

# The heat is on

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A list of sources can be found online

[www.economist.com/surveys](http://www.economist.com/surveys)

An audio interview with the author is at

[www.economist.com/audio](http://www.economist.com/audio)



Global warming, it now seems, is for real. Emma Duncan examines the nature of the problem, and possible solutions

THE world's climate has barely changed since the industrial revolution. The temperature was stable in the 19th century, rose very slightly during the first half of the 20th, fell back in the 1950s-70s, then started rising again. Over the past 100 years, it has gone up by about 0.6°C (1.1°F).

So what's the fuss about? Not so much the rise in temperature as the reason for it. Previous changes in the world's climate have been set off by variations either in the angle of the Earth's rotation or in its distance from the sun. This time there is another factor involved: man-made "greenhouse gases".

When the sun's energy hits the Earth, most of it bounces back into space. But carbon dioxide and around 30 other greenhouse gases, such as methane, help create a layer that traps some of the heat from the sun, thus warming the planet. And, because of the burning of fossil fuels, which contain the CO<sub>2</sub> that the original plants breathed in from the atmosphere, levels of CO<sub>2</sub> have increased from around 280 parts per million (ppm) before the industrial revolution to around 380ppm now. Studies of ice cores show that concentrations have not been so high for nearly half a million years. At the current rate of increase, they will have reached 800ppm by the end of this century. Given that CO<sub>2</sub> being emitted now stays in the atmosphere for up to 200 years, getting those concentrations down will take a long time.

The first person to spot the connection between temperature and human activity was a 19th-century scientist called Svante Arrhenius. He speculated that emissions from industry could double CO<sub>2</sub> levels in 3,000 years, thus warming the planet. Being a Swede, he thought that was just fine. In 1938 a British engineer called Guy Callendar gave a talk to the Royal Meteorological Society in which he claimed to have established that the world was warming, but he was regarded as an eccentric. The idea of global warming seemed bound for the intellectual dustbin.

### Chill out

If interest in climate change was lukewarm in the first half of the 20th century, it went distinctly chilly in the second half, for the good reason that the world was getting cooler. In 1975 *Newsweek* magazine ran a cover story entitled "The Cooling World" that gave warning of a "drastic decline in food production—with serious political implications for just about every nation on Earth"—a prediction repeated with understandable glee by those who suspect the current worry is just another such scare.

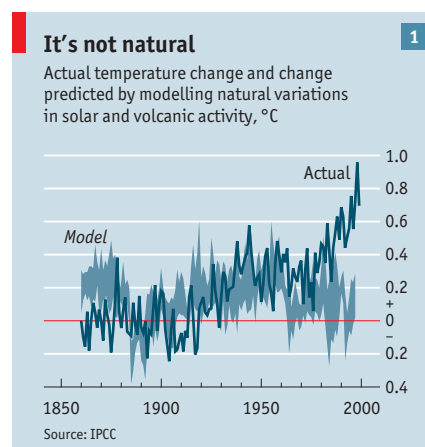
The mid-20th-century blip turns out to ▶▶

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This survey, which generated about 118 tonnes of carbon dioxide from flights, car journeys, paper production, printing and distribution, has been carbon-neutralised through the Carbon Neutral Company. The cost was £590; the money was spent on capturing methane from an American mine.

▶ have been the consequence of another by-product of human activity: sulphur and other airborne particles that bounce back sunlight before it can hit the Earth, thus offsetting the greenhouse effect. By the late 20th century, efforts to control that sort of pollution were having an effect. The particulate content of the atmosphere was falling, and the world began to heat up once more. The idea of global warming was retrieved from the bin and turned into one of the biggest arguments of our time.

The debate involves scientists, economists, politicians and anybody interested in the future of the planet. It is charged by the belief on one side that life as we know it is under threat, and by the conviction on the other that scientists and socialists are conspiring to spend taxpayers' money on a bogey. It is sharpened by a moral angle—the sense, deep at the heart of the environmental movement, that the consequence of individual selfishness will be collective doom: the invisible hand is a fist, and original sin an SUV.

The argument is peopled by big characters: James Lovelock, a British scientist who believes that mankind has fatefully unbalanced the delicate mechanisms of a world he calls Gaia; Bjorn Lomborg, a hyperactive Danish statistician who believes that scientists are twisting figures to scare people; Arnold Schwarzenegger, the gov-



ernor of California, whose mission is to terminate climate change; and James Inhofe, chairman of the environment and public works committee in America's Senate, who says it is all nonsense.

Unfortunately, the argument is also fuelled by ignorance, because nobody knows for sure what is happening to the climate. At a macro level, modelling what is one of the world's most complex mechanisms (see box below) and projecting 100 years ahead is tricky. At a micro level, individual pieces of data contradict each other. One shrinking glacier can be countered by another that is growing; one area

of diminishing precipitation can be answered by another where it is rising.

Ignorance and fear have spawned an industry. Governments, international bureaucracies and universities are employing many thousands of clever people to work out what is going on. Foundations are pouring money into research. Big corporations now all have high-level climate-change advisers with teams of clever young things scurrying around to find out what the scientists are thinking and what the politicians are planning to do.

The establishment of an Intergovernmental Panel on Climate Change under the auspices of the UN was designed to silence the arguments and give policymakers an agreed line on what the future holds. But given how little is known about either the climate's sensitivity to greenhouse-gas emissions or about future emissions levels, that proved difficult. Not surprisingly, the IPCC's latest report, published in 2001, offers a wide range of predicted temperature rises, from 1.4°C to 5.8°C by the end of this century.

This huge range limits the usefulness of the IPCC's findings to policymakers. Nor has the panel's existence quietened the debate. Scepticism about its science and especially its economics has led a number of people to disagree with its findings. Some challenge the evidence that climate ▶▶

## In the loop

**T**HE baffling complexity of the climate—and thus the difficulty of predicting what is going to happen to it—arises principally from its feedback loops. Scientists are finding out about ever more of them, which is why things don't seem to be getting much clearer over time.

Feedback loops may be either positive, thus reinforcing warming, or negative, countering it. Most of the main ones scientists have identified are positive; others are little understood and might go either way.

Feedback is the source of the scientists' biggest worry. Looking at previous episodes of dramatic climate change, they reckon that a bit of warming may set off mechanisms that lead to much more

warming; and that once that starts happening, mankind will lose the opportunity to control the pace of change. Among the main feedback loops are:

- **Albedo**—the tendency to reflect rather than absorb light. White areas reflect sunlight and dark areas absorb it, so as ice melts and the Earth's albedo decreases, the world absorbs more energy and warms up even more.
- **Ocean absorption.** The sea absorbs CO<sub>2</sub>. Colder seas absorb more than warmer ones, so as they warm they will tend to absorb less, leaving more in the atmosphere.
- **Soil respiration.** The soil emits CO<sub>2</sub>. Warming may lead to an exponential rise in microbial activity, which would cause emissions to rise faster than the increase

## Warming may set off mechanisms that make it warmer still

in vegetation could absorb them. There is a particular worry about greenhouse gases in tundra around the Arctic: if the tundra melted, they would start to be released.

- **Clouds.** Whether the feedback from clouds is positive or negative is the source of a big argument among scientists. Professor Richard Lindzen at the Massachusetts Institute of Technology, one of the few remaining serious scientists who doubt that climate change is a problem, believes in what he calls the "iris effect": that, just as the eye's iris closes up when a bright light is shone upon it, so a warmer world will produce more water vapour which will form clouds and block out sunlight. Others argue that the clouds thus formed will merely shut in the heat.

► change is happening; others accept that it is happening, but argue that it isn't worth trying to do anything about it.

Since that IPCC report five years ago, the science has tended to confirm the idea that something serious is happening. In the 1990s, satellite data seemed to contradict the terrestrial data that showed temperatures rising. The disparity puzzled scientists and fuelled scepticism. The satellite data, it turned out, were wrong: having been put right, they now agree with terrestrial data that things are hotting up. Ob-

servations about what is happening to the climate have tended to confirm, or run ahead of, what the models predicted would happen. Arctic sea ice, for instance, is melting unexpectedly fast, at 9% a decade. Glaciers are melting surprisingly swiftly. And a range of phenomena, such as hurricane activity, that were previously thought to be unconnected to climate change are now increasingly linked to it.

This survey will argue that although the science remains uncertain, the chances of serious consequences are high enough

to make it worth spending the (not exorbitant) sums needed to try to mitigate climate change. It will suggest that, even though America, the world's biggest CO<sub>2</sub> emitter, turned its back on the Kyoto protocol on global warming, the chances are that it will eventually take steps to control its emissions. And if America does, there is a reasonable prospect that the other big producers of CO<sub>2</sub> will do the same.

But first, to the science, and some of the recent findings that have sharpened people's worries. ■

## Those in peril by the sea

Two of the big risks from climate change are a shutdown of the Gulf Stream and a rise in sea levels

**A**SVERDRUP, the unit in which ocean currents are measured, is one million cubic metres of water per second. The Gulf Stream, the northern part of a circulation system known as the North Atlantic Gyre, reaches 150 Sverdrups at its peak. On average, it flows at around 100 Sverdrups. North of Britain, where the surrounding water temperature is around zero, the Gulf Stream is around 8°C. With its huge volumes and its sharp temperature difference to surrounding waters, it carries so much tropical heat from the mid-Atlantic to western Europe that Norway's coastline is, in winter, 20°C warmer than similar latitudes in Canada.

