TWELVE THINGS WE´VE LEARNED ON THE ROAD TO PARIS

Highlights from ICSU's Road to Paris journalism project: The science and politics of climate change and sustainable development, 2014-2015

ROAD TO PARIS
Science for Smart Policy

ICSU
International Council for Science

A note from the editors

In July 2014, the International Council for Science launched Road to Paris, an experiment by the scientific community to create an independent media project around climate change and sustainable development. Looking ahead at the pivotal year of 2015 that was to bring new international political agreements on climate change, disaster risk reduction and sustainable development, we identified a niche for a new voice that would connect the dots across the science/policy/economics nexus. Road to Paris was designed to be that voice. The ambition was to complement and augment existing coverage of this space by providing a science focus on these politicized issues.

From the start, Road to Paris was designed with an end date in mind. It will shut down right after the historic Paris climate change talks in December 2015. With that date approaching, this magazine assembles some of the stories that we feel best live up to our ambition: stories that will continue to be valuable for readers beyond the Paris talks. They are some of the most read or most shared pieces on the site. They showcase the diversity of the content on Road to Paris, and demonstrate its unique value: providing easy reading on heavy subjects.

For us as editors, it has been a journey of learning and discovery. We were privileged to work with a team of truly outstanding writers. It is thanks to their hard work that Road to Paris attracted key stakeholders among its readers, such as French Foreign Minister Laurent Fabius and Christiana Figueres, Executive Secretary of UNFCCC. We believe that the Road to Paris is a proof-of-concept that the research community can work side by side with traditional media organizations to improve public understanding of complex issues. We hope you will enjoy this magazine and the stories contained within. If you have any feedback or suggestions, please do get in touch at info@roadtoparis.info.

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ROAD TO PARIS

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Everything you need to know about climate change in five minutes

ALICE BELL

Why's everyone so down on carbon?

Carbon dioxide is one of a set of so-called greenhouse gases. They get this name because they let sunlight in, but won't let heat back out into space, keeping the Earth warm, acting a bit like a greenhouse.

We want some of this effect. Without it, Earth would be a lot colder. The problem is that human activities — especially over the last few centuries — have increased greenhouse gas emissions to a point where it's dangerous.

The reason everyone focuses on carbon dioxide is simply because we modern humans produce so much of it, making it the largest greenhouse gas. This is partly due to burning fossil fuels, but it's also because land-use changes like deforestation generate carbon dioxide emissions. And we cause significant methane emissions too from activities like agriculture — it's not just carbon dioxide.

Won't it just be a bit warmer?

When people talk about a degree or two increase in temperatures, it might sound ok. It could even sound nice if you live in a cold country. But this is increase in global average temperatures, it's not the same as it being a bit warmer on a sunny day.

The term 'greenhouse' might be a bit misleading. It's not that cozy, or quite so optimal for life to flourish in.

As ice melts, sea levels rise — coastal communities are already reporting this as quite obvious. Fresh water will be less plentiful. Ecosystems will change, with many species becoming extinct and food chains put at risk. Parts of the world can expect extreme heat waves, drought and wildfires. We can also expect increased rainfall in some places, causing floods. Hurricanes will become stronger. At times and places it'll be much warmer, for others it will just be very cold and wet, and they may possibly be hungry and thirsty.

How do we know carbon in the atmosphere is increasing?

This is a nice question because it lets us show off the cleverness of humans.

We have great data for the last few decades because, back in 1958, a visionary scientist named Charles David Keeling started continuous measurements of concentration of carbon dioxide in Earth's atmosphere from an observatory in Hawaii.

Today this work is continued by his son Ralf, and it's known as the Keeling Curve. Keeling after the scientists, and Curve because it is quite clearly going up. You can follow it on Twitter @keeling_curve.

But if we want to know how much carbon dioxide was in the atmosphere before the 1950s we have to engage in a bit of super-sneaky scientific time travel. Researchers use something called ice cores — long cylinders of ice drilled out of glaciers in Antarctica and Greenland. The deeper parts of these cores include tiny bubbles of air from centuries past, preserved in the ice, time cables of the atmospheres of our ancestors. They can then run chemical analysis on these air bubbles to give us

empirical evidence of how greenhouse gas concentrations have changed over the last millennia. It's from ice cores that we know that the concentration of both carbon dioxide and methane was relatively stable up until the start of the 19th century, and then rose rapidly.

Human ingenuity might be what caused a lot of this problem, but it's also what's letting us see it in time to tackle it too.

How do we know the Earth's warming?

We can't just stick a thermometer under the Earth's armpit, but scientists do just take it's temperature, via thousands of weather stations spread all over the planet. They check the temperature on land, but also test sea temperature using ships, and satellites and weather balloons measure temperature higher up too. We have detailed temperature records from the middle of the 19th century. To get earlier data, researchers look for markers in nature to get a sense of how temperature's changed over time.

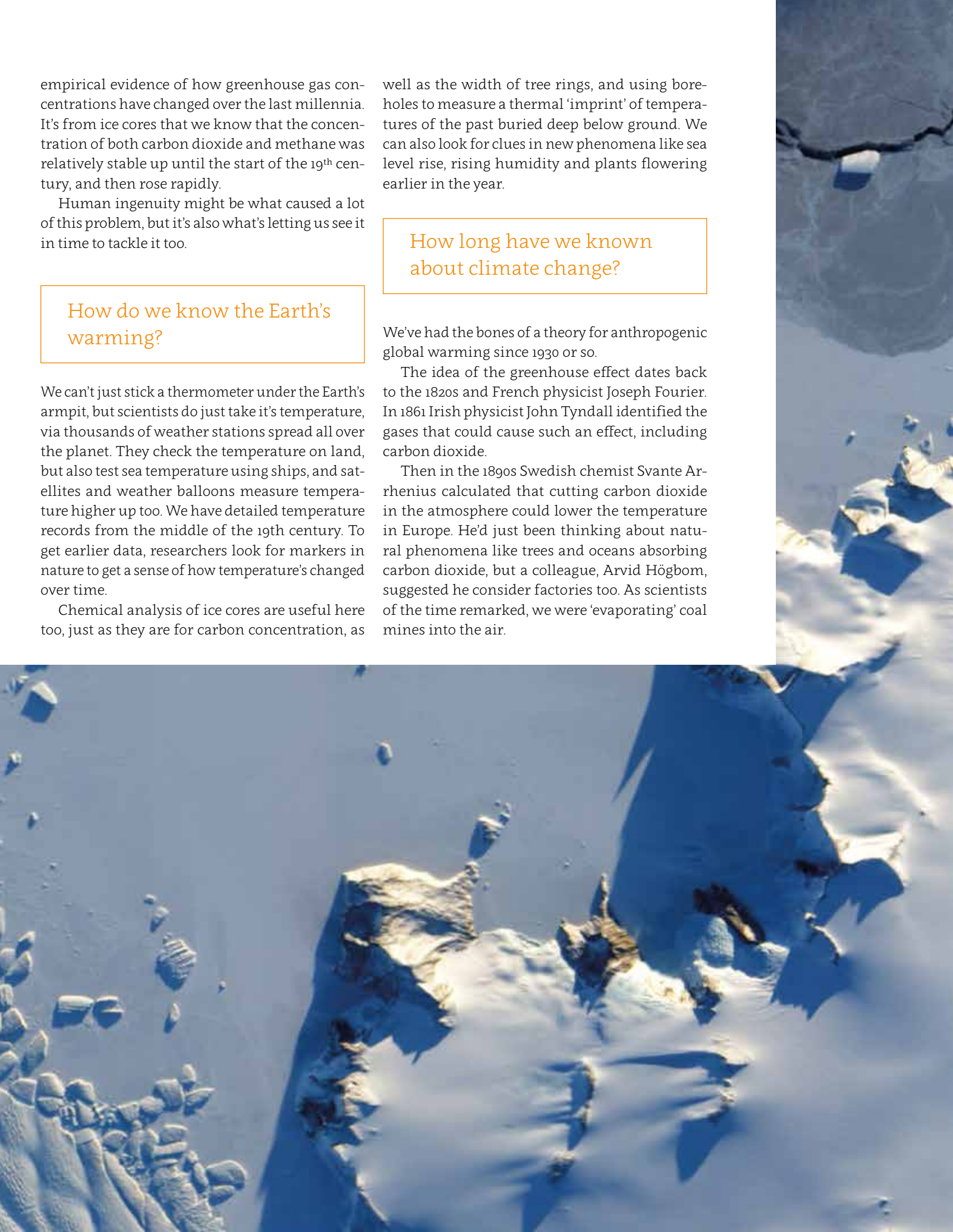
Chemical analysis of ice cores are useful here too, just as they are for carbon concentration, as well as the width of tree rings, and using boreholes to measure a thermal 'imprint' of temperatures of the past buried deep below ground. We can also look for clues in new phenomena like sea level rise, rising humidity and plants flowering earlier in the year.

How long have we known about climate change?

We've had the bones of a theory for anthropogenic global warming since 1930 or so.

The idea of the greenhouse effect dates back to the 1820s and French physicist Joseph Fourier. In 1861 Irish physicist John Tyndall identified the gases that could cause such an effect, including carbon dioxide.

Then in the 1890s Swedish chemist Svante Arrhenius calculated that cutting carbon dioxide in the atmosphere could lower the temperature in Europe. He'd just been thinking about natural phenomena like trees and oceans absorbing carbon dioxide, but a colleague, Arvid Högbom, suggested he consider factories too. As scientists of the time remarked, we were 'evaporating' coal mines into the air.



In the 1930s, Guy Callendar — an engineer by profession, but a keen meteorologist in his spare time — used weather stations' records to show that temperatures had risen over the previous century. He also noted the increase in carbon dioxide concentrations over the same period, and suggested a link.

We've supplemented this with a lot more detail and evidence since, but the basic tenets are pretty old.

How much more can we burn?

It depends on how hot you are willing for it to get. For the last decade, scientists have compiled annual global carbon budgets to give a sense of how much more carbon dioxide we can put up there in the atmosphere and stay within two degrees warming.

According to the 2014 budget — published last September — emissions from fossil fuels and deforestation are set to reach 40 billion tonnes, the largest amount in human history, and our 'quota' will be easily used up in a generation.

A paper published at the start of this year by UCL's Christophe McGlade and Paul Ekins argued that a third of oil reserves, half of gas reserves and over 80% of current coal reserves globally should not be used before 2050 if global warming is to stay below that two degree target.

Why two degrees? It's all ok before then, yes?

No. Not for everyone, no. But everyone has sort of settled on it as a target of sorts (a weird target, as very few people actually want to hit it). In the last century, there were a range of ideas about what 'dangerous' climate change might look like. But two degrees won over, even though it still condemns a lot of people, non-human species and places.

What are world leaders doing to tackle climate change?

They were slightly slower than the scientists in noticing, but they've been at it a while too. Attempts at action on climate change are older than you might think.

1972 saw the first UN environment conference. Climate change didn't have a starring role, but it was there and the conference led to the establishment of the United Nations Environment Programme. This, in turn, established the Intergovernmental Panel on Climate Change (IPCC) in 1988 — a massive undertaking which collects and summarises advice from scientists.

In 1992, the United Nations Framework Convention on Climate Change (the UNFCCC) was established at the Rio Earth Summit. It's formally a treaty, but doesn't contain anything legally binding and is more a system for negotiating the issue. Looking through the history of UNFCCC meetings, you could be forgiven for saying that's all they've done — negotiate. But they've tried out policy ideas, set up projects, worked through arguments, helped popularise the issue, offered spaces to forge alliances and there's hope that we might see something finally in Paris at the end of this year.

