaves. Calculations at Bristol University suggest that this could be surprisingly effective. "Our current studies on crop reflectivity are at an early stage, but our initial results are really encouraging," says Joy Singarayer of Bristol.

Andy Ridgwell, who organised the Royal Society meeting, says reflective crops typify the kind of imaginative but achievable geoengineering that could make a difference.

"Although reducing carbon emissions must remain the priority of all nations in order to minimise the potential impacts of climate change, relatively cost-effective and non-disruptive proposals such as planting more 'climate friendly' varieties of crops could provide a helpful step in limiting the degree of climate change," he says.

Meat eaters pose bigger threat than CO_2 output

Livestock

Ross Tieman reports on the consequences of a rising appetite for animal products

The figures are stark. Livestock produce 18 per cent of global greenhouse gas emissions, more than all the aeroplanes, trains and automobiles combined. They chomp what grows on 80 per cent of the world's agricultural land and swallow up, directly or indirectly, 8 per cent of our water.

To feed 6.8bn people, we nourish 1.3bn cattle, 1bn sheep and 16bn chickens. Ruminants such as cows digest grass, a useful ability since we cannot. But in the process they burp vast quantities of methane, which is 23 per cent more warming to the atmosphere than carbon dioxide.

The world's appetite for animal produce grows apace, as populations in emerging countries become richer. In 1980, the average Chinese citizen consumed 12.8kg of meat a year, 2.3kg of dairy products and 2.5kg of eggs. By 2005, meat consumption per person had risen fourfold to 59.5kg, dairy consumption rose 10-fold to 23.2kg and egg-eating had reached 20.2kg, an eightfold increase.

While China is the most striking example, similar increases in the amount of animal-based protein consumed are seen in every region of the world where prosperity has risen. Even in developed countries, which top the tables, meat consumption edged up to 82.1kg, despite a trend towards eating white meat in place of red. Only in sub-Saharan Africa did intakes decline, to 13.3kg of meat a year.

Partly in response to surging demand, the livestock sector has undergone an unsung revolution in the past couple of decades, as the United Nations Food and Agriculture Organisation (FAO) showed in its report The State of Food and Agriculture 2009 – Livestock in the Balance.

Intensive production and vertically-integrated food processing have developed closer to urban populations, often supplied with feedstuff grown far away. Though livestock graze a quarter of the world's surface, they also swallow a third of the crops grown, notably in the form of soya beans in an area of Brazil known as the Cerrado, once renowned as a woodland-savannah.

The FAO expects further growth in meat consumption by 2050, and even a belated doubling in sub-Saharan Africa, to 22kg per person each year.

Little wonder, then, that tackling the environmental consequences, and above all the emissions, is increasingly recognised as an urgent task by many in the livestock industry, as well as by policymakers and environmental campaigners.

Yet, according to the FAO, almost 80 per cent of the world's 1bn undernourished people live in rural areas, and in many poorer countries up to 60 per cent of rural households keep livestock, providing them not just with food, but also a source of income.

Vicki Hird, senior food campaigner at Friends of the Earth UK, an environmental group, notes the contrast between obesity and heart disease compounded by excessive animal protein in some countries, and the need for many poor people to consume more of these foods.

> Tackling environmental consequences is increasingly recognised as an urgent task by the livestock industry

She argues in favour of a three-pronged approach to the environmental challenge faced by the livestock industry. Production systems should be reshaped, she says, to reduce pressure on farmers to use ever-more-intensive methods that require feedstuffs imported from afar instead of pasture and generate large amounts of waste.

Consumption should be a second focus, with western consumers ideally reducing the amount of meat and dairy products they swallow – thereby creating headroom for undernourished populations to increase their meat and dairy intake.

Much more research is also needed, she says, into animal breeds, farming techniques and land use, to provide the data on which to take policy decisions that will minimise environmental impacts.

Brian Lindsay, chairman of the standing committee on the environment at the International Dairy Federation (IDF), says: "We recognise that there is an issue that we need to deal with." But there are no simple policy prescriptions, he says.

The dairy industry provides more than half the world's beef, but an FAO study, Greenhouse Gas Emissions from the Dairy Sector, showed huge variations in emissions per kilo of milk product. Emissions from farming in developed countries were as low as 1kg of CO_2 per kg of dairy produce. In sub-Saharan African they averaged 7.5kg.

Mr Lindsay says the IDF has just launched guidelines on standardising emissions data, so that it will become possible to compare mitigation project effectiveness.

Though the UK, for example, has set a target of reducing livestock emissions by 25 per cent by 2020, the scope for improvement at individual farms is subject to many variables.

Sharing knowledge may have great potential, especially in sub-Saharan Africa, where better feed could unlock dairy productivity and improve emission ratios. But mitigation must be tailored to farms and cultures. And what about consuming fewer animal proteins? "That is a personal choice," says Mr Lindsay.

Cow calculations: to feed 6.8bn people, we nourish 1.3bn cattle Reuters

Recycling Goes a long way in the UK

When managing waste, companies often focus on the cost of sending materials to landfill sites. But waste contributes to the creation of greenhouse gases. Companies that cut waste and increase recycling rates are therefore also reducing their carbon footprint.

First, waste prevention avoids or reduces the use of virgin resources.

In the case of wood, its use has a more direct impact on climate change. Because forests store carbon, when they are logged or burnt, they release carbon into the atmosphere – some say this contributes to one-fifth of the world's man-made emissions.

Moreover, sourcing virgin materials is an energy-intensive process, particularly when it comes to those that must be mined, such as bauxite, the raw material used in aluminium and alumina production, or potash. which is used in the production of fertilisers.