The prospects for the Gulf Stream are therefore of considerable interest not just to climatologists but also to farmers, businessmen, politicians and any western Europeans who prefer mild winters to the prospect of living somewhere like Newfoundland. So a recent paper suggesting that it was slowing down aroused plenty of interest.

The Gulf Stream is driven both by the rotation of the Earth and by a deep-water current called the Thermohaline Circulation. The THC pulls warm salty water from the tropics northwards. It gradually loses heat as it does so and, as it approaches the Arctic, begins to sink because it is saltier, and therefore heavier, than the surrounding water. As it sinks, it pulls in more warm water from the tropics. The deeper, colder water returns to the tropics through the Deep Southerly Return Flow, which passes by Florida, and the Subtropical Recirculation, which curls round the west coast of Africa.

There are good reasons to be nervous about the Gulf Stream's future, because it has not been reliable in the past. Since the most recent ice age 20,000 years ago, it has packed up several times—most recently, it seems, around 8,200 years ago, when a sudden flood of fresh water from a North American lake tipped into the North Atlantic. The fresh water seems to have diluted the Gulf Stream's saltiness and thus weakened its flow.

That, fear climate-change watchers, is what could happen as the Arctic ice melts. But the models did not predict that it would start happening yet, which is why the climatological world sat up when a paper was published last year claiming that the flow appeared to be slowing.

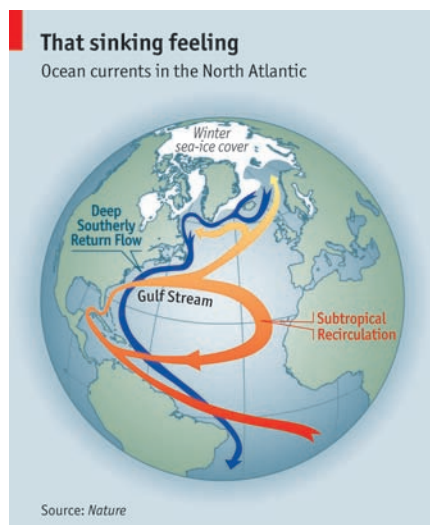
The paper, by Harry Bryden and some

colleagues at Britain's National Oceanography Centre in Southampton, was based on five sets of measurements of the THC taken over half a century. The first three showed no discernible change in its speed; but results in 1998 and again in 2004 suggested a noticeable slowing, which Dr Bryden and his colleagues estimate at 30% of the current's volume.

Some scientists, such as MIT's Professor Carl Wunsch, caution against drawing conclusions from so few data points. "The oceans are like the atmosphere. The system is exceedingly noisy. You get weather in the oceans like you get weather in the atmosphere. This paper is based on five crossings of the Atlantic over 47 years. It's as though you went out on five different occasions in five different places in North America over half a century and measured the wind speed. You say there's a trend. There's a trend in your figures, but you have no evidence of a secular trend. Much of the community would say you have five data points."

Professor Wunsch is not a climate-change sceptic. He believes that there will be "serious future climate change: it's almost guaranteed," and he thinks there should be attempts to mitigate it. But he is fed up with too much being read into thin research.

Although the data about what is happening now may not be solid enough to bear too much interpretation, the models' predictions are not reassuring either. A paper by scientists from the Hadley Research Centre of Britain's Meteorological Office and others, presented earlier this year at a symposium on "Avoiding Dangerous Cli- ►►





Now you see it, now you don't: Blomstrandbreen glacier, Norway, 1918 and 2002

mate Change”, rated a shutdown of the Gulf Stream over the next century as “unlikely”, but reckoned that a slowdown of up to 50% was likely. Another paper presented at the same meeting saw a two-in-three chance that it would shut down over the next 200 years.

How much would a shut-down matter? That is another thing that the big guns of climate change disagree on. “You could have icebergs around Britain,” says David Griggs, director of climate research at Britain’s Met Office. Daniel Schrag, professor of geochemistry at Harvard’s department of Earth and planetary sciences, has a different take. “Models that predict THC shutdown caused by warming never produce overall cooling, but only reduce the warming effect in coastal areas of Scotland and Scandinavia.”

The other marine subject that has caught people’s attention recently is the

rise in sea levels. So far this has been relatively small, but if it accelerates, it could become the most serious consequence of climate change.

#### Brimming over

In March 2002 Ted Scambos, a scientist from the University of Colorado, was examining images from NASA’s Modis satellite and noticed something odd going on at the Larsen B ice shelf (a floating extension of a glacier) on the Antarctic Peninsula in the west of the continent. He alerted the British Antarctic Survey in Cambridge, which sent a ship over to have a look. Meanwhile, an Argentine glaciologist based in Antarctica, Pedro Skvarca, took an aeroplane over the shelf. That is how pictures of the first recorded collapse of a big Antarctic ice shelf were obtained.

Most of the ice in the Arctic is sea ice, so when it melts the sea level doesn’t change

much. Ice in Greenland and Antarctica, by contrast, is mostly on land. Greenland’s ice sheet is up to 3km (1.9 miles) thick; Antarctica’s 4.2km. If all of Greenland’s ice were to melt, sea levels would rise by around 7 metres; if West Antarctica’s were to go, that would add another 6 metres; and if East Antarctica’s ice melted—which nobody thinks likely for the foreseeable future—sea levels would go up by a devastating further 70 metres. Even a 1-metre rise would flood 17% of Bangladesh’s land mass and cause serious problems for coastal cities such as London and New York.

The sea level has varied sharply during the Earth’s history. At the peak of the most recent ice age, around 18,000 years ago, it was 130 metres lower than it is now; but through most of the planet’s history it has been much higher. Over the past 100 years, it seems to have risen, on average, by about 10-20cm, but measuring that accu- ▶▶

## Bringing back the barley

THE Middle Ages were unusually warm in northern Europe, and it was during that period that the Vikings settled in Greenland. They cultivated land, growing mostly barley. The climate then cooled down, which made the place too chilly for arable farming. These days Greenland’s 56,000 people rely largely on sheep farming in the south, hunting in the north and fishing in the west.

Or at least they did until the world started warming up again. Average temperatures in Greenland have risen by 1.5°C over the past 30 years. The barley is back. Kenneth Hoeth has been growing it, but only as an experiment. Several farmers in southern Greenland are now farming potatoes, turnips and iceberg lettuces

commercially. Mr Hoeth is trying out other crops: he is pleased with his Chinese cabbage, which he says is particularly crispy.

The weather has helped sheep farming, too. Sheep are kept in barns all winter and have to be fed with hay or other fodder. Because grass grows more plentifully these days, sheep farmers need to import less fodder, so costs have fallen. The only downside, says Mr Hoeth, is bugs: caterpillars are proliferating. But, he says, “generally the warming is good for us.”

Not everybody in Greenland is so pleased, though. Hunters in the north, who catch narwhals, seals, walrus and polar bears, use dog sledges, which are tricky to use when the ice melts and the

## Mild weather in Greenland pleases some but not others

soil is mushy. The weather is less predictable, too. “Earlier,” says Alfred Jacobsen, Greenland’s deputy minister for environment and nature, “local people could count on the weather. Now they don’t know whether there will be a north wind, which brings stable weather, or a south one, which brings snowstorms.”

And for the fishermen in the west, who use big trawlers to catch shrimp, it could go either way. “Ice can be a problem for us,” says Jens Lyberth of the Fisheries and Exports branch of the Greenland Employers’ Association. “Less ice is less problem.” And cod, which used to be plentiful until the 1960s, then disappeared, are coming back; but cod eat the shrimp the fishermen are after.

▶ rately has proved surprisingly hard.

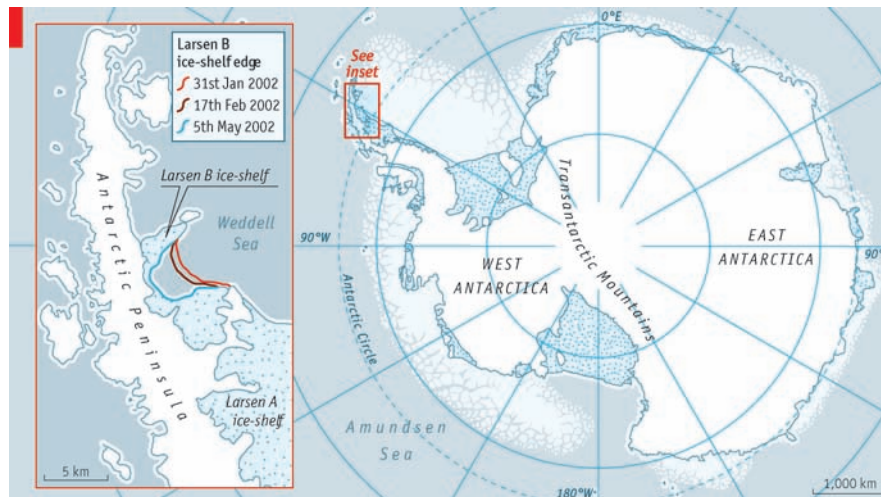
The sea is not like a bath. If you pour water in at one end, it does not necessarily spread itself evenly. Sea levels are currently falling in the northern Pacific, the north-west Indian Ocean and near Antarctica; they are rising over most of the tropics and subtropics. That is because some seas are warming (and hence expanding) and some cooling (and hence contracting), and because the wind shifts water around.