What can I do?

There's basic things like changing lightbulbs, swapping to a flexitarian diet, being conscious about energy efficiency in your home and thinking more carefully about your travel options. That's all important — our individual actions add up — but a lot of what we need to do on climate change takes collective action, with a focus on changing social, economic, political, cultural and built infrastructure.

Register to vote, and ask your politicians what they're doing about climate change. Ask questions of the companies you buy products from too. Simply chat about climate change with your friends and families too. Because we need to unlock the way its been allowed to become an issue we avoid, shove under the carpet or leave for tree-huggers.

Learn about climate change and talk about it, let an awareness of the issue become part of how you work through the world. Get used to it. Because it's here.

Is it hopeless?

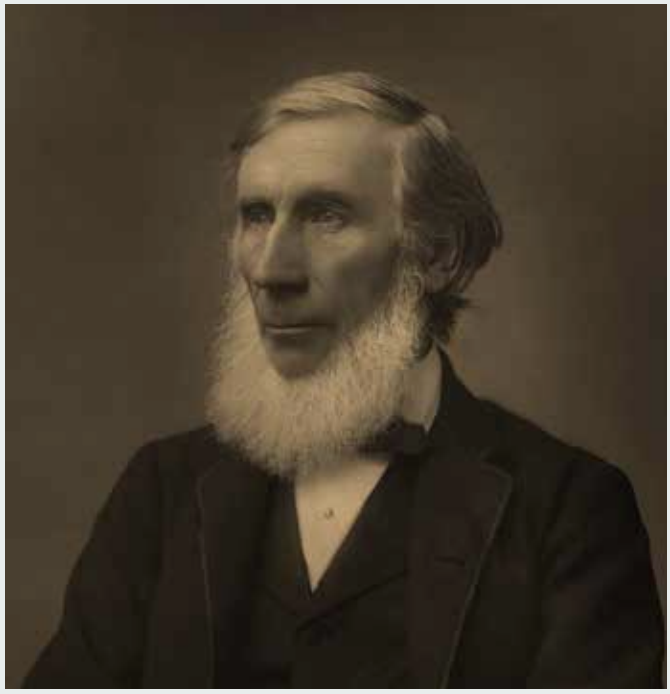
Climate change is more a matter of mitigating losses than simply winning a fight. And that's part of what makes it hard. Still, just look at how much of the world we could avoid losing if we act. There's a lot of hope there. And many people are already taking positive actions. Even if we're not doing enough yet, there's a lot we can do.

A very short history of climate change research

ALICE BELL

The story of scientists discovering climate change is longer than many of us tend to imagine. We've had a sense that what humans do might affect the climate since Antiquity. Studies of glaciers in the mid-18th century got people wondering what had changed since the Ice Age. It was back in 1824 that French physicist Joseph Fourier first started talking about something called the 'greenhouse effect'. He already knew the atmosphere protected us from the sun. What was new was the suggestion that the composition of this atmosphere might change, and that could lead to a warming of the Earth, a bit like a greenhouse warms its contents.

A few decades later, in 1861, Irish physicist John Tyndall identified the gases he thought might cause such an effect, including carbon dioxide. A keen mountaineer, Tyndall had a hands-on knowledge of Alpine glaciers and was drawn to the puzzle of their history. Based at London's Royal Institution, he didn't just sit in a lab on his own and write letters to other scientists. Rather, he devised public demonstrations, drawing huge crowds in both London and for international tours. He also had a great beard.



A ca. 1885 photograph of John Tyndall, an Irish natural philosopher and scientist. He was the first to consider carbon dioxide a greenhouse gas.

Despite Tyndall's commitment to public engagement, the idea of CO_2 as a greenhouse gas might have been left underdeveloped if it had not been picked up by Swedish chemist, Svante Arrhenius. He was also puzzled by the Ice Age, and figured CO_2 might offer an answer. By 1896 Arrhenius had calculated that cutting CO_2 in the atmosphere by half could lower the temperature in Europe by 4-5°C. A colleague of Arrhenius, Arvid Högbom, thought it might be worth looking at the CO_2 emitted by factories too, not just volcanoes and natural carbon sinks like trees or oceans.

They didn't realise at the time, but that's a significant point; the moment we realised human activities were adding a gas to the atmosphere

Alice Bell (@alicebell)

Alice Bell is a researcher, campaigner and writer based in London, specialising in public engagement with energy. Alice spent much of the last decade in academia, lecturing in science media and policy as well coordinating an interdisciplinary undergraduate course on energy and climate change. She has degrees in history of science, sociology of education and a PhD in science communication, and spent several years working in the children's galleries at the Science Museum. Alice was founder member of the science policy blog at the Guardian and has written for, amongst others, the Observer, BBC, Times, Al Jazeera, New Humanist and China Dialogue.

which we thought might cause global warming. As scientists of the time remarked, we were 'evaporating' coal mines into the air. Still, realising the significance of this, and taking action, is another matter.

Following Arrhenius' work, we also see the development of climate scepticism. That's another thing that is quite old, even if – just like the science it responds to – the people and motivations of the movement have changed a lot over time. The initial scepticism was, arguably, quite reasonable. Arrhenius had simplified the system to make his calculations, and the lab equipment could have been better. The main barrier to the idea being picked up, however, was probably just that scientists turned their attention to other topics. Even Arrhenius wasn't too worried. Scepticism wasn't so much the problem as a general feeling of 'meh'.

In the 1930s, Guy Callendar – an engineer by profession, but a keen meteorologist in his spare time – used weather stations' records to show that temperatures had risen over the previous century. He also notes the increase in CO_2 concentrations over the same period, and suggested a link. This was dismissed by meteorologists at the time, but we now know it is fundamental.

So although we had the bones of a theory for anthropogenic global warming, people remained pretty unconcerned. We might be 'evaporating' coal mines (and oil rigs, and gas pipes) into the air, but anyone who noticed this also assumed the oceans would absorb it. The inaccuracy of this assumption was gradually uncovered in the middle of the 20th century, via an unlikely source. Researchers at the University of Chicago were studying the use of radioactive carbon-14 to find the age of ancient materials like Egyptian mummies. More than a matter for archaeologists, military interest in radiation meant the research attracted support from the US Air Force. These techniques were then picked up by chemist Hans Suess, who first applied it to studying carbon in trees and then, crucially, oceans. Working with oceanographer Roger Revelle – who was also assisted by military in his work, this time the Navy – researchers concluded oceans could only absorb about a tenth of the carbon predicted. In the conclusion to his paper, Revelle wrote the haunting line: 'Human beings are now carrying out a large scale geophysical experiment'. That was 1957. 1957 was also the International Geophysical Year.

One of the key projects the International Geophysical Year offered support for was Dr Charles D. Keeling's project measuring the concentration of carbon dioxide in the atmosphere. This has been running from an observatory in Hawaii since 1958, now led by his son Ralph. The graph of the resulting data is known as the Keeling Curve: Keeling after the scientists, and curve because it is going up. Today, you can follow it on Twitter @keeling_curve. Although crucial to our understanding of climate change, it struggles to maintain funding, just as it always has. By the 1980s, this data was supplemented with empirical research studying air bubbles trapped deep in Antarctic and Greenland ice caps. A sort of natural time capsule, the ice had

encased the gases of previous eras allowing scientists to study its composition. You can see one of the ice cores on display at the London Science Museum.

Perhaps it was just the Cold War putting a stench of global catastrophe in the air, but the emerging climate science started to worry people. In 1965, a report from the Environmental Pollution Panel of the US President's Scientific Advisory Committee included a section on carbon dioxide from fossil fuels as 'the invisible pollutant'. Chaired by Roger Revelle and supported by Charles Keeling, it repeats the line that 'Man is unwittingly conducting a vast geophysical experiment' and perhaps too-dryly concludes that it 'could be deleterious from the point of view of human beings'.

Throughout the 1960s and 70s, we also see the growth of a popular green movement. The major NGOs were initially hesitant to work on climate change. Like many scientists and politicians, they were maybe just more concerned with other issues. However, it is probably fair to say climate change is at the centre of most green activism today. Running alongside this is a rise in sceptic activism, although it has tended to be a phenomenon limited to the English-speaking world.

1972 saw the first UN environment conference. It might have been more interested in whaling than climate, but it was a start, and led to the establishment of the United Nations Environment Programme. This, in turn, established the Intergovernmental Panel on Climate Change (IPCC) in 1988. The IPCC doesn't carry out its own research. Rather it looks at the literature published elsewhere, relying upon the work of thousands of scientists the world over. It is probably best understood as a machine of scientific advice to governments. Each IPCC is a massive undertaking. There have been five in total: 1990, 1995, 2001, 2007 and 2014. Since the third report, they've been split into three Working Groups; one on the physical science explanation of what is going on, one on the impacts of climate change and, finally, one considering options for limiting emissions and mitigating climate change.

In 1992, at the Rio Earth Summit, the United Nations Framework Convention on Climate Change (UNFCCC) was established. It's formally a treaty, but doesn't contain anything legally binding. Rather, it provides a framework for negotiating specific international treaties. Or to put it another way, it's an agreement to have a lot of meetings. They have met annually since 1995 under 'Conferences of the Parties' (better known as COPs). COP3 is perhaps the most significant. Held in Kyoto in 1997, it led to the 'Kyoto Protocol' which aimed to add some teeth to the initial framework, with binding targets for greenhouse-gas reductions. There were high hopes for the 2009 COP15 in Copenhagen, but it was largely considered, at best, a disappointment. The world is still waiting for strong global action on climate change.

And all this time, we've kept emitting. The fossil fuel based growth which Victorians like Fourier, Tyndall and Arrhenius were already familiar with has only increased and engrained itself further into society. Against the backdrop of people measuring the climate and waking up to what that might mean, we've done much more to increase global warming than stop it. We knew 350ppm was a dangerous point on the Keeling Curve – a whole campaign was named after it – but still let ourselves go far beyond that. And yet, the story of climate change is still a hopeful one. Often despite ourselves, we noticed, and we've at least started to take action. We humans are really clever, even if we can also be phenomenally dumb. We've done some things, so we can do more.

10 new climate change controversies – now that the cause is settled

Too often, the media is still stuck on the tired question of whether man-made climate change is happening or not. With a strong scientific consensus on that issue, it's time to look at areas where things aren't quite so sure. Our authors Alice Bell and Leigh Phillips have summed up the state of play on the ten key issues that should be at the top of the climate agenda.

1
Is two degrees warming possible?

Everyone's favourite climate goal may not be that useful – or even attainable.

Since the 1990s, many in climate policy have held up the idea of 2° as a line not to be crossed. When they say 2°, they mean 2° C warming of the Earth's average surface temperature, above preindustrial levels. It's a bit arbitrary and simplistic, but gave policy-makers something to hook onto. Increasingly, however, the validity of this benchmark is being questioned.