Turning virgin materials into goods also requires energy in production, processing and distribution. "A significant proportion of greenhouse gas emissions comes from transporting materials that ultimately end up as waste," says Laura Timlin, senior consultant at the Carbon Trust, a UK government-funded group that helps companies cut their emissions.

Product design can help minimise energy use in other parts of the distribution chain.

"We use the minimum thickness of foil that's commercially available for our packages," says Mario Abreu, director of recycling and supply chain support at Tetra Pak, the world's biggest packaging company. "But that foil also avoids the need for refrigeration during distribution."

The Waste & Resources Action Programme (Wrap), the UK advisory body, says recycling in the UK is estimated to save more than 18m tonnes of carbon dioxide emissions a year, the equivalent to taking 5m cars off the road.

Because of the complexity of global food chains – which encompass sectors ranging from agriculture to processing and packaging – food waste is a significant producer of greenhouse gas emissions.

Jeff Senne, director of environment and marketplace at PwC, explains: "There is the carbon associated with the transport of food as well as the distribution of the seeds, the manufacture of the fertilisers used and the land use change to grow that food."

Meat has a particularly large carbon footprint. Livestock produce large amounts of methane, a highly damaging greenhouse gas.

Meat also requires the production of fertilisers (using mined potash) as well as land (contributing to deforestation) to cultivate animal feed.

Taking all the related emissions into account, the United Nations Food and Agriculture Organisation has estimated that livestock produce more greenhouse gases than global transport.

To reduce the food waste going to landfill sites, Wrap has worked with the grocery sector under its Courtauld Commitment, a voluntary resource efficiency initiative, which between 2005 and 2009, helped the sector divert 670,000 tonnes of food waste and 520,000 tonnes of packaging from UK landfills – avoiding carbon dioxide equivalent emissions of about 3.3m tonnes.

Another option is to turn food waste into energy. Companies such as Marks and Spencer and Tesco are using anaerobic digestion, technology that breaks down organic waste to produce biogas, which replaces fossil fuels in power generation.

Ms Timlin says: "We have seen a marked increase over the past year in the number of companies coming to us to seek advice on how this technology can help them achieve their low carbon business strategies."

Food is not the only form of waste that can be turned into energy. In Spain, Tetra Pak is working with a plant in Barcelona that is using the polymers in packaging to produce energy.

"You have to look at every step of the production cycle to see what you can do," says Mr Abreu.

Sarah Murray

Rubbish: recycling saves the UK 18m tonnes of carbon dioxide emissions a year

There is profit to be made from solutions

Adaptation

Some will gain from rising temperatures, says **Sarah Murray**

Recent weather events such as the Pakistan floods and the severe drought in Russia have highlighted a stark reality – the world's climate appears to be changing.

While many governments and businesses are working to cut the greenhouse gases thought to contribute to climate change, long-term planning and immediate action are also needed to cope with the changes materialising in the climate now. This is not all bad news. Some parts of the world may be able to gain from rising temperatures and other changes.

Tom Mitchell, head of the climate change programme at the UK's Overseas Development Institute, says: "Climate change brings both threats and opportunities ... many governments have been thinking about the threats without giving enough thought to the opportunities."

In north-west China, for example, there is evidence to suggest higher temperatures could increase yields in areas once not suitable for agricultural production. In the UK, farmers in the southern part of the country are experimenting with olive growing. At the same time, however, the negative impact of climate change on agricultural production is likely to be severe.

While direct links between increased rainfall and rising temperature have not been demonstrated decisively, there is evidence that intense weather events, including severe rainfall, are on the rise.

"Many of the disaster events we have seen in 2010 match closely the predictions of the 2007 Fourth Assessment Report of the IPCC [Intergovernmental Panel on Climate Change]," says Mr Mitchell. "So the overall weight of evidence is stacking up."

The changes disproportionately affect the world's poorest people. According to Oxfam, the UK-based charity, 1.7bn farmers are vulnerable. In severely affected countries, initiatives are under way to build resilience into the agricultural economy. Oxfam argues that, in some cases, ancient knowledge can be put to work to create systems that are more resistant. In Trinidad, for example, it is working with the Kenneth Lee Foundation to build modern *camellones* – an ancient system of agro-hydrology – to produce fertile soil and water management that can adapt to changes in climate.

The overall weight of evidence is stacking up, says Tom Mitchell

But, while development specialists often point to poor rural areas as being most severely affected, cities are also vulnerable to flooding and the resulting damage to infrastructure.

In some, authorities are encouraging citizens and businesses to plant green roofs, which act as giant sponges, soaking up water and letting it drain off more gradually. Meanwhile, some governments are taking a more comprehensive approach. In northern India, Surat has launched a competition to find climate-resilient housing design and urban planning solutions. The competition reflects the city's decision to live with climate change, rather than move its residents to a new flood-free region.

Cristina Rumbaitis del Rio, associate director of the Climate Change Resilience initiative at the Rockefeller Foundation, says: "The authorities want to ensure the poor, who live in more marginal areas, aren't put into greater areas of vulnerability."

Ms Rumbaitis del Rio believes that, as developing cities expand, they have an opportunity to build resilience into their infrastructure. "They can either get it right now on land use and infrastructure as they develop," she says. "Or ... get locked into decades of vulnerability that will be very difficult to reverse."

The private sector needs to develop resilient supply chains, and make provision for the fact that crop failures, floods or power cuts in one part of the world could affect business operations in another. "Companies are recognising that they need to look across the whole supply chain," says Mr Mitchell.

"There is a recognition that the private sector has a role in adaptation," adds Mr Mitchell. "But the other side of this is the private sector is increasingly seeing money to be made from climate change adaptation."