At the same time, land is moving up and down, because parts of the northern hemisphere are still bouncing back from the weight of the ice sheets they were carrying 20 millennia ago, and the southern parts of those continents are going down as the northern parts go up. So Scandinavia is rising by around a metre a century; Loch Lomond in Scotland is rising by around 1mm a year; and London is sinking by about the same amount.

Until 13 years ago, all the available data on sea levels were collected by hand from ancient tide-gauges. But in 1992 satellite data became available that allowed sea levels to be measured in the middle of the oceans as well as at their edges. Those data suggest that sea levels are currently rising by around 3mm a year; land-based data suggest that the rise accelerated from an average of around 2mm a year over the past century to 4mm in the 1990s.

Sea levels are rising for two reasons—because water expands as it warms, and because ice is melting. That is where Larsen B, and some new findings from Greenland, come in.

The collapse of Larsen B was not, in itself, all that important. What matters is the relationship of ice shelves to the glacier and the ice sheet behind them. “If ice



sheets are cathedrals,” says Richard Alley, a glaciologist at Penn State University, “ice shelves are the flying buttresses that secure them.” Ice shelves are especially vulnerable because there is water underneath them; and if the water warms, the ice shelves get thinner. Mr Alley reckons that for every 1°C increase in water temperature, ice shelves shrink by 10 metres.

#### Galloping glaciers

Scientists knew that Larsen B was deteriorating, but had not expected what happened after it collapsed. It turned out to have been acting as a brake on the glaciers behind it. When it went, they started moving faster; and the faster they move, the faster they melt. According to data analysed by Dr Scambos, the four glaciers behind Larsen B were moving between two and six times as fast in 2003 as they were in 2000. Another paper, by Eric Rignot, a NASA scientist, showed speeds increasing by up to eight times. Even so, the pace remains glacial: before the shelf collapsed, the ice was travelling at a few hundred metres a year; after, at a couple of kilometres.

In southern Greenland, too, change is afoot. Jakobshavn Isbrae, Greenland’s

largest glacier, which drains 6.5% of Greenland’s ice-sheet area, doubled its speed between 1997 and 2003. It is so large that its contribution to sea-level rise is measurable: about 0.06mm a year, or roughly 4% of the rate of sea-level increase in the 20th century.

However, the rate of glacier melt by itself does not determine sea levels. The big issue is the “mass balance” of ice in Greenland and Antarctica—whether, overall, ice sheets are growing or shrinking. There are no signs of glaciers in northern Greenland or East Antarctica speeding up. In West Antarctica, one of the three main outlets (which includes the glaciers behind Larsen B) seems to be speeding up, but another (the most volatile) may be slowing down. Meanwhile, snow falls on ice sheets, replacing some of the lost ice.

Nobody knows what is happening to the mass balance of Antarctica. Greenland’s does seem to be shrinking very slightly—by around 0.4mm a year, in sea-level equivalent. That would be only 4cm a century, if the rate stayed constant. But there is no reason to think that the rate will stay constant—nor, if it did accelerate, that anything could be done to stop it. ■

## Reaping the whirlwind

Hurricanes used to be thought unconnected to climate change. Now a link is emerging

CLIMATOLOGY was once a rather peaceful science, insulated by the long-term nature of its inquiries even from the passions aroused by weather forecasts. Now that it is being asked to predict the future of the world, it has understandably become politicised and argumentative.

The science of hurricanes is a case in point. Hurricanes are the main climatological hazard on America’s wealthy east coast, so predicting them and following

their progress has long been a sizeable industry. That has been especially true since 1995 when, after a quiet three decades, the frequency and intensity of hurricanes in the Atlantic picked up. Interest in them has been especially sharp since 2004, the most active year on record. The following one, more turbulent still, brought Hurricane Katrina, which did more economic damage than any previous weather event anywhere. So politicians, businessmen and

the public have all turned to hurricane scientists to tell them what is happening.

But establishing trends in hurricane frequency and intensity is much more difficult than in temperature. Whereas temperature can be measured every day, all around the world, with hurricanes the data points are far fewer and further between. What’s more, the records before 1970 are poor. Nevertheless, an increase in the number of storms in the 1940s and ▶▶

▶ 1960s, followed by a quiet period, and the subsequent increase in activity in the 1990s, had led to the notion of the Atlantic Multi-decadal Oscillation (AMO), a little-understood cycle believed to be caused by changes in the ocean, which was responsible for hurricanes.

The AMO was widely accepted in the hurricane business. Climate models did not predict an increase in hurricane activity as a result of global warming, and the IPCC's 2001 report said there was no evidence of a connection between the two.

But two influential papers published in 2005 argued otherwise. One, by Peter Webster, Judith Curry and colleagues, said the data supported the idea that there was a long-term increase in the number of category four and five (intense) hurricanes; the other, by Kerry Emanuel, professor of tropical meteorology and climate at MIT, suggested that the intensity of Atlantic storms had on average doubled over 30 years.

The Webster paper was a surprise, but Professor Emanuel's came as a real shock. He is a big noise in the hurricane world and had been a supporter of the AMO. "Initially," he says, "I was very enamoured of the idea of natural cycles. But we've gone back to look at the data, and what you see is anything but a natural cycle."

### Oscillating theories

Hurricanes are closely related to sea-surface temperatures. These rose during the first half of the 20th century, then fell back, then started rising again in the 1970s. Hurricane activity followed the same pattern, which prompted the idea of the oscillation. But Professor Emanuel now believes that what looked like an oscillation is, in fact, a long-term trend, masked in the 1950s-70s by an increase in atmospheric pollution by particles such as sulphur that led to a period of global cooling. Now that sulphur levels have been reduced, atmospheric temperatures are on their way up again—and so are sea-surface temperatures and hurricane activity.

Not everybody agrees. Bill Gray, a professor of meteorology at Colorado State University, who runs a hurricane-forecasting centre and is the man America always turns to when a big hurricane threatens, doubts the methods of the climatologists. "I'm a great believer in computer models," he told the 27th Conference on Tropical Meteorology earlier this year. "I am—out to ten or 12 days. But when you get to the climate scale, you get into a can of worms. Any climate person who believes in a model should have their head examined."



Thicker and faster

But mostly the hurricane world has come round to the view that global warming, by raising the sea-surface temperature, is causing the increase in hurricane activity. "There's no denying that there's an apparent oscillation in the North Atlantic," says Tom Karl, director of the National Climatic Data Centre of America's National Oceanic and Atmospheric Administration. "But the increase in sea-surface temperatures has clearly had an important role—and they're not simply due to natural oscillations. It's very clear that there is a human contribution in play."

Debate centres mostly on the question of degree. Robert Muir-Wood, head of research at Risk Management Solutions, a firm that creates catastrophe models for use in the insurance industry, says that "if you ask climatologists how much of the extra activity is the result of climate change, the range of opinion is between 10% and 60%."

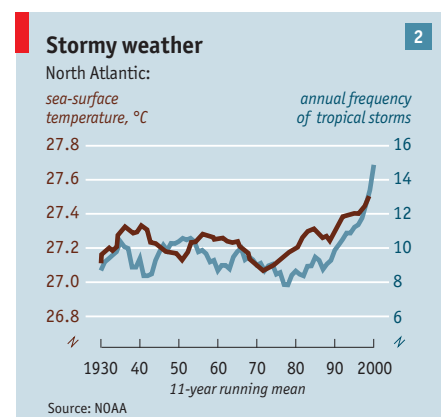
The insurance industry has a strong interest in these matters. In 2004 and 2005, the two most active hurricane years on record, weather-related losses amounted to \$145 billion and \$200 billion respectively. The big losses of the past two years have pushed reinsurance prices up. "When events occur, prices rise," says Christian Mumenthaler, chief risk officer with Swiss Re. "Post-Katrina prices in this bit of the reinsurance business have doubled. Such events usually pay themselves back."

If prices are rising, that should be a signal to people and businesses to avoid settling in risky areas. The economic centre of the hurricane business is Florida, which is

both the most vulnerable part of America and the most valuable. In 2004 the total value of insured coastal property in Florida was \$1.937 trillion, compared with \$1.902 trillion in New York. Unfortunately, the signal is not getting through to homeowners in Florida, because the government is cushioning the blow. Insurance companies in America may not set their own prices. The rates they charge customers (and indeed the models on the basis of which they calculate their rates) are regulated by state governments. "Communism survives in three parts of the world," says Mr Muir-Wood: "North Korea, Cuba and the American insurance market."

Not surprisingly, insuring property in Florida is not very profitable. According to the Insurance Information Institute, the cumulative underwriting loss on Florida homeowners' insurance in 1992-2004 was \$8.6 billion. As a result, insurers are going bust or pulling out. Ten collapsed after Hurricane Andrew in 1992; three companies owned by Poe Financial Group, Florida's second-biggest home insurers, went into liquidation this summer. Allstate decided last year not to renew 12.5% of its 758,000 policies in Florida.