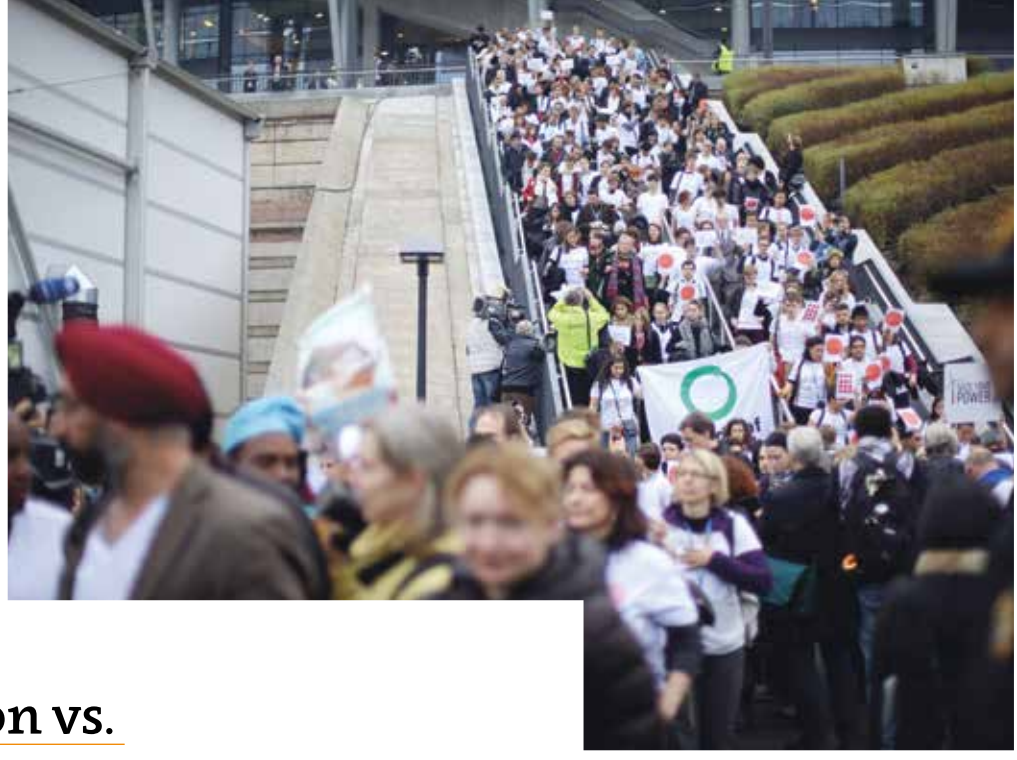
In February 2014, a paper from the Union of Concerned Scientists warned we are already on track for warming way beyond 2°. Timed for the Doha talks in December 2012, another Nature Climate Change paper argued there's no way we'll meet the 2° target without radical emission reduction policies.

One element of the 2° controversy is urgency of action, and how much we will have to do to avoid the benchmark. This can overlap with activities of climate sceptics, or at least it may serve the same interests. As sceptic activity shifts from denial and towards delay and/or dilution of concern, we see people agreeing climate change is happening, just arguing it's not happening that fast and/or we don't need to do much. We might also question the ethics of the idea of 2°, and if society is up for the necessary public debate on such targets, or how to limit global warming. Scientist James Hansen of the Earth Institute at Columbia University, for example, has argued repeatedly, 2° is still way too much and, as Chris Shaw of the University of Sussex argues, we never really had a public debate on this.

If you want to read more: Brad Plumer's primer is clear, albeit depressing. Plumer's title 'how the world failed on climate change' offers a sense of where he stands on the issue.

If you want to read more:

Brad Plummer's title 'how the world failed on climate change' offers a sense of where he stands on the issue. ➜http://bit.ly/1fjWCW9



2 Mitigation vs. Adaptation

Which one matters more?

Most people with skin in the climate game do not disagree that there needs to be an "integrated portfolio" of policies involving both trying to avoid greenhouse gas emissions (mitigation) and those working to cope with the impacts of global warming (adaptation). The disagreement is over where the emphasis should be.

Now, a growing chorus calls for a sober look at how little progress has been made toward curbing greenhouse gas emissions in the past 25 years. Since the 1990s, 2° C has been the threshold planetary temperatures must not cross lest the Earth risk catastrophic climate chaos. Yet, the planet's average temperature is already 0.8° over preindustrial levels, and atmospheric CO_2 soared past 400 ppm last year. Many scientists are arguing that more realistically, the Earth is looking at an increase of 3°-4° by the end of the century. Even with the most ambitious global agreement to curb emissions – still far away – they say it is probably too late to prevent global warming.

Geoscientists Jasper Knight and Stephen Harrison argue that as feedbacks within the Earth system are themselves key drivers of climate change, addressing greenhouse gas emissions alone is insufficient for managing global warming. They note that different jurisdictions, industries and even disciplines have conflicting measures for carbon budgets, with vested interests engaging in budgetary sleights-of-hand.

Some high-profile figures began to argue after the 2009 UN climate talks debacle in Copenhagen that the focus needs to shift to adaptation, particularly in the developing world where climate change effects are most deleterious. Rather than tough mitigation agreements, the emphasis should be on building greater societal resiliency through water conservation, flood defense, dike construction and development of drought-tolerant crops. Land corridors should be created to help species migrate, and in some areas abandoning settlements should be considered, with residents to move inland.

Countering the adaptation champions, others warn that some impacts from climate change are fiendishly difficult to accommodate such as ocean acidification, more dangerous and frequent wildfires, and the creation of climate refugees. There's also a worry that a switch to an adaptation emphasis would use up the limited government and private resources set aside for mitigation. Thus, without mitigation, the need for adaptation would again become greater.

There is a reckless, almost climate-sceptic, bent to the pro-adaptation argument, some experts argue, in which fossil-fuel companies and industry are let off the hook, and the pressure to reduce emissions is eased. Certainly, many free-market advocates like the American Enterprise Institute have long favoured adaptation over emissions reduction. MIT professor of systems dynamics John Sterman argues that if people believe they are protected from rising seas or more intensive storms, they could be less amenable to supporting mitigation policies.

If you want to read more:

The World Bank Research Observer journal

➔http://bit.ly/1LVBaZN

Peter Terpstra of the World Resources Institute

➔http://bit.ly/1pfbZHE

Finally, adaptation is already the ugly sister at the private finance ball, compared to mitigation, as seawalls, building code amendments and water-use efficiency projects aren't the money spinners that clean energy projects can be.

If you want to read more, the World Bank Research Observer journal considers the options, leaning toward mitigation as the cheapest option, while Peter Terpstra of the World Resources Institute considers how adaptation has been shortchanged in terms of climate finance commitments.

3 Geoengineering

Useful mitigation tool or just an excuse for business-as-usual?

Geoengineering is the deliberate large-scale intervention in the Earth's natural systems, as opposed to accidentally filling the atmosphere with carbon. Geoengineering is increasingly being explored as a response to climate change, with a range of techniques on offer. Solar projects might chemically increase the reflectiveness of clouds, or build Space mirrors to reflect the Sun's energy. Or we might remove carbon dioxide from the atmosphere with massive new forests (and they would be really, really massive) or by adding nutrients to the ocean.

There are many worries about the risks involved with specific projects, as well as scepticism of the whole business. Some worry that even research into geoengineering legitimises the idea. We might also question the motivations of its supporters; why are they so wary of social change over techno-fix? As Doug Parr argued in 2008, geoengineering's attempt to fix nature rather than our society amounts to "an expression of political despair."

Efforts to consider geoengineering's ethics and politics have been developed through the so-called 'Oxford Principles' and, most recently, the Berlin Declaration. But this is still a largely academic and political exercise, with limited public debate, even if the Berlin Declaration seemed to be released via Vice magazine. There's the compounding worry that public engagement might act as a form of public relations, legitimising geoengineering rather than opening debate. Arguably to have a robust public debate on geoengineering we also need one on climate change, and it's questionable whether we're ready.

If you want to read more: The Royal Society's 2009 report is still a good primer, and look out for one due from the US National Academy of Sciences at the end of the year. For the sceptical argument, see , perhaps balanced with Matt Watson's blog, the Reluctant Geoengineer.

If you want to read more:

The Royal Society's 2009 report

➔http://bit.ly/1PszNnJ

Matt Watson's blog, the Reluctant Geoengineer

➔http://bit.ly/1WCmmrb

4 The rise of green capitalism

Can capitalism and the climate ever be friends?

A narrative of capitalism versus the climate is a well-worn one, but leaves out several key voices, not least that of green capitalism. But this argument is growing.

For many, this isn't a problem at all. Quite the opposite, a flourishing environmentalist centre-right is an opportunity to build meaningful action on climate change. But that doesn't mean it is uncontroversial either. Most environmentalists agree climate change demands social change of some sort; it's just what kind of change, how drastic, where, and who takes the burden of risk. Do we want this new world built on capitalist distributions of power any more than we want socialist ones? Even if we agree on a form of capitalism, there are questions of which form, and who gets to take the bulk of a possibly new distribution of power. It might be Bloombergs rather than Bushes, and Unilever rather than BP, or it might be something else entirely.

With post-Occupy debate over economics still very much on the political agenda, the ideologies of climate change feel slightly less binary. Once we agree on the science, the political differences can become all the more stark. Tackling this requires environmentalists to admit their own ideological stances, work out how to constructively disagree with each other, and where to productively collaborate or compromise.

If you want to read more: This is a controversy likely to build, so look out for Felipe Calderón's Commission on a New Climate Economy and discussions around Naomi Klein's new book. This Changes Everything.

If you want to read more:

Felipe Calderón's Commission on a New Climate Economy

➔http://newclimateeconomy.net/events

Discussions around Naomi Klein's new book

➔http://thischangeseverything.org/

5 The Hiatus

Has the climate stopped warming?

Carbon dioxide in atmosphere shows steady rise, so why are temps not higher?

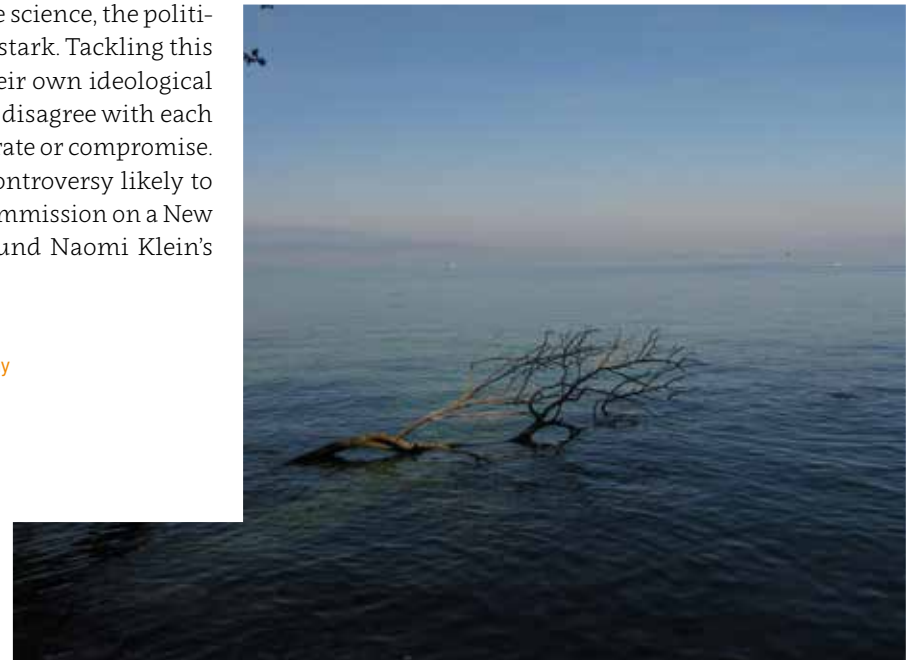
The steadily increasing concentrations of carbon dioxide in the atmosphere since 1998 have not led to the predicted rise in average global temperatures, and this discrepancy has fuelled arguments against climate change as well as confused the public.