But Floridians need not fear being left without insurance in a hurricane. The state provides cover, through the Citizens Property Insurance Corporation. Some 900,000 Floridians now get their home insurance from Citizens, which taps the taxpayer to cover its deficits. In May, Jeb Bush, the state's governor, signed a bill for a \$715m subsidy to help the company cover last year's \$1.6 billion hole. According to Robert Hartwig, chief economist of the Insurance Information Institute, bailing out Citizens requires "grandmothers living in trailer parks on fixed incomes in [inland] Gainesville to subsidise million-dollar homes in Marco Island".



Thanks to subsidised insurance, the risks of living on Florida's coast are not reflected in property prices. In 2005—the year after the most damaging hurricane year ever—six of the nine metropolitan areas with the fastest-rising house prices in America were in Florida. The state's population is expected to rise by 52% between 2003 and 2030, as against 21% for the country as a whole. The insurance industry is not impressed. "You've got to send a proper price signal," says David Unnewehr of the American Insurance Association. "You can't subsidise development

through insurance."

What would Florida look like if the price signals were getting through? More like Grand Bahama, probably, which is covered by the British insurance market. The Queen's Cove canal estate in north Grand Bahama, which has been flooded three times in six years, is no longer insurable. People are moving out and new houses are being built on stilts.

The foolishness of pouring money into vulnerable areas is one issue that unites those divided hurricane scientists. In July, a group including Mr Emanuel and Phil

Klotzbach, Bill Gray's sidekick, put out a joint statement. "We are optimistic", they said, "that continued research will eventually resolve much of the current controversy over the effect of climate change on hurricanes. But the more urgent problem of our lemming-like march to the sea requires immediate and sustained attention. We call upon leaders of government and industry to undertake a comprehensive evaluation of building practices and insurance, land-use and disaster-relief policies that currently serve to promote an ever-increasing vulnerability to hurricanes." ■

## Where the wild things are

Not where they used to be, as the world gets warmer

**E**DITH'S CHECKERSPOT is an unremarkable brown, white and black spotted butterfly whose main distinguishing characteristic is that it is watched, with obsessive but benevolent attention, by Camille Parmesan, a biologist at the University of Texas. Ms Parmesan is troubled by what is happening to the butterfly. The populations at the southernmost end of its range, in California, have been dying out. The vegetation it lives on is getting dryer, which makes it hard for newborn caterpillars to survive.

"The tiny, one-to-two-day-old caterpillars were unable to walk the inch or more to nearby plants and thus starved to death," records Ms Parmesan in a paper on the subject. (The source is affectionately cited as: Parmesan, personal observation.) The species' range has extended 55 miles (88km) northwards, but that is not much help to the three endangered subspecies—the bay checkerspot, Taylor's checkerspot and Quino checkerspot—living at the southern end of its range.

Whereas people these days are mostly able to adapt their environment to suit themselves, the world's other inhabitants still have to adapt themselves to their environment. When circumstances change, they adjust in two main ways: by changing the timing of important life events, such as hibernation, migration and breeding; or, like Edith's checkerspot, by moving to find more comfortable living quarters.

Ms Parmesan and Gary Yohe of Wesleyan University, Connecticut, who looked at data on how species were adapting, found that, of a total of 677, nearly

two-thirds had brought forward the important events in their calendar. The Mexican jay in the Chiricahua Mountains in Arizona, for instance, is breeding ten days earlier than it was 30 years ago. Tree swallows' breeding season advanced by an average of nine days between 1959 and 1991. In the Rocky Mountains, the yellow-bellied marmot is emerging from hibernation 23 days earlier than it did in the 1970s.

Of the 434 species that had moved their range, four-fifths had moved northwards or to higher ground. The red fox, for instance, has colonised an extra 600 miles of Baffin Island. That's fine for the red fox, which, as the owner of any British dustbin knows, is in no danger of dying out, but less good for the Arctic fox at whose heels it is snapping.

Still, there is only so far a species can move, as the polar bear has found to its cost. Thinning Arctic ice is making hunting more difficult for it, and there is nowhere colder to go. The only long-term study of a polar-bear population—from Hudson Bay, in Manitoba in Canada—suggests that the animals are, on average, 15% thinner than they were 30 years ago. The population has dropped by 17% in the past ten years. America's Fish and Wildlife Service is thinking of putting the polar bear on the endangered-species list.

Some species, of course, are doing very nicely out of climate change. Warming aside, plants are likely to flourish with more carbon dioxide around. Northern areas are likely to see an increasing diversity of species.

There is, however, a common difficulty



A chequered future

for all animals and plants: they find it harder to adapt these days because people get in the way. Cities, roads, farmland and all the other manifestations of human civilisation leave less space for other species. That is one reason why some of them are in danger of dying out. Chris Thomas, professor of conservation biology at Leeds University in Britain, and colleagues, reckon that, if the IPCC's mid-range climate-change scenario (a 2-3°C increase by 2100) is right, between 15% and 37% of the species whose prospects they modelled will be extinct by 2050. ■

# Dismal calculations

The economics of living with climate change—or mitigating it

SCIENTISTS are better at getting headlines than economists are: doom for the planet makes better copy than cost-benefit analyses. That may be why some economists feel that the issue has been captured by economically illiterate climatologists who do not seem to understand that mitigating climate change means spending real money now in exchange for uncertain benefits in a remote future. They have been working hard to put figures on the costs and benefits of climate change and of trying to mitigate it.

That has not been easy. Economists struggle under a cascade of uncertainties—how much carbon dioxide the world goes on emitting (which itself depends on whether governments pay attention to the scientists' warnings); how fast temperatures will increase in response to greater concentrations of carbon dioxide (which depends on feedback mechanisms); what effect climate change will have on economies (which depends on how good people are at adapting to it); and many more.

Not all the change will be bad. An extra couple of degrees might not do northern Europe any harm. Russia could benefit hugely from a bit of warming: large parts of the country that are currently uninhabitable could become comfortable enough to live in. The 25% of the world's undiscovered oil and gas reserves that are reckoned to be in the Arctic, much of them in Russia, would become easier to get at. According to one estimate of the costs and benefits of climate change, by Robert Mendelsohn, a professor at Yale University, a 2.5°C increase in temperature would increase GDP in the former Soviet Union by 11% (compared with a 0.3% rise in North America). A less optimistic estimate by the father of climate-change economics, William Nordhaus, published in 2000, predicts a reduction in American GDP of 0.5%.

The world as a whole looks likely to lose out. In Mr Mendelsohn's model, global output falls very slightly, by 0.1% a year. In Mr Nordhaus's model, it drops by 2%. That is because Africa and India pull the average down: Mr Mendelsohn has Indian GDP falling by 2% and no figure for Africa; Mr Nordhaus has India dropping by 5% and Africa by 4%. It is not just that Africa

and India are already hot; being poor, they are also more dependent on agriculture than the rest of the world; and agriculture is more vulnerable to climate change than are investment banking or car assembly.

Estimates of the effect of climate change on global output are rising, partly thanks to new work on economics and geography, in particular by Jeffrey Sachs, director of Columbia University's Earth Institute, and Mr Nordhaus, who has come round to the view that temperature has a profound impact on economic development. Putting more weight on temperature as a factor in growth raises estimates of the damage from climate change. In his latest paper on the subject, Mr Nordhaus puts the damage to the global economy of a 2.5°C temperature rise at 3% of global output, up from the 2% he estimated in 2000.

The other reason that estimates are tending to rise is the science. More papers suggesting that the glaciers are melting and the Gulf Stream is slowing mean that more economists are building outlying possibilities of catastrophe into their calculations of potential damage.

## The bill

So how does the estimated cost of climate change compare with the cost of mitigating the effects? Unsurprisingly, that is not easy to calculate either. First, what is meant by mitigation? Many experts would settle for stabilising the carbon content of the atmosphere at around 550 parts per million. There is no particular magic to that figure, but given that carbon concentrations are now at 380ppm, it looks

achievable and does not make most scientists' hair stand on end.

The costs of mitigation depend principally on three factors. First, how far energy demand can be reduced by relatively cheap energy-efficiency measures. Plenty, according to the International Energy Agency: new buildings, for instance, can be made 70% more efficient than average existing ones. The IEA reckons that by 2050, energy-efficient technologies can bring emissions back to 2000 levels at moderate cost.

The second factor is how fast the price of renewable technologies will fall. The gap between some of them and fossil-fuel-based energy should shrink (see table 3) as technologies mature and manufacturing volumes rise. That's already happened for some renewables. The cost of wind-power generation, for instance, has come down from 8-10 cents to 3.5-4 cents per kwh since 1990 because of better-designed turbines and higher volumes.

The third factor in the cost of mitigation is how fast emissions are brought down. Worried scientists argue for doing this as swiftly as possible. Cost-conscious economists plead for gradualism. They point out that, as CO<sub>2</sub> hangs around in the air for up to 200 years, a tonne produced now is not much worse than a tonne produced in 20 years' time.

Moreover, cutting emissions gradually is a great deal cheaper than doing it quickly, because machinery can be replaced with new, lower-emissions varieties at the end of its life-cycle instead of being written off prematurely. Richard ▶▶

## Forget cheap energy

Illustrative costs of emissions-reducing technologies relative to a marker\*

Technology	Marker	Cost/unit	Cost of marker	Cost of substitute	
				short-term†	long-term
Nuclear	Natural-gas combined-cycle power plant	US cents/kWh	3.5-4	6	5
Electricity from fossil fuels and carbon capture and storage	Natural-gas combined-cycle power plant	US cents/kWh	3.5-4	5	6
Wind	Natural-gas combined-cycle power plant	US cents/kWh	3.5-4	5	6
Photovoltaic‡	Grid electricity	US cents/kWh	10	15	8
Biofuels	Petrol	\$/gigajoule	12	15	15

Source: Dennis Anderson, Imperial College, London

\*The technology that would be displaced by the new technology  
†Solar input=2000 kWh/m<sup>2</sup> ‡10 years



There's nowhere else to live

► Richels of the Electric Power Research Institute reckons that the cost of stabilising emissions at 550ppm would be a quarter of doing so at 450ppm, which would require existing plant to be scrapped.

The range of estimates of the cost of mitigating climate change is not quite as large as that of estimates of the damage caused by climate change, but big enough to make it hard to decide between action and inaction. Britain's House of Lords report on the economics of climate change came up with a range of 0.2-3.2% of global output a year for the cost of mitigation, but pointed out that unless developing countries start doing their bit, rich countries will end up spending more. Some consider the House of Lords figures too high: evidence to Sir Nicholas Stern, a former chief economist at the World Bank and head of Britain's Government Economic Service, who is due shortly to report on the economics of climate change, suggests costs in the range of 0.4%-1% of global GDP.

### Beyond price

But deciding whether it is worth taking action against climate change is not as simple as setting the costs of climate change against the costs of mitigation. There are a couple of ethical questions that shift the argument towards mitigation.

One involves the difficulty of doing cost-benefit analysis across borders. Money is worth more in the poor world than it is in the rich world. The sharpest ex-

ample of that is the implicit price of life: the amount of money spent on health care in Britain and India implies that the life of a Briton is worth more than the life of an Indian. Politically, however, that is hard to sustain; indeed, the first meeting of the IPCC nearly fell apart on this question. Many economists therefore go for some "equity weighting"—putting a greater value on a dollar of damage in India than in Britain. And, because climate change is likely to do more damage to India than to America, the higher the equity weighting, the higher the social cost of carbon.

The other question concerns doing cost-benefit analysis across many generations. In standard cost-benefit analysis, each pound or dollar spent this year is reckoned to be worth slightly more than one spent next year, partly because economic growth will usually make people richer next year than this. This preference is expressed in a discount rate which, depending on interest rates, is usually set at somewhere between 3% and 6%. So with a discount rate set at a normal level, the benefits beyond half a century barely count. This usually does not matter much, because most of the investments in question have a time horizon of 20-50 years. But climate change is not expected to do much damage within the next 50 years, so at a normal discount rate mitigating climate change does not seem worthwhile.

Some economists try doing their sums instead with a discount rate which holds

future benefits equal in value to current ones. That gives a much higher social cost of carbon than a normal discount rate, so mitigating climate change becomes correspondingly more attractive. This is justified partly through economics—that the consequences of not taking action may be so catastrophic that normal economic growth cannot be assumed—and partly through ethics—that the interests of future generations are worth as much as those of the current one.

Critics such as Bjorn Lomborg, author of "The Skeptical Environmentalist", question the grounds for giving this problem such special treatment. Given the uncertain returns from taking action against climate change, they argue, the money would be better spent on investments that have clear benefits. If climate change is likely to do most damage in poor countries, why not instead spend the money on, say, education there? Not only would that benefit poor people now, it would also equip them better to deal with the risks that climate change brings.

After all, the reason why Bangladesh is so vulnerable to a 1-metre rise in the sea level is not just its flatness; it is also its poverty, as a result of which too many of its people live on subsistence agriculture around the Bay of Bengal. If Bangladesh were South Korea, more people would be working in offices and factories and living in cities. The best protection for Bangladesh, in other words, is development. And anything (including climate-change mitigation) that reduces the global rate of economic growth is likely to slow development in Bangladesh, thus making the place more vulnerable to climate change than it otherwise would be.

That may well be true. But the consequences of climate change could amount to more than a 1-metre rise in the sea level. It is quite possible that the Gulf Stream will switch itself off, that the ice sheets in Greenland and West Antarctica will start losing mass quickly, and that the release of methane from tundra will send temperatures spiralling upwards. If those disastrous outlying possibilities are included in the calculations and the potential damages are averaged over the moderate to the catastrophic, the protective effects of a developed economy fall and the benefits of action—to both the rich and the poor world—rise.

It is those outlying possibilities that have persuaded some economists that it is worth trying to mitigate climate change. As Cameron Hepburn of Oxford Univer- ►►

city says, "I'm not especially worried about the mean. It's the tail. If governments should ever be risk-averse, it's in the face of this sort of distribution. You can think about the risks as similar to those from terrorism."

Sir Nicholas Stern seems to agree. In a paper published in *World Economics* in June, he writes:

Policymakers need to take into account the risks of greater dangers as well as central

expectations, because the consequences if these risks were to materialise would be very serious. For example, extreme, abrupt and dangerous climate-change scenarios based on loss of carbon sinks and melting permafrost may not accord with the climate scientists' central expectations, but their possibility must be recognised when considering the appropriate vigour of policy responses. The prudential approach is common in other areas of policy, from defence to financial stability, and warrants more public action to mitigate climate change, not less.

Out of the fog of uncertainty over the economics of climate change, the outline of a few conclusions emerges. Global warming poses a serious risk, and the costs of mitigation are not so large as to be politically unthinkable. Mitigation is better done gradually than swiftly, because the faster it is done, the more it will cost. That said, the economics of the subject are too uncertain for policymakers to lean heavily upon them, so in the end it will be the politicians who decide. ■

## Selling hot air

Kyoto's main achievement was to create a market in carbon. It's flawed, but better than nothing

THE huge hall at the Koelnmesse, Cologne's massive conference centre, looks like any other trade fair: rows of sellers' booths, some with buyers milling around them, some deserted. The participants' costume is a little unusual—not just the standard suits, but also chinos and t-shirts with green slogans. But what is being sold is very different: industrial gases to be captured from Chinese factories, trees to be planted in Africa, methane to be extracted from pig-effluent in Brazil. This is the carbon market, the main achievement of the Kyoto protocol.

Kyoto was a hard-fought attempt to do something immensely difficult: create a global mechanism for solving a long-term problem. Not surprisingly, its achievements have been limited. America and Australia did not ratify the treaty. Canada looks as though it may fail to comply. It signed up for a 6% reduction below 1990 levels by 2012, but the latest figures suggest that it is now running around 23% above

1990 levels. According to the new environment minister, Rona Ambrose, "it is impossible, impossible, for Canada to reach its Kyoto targets."

Japan is supposed to be cutting its emissions to 6% below 1990 levels. It has no mandatory scheme, but many companies are participating in a voluntary one. Still, emissions are currently running at 24% above 1990 levels, so it will probably have to buy credits from other countries.

The EU has taken Kyoto most seriously. In 2005 it launched the European Emissions-Trading Scheme (ETS), which is supposed to cut emissions from the EU's five dirtiest industries. Most big European countries have additional schemes to penalise big CO<sub>2</sub> emitters and to boost renewables, which is why wind farms are sprouting all over Europe. Some big European countries, such as Germany, France and Britain, are either near to meeting their targets or have already done so by cutting domestic emissions. Others, such as Spain

and Italy, are further behind.

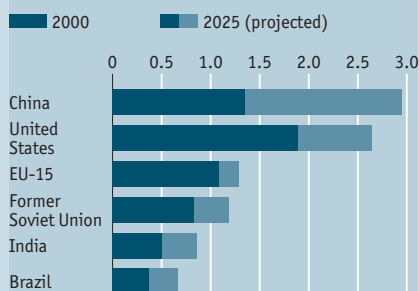
America was heavily involved in the design of the Kyoto protocol, and insisted that it should include the possibility of a market in emissions credits, on the ground that its trading scheme to reduce sulphur-dioxide emissions had been a big success. Europe reluctantly agreed and, once America walked away from Kyoto, turned out to be the mainstay of the carbon market that the protocol has created.

The carbon market works like any other commodity market: companies trade and the market sets prices. But it is unusual in that the commodity being bought and sold does not exist: it is the certified absence of carbon emissions. The market is big, and growing fast. In the first half of 2006, carbon to the value of €12 billion (\$15 billion) was traded, five times more than in the same period in 2005.

There are two parts to the carbon market. The first, and largest in terms of cash, is the trade in allowances handed out to ▶▶

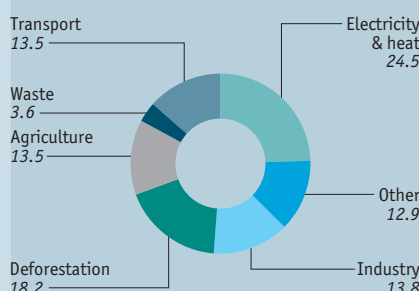
### A tour of the greenhouse

Greenhouse-gas emissions, bn tonnes of carbon equivalent

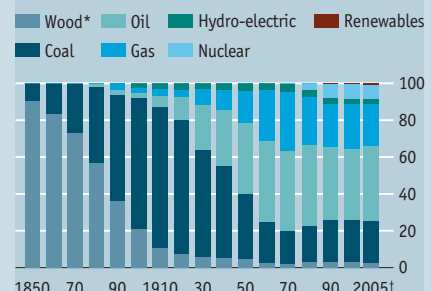


Sources: EIA; World Resources Institute

World greenhouse-gas emissions by sector, 2000, %



US energy sources, %



\*Biomass from 1950 onwards †Preliminary

## Anti-hero

THE few remaining cyclists in Beijing risk death one way or another. If the city's 4m cars, jammed onto the multiplying ringroads and flyovers, do not get them, the polluted air will. It is so thick that you cannot see the sun, even on a sunny day.