Scientists point out that the lack of global temperature rise does fit within their predictions for two possible reasons: surface temperature fluctuations over periods of ten to fifteen years are common, and 1998 was a particularly hot year, making it possibly not the best year for statistical comparison.Others have put forth a number of alternative explanations.

A US-Australian study published in February suggests that unusually strong Pacific trade winds over the past two decades have been powerful enough to push warm surface water much deeper than previously thought, limiting the amount of heat that goes into the atmosphere, a phenomenon that the models have missed.

Mexican researcher Francisco Estrada points to positive changes such as the ban on chlorofluorocarbons in the atmosphere and the drop in microbial sources of methane as a result of greater use of synthetic fertilizers and more efficient water use to grow rice in Asia.

Climate modellers Benjamin Santer and friends suggest an increase in sulphur aerosols from volcanoes may play a role – or a drop in sea surface temperatures across the eastern equatorial Pacific Ocean due to La Niña. Others argue insufficient data from frequently under sampled parts of the world, in particular the poles and Africa, may be the cause.



Meanwhile, Ocean University of China researcher Xianyao Chen argues in a paper published in Science magazine in August 2014 that the heat is being sunk instead in the Southern and Atlantic Oceans, and that the trapped heat in the Pacific is insufficient to account for the pause.

Finally, a commentary in Nature in March 2014 brings most of this together to conclude that a gaggle of factors, including volcanic eruptions, the concentration of aerosols in the atmosphere and solar activity, all conspired to dampen warming trends and make the climate modellers look bad.

Ocean researcher Martin Visbeck's comments in Nature Geoscience that regional fluctuations stress the coping strategies of the developing world.

If you want to read more, researchers John Fyfe, Nathan Gillett and Francis Zwiers of the Canadian Centre for Climate Modelling and Analysis offer a comprehensive commentary, as does Caitlyn Kennedy of the National Oceanic and Atmospheric Administration. For a more popular take on the same topic, Chris Mooney writes up the issue in Mother Jones magazine.

If you want to read more:

John Fyfe, Nathan Gillett and Francis Zwiers of the Canadian Centre for Climate Modelling and Analysis offer a comprehensive commentary

➜http://bit.ly/1WCnR8P

As does Caitlyn Kennedy of the National Oceanic and Atmospheric Administration

➜http://1.usa.gov/1WF8hUE

Chris Mooney writes up the issue in Mother Jones magazine

➜http://bit.ly/1fahyzl

6 Planetary Boundaries

Where do you draw the line?

A group of earth-system scientists in 2009 proposed a new framework of "planetary boundaries" that attempted to comprehensively consider every aspect of humanity's transformation of the environment, from climate change to biodiversity loss. They wanted to establish an easily understandable guide to what was left of an optimum "safe operating space for humanity." Beyond these boundaries, the researchers said, there is a risk of "irreversible and abrupt environmental change" that would make the planet significantly less habitable for humans.

The researchers, led by Johan Rockström of the Stockholm Resilience Centre and Will Steffen of the Australian National University, identified nine such boundaries. Currently, the Earth appears to have crossed the boundaries of climate change, biodiversity loss, and the nitrogen cycle (but not the phosphorus cycle).

While endorsed by a number of organizations, the debate over this approach centers on whether these boundaries represent rigid, permanent upper limits to human societal growth, or whether theys should be considered more like a rule of thumb.

There is a sense of unease in some quarters at the presumption of global governance that the concept implies. Others worry that the concept is a bit Malthusian – that planetary limits on people and resources limit growth.

A number of self-styled 'eco-modernists' such as the Breakthrough Institute, a U.S. environmental organization, disagree whether limits can truly have meaning for our species, given our historic ingenuity in the face of obstacles, or that the concept of carrying capacity can apply to humanity.

"Ever since early humans discovered fire and the benefits of collaborative systems such as collective hunting and social learning, human systems, not the classic biophysical limits that still constrain other species, have set the wider envelope for human population growth and prosperity," argues ecologist Erle Ellis, an associate of the Breakthrough Institute.

If you want to read more, a special issue of Nature explored the topic in great detail, including critical commentaries from researchers not associated with the original paper. The Stockholm Resilience Centre website contains videos and a host of further research links. For the other side, Ellis' essay for the Breakthrough Institute, "Planet of No Return," also offers a series of further reading recommendations.

Critics of a Malthusian reading of the planetary boundaries concept include Steve Rayner, Ted Nordhaus and Michael Shellenberger, and Keith Kloor.

If you want to read more:

A special issue of Nature explored the topic in great detail

➜http://bit.ly/1MCKBuv

The Stockholm Resilience Centre website

➜http://bit.ly/1gUqmdk

Ellis' essay for the Breakthrough Institute, "Planet of No Return,"

➜http://bit.ly/1iHOEOk

7 Offsetting and trading

Will planting a few trees save us?

Carbon is generally seen as a problem in the climate debate. What is less often recognised is that for many years it has also been a commodity.

You've probably come across domestic carbon offsetting. You may have balanced the carbon emissions of a holiday by paying a bit extra to investment in wind farms or energy efficient light bulbs in the developing world, for example. It's not just a domestic activity though, the larger story is of governments and business trading carbon they've emitted to comply with emissions caps, a process which has long been embedded in policy.

As well as carbon offsetting, there is increased discussion of biodiversity offsetting: build on green space in return for paying to restore or maintain equivalent environments elsewhere. This brings up a whole host of further possible controversies; There are scientific, political and ethical questions over the validity of putting an economic price on nature.

Critics of the approach argue it is short-term, and unjustly shifts the problem to the global south. Researchers at the Institute of Development Studies have explored the issue of 'green-grabbing' – land appropriated for environmental activities – across Africa, Asia and Latin America. Other critics point out the opportunities offsetting provides for 'greenwash' – when a company's marketing of its green image exceeds its efforts to become green. Or they worry that carbon trading has simply created new markets ripe for exploitation while climate change continues largely unabated. Advocates, however, argue it offers a workable system for making our current economic systems work for the environment. There is space for improvement, but to many it also offers hope.

If you want to read more: A recent round-table on natural capital offers a range views on the topic. For a longer read, try Donald MacKenzie's Political Economy of Carbon Trading.

If you want to read more:

A recent round-table on natural capital

➜http://bit.ly/WTlyBD

Donald MacKenzie's Political Economy of Carbon Trading

➜http://bit.ly/1kfonbH

8 Migration

Moving away from the effects of climate change may be the smart thing.

In May 2014, Ioane Teitiota, from the South Pacific island nation of Kiribati, had his bid to become the world's first climate change refugee rejected. But later this summer, New Zealand granted a Tuvalu family residency on humanitarian grounds that referred to climate change. Keen to avoid opening 'floodgates' (their term) to similar claims, the tribunal stressed this family's connections to New Zealand. It appears headlines like 'the era of climate refugees has begun' are misleading, but it is a case to watch.

There's a small thread of anti-immigration green politics, and environmental rhetoric gets used by anti-immigration groups (even climate sceptic ones) but the problem is usually larger than that. More broadly, the issue of immigration is a good example of how climate change can intersect with other political controversies. Climate change aggravates already heated immigration rhetoric; likewise, immigration can disrupt climate discussion.

For example, March 2014's publication of the IPCC report on impact, adaption and vulnerability led to headlines prophesying doom, with tales of climate change to displace millions. In fact, the report argued migration could provide a way for some to deal with climate change, reducing vulnerability for many populations. It also included much more, but the immigration issue could be folded into other news controversies. Similarly, those seeking to migrate because of climate change find themselves working within harsh and rigid legal and cultural systems which are the product of other political and economic problems and fights.

If you want to read more: the BBC looked in detail at claims about the quantity of climate migrants. Whatever the numbers, people do move in the context of environmental change, and the Climate Outreach and Information Network have produced an engrossing report based on the testimonies of migrants themselves.

If you want to read more:

The BBC looked in detail at claims about the quantity of climate migrants

➜http://bbc.in/1Pf8u1O

Climate Outreach and Information Network have produced an engrossing report based on the testimonies of migrants themselves

➜http://bit.ly/K6Q1Fo

9 Climate finance

At the end of the party, somebody will have to foot the bill.

The climate finance debate is ultimately a fight over who is responsible for climate change and who has to pay. Cost estimates vary widely depending on the assumptions used, but they all share one trait – their magnitude is far greater than the sums pledged and dispersed to deal with the problem.

An aggregation by the South Centre, a developing country think tank, of the various assessments that also bundles mitigation and adaptation together, found that the core of climate finance necessary ranged from $600 billion to $1.5 trillion a year.

At the Copenhagen UN climate talks, the developed world committed $30 billion from 2010-2012 as a good faith gesture known as 'fast start' finance and agreed to $100 billion a year by 2020. But so far the cupboard of the UN's Green Climate Fund (GCF) is pretty bare, holding little beyond the South Korean government's contribution of $40 million to cover administrative costs of the GCF in Incheon.

Oxfam, the international development organization, reported that climate finance contributions claimed by developed countries last year amounted to $16.3 billion. However, if loans that are expected to be repaid are excluded, this drops

to just $7.6 billion. Pledges have plateaued or declined due to the global finance crisis, and many countries are simply relabeling development aid as climate finance.

At the same time, developed countries have steadily shifted from pledging public funds to offering private money as a way to meet the $100 billion Copenhagen pledge. Public funds already committed would catalyse private investment.

Developing countries for their part are concerned about a lack of what is termed "country ownership" of resources, meaning that national and local governments are to decide which projects are to go forward in their own areas, and to manage how resources are distributed – albeit while operating under international guidelines. Direct access to funds in this way, or "enhanced" direct access with an even deeper domestic devolution of management, has become a major sticking point, with the United States particularly reluctant to support this approach.

Developed nations have pressed emerging economies to commit to targets capping CO_2 emissions, but the BRICs – Brazil, India, China and South Africa – refuse to even countenance such a move before the global north delivers on its climate finance pledges. The UN Framework Convention on Climate Change holds that industrialised countries played the main role in causing the climate crisis and are to pay for it. All of this makes it much harder to reach a new global climate pact in Paris in December 2015.

If you want to read more, visit the Green Climate Fund's website, or for a discussion of the geopolitics of climate finance, researcher Luis Gomez-Echeverri of Austria's International Institute for Applied Systems Analysis has a comprehensive essay in the Climate Policy journal. Climate finance watchdog group Climate Markets has a series of critical essays and videos, and development group Oxfam follows the issue closely from a third-world point of view.

If you want to read more:
visit the Green Climate Fund's website
➜http://www.greenclimate.fund/home
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➜http://bit.ly/1iHRClO
Oxfam follows the issue closely from a third-world point of view. ➜http://bit.ly/1Q8F2ut

Leigh Phillips (@leigh_phillips)

Leigh Phillips is a science writer and European Union affairs journalist. He has written for Nature, the New Scientist, the Guardian, the Daily Telegraph, the New Statesman and Jacobin, amongst other outlets. He spent much of the last decade in Brussels covering the EU as reporter and deputy editor with the EUobserver, but is now science writer for the Pacific Institute for Climate Solutions at the University of Victoria, Canada. His first book, 'Austerity Ecology & the Collapse-porn Addicts: A defence of growth, progress, industry and stuff', was published in 2015 by Zero Books. His follow-up, 'The People's Republic of Walmart', on the science, economics and politics of logistics and economic planning, will be out in Spring 2016 from Verso.

10

The role of nuclear power

Is it a threat or a promise?