At present, rich countries emit more CO<sub>2</sub> than developing countries do. But developing countries as a whole will overtake rich countries shortly; and China, the most populous of the emerging economies, will become the world's biggest greenhouse-gas emitter in 2015.

Every year China builds 60 gigawatts of power-generation capacity, almost as much as Britain's entire existing capacity. Four-fifths of Chinese power is generated by coal, the dirtiest source of electricity. China currently uses 40% of the world's coal—more than America, Europe and Japan put together.

Pollution has not been a priority for the Chinese government. "All departments and ministries are oriented towards GDP. Some comprehensive economic departments should be in charge of planning, but all they want to do is authorise projects. Local leaders are the same. So the Environmental Protection Agency is pretty weak," according to Pan Yue, vice-minister of the State Environmental Protection Agency.

But the government is becoming increasingly concerned about the problems that pollution brings, such as sickness from filthy air and arid soil from acid rain, which has made it keen to boost the use of renewables and increase energy efficiency. It is building huge wind farms on its coastline and even runs some hydrogen-fuelled buses in Beijing. Last year it pushed up fuel-efficiency standards for cars sold in China, and by 2008 it will raise them above federal American levels. The 11th five-year plan, published earlier this year, requires the economy to become 20% more energy-efficient by 2010.

Between 1980 and 2000 China's GDP quadrupled, whereas energy consumption only doubled. The Chinese government intends to repeat that trick. But decentralisation, deregulation and a huge infrastructure boom have boosted demand for power, and China's economy is now becoming more, not less, energy-intensive. The energy elasticity of GDP (the relationship between changes in energy consumption and changes in GDP) rose from 0.5 in 2000 to 1.5 in 2004. "The government has lost control of industry," says Jiang Lin of America's Lawrence Berkeley National Laboratory.

Moreover, the goals of reducing pollution and mitigating the effects of climate change sometimes conflict. The harmful

Within a decade, China will emit more greenhouse gases than any other country



Murky business

pollutants released into the air by coal-fired electricity generation, such as sulphur, also dampen the greenhouse effect. Take them out and your people's health will improve, but the world will get warmer, as the West found in the second half of the 20th century. China, too, seems likely to choose cleaner air.

▶ companies in the EU's five dirtiest industries under the ETS. Those companies have also been given emissions-reduction targets, which they can meet by cutting their own emissions, or by buying allowances from other companies, or by purchasing credits from developing countries. That is the second bit of the carbon market. The trade in allowances does not actually reduce emissions. The trade in developing-country credits does.

The Carbon Fair in Cologne, organised by the World Bank, is the annual get-together of the second bit of the market. The buyers are from the participants in Europe's ETS and Japan's voluntary-reduction scheme. The sellers are developing countries. The rich countries that ratified Kyoto are expected to produce 3.5 billion

tonnes of carbon above their targets by 2012, so the prospects for sellers look good.

Some of the sellers at the Koelnmesse are more popular and better organised than others. The Chinese state planning committee stall has a glossy 200-page book crammed with projects, and a crowd of potential buyers. The man on the Senegalese stall has a photocopied piece of paper with six projects, and no customers.

The middlemen are niche investment banks, such as Climate Change Capital and Natsource, and project-management companies, such as Camco and AgCert. Camco, which floated earlier this year, works mainly in China. It identifies factories that emit lots of greenhouse gases and works out how to cut emissions; AgCert builds sealed pools to contain the pig-

effluent in Brazil and Mexico, captures the methane it produces and burns it to produce electricity.

Projects have to be certified by the UN. Most involve cutting emissions not of CO<sub>2</sub> but of more potent greenhouse gases. HFC, for example, an industrial gas, has 11,000 times the greenhouse effect of CO<sub>2</sub>. Some 58% of the credits sold between January 2005 and March 2006 were for HFC projects. Capturing it costs little—under \$1 per tonne of CO<sub>2</sub>-equivalent—and selling it is lucrative. Thanks to the insatiable demand for credits, developing-country sellers have been getting up to \$24 a tonne. Two Chinese deals alone, set up by the World Bank, which has put together a consortium of buyers, are worth \$930m. At current prices, China is reckoned to have ▶▶

▶ about \$6 billion-7 billion-worth of HFCs that could be captured.

Not surprisingly, given both Chinese efficiency and the amount of dirty industry in the country, two-thirds of the deals signed between January 2005 and March 2006, by value, were with China. Keen to keep hold of the cash for its own purposes, the Chinese government has slapped a 65% tax on HFC projects and is funnelling the money into a “sustainable development” fund. “Sustainable development!” snorts a Chinese official. “It’ll be spent on infrastructure.”

### All right for some

Observers have three concerns about the carbon market. The first is about profits and prices. Giving the ETS allowances away (rather than auctioning them) made the scheme easy for the power-generators and other polluters to swallow. But it also, in effect, handed them wads of cash: they simply passed the extra costs on to consumers and pocketed the money. Accord-

ing to a report by IPA Energy Consulting, Britain’s power-generation sector alone made a profit of around £800m (\$1.5 billion) from the scheme in its first year.

Meanwhile, power prices went up steeply. According to a paper by Jos Sijm of the Energy Research Centre in the Netherlands, when allowances were €20 a tonne, European generators passed on between €1 and €19 per MWh to customers, depending on the structure of the market and the sources of electricity. In France, where the price is determined largely by carbon-free nuclear generation, they passed on at least. In Germany, where it is largely determined by coal, they passed on most. Partly as a result, German off-peak electricity prices doubled in the two years to January 2006, to just over €40 per MWh, setting consumers squawking.

The second worry is about the purchase of credits from developing countries. Partly thanks to the Chinese government’s 65% tax on emissions-reduction credits, European companies are paying

many times the actual cost of reducing emissions. That price they pay is passed on to European consumers, who may eventually revolt when they realise how much money they are pouring into Chinese government coffers.

Third, the time-horizons for Kyoto (up to 2012) and, even more, for the ETS (whose first period runs only up to 2008) are too short. So whereas projects in the near term (such as capturing nasty Chinese gases) are financially worthwhile, longer-term ones that may be just as desirable (such as investing in cleaner power-generating plant) are not.

All that said, this is the first attempt to deal rationally with a hugely complex problem, so it would be odd if it did not encounter difficulties. And it has made some headway: last year it got rich-world consumers to invest \$2.7 billion to cut developing-country greenhouse-gas emissions by around 374m tonnes of CO<sub>2</sub> equivalent. That is only about half of Texas’s annual emissions—but it’s a start. ■

## A coat of green

Business is becoming more environment-minded, but only because government is pushing

**C**ARBON DIOXIDE is a waste product from turning heavy oil into hydrogen. Pumped into greenhouses to boost plant growth, it is also an input into the market-gardening business, where it can increase productivity by a quarter.

In the Botlek area of the Netherlands, a Shell refinery used to release around 1m tonnes of CO<sub>2</sub> a year into the air. Meanwhile the greenhouses in the area were making their own CO<sub>2</sub>. In the winter it was a by-product of their heating systems, but in the summer they had to burn gas to make CO<sub>2</sub> and release waste heat.

Shell realised that its supply of CO<sub>2</sub> and the market gardeners’ demand for the stuff could be put together to both businesses’ advantage. So, since last year, it has been pumping some of its CO<sub>2</sub> directly into 500 greenhouses full of roses, tomatoes and cucumbers. As a result, its CO<sub>2</sub> emissions into the air are 170,000 tonnes a year down, and the greenhouses are using 95m fewer cubic metres of gas.

Business seems to be buzzing with green activity. Newspapers are full of advertisements from companies parading their environmental credentials. Some of

this is driven by consumers. Greenness has become a moral issue, and companies such as Wal-Mart, which are seen by some as oppressing their workers and destroying communities, can improve their image by looking good environmentally.

Some of it is driven by recruitment. Oil companies need talented graduates, many of whom want to make the world a better place. Chris Mottershead, BP’s adviser on energy and the environment, says the company is happy with the green splash it has made: “We are attracting the best graduates again. When they come for an interview, they find that people are talking about things that resonate with them.”

Some of it is about saving money. In most companies energy consumption has not, until recently, been much of an issue. “Nobody ever became vice-president by cutting the electricity bill,” says Alex Farrell, of the Energy and Resources Group at the University of California at Berkeley. But rising electricity prices have focused attention on energy, and companies that cut their electricity bills also cut their emissions, and can boast about that.

Most of the wave of greenery, how-

ever, is driven by government. Companies are investing in climate-friendly products and processes because governments have changed the rules to make it worthwhile doing so, and because companies believe that there will be more of the same in the future. That is the main reason for the advertising, the public relations and the quieter but energetic lobbying.

If there is going to be regulation, companies want to help shape it. “We started looking at this issue a few years ago,” says David Hone, Shell’s group climate-change adviser, “and realised that there would be new products and new rules. It was in our interest to be part of the discussion, in a constructive way.” Companies that were hostile to green regulation were not going to be invited to the table, so those that wanted to be involved had to acquire some green credentials and flaunt them.