Few disagree that fossil fuels need to be replaced with clean sources of energy, but the role of nuclear power in the mix remains hotly contested.

The risk of meltdown; the threat posed by long-term exposure to low-level radiation to power workers and those who live near plants; and nuclear waste disposal are the main obstacles to new nuclear power plant construction. High cost, the long construction time, government assumption of liability insurance, and risks of nuclear weapons proliferation and terrorism are other worries.

In the early 2000s, there had been widespread talk of a "nuclear renaissance," and construction of nuclear power plants picked up briefly. But the 2011 accident at the Fukushima plant in Japan killed this off, and led many countries to block new construction or even shut down reactors.

Interestingly, some conservative groups and private industry have joined the "greens" on the left in objecting to new plants. The libertarian Cato Institute has warned against the "risky business" of nuclear power, which it links to government loan guarantees and construction cost overruns that could leave the public paying much of the bill. Based on political objections to the large government investment necessary, the conservative American Enterprise Institute and free-market-boosting Economist magazine recommend nuclear power play a minor role.

A shift in thinking has begun, however, among a number of high-profile climate scientists, particularly in the United States and Britain, and some anti-nuclear activists who are convinced that there is no alternative. Renewable sources such as solar and wind are intolerably intermittent; hydroelectric and geothermal are limited by geography and have a limited scalability. Meanwhile, economic growth adds electricity demand equal to a year's consumption in Brazil that must be met.

Nuclear advocates argue state-of-the-art reactor design actually consumes nuclear waste, and also eliminates the threat of meltdown. Moreover, they say, nuclear has the fewest number of accidental deaths per unit of energy generated of all major sources of energy generation, lower even than solar power. Zero radiation related deaths have occurred as a result of the accident at Three Mile Island, and there were no casualties officially reported to be caused by radiation exposure at Fukushima.

If you want to read more, some of the major anti-nuclear campaign groups include Greenpeace, Friends of the Earth and the Campaign for Nuclear Disarmament, while noted environmentalists who have written extensively in favour of nuclear power include George Monbiot and Mark Lynas. The 2013 documentary Pandora's Promise gives an easy to understand and visually arresting overview of the pro-nuclear argument.

If you want to read more:

Greenpeace ➜http://bit.ly/1jaUqab

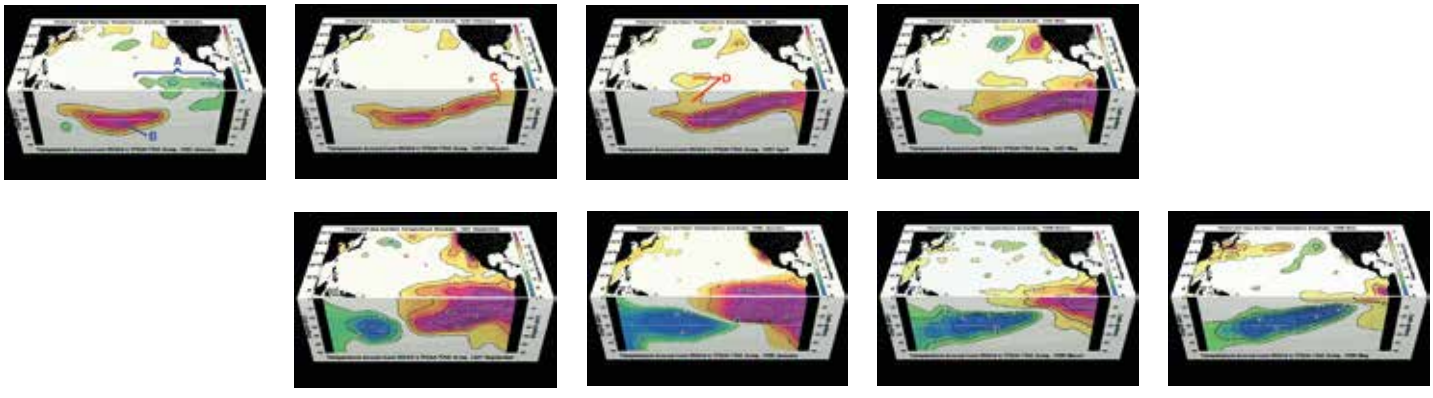
Friends of the Earth ➜http://bit.ly/20djlNl

Campaign for Nuclear Disarmament ➜http://bit.ly/1yM9Djq

The 2013 documentary Pandora's Promise ➜http://bit.ly/1ealja6

DANIEL A. GROSS

Fishing in pink waters: How scientists unraveled the El Niño mystery



It was January 1997, and the Pacific was turning pink. The color was spreading from deep beneath the surface, starting near New Guinea and creeping east toward the coast of Peru—a distance of nearly 11,000 kilometers. On the map, it seemed as though the patch might come to encompass the entire ocean, growing and rising, expanding at the surface almost like the film of an oil spill.

In the actual ocean, there wasn't much to see. David Pierce was looking at a map superimposed with projected ocean temperatures, and pink was a representation of anomalous warmth in the Pacific. The map told Pierce that according to the climate model developed by him and his colleagues at Scripps Institute of Oceanography, huge swaths of the southern Pacific were about to heat up.

A warmer ocean would mean a lot more than better surfing in Baja California. In fact, it would mean torrential rainfall across South America, record winter warmth and wetness in the United States, and $4 billion of damage in the country of Ecuador alone. Climate scientists had even found that through long chains of cause and effect, warm Pacific temperatures were linked to warm air over the Arctic and cold air over Russia—regions that were literally half a world away.

It felt a bit unreal to Pierce that nearly a year in advance, a computer could identify such a drastic development in the climate. The forecast was far from certain knowledge, but if it proved correct, a big El Niño was brewing. Temperature anomalies started in the Pacific, but they could have repercussions across the planet.

Pierce remembers that back in 1997, there weren't many forecasters focused on El Niño, and the few existing climate models were sluggish and tedious. So he wasn't sure that any of his scientific colleagues had yet seen results like this. It gave him an odd and potent feeling, like he had a private glimpse into a likely future. "It was part wonder and part responsibility," he says. "This thing was coming and it would disrupt lives and economies across the planet, and I realized I might be the only one on Earth who knew it."

trouble in 2014—is how to foresee an El Niño many months or years in advance. This is more than a question of pulling out the umbrella before the rain comes. It's a question of understanding a pivotal and fundamental part of the Earth's climate.

Here's the basic idea of El Niño. Every few years, a relatively warm patch of water—the pink on Pierce's map—forms beneath the Pacific. The difference is just a few degrees, but in a global context, the extra heat can transform the seasonal climate. Some years, the warm region spreads outward and eventually upward, where it meets with easterly trade winds. This creates a feedback loop. Warm water undermines easterly winds that normally enable an upwelling of cool water, which amplifies warming and in turn further slows the winds. It's this moment of atmospheric-oceanic coupling that helps scientists define the start of El Niño.

See the interactive version of this map at http://roadtoparis.info/embeds/el-nino-global-phenomenon-map/

* * *

El Niño is far older than its name, dating back thousands of years according to geological records. Long before climate scientists started to study it, South American fishermen knew how to read it in the water. In a strong El Niño year, the eastern Pacific can rise 30cm and feels palpably warmer to the touch. Species of fish usually caught in June are netted in December. Epic rains fill coastal deserts with lakes, and vegetation sprouts where there should just be dirt.

On the west coast of South America, residents have long interpreted warming water as the sign of an impending El Niño. By the time coastal temperatures rise, however, the phenomenon is typically well on its way. The problem scientists are still trying to solve—the one Pierce was working on in 1997, and that has given researchers special

Wind and water exist in delicate balance with the rest of the climate—so El Niño sets off a cascade of effects. Among its most drastic consequences are increased temperatures along the Pacific and heavy rains along South America's western coast.

That's only the beginning, however. El Niño must have transformed the harvest and thus the fortunes of the Incan Empire. In the 16th century, the Spanish conqueror Pizarro repeatedly attempted to sail down the Peruvian coast, but historical records suggest he failed until El Niño's winds came. It was only after Pizarro's time that fisherman named the yearly rains and warming for the child of Christ, because they tended to arrive around Christmas.

In a tangled and interconnected system like the climate, a seemingly regional phenomenon like El Niño becomes global—and so does the science

Jacob Bjerknes was the first to understand that the Southern Oscillation and El Niño are part of the same phenomenon. Photo: GFI/Geophysical Institute, University of Bergen.

deployed to understand it. In the 19th century, El Niño was understood as warming in the Pacific, but its secondary effects (if any) were a matter of debate. Scientists were just starting to consider that patterns of regional weather might be connected over vast distances. Increasing air pressure in one part of the world, for instance, was surprisingly correlated with decreasing air pressure elsewhere in the world.

Climate science developed regionally, like pieces of a puzzle that have only gradually been put together. In 1895, Victor Eguiguren postulated a link between heavy rains in Peru and the El Niño cycle. Early in the 20th century, Gilbert Walker theorized a link called the Southern Oscillation between atmospheric pressure in the Indian and Pacific oceans. These pieces were refined independently until the 1960s, when Jacob Bjerknes put them together and found he had a match: The Southern Oscillation and El Niño could be understood as two faces of the same phenomenon, soon known as the El Niño Southern Oscillation (ENSO). Fluctuating pressure provided a causal link between the behavior of wind and water. It also helped explain cooling phases called La Niña, which alternated with El Niño years.

ENSO's impacts have proven to be subtle and far-reaching. The climate historian César Caviedes argued that ENSO helped chill the winter of Napoleon's march to Moscow, just as it helped freeze the soil during Hitler's attempt at the same maneuver. It contributed to drought in the Horn of Africa that, in 1974, led to the collapse of the Ethiopian Empire.

The scope and diversity of these impacts makes it clear that accurate ENSO prediction would revolutionize our understanding of the climate. Advancing science has made it possible to trace El Niño's many consequences in the past and the present, all across the globe. But a crucial question remains: Can scientists reliably see an El Niño coming?

* * *

As 1997 wore on, David Pierce kept his eyes on the news. He and his colleagues at Scripps in California had notified the media that a potentially large El Niño was on its way, and the announcement—echoed by ENSO scientists elsewhere in the world—trickled slowly through the areas likely to be affected.

The Scripps model had started with existing conditions in the Pacific and, using a handful of equations to represent climactic processes, had extrapolated them into the future. In using this method, scientists across the world were departing from the historical standard of ENSO prediction that had dominated in the 1980s. Back then, researchers had looked at past instances of El Niño and tried to guess when the next one would come. This method has its insights, since ENSO is a cyclical process, but it has clear shortcomings: Imagine trying to predict the success of the New York Yankees based on its World Series titles in 1978, 1981, and 1996.

News of the impending El Niño reached Rodney Martinez when he was a scientist in Ecuador, researching climate in a branch of the country's Navy. All the early warning signs for a large El Niño were there, he recalls, from oceanic warming to atmospheric coupling to early shifts in rainfall and temperature. "We had a global consensus in June," he says, even though most years it takes much longer for climate scientists to fully agree. "Everybody knew that El Niño would be extraordinary."

As Pierce saw in the headlines, and as Martinez saw with his own eyes, El Niño struck with a bru-

tal and unrelenting force. On some days, more than 13cm of rain fell on parts of Peru. Streams and rivers rose and widened, and vast pools covered over arid areas where the hard ground was formerly riddled with cracks. Mosquitoes multiplied in standing water; houses and even villages were washed away by flooding. "Roads, infrastructure along the Ecuadorian coast were destroyed," says Martinez, who conducted a 1998 damage assessment and now works for CIIFEN, a UN-funded El Niño preparedness organization. "There were isolated people, all of the sanitary and water supply infrastructure collapsed."