There were indeed new rules, in the form of Europe’s Emissions-Trading Scheme, and industry did well to be involved in the discussions. Economists were arguing for a carbon tax. Industry wanted emissions limited by quantity, rather than by price. “We didn’t want a ▶▶

tax," says a BP executive. "We didn't want a system in which the level was set by the budget deficit rather than by the cost of carbon." Industry won.

Economists argued that the most efficient way to run the system would be to auction permits to emit CO<sub>2</sub>. Industry wanted permits handed out free. Again, industry won, and has profited nicely from the scheme. The fact that so many European polluters have done so well out of the ETS is one reason why some airline bosses, including Sir Richard Branson of Virgin and Sir Rod Eddington, the former chief of British Airways, are arguing for a trading scheme for their industry; and why American companies are now less hostile to the idea than they were before the ETS started up.

But there is more than just lobbying going on. Climate-change regulation, and the prospect of more of it, is changing the way business thinks about carbon and leading it to invest in new areas.

The Shell greenhouse project is an example of how regulation drives investment. Thanks to the ETS, says Mr Hone, "CO<sub>2</sub> gets attention from people like oil-refinery managers these days. There's a clear price signal. Projects to control emissions are worth investing in."

And there is a bit more investment in cleaner technology and renewable energy than there used to be. The wind business, for instance, is booming, thanks to subsidies in Europe and America. "We've had a wonderful run," says Lorraine Bolsinger, head of GE's green Ecomagination division. "The business is growing at 18%. We've sold out to the end of 2008. We're investing \$70m annually in R&D."

### Flaunt it

But the green-business boom needs to be kept in perspective. Take BP, which announced last November that it would be investing up to \$8 billion in renewables and alternatives over ten years. It sounds a lot, but at this year's rate of capital spending it would be only 4% of BP's total over that period. Shell is spending \$1 billion on renewables over five years.

GE has made much of Ecomagination, which is made up of 32 clean-technology products. Ecomagination recently announced revenues of \$10 billion last year, and forecast that at the current rate of growth they would rise to \$20 billion by 2010. R&D spending on Ecomagination products is to rise from \$700m (out of a total of \$5 billion for GE as a whole) to \$1.5 billion by 2010.



A fair wind

Ecomagination is certainly ahead of the rest of the business, which is growing at around 6% a year. But there is a bit less to all this than meets the eye. First, GE's overall revenues are \$150 billion, so Ecomagination does not loom very large. And second, the division's products are not that different from the rest of GE's offerings.

To qualify as part of Ecomagination, says Ms Bolsinger, a product has to be both "environmentally better or inherently green" and also "economically better than what it's replacing". But new products tend to be more efficient than old ones (which is one reason why rich countries' energy efficiency increases by around 2% a year); and if some of that efficiency is used to cut fuel consumption, they can be defined as environmentally better. It would, therefore, be surprising if quite a lot of GE's newer-generation products were not environmentally better than the older ones.

Indeed, much of the Ecomagination product list is made up of new, somewhat more efficient, versions of old products. The GENx aero-engine, for instance, is 15% more fuel-efficient than the one it is replacing. The new Evolution rail engines are 4% more efficient. Both qualify as Ecomagination products, but sound more like the consequence of run-of-the-mill product improvement than a green revolution.

Shareholders should draw comfort from this. If GE really were the revolutionary it makes itself out to be, it might be quite a risky investment. But the bet it is making is small and perfectly sensible.

GE, BP, Shell and their peers all believe that governments will regulate CO<sub>2</sub> a bit more in the future than they have done in the past. That will tip the market towards greener technologies, and the modest investments they have made in environment-friendly products will pay off. "This

is contingent investment," says Mr Motterhead. "We think the political commitment to renewables around the world will grow, and we'll have more of the answers than our competitors will. We're happier with our position than we were three years ago, because the world seems more inclined to change."

There is some evidence that managers are rewarded for being green. "We have made a notable attempt to make this part of the way we analyse people," says Abby Cohen, Goldman Sachs's chief American investment-portfolio strategist. "When you look at the at-risk industries—those that make their living out of environmentally challenging businesses—some players have made a much better job of moving the technology forward."

Ms Cohen points to important pools of assets—such as CalPERS, the Californian state employees' pension fund, and CalSTRS, the Californian teachers' pension fund—that prefer to invest in green companies. The number of such investors may be increasing. At the first conference of the Investor Network on Climate Risk, in 2003, participants represented assets of \$600 billion. Last year, they represented \$2.7 trillion.

In a paper published last year in the *Financial Analysts Journal*, Jeroen Derwall of the RSM Erasmus University in Rotterdam and colleagues found that the average annual return between 1995 and 2003 on a portfolio of companies that ranked high on greenery was 12.2%, compared with 8.9% for low-ranked companies. Maybe easier access to capital (which the green investors presumably offer) helps. Maybe it's just that companies that are well-managed overall also tend to pay attention to their environmental profile. Either way, greenery seems to go with success. ■

# Doing it their way

American attitudes to global warming are complex, and are changing

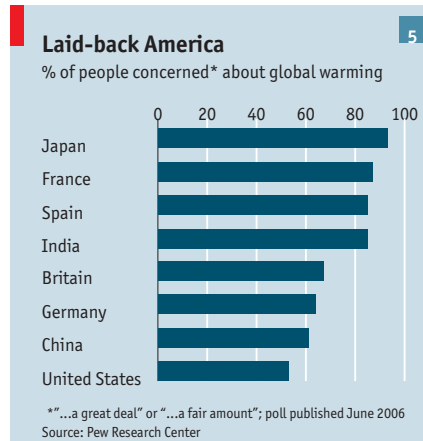
**J**AMES INHOFE, chairman of the American Senate's environment and public works committee, has described the threat of catastrophic global warming as the "greatest hoax ever perpetrated on the American people". His fellow Republican, Arnold Schwarzenegger, the governor of California, has a different take: "I say the debate is over. We know the science. We see the threat. And we know the time for action is now."

The passionate argument about climate change going on inside America is not always obvious to the rest of the world. Some greens in other countries tend to write America off because it chose not to ratify the Kyoto protocol, because the federal government has consistently refused to adopt a mandatory system for restricting emissions, and because American public opinion is relatively indifferent to global warming (see chart 5). Yet the politics of global warming in America are more complex than that, and are changing.

The federal government's inaction contrasts with a flurry of activity at lower levels of government. The mayor of Seattle has started an initiative to get cities to aim for Kyoto targets, and 279 cities have signed up. Seven north-eastern states have set up the Regional Greenhouse Gas Initiative—emissions stabilisation followed by cuts, with a trading scheme—and six western governors are agitating for federal action.

California is particularly interesting, for two reasons. First, the Hummer-driving Mr Schwarzenegger is, improbably, one of the greenest politicians in the world. This may in part reflect his personal convictions, but also chimes with the views of Californians, who are much more environment-minded than other Americans. Second, the state has long experience of adopting tougher environmental regulations than other parts of America, and of gauging their economic impact.

On August 31st, California became the first state to legislate for cuts in greenhouse-gas emissions—by 25% by 2020. The bill was opposed by most Republican legislators. Mr Schwarzenegger has also set a target for cutting emissions to 80% below 1990 levels by 2050. (Oregon has a target of 75%, and the governor was clearly deter-



mined not to let some northern girlie-man steal the crown of greenest governor.) By 2010, 20% of California's energy is to be generated from renewables.

Allan Zaremberg, president of California's Chamber of Commerce, says these targets will impose huge new costs on local businesses. They will also cause CO<sub>2</sub>-heavy factories to migrate to developing countries where they will be subject to less stringent restrictions and will therefore produce more CO<sub>2</sub>.

Similar complaints were heard in the 1970s, when California imposed unusually tough emissions standards for other pollutants. Yet Mr Zaremberg concedes that business has benefited from tough clean-air regulations. They have made California's environment more attractive, and the state has developed technologies for things like energy-efficient buildings that have subsequently been sold elsewhere. California's economic performance (despite power prices which, partly because of regulation, are 40% above the American average) makes it hard to argue that business in the state is groaning under its heavy regulatory burden.

California is also forging ahead on vehicle-emissions standards. In 2004 it became the first American state to legislate to cut carbon-dioxide emissions from vehicles. The law stipulated that CO<sub>2</sub> emissions from vehicles had to be reduced by 30% by 2016. Carmakers claimed that this would add \$3,000 to the price of a car and

cost thousands of jobs. They took California to court, where the matter is stuck.

If the vehicle-emissions standards get through, ten other states say they will follow. Californian standards tend to spread around the world because no manufacturer wants to be shut out of the Californian market.

## Coming round

Opinion in America as a whole is shifting a little in California's direction. Hurricane Katrina brought the issue to the fore. Scientists had given warning that climate change might cause "extreme weather events". Katrina demonstrated what such an event—for which the government was unprepared—could look like. Individuals thought about their safety; businesses about their balance sheets.

The White House's sceptical stance lost credibility last year when it emerged that Phil Cooney, chief of staff at the Council on Environmental Quality, had been editing scientific reports to emphasise uncertainties in climate science. Mr Cooney resigned and joined Exxon Mobil.