Humans have only been keeping climate records for a few decades, so every instance of El Niño teaches scientists a great deal, but the El Niño 1997/98 was especially pivotal. It was the first event of its size that scientists really saw coming. Yet even with the foresight, its effects killed more than 2000 people and caused over $30 billion in damage worldwide. Put simply, El Niño 1997/98 made policymakers pessimistic and scientists optimistic.

Martinez remembers that he and his colleagues in South America struggled to get the word out. "You can have the best models in the world, but that does not necessarily mean that you will reduce the impact in a particular region." As a result, many national and international programs to prepare for and adapt to El Niño began in 1998.

On the other hand, David Pierce remembers that back then, only a few groups were working on ENSO prediction. Partly thanks to the buzz generated by El Niño 1997/98, research has come a long way. These days, ENSO is a much larger part of academic and national research programs, and there are more than 20 major climate models

El Nino storms cause the 1998 Rio Nido mud slides in northern California, damaging houses and cars. Photo: Dave Gately/FEMA News Photo

Residents of Laguna Niguel, California, work together to save the belongings of a condominium that was heavily damaged in a landslide resulting from El Nino storms. Photo: Dave Gately/FEMA News Photo

that help predict it. Many model the entire climate, not just El Niño, and thanks to computing power and advancing research, their complexity make the 1997 Scripps model look rather crude in retrospect. Not every El Niño gives as strong a signal as 1997/98, and newer models aim to extract a prediction even when the warning signs are weak. That was exactly the challenge in 2014.

Still, complex models create new challenges: Scientists don't always understand how they work, or how to improve them. Which brings us to the present, when even after two decades of advancing climate science, uncertainty can win the day.

* * *

Early in 2014, the water beneath the Pacific started getting warmer. Data from buoys and satellites, many deployed by the National Oceanic and Atmospheric Administration in the United States, fed into climate models around the world, which produced a fairly uniform result: an El Niño seemed to be brewing, with approximately 75% likelihood of developing.

ENSO predictions have come a long way since the 1990s, but there's plenty of work left to do. A 2012 survey of many ENSO models showed that 6-month forecasts have slowly but steadily improved since the 1990s. Even so, thanks to limitations of computer power, data quality, and model reliability, however, the 2014 forecasts were tentative.

In the spring of 2014, word of a potentially developing El Niño reached media organizations. From there, the news spread quickly and loudly. Many publications announced an impending "monster" El Niño, while some scientists went so far as to compare 2014 conditions to the destructive winter of 1997/98.

And then—very little happened. Waters near the coast of South America warmed up, and rainfall spiked in some regions near the coast. But as autumn began, atmospheric coupling still hadn't occurred, leaving many scientists scratching their heads.

A model is a description of the world in miniature, built of a series of equations taken to be fundamental. These equations can't be solved for a specific answer, but they can be tested in simulation and averaged for a good guess at the future.

The obvious problem is that the climate is layered and complicated. Climate models aim to simplify real-world phenomena, but sometimes, says University of Exeter climate scientist Mat Collins, "they are almost as complex as the real world."

The very latest 2014 predictions tell us that El Niño still hasn't begun, but warm water anomalies continue in the Pacific. Most forecasters—now more cautiously—still expect El Niño to arrive in the next couple of months.

Regardless of the outcome, future models will need to reckon with the bizarre mixed signals that have emerged in 2014. Although the general principles of climate models seem sound, many scientists suspect something crucial is misrepresented or missing. "Every time we have a new El Niño event, we have a revision of the theory about how El Niño seems to be working," says Collins. These new models may be radically different from their predecessors. "It's usually more than tweaking the old model," says Anthony Barnston, who co-authored the 2012 paper analyzing various ENSO forecasts. "It's usually different physics."

Perhaps we don't study climate phenomena despite their complexity, but because of their complexity. The science of El Niño provides some profound insights into the climate at large. ENSO models continue to vex scientists for the very reason that ENSO seems worthy of study: Its impacts can be vast, global, and dizzyingly diverse.

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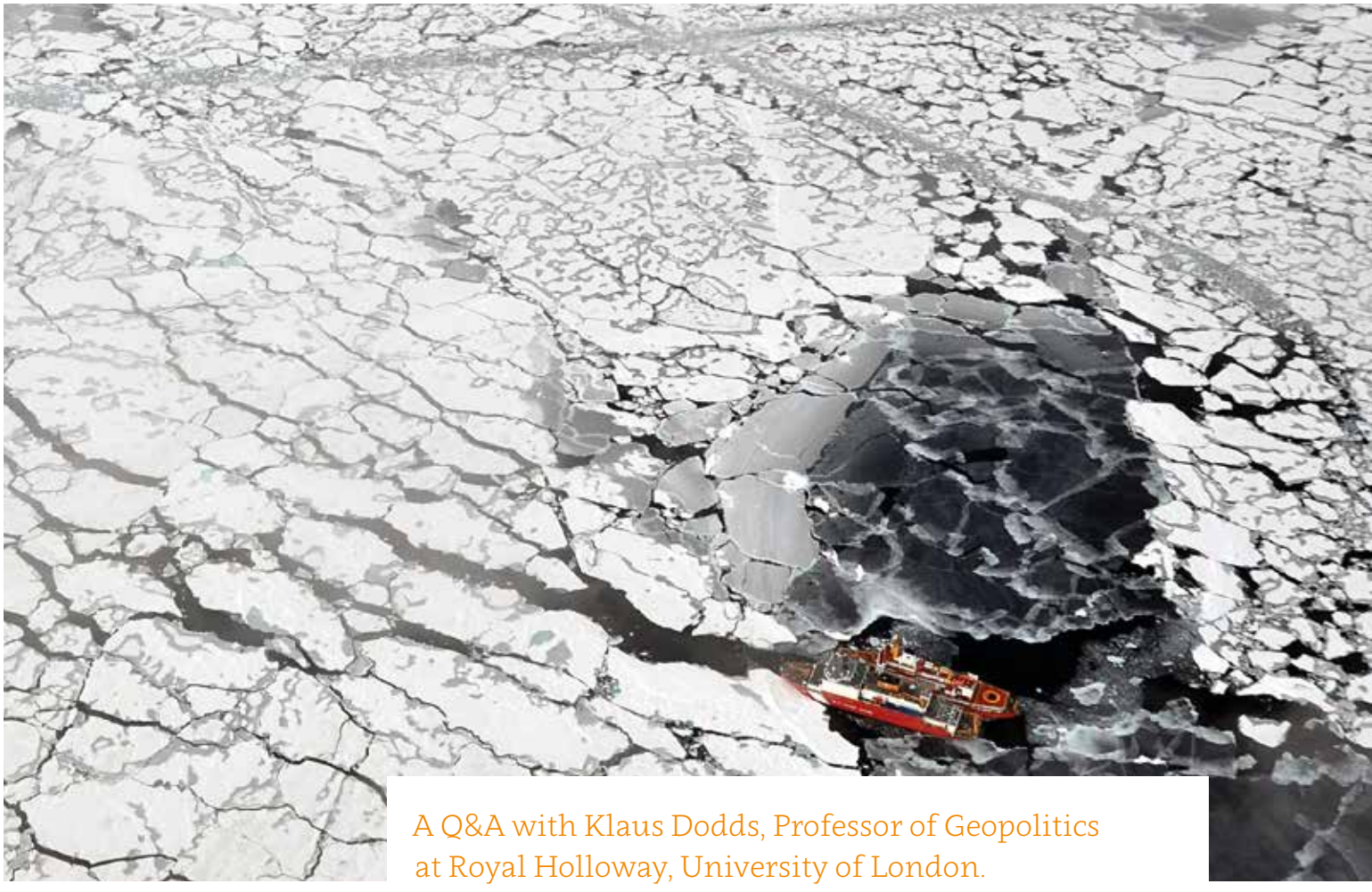
Greg Laden contributed additional reporting for this story.

Q&A with Klaus Dodds: the geopolitics of the Arctic



A Q&A with Klaus Dodds, Professor of Geopolitics at Royal Holloway, University of London.

ALICE BELL

What do you think's interesting about the Arctic at the moment, in terms of the geopolitics?

Klaus Dodds – One of the most interesting aspects of the Arctic is a tension between, on the one hand, a remote, exceptional and poorly understood space, and on the other, one that is increasingly globalised and of interest to far more people than ever before. It's really interesting to see this place, this complex place, become the subject of so much more public interest than it was, say, twenty years ago.

Do you think it's a space that has been a bit ignored?

Within many countries, even those countries within the Arctic, it's a space that has been reasonably neglected. It's worth bearing in mind that, for example, for southern Canadians, the Canadian Arctic will seem like a very remote place –

they are far more likely to travel to Europe than to go to Nunavut or the North West Territories – and I think part of it is the legacy of the Cold War. In a sense, it was one of the most politicised places on the planet and, in a lot of cases, not particularly easy to travel to.

The Arctic includes a range of different nations, could you give us a sense of who the various actors are?

The first thing to say is that the Arctic has four million residents. Most of them live in the Russian Arctic, and then the ratio between the indigenous residents and Northern – non-indigenous – residents varies enormously. There are eight different Arctic states: the United States, Canada, Norway, Denmark via Greenland, Finland, Sweden, Russia and Iceland. Five of them are the ones that have Arctic Ocean interests: the United States, Canada, Norway, Denmark/Greenland and Russia. So when we talk about the geopolitics of the Arctic, we have to bear in mind there are lot of people who live there, but there are these eight key states which all think of the Arctic as their neighbourhood.

From the climate perspective, one of the biggest changes attracting attention to the Arctic is ice melt, and this possibly opening up new spaces, and with it, business opportunities. Do you agree that's a big change, and if so how do you think it's playing out?

There's no doubt that one of the biggest drivers of increased global interest in the Arctic has been this relationship between the idea that the Arctic might become more accessible because of climate change, and in particular, sea ice thinning, and this also being linked to greater resource extraction, or at least resource speculation. Resource extraction has been a feature of the Arctic for a very long time. There's been mining in Greenland for several hundred years. Resource extraction is not new. But what is newer is the idea of the Arctic becoming more accessible, and that's encouraged a great deal more interest, particularly from countries outside the eight Arctic states, to think of the Arctic as a new resource frontier. But for many people the Arctic is also being thought of as the climate change frontier.

That brings in two other actors – businesses, multinationals, and some national companies linked to Arctic states, but also citizens in other parts of the world. How are they able to express their interest – or trying to express their interest – in the Arctic?

In terms of business, this growing sense of the globalisation of the Arctic goes hand in hand with the idea that business and commerce is increasingly playing an important role, and that can happen in all kinds of ways. It's about business and commerce taking actions with states, but also with indigenous communities, and Northern communities. It's important to say indigenous and Northern communities are also involved in businesses which are going beyond the Arctic as well. It's not one-way traffic. Business and commerce, and the networks that sustain it, are going in and out of the Arctic.

For citizens, it depends on what group you are talking about, but NGOs like Greenpeace, through their Save the Arctic campaign, have played a part in raising a sort of Arctic consciousness in citizens both within the Arctic states but also, increasingly, beyond. I think they're trying to make the Arctic more demanding of our attention in a more global sense, to stop seeing it as a place that is disconnected and remote from our experience.

Do you see them as being able to have much success in that? They've got a fair number of people supporting them, but can they translate this into political power?