The steady drumbeat of stories attributing all manner of evil to climate change is getting louder: California burning (because the woods are too dry); ski resorts struggling (because the snow line is rising); alligators in Florida eating people (because their pools and thus their food supplies are drying up); polar bears eating each other (because melting ice makes it harder for them to hunt).

Several of America's wealthiest and best-organised foundations have raised the temperature by making climate change one of their big issues. The Hewlett Foundation's Hal Harvey and the Pew Center on Global Climate Change's Eileen Clausen are key figures in commissioning research and working on politicians. The sceptics can call on funding from companies keen to avert federal action, but the green think-tanks outgun them. Myron Ebell of the Competitive Enterprise Institute, who calls them "the forces of darkness", says they receive "huge amounts of money from charitable foundations. The children and grandchildren of capitalist buccaneers are soft left." ▶▶

▶ Their activities have helped create a curious new alliance whose members disagree about almost everything except global warming. Jim Woolsey, a Prius-driving former head of the CIA, who numbers himself among them, calls it “a coalition of tree-huggers, sod-busters, cheap hawks and evangelicals.”

Sod-busters, explains Mr Woolsey, is a south-western term for farmers. Farming subsidies are continually under threat, but when the federal government started subsidising ethanol production and wind power, farmers realised that renewable energy offers new streams of revenue. Turbines are a lucrative alternative to turnips.

The cheap hawks, which Mr Woolsey says include him, are concerned about the vulnerability of oil installations in the Middle East. “Relying on this unstable part of the world for this very important part of our economy is rather worrying.” America does have coal, but coal supplies won’t last forever, so demand for fossil fuels needs to be cut. Mr Woolsey, who backed the Iraq war, is on the advisory board of the Institute for the Analysis of Global Security, which argues for subsidies to make cars more fuel-efficient and for plant-based alternatives to petrol.

Earlier this year, Christian evangelicals, who have a direct line to the White House, launched the “Evangelical Climate Initiative”, signed by 86 evangelical leaders, including Rick Warren, who runs a megachurch and wrote a bestseller, “The Purpose-Driven Life”. It says that “millions of

people could die in this century because of climate change, most of them our poorest global neighbors.”

Not all evangelicals go along with this. According to an opinion poll last year, 33% of evangelicals think hurricanes are a deliberate act of God—which presumably means that man should not mess with them. (Some 13% of non-evangelical Protestants, 15% of Catholics and, bizarrely, 17% of non-religious people agree.) Twenty-two leading evangelicals wrote to the National Association of Evangelicals asking it not to endorse the climate initiative. It didn’t.

Two more important lobbies are coming round to the view that something needs to be done. Hunting and shooting lies close to the heart of the Bush administration (as Dick Cheney showed when he accidentally peppered an old friend). One-fifth of voters hunt or shoot, and two-thirds of hunters and anglers vote Republican. In the first poll of their views, carried out in May this year, 76% of these sportsmen said they had personally noticed climate change, and 78% said that the right way to address America’s energy needs was to conserve more, develop fuel-efficient vehicles and use more renewables. Only 15% thought the right approach was to drill for more oil.

Business is doing its bit. In April this year, eight big energy companies, including GE, Shell and the two largest owners of utilities in the United States, Exelon and Duke Energy, were being questioned by

the Senate Energy and Natural Resources Committee. Six of the eight said they would welcome or at least accept mandatory caps on their greenhouse-gas emissions. Wal-Mart was keen, too.

Does all this add up to federal legislation on mandatory controls? The progress of two bills says “not yet”. One, from Senators John McCain, a Republican, and Joseph Lieberman, a Democrat, has been voted on twice, and got slightly less support in the second vote than in the first. The other, a comparatively modest proposal based on a scheme put together by the National Commission on Energy Policy for a cap-and-trade system with a price limit of \$7 per tonne, was part of an energy-bill amendment initially proposed by Jeff Bingaman, a Democrat, and Pete Domenici, a Republican. Mr Domenici backed away at the last moment. Earlier this year he and Mr Bingaman published a white paper on how a trading scheme might work.

So on Capitol Hill the issue is not dead but resting. Three things might wake it up: first, a strong performance by Democrats in the mid-term elections; second, and more important, a new president. The favourites for the two parties’ nominations, Mr McCain and Hillary Clinton, both favour mandatory federal emissions controls. Third, the Supreme Court is to rule next year on whether the federal government has the right to control carbon-dioxide emissions under the Clean Air Act. That will either pave the way for legislation or kill off the possibility. ■

## Where to start

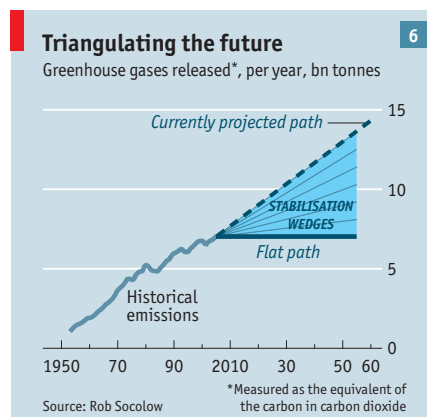
Technological and economic solutions to climate change are available. The problem is politics

THE sheer number of scientists, economists, businesspeople and policymakers working on climate change endows it with a kind of blitz spirit. Surely, given so much will and enthusiasm, we can defeat this threat? Yet the projections are not encouraging. The concentration of CO<sub>2</sub> in the air has risen from 280ppm before the industrial revolution to around 380ppm now, and the IPCC reckons that if emissions continue to grow at their current rate, by 2100 this will have risen to around 800ppm. Depending on population changes, economic growth and political will, this could be adjusted to somewhere between 540ppm and 970ppm. The pros-

pect of anything much above 550ppm makes scientists nervous.

In order to control these figures, it is important to pick some priorities. The sources of this problem range from smokestacks through Amazonian deforestation to pig effluent; from Mexico to Mauritania. But identifying the main countries and sectors responsible will help target efforts.

The widely held notion that gas-guzzling cars are the core of the problem is wrong. Transport (including planes and ships as well as cars) produces only 13.5% of emissions. The biggest contributor is power generation (24.5%); and the biggest contributor among sources of power is





Green Bush

► coal. Coal is cheap. Coal is dirty. America has lots of coal and China has vast reserves to fuel its economic boom. And rocketing natural-gas prices have led to a boom in the building of coal-fired power plants in recent years.

The second-biggest source of emissions is deforestation (18%). The tendency to focus on fossil fuel explains why this source gets left out when solutions are drawn up; and why campaigners are lobbying hard to get deforestation included in the European Emissions-Trading Scheme.

When it comes to the contribution of individual countries, America is still the principal source of greenhouse gases, but China is closing in and India is coming up from behind. If those three and Europe took the problem seriously, there would be a good chance of solving it.

But there is no silver bullet. If an answer is to be found, it lies in using a combination of economics and a broad range of technologies.

Robert Socolow, an economist at Princeton University, offers an encouraging way of thinking about this. His “stabilisation wedges” (see chart 6, previous page) show how different ways of cutting emissions can be used incrementally to lower the trajectory from a steep and frightening path towards a horizontal one that stabilises emissions at their current level.

One wedge might be carbon sequestration (storing carbon dioxide underground or below the oceans) to deal with emissions from coal-fired power plants. Sequestering CO<sub>2</sub> emissions might raise the price of coal-generated power by 50%, but coal is such a cheap source of power that it might still be attractive. And it may have huge potential: a paper just pub-

lished by Harvard’s Daniel Schrag and colleagues argues that thousands of years-worth of American emissions could be stored under American coastal waters.

Another might be renewable energy sources. They supply around 14% of world energy now and the figure is unlikely to increase sharply in the near future. But their share can rise enough to bring the trajectory down a little.

Economics can help make these technologies viable. That can be done in two ways. One is to subsidise early-stage R&D to bring down the price of alternatives. The second is to tax carbon (or set up a cap-and-trade system similar to Europe’s ETS) to push up the price of fossil fuels. Given that governments are reluctant to make themselves unpopular by taxing consumers or constraining companies, there is probably a need for a bit of both.

That leaves the hardest bit of the puzzle: the politics. The best solution would be to get the world’s biggest polluters to share the burden. Kyoto tried to do that, and failed. America, which is now allergic to the word, is not going to accept the protocol, and over time Europe will get fed up with paying for something that is doing no global good. So, in the short term, the world is faced with the choice of no solution or a better-than-nothing approach that might improve over time.

America is the key. If America does nothing, then the developing world’s big polluters will do nothing. If America decides, independently, to constrain emissions at a federal level (and cap-and-trade is much likelier to be acceptable than anything that includes the dread word “tax”), then China and India might come to accept that they have as much to lose as everybody else, and that they should lead the rest of the developing world towards cutting emissions.

Or America might restart the process of involving the rest of the world, possibly at a regional level, through the Asia-Pacific Initiative that it set up in competition to Kyoto. For the moment, the chances of that happening do not look great. But as the weather changes, so does the political climate. Another heatwave, another disastrous hurricane season, and the pressure to take action will become harder to resist. It would need a different name, of course: the Peoria Protocol, perhaps, or the Indianapolis Initiative. Or what about the Crawford Convention, Mr Bush? That would stick the personal brand of the man who likes to enjoy the natural world at his ranch on America’s attempt to save it. ■

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