That's going to be a difficult objective, for a number of reasons. First of all, you'd probably find that a lot of Arctic residents would have rather negative views about environmental NGOs. The idea that the Arctic needs saving might actually be slightly offensive to some of the people who live there. For many Arctic communities, resource extraction is a key employer and something that is seen as a wealth creator, and for many of these communities that's important because their livelihoods can often be quite precarious. If you stopped oil and gas extraction, mineral extraction – such as zinc or copper or iron ore – or timber, then that could have

Klaus Dodds is Professor of Geopolitics at Royal Holloway, University of London and an expert on the Arctic, Antarctic and Falklands. He spoke to us in a personal capacity.

quite a serious impact on those communities. When you also juxtapose it with high profile trade bans on things like seal products, then it has led, I think, to a rather jaundiced view of what NGOs outside the Arctic are trying to campaign for. I think Greenpeace's Save the Arctic campaign is most likely to be successful in Great Britain, the Netherlands, Germany, but not in the Arctic states themselves.

Staying on the issue of global conversations, how do you see concerns from people who live in the Arctic – or work in, or study the Arctic – as able to influence global discussions on climate change, such as the UN talks?

For me, one of the biggest ways one might shape or influence debate regarding the relationship between climate change and the Arctic is to recognise that the indigenous and Northern residents have a multitude of views about climate change. In Northern Canada, for example, you often get a view about climate change that is very apocalyptic. But in Greenland you can get a response that is almost that we welcome the changes that climate change might bring, particularly if it brings new opportunities for us as a people who want to be independent in the future. One of the problems with the Save the Arctic campaign is that it keeps talking about the Arctic in the singular. But there are multiple Arctics. There are different Arctic stakeholders who have different views on what climate change represents.

What do you think about the ways in which indigenous voices are folded into global political debates? Do they get collectivised together too much in the UN, for example? Do they have a voice through the various nation states, or do they get silenced by the various legacies of colonialism?

The most important venue is the Arctic Council. Within their structure, since 1996, six umbrella indigenous organisations are what are called permanent participants. There is a dilemma though, on one hand you want to recognise that indigenous voices are plural, but on the other hand, if there is an excessive celebration of diversity, then there is a danger that some fundamental messages like colonialism, imperialism, racism, marginalisation, deprivation get lost. One of the interesting things in Canada with the Idle No More movement was to gather together those voices and to raise some quite fundamental inequalities and legacies that Canada has to confront. And one of those, for example, would be land claims.

Moving to a slightly different focus now, how well do you think the scientific expertise is embedded in political discussions in the Arctic? And possibly vice versa too, do you think the scientists working in the area pay enough attention to the politics of the region?

Whether we use the term military-industrial-academic-complex or not, scientists are embedded in wider structures of power, and I think most scientists recognise that. On one hand, in places like Canada there are now quite elaborate rules and regulations governing how scientists work with indigenous communities. But on the other hand, I think science is absolutely integral to geopolitical performances of states. To give an example, at the moment, oceanographers, geologists and environmental scientists are playing a critical role in helping to track the seabed of the Arctic Ocean and the sole purpose, as far as states are concerned, is to enable them to extend their sovereign rights. That's a classic example of scientific knowledge being essential to sovereignty and security projects. But you also find in certain Arctic states, science may also be able to speak openly about, for example, climate change, or permafrost thawing. Because of the politicisation of Arctic science, it's true in several countries that scientists feel they are constrained and can't speak openly. There is a strong connection – and a long-standing one – between science and geopolitics.

Is there anything else that you want to mention that our readers might find interesting, or you think we should look out for in terms of geopolitical changes in the Arctic?

In May 2013 a number of countries became observers to the Arctic Council, including China, Japan, Singapore and India, and something to look out for is what role these predominantly Asian states might play to increasingly shape the politics of the region. They might do this quite subtly. For example, producing their own Arctic scientific knowledge, but playing a role in terms of trade, investment, business. We've already begun to see this in places like Iceland and Greenland.

Overall, the relationship between climate change, science, resource extraction and geopolitics is likely to become ever more important, and interesting in the Arctic. And probably ever more contested.

Read more about the arctic on Road to Paris:

Q&A with Liz Morris: work of glaciologists in Canada "utterly disrupted" ➜ http://bit.ly/1Mw7Hcj

Q&A with Greenpeace's Ben Ayliffe: "The Arctic is the defining environmental battleground of our age" ➜ http://bit.ly/1uK31q9

MIT uses the state of the art facilities at the Massachusetts Green High Performance Computing Center for carbon price modelling.

Pricing carbon is a very complex challenge, and not just politically

DANIEL A. GROSS

Most economists agree that if we want to efficiently reduce CO_2 emissions, we'll need to put a price on carbon. But a nagging question remains. How are we supposed to figure out a price for an invisible, amorphous gas that underpins the economy and transforms the climate?

It's relatively easy to put a price on a t-shirt or a pound of apples. Calculate the cost of all the inputs, from raw materials to labor to shipping. Then add a margin for profit, and the product is ready to be sold.

The costs of carbon, by contrast, are diffuse and diverse—which helps explain why the estimated prices of CO_2 vary wildly across countries and companies. The US government uses an estimate of $33 per ton of CO_2, while Sweden uses the strikingly high figure of $168. In internal calculations, Google Inc. uses $14 per ton, while (perhaps surprisingly) oil companies like BP and Exxon-Mobil use fairly high prices of $40 and $60, respectively. So where do these carbon price tags come from? Whenever you see dollar amounts tacked on to tons of carbon, economists likely used one of two methods to calculate them.

The first method is like a very long addition problem. The strategy, according to World Bank senior economist Stephane Hallegate, "is to look at the damages on the environment and societies and people that one ton of carbon would create." In other words, economists use computer models to tally up all the negative impacts of carbon, and set a carbon price high enough to offset those costs. "If the damages are going to be high, that justifies quite a high carbon price," explains Niven Winchester, an MIT environmental economist.

In practice, however, adding up the costs of carbon can be extremely tedious. "You're solving a puzzle," he says—but the puzzle has a huge number of finicky pieces. A dizzying array of factors can affect the estimated cost of carbon. For example: How much will solar energy cost in 30 years? How much meat will humans consume, one century from now? How much CO_2 would cause the Greenland ice sheet to melt? Because there are

so many factors to estimate, MIT outsources its calculations to a massive computing center 100 miles west of Boston, the Massachusetts Green High Performance Computing Center (MGHPCC). Unlike simplified models of the economy, "integrated models" may generate datasets of many terabytes — a reflection of the many environmental and economic processes that researchers hope to capture.

To generate an accurate carbon price, models also need to incorporate new insights from economics and environmental science. As Stanford economist Michael Mastrandrea wrote in 2009, models "must contend with an ever-changing body of underlying literature." On a scale from 1 to 10, Winchester estimates the difficulty of accurately linking models of the environment and the economy as "getting toward a 9 or 10."

A simple example helps illustrate the challenge. Let's say the cost of carbon increases, and causes reductions in agricultural output and increases in electricity costs. These shifts lead to second-order consequences: Farmers might choose different crops, while factories might relocate to countries that lack effective carbon taxes. In short, the economy affects the environment, which affects the economy—producing a feedback loop.

This helps explain why—at least for now—most economists favor a simpler strategy for pricing carbon: Choose a particular aim, and then calculate a price for carbon that would help achieve it. "First you assess the risk; you decide your goal," says Hallegate. Right now, that goal is to limit global warming to 2 degrees by 2100. "Then you look at what you need to achieve this goal."

Practically speaking, this means economists can rely on much simpler models when making carbon price calculations. Instead of trying to mimic the entire economy and environment in coupled models, they can rely solely on economic models that estimate the impact of carbon prices.

Arguably, both approaches are rooted in the same principles. Emissions figures like the 2 degree target are often tested by climate models. Integrated models like the ones used at MIT are just a more dynamic and precise way to capture the effects of not only carbon on society, but also also society on carbon.

Regardless of which method you choose, Hallegate says the cost of carbon contains more than the sum of the damage carbon causes. The price is sort of like home insurance against fire or flooding. Many homeowners end up paying more for insurance than they'll ever receive from insurance companies—but they have protection if the house goes up in flames. "When we estimate the price of carbon, a lot of this value is really about the hedge. It's insurance against things getting very, very nasty."

In other words, the carbon price isn't ever just a tally of damages, but a figure that covers a range of best- and worst-case scenarios. That's why many carbon prices, like the U.S. Environmental Protection Agency's "Social Cost of Carbon" (which was generated with the first method of adding up all the estimated burdens of CO_2), include several staggered prices depending on the severity of climate change. A price range acknowledges the uncertainty in projecting our future climate.

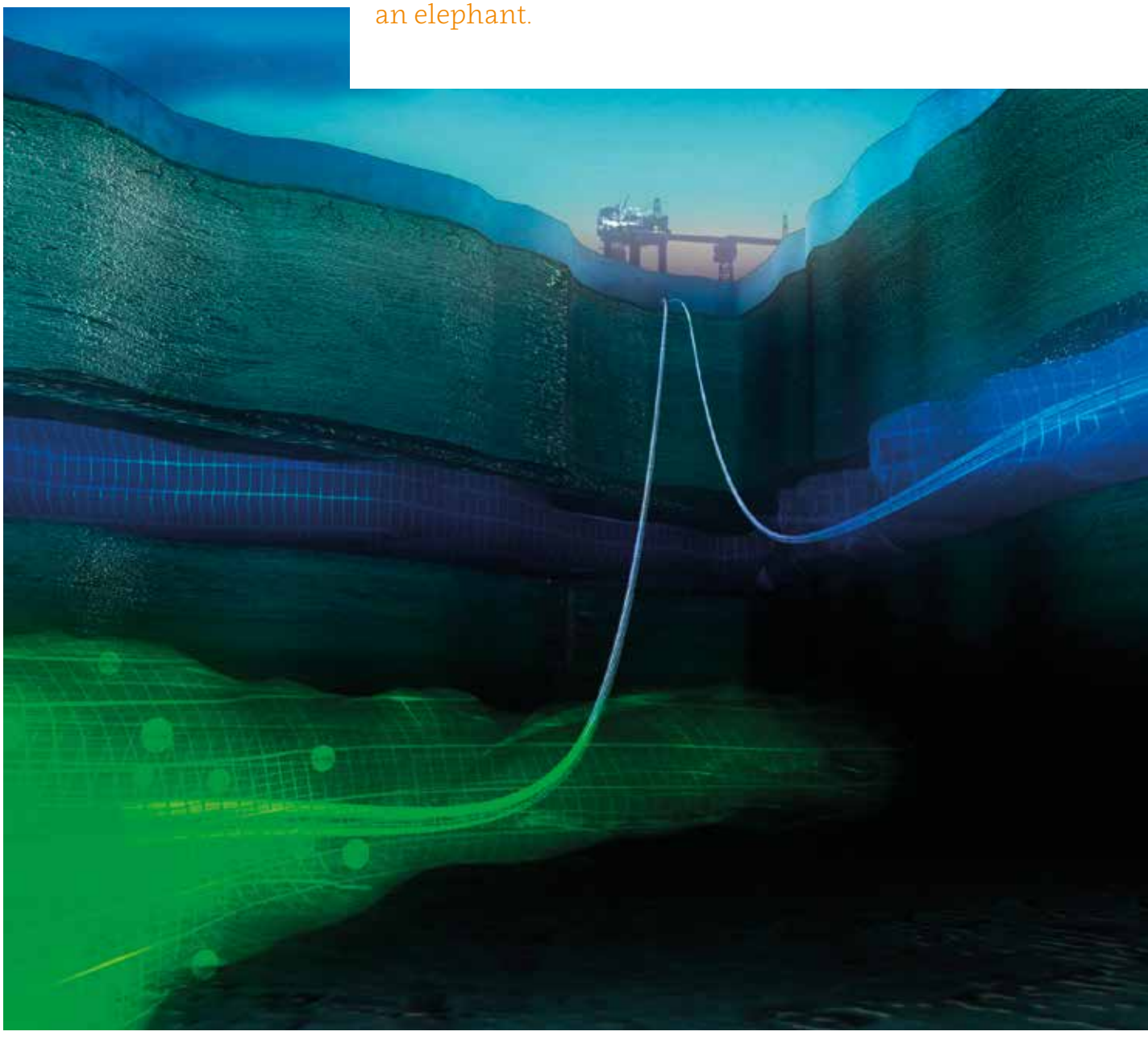
And as climate scientists know, there is plenty of uncertainty. "A ton of carbon will stay in the atmosphere for hundreds or thousands of years," Hallegate points out. It's a tall order to try and predict the damage caused by CO_2 in our lifetime—and the cumulative impacts it will have in the future.

Still, carbon prices have a simple advantage. Even when the underlying calculations lack clarity, price tags make sense to companies and consumers, and may be easier to grasp than new laws or regulations. Whether we're buying a house or a handbag or a ton of carbon, prices pack an incredible amount of information into a few digits and a decimal point. When it comes to pricing CO_2, the central challenge is starting with the right information, so we end up with the right price.

LEIGH PHILLIPS

Will negative emissions technology get us to 2 degrees?

There is an elephant in the climate mitigation room. Actually, if we're honest, what's in the room is quite a bit bigger than even an elephant.



Concept for carbon storage at the Sleipner Platform.

For the latest report issued in 2014 by the Intergovernmental Panel on Climate Change (IPCC), researchers looked at over 1,000 different greenhouse gas emission scenarios over the course of the rest of this century. Of these thousand scenarios, there are ones that are terrifying in the amount of carbon that could be emitted, leading to terrifying temperature increases. There are IPCC scenarios that are in line with the internationally agreed target of limiting warming to below 2° Celsius above pre-industrial temperatures. We can call these the 'worrying' scenarios. And there are scenarios in between. What lies between worrying and terrifying? How about we call these scenarios the 'frightening' ones.

Here's the thing though. The vast majority of the scenarios that allow us to stick to the two-degree limit—the worrying ones, that is—assume that by some point in the second half of this century, we will have achieved net negative emissions. In other words, we will be taking more greenhouse gases out of the atmosphere than we put into it.

Even many of the scenarios that will likely lead to three degrees of warming—the frightening ones—still assume a large role for negative emissions. Even if we don't manage to achieve net negative emissions, there are a lot of scenarios that require bulk CO_2 removal from the atmosphere. It's just that the amount removed does not exceed the rest of the emissions pumped out, so this will not be enough to dip below zero.

"We are late with mitigation," economist Sabine Fuss of the Mercator Research Institute on Global Commons and Climate Change reminds Road to Paris. "As a result, many scenarios require negative emissions."

Negative emissions depend on BECCS

Negative emissions—net or otherwise—would require the widespread adoption of a suite of technologies collectively known as carbon capture and storage (CCS), used in conjunction with the production of bioenergy.

The plants that are used to produce bioenergy take carbon out of the atmosphere as they grow. Then when we combust the bioenergy, that carbon is put back, in principle leading to no net new carbon emissions. But if bioenergy is combined with CCS, which scrubs carbon out of the combustion process and later stores this carbon dioxide underground or deep under the seabed, then we could begin to enjoy negative emissions.

Most of the merely worrying scenarios require that the world emit a total of no more than 1,200 gigatonnes of carbon by the end of the century. That's about 30 years' worth of carbon emissions at current levels. But these scenarios also foresee absorption of up to 1,000 gigatons of carbon via the aforementioned blend of bioenergy and CCS—a combo known by the acronym BECCS. This combo then would allow the total positive emissions to increase from 1,200 to 2,200 gigatonnes – and make the effort that much easier.

There are other options, including afforestation (planting trees), increasing the carbon stored in soil, and direct air capture of carbon. But the first two involve a sequestration of carbon dependent on land-use change that can be changed back at any time (if someone chops down a tree, for example). Soil carbon stocks are constantly at jeopardy of being disturbed. Direct capture technologies such as artificial trees and scrubbing towers are impressively gee-whiz and show great promise, but are years away from commercialization, currently even more expensive than already very expensive CCS, and we shouldn't forget that they have a voracious energy appetite themselves.

Other possibilities such as the geoengineering techniques of ocean fertilization or enhanced weathering of natural or artificial minerals remain unproven at scale and are already raising hackles amongst some environmentalists. And these are not prominent in any of the considered scenarios. As a result, BECCS remains the top bet in the negative emissions sweepstakes.

But there are a few unanswered questions

But a bet it is, and not by any stretch a sure one. In a 2014 commentary in Nature Climate Change that has so far drawn little attention in the media, 14 prominent climate researchers with the Global Carbon Project, including Fuss, laid out the difficulties with banking on BECCS.

"Its credibility as a climate change mitigation option is unproven," the researchers bluntly wrote with regard to BECCS, "and its widespread deployment in climate stabilization scenarios might become a dangerous distraction."

First we have to consider what sort of bioenergy we are talking about. We already know that first-generation biofuels that use feedstocks such as palm oil, sugarcane, soy, rapeseed or cereals produce greater carbon emissions than fossil fuels due to direct and indirect land-use change. In addition, such biofuels place pressure on food prices as farmland shifts away from food production, with worrying impacts on food security. And while second-generation biofuels from waste or crop residues were once a great hope, recent research has shown there too, according to a $500,000 study funded by the U.S. Department of Energy published in 2014 in Nature, the removal of residues from cropland can release carbon trapped in the ground – known as soil carbon – and

produce an overall increase in CO_2 emissions. So we are left with third-generation biofuels from algae. This at least has the benefit of not competing for arable land. But this fuel remains considerably more expensive than conventional fuels and will remain so for the near future pending more basic research. Many of the early pioneers in the field are pulling back from their bullish claims of near-term results.

Meanwhile, IPCC two-degree scenarios imply vast demands for biomass, between 100 and 300 exajoules' worth per year by 2050. An exajoule, or one quintillion joules, is a gargantuan unit of energy: the 2011 Tohoku earthquake for example clocked in at 1.41 exajoules, while the entire energy used in the US per year comes to 94 exajoules.

These same scenarios expect a delivery from BECCS of between two and 10 gigatons annually by mid-century, which corresponds to between five and 25 percent of global CO_2 emissions in 2010. The Global Carbon Project researchers make another sobering comparison: every year, oceans remove just under 10 gigatons of CO_2.

Put another way, our use of BECCS would be like trying to add a whole extra carbon sink on the scale of the oceans to the world's carbon cycle.

"Huge upscaling efforts will be needed to reach this level," the researchers dryly remark.

Then with respect to the other part of the BECCS combo from bioenergy, the CCS bit, the researchers note that the International Energy Agency's CCS roadmap indicates again that huge upscaling efforts will be needed to achieve the level of CCS implementation required by the aforementioned scenarios. As of this year, despite considerable research and development and while the carbon scrubbing processes have been successfully demonstrated, there is only one commercial scale industrial application worldwide, a rebuilt coal-fired generation unit with carbon capture technology in Saskatchewan, Canada.

Not to mention some risk

Meanwhile, all CCS development is predicated on the assumption that stored carbon won't leak out.

"[P]rogress in deploying CCS has stalled," declared a 2013 survey of the state of play appearing. "Governments have to either increase commitment to CCS through much more active market support and emissions regulation, or accept its failure."

There are just nine scenarios out of the thousand considered that manage to achieve the 2° cut-off but don't depend on BECCS. But each of these nine have extreme mitigation rates, often involving very large deployment of nuclear, wind, solar, or bioenergy without CCS.

"So if we don't have BECCS, then we will need a lot of something else," says Glen Peters of the Center for International Climate and Environmental Research (CICERO) in Oslo. "If we are good at CCS and BECCS, it may crowd out nuclear and renewables. If we are good at renewables, and accept nuclear, then it may crowd out many CCS options. But, it all comes back to the same ultimate point. More mitigation now, the less effort later—including BECCS."

The researchers are careful to stress that they are not dismissing BECCS, noting that some of the non-carbon-dioxide greenhouse gases such as methane and nitrous oxide from agriculture and some CO_2 from industry such as steel and cement production will be very difficult indeed to mitigate completely. But policymakers need a much more detailed understanding of the challenges involved.

"Determining how safe it is to bet on negative emissions in the second half of this century to avoid dangerous climate change should be among our top priorities," they argue.

Because so many of the current scenarios depend on negative emissions despite so little being known about how to achieve this, the researchers, perhaps unsurprisingly, want to see more research, done carefully and quickly, but also call for rigorous monitoring, reporting and verification in the event of any deployment.

We know we need to go negative, and quickly. But we also need to know how we're going to do that, rather than just assuming that somehow the green pixie of BECCS will appear and magic away vast, leviathan quantities of carbon.

20 women making waves in the climate change debate

When we asked people in 2014 who they'd like to hear more from on climate and sustainability issues, some simply replied women.
In compiling our list of top fifteen voices in climate change, it was striking that whereas the long list included a lot of women, only three made the final list.
So here's a list of twenty women making waves in the climate change debate, offered in alphabetical order, and without any men to get in the way. We hope it shows off some of the quiet – and not so quiet – power women do have on this issue, and the diversity of the debate. Gender aside, this list reflects other diversities of the climate debate, with expertise in financial systems, workers' rights, science, politics, development, media, diplomacy and more.

Barbara Buchner
How will we pay for action on climate change?
An Austrian Citizen, Buchner holds a PhD in Economics from the University of Graz and currently leads the Climate Policy Initiative' work on global climate finance. As climate finance systems – or simply, how we pay for action on climate change – become an ever-more dominant theme of climate policy debate, expertise like Buchner's will increasingly be in demand. You can watch an interview with Buchnerconducted by Climate Change TV at the Warsaw climate talks last year.
Watch an interview with Barbara Buchner ➔ http://bit.ly/1Md4VDr

Sharan Burrow
Leading the workers' fight on climate
Initially trained as a teacher, Burrow has been active in the Australian trade union movement for several decades. In 2010, she became head of the International Trade Union Confederation, the world's largest trade union federation which through its 325 affiliated organisations represents 176 million workers in over 160 countries. In May 2014 Burrow led a renewed 'Unions4Climate' movement, explicitly designed to contribute to the political debate on the run up to Paris 2015 and offering the powerful line that 'There are no jobs on a dead planet'. You can follow her on Twitter @SharanBurrow.

Winnie Byanyima
Oxfam's leader bringing expertise on gender and climate change

A Ugandan aeronautical engineer turned politician, Winnie Byanyima has been Executive Director of Oxfam International since May 2013. A world authority on the gender dimension of climate change, you can watch an interview with her held at the Durban climate talks on the topic. As Director of the gender team of the United Nations Development Program, she co-founded the Global Gender and Climate Alliance. At the Warsaw climate talks in 2013, she led a mass walk out from civil society organisations under a "polluters talk, we walk" banner, especially frustrated by the idea that 'clean coal' might be suggested as action on climate change. Byanyima has also recently acted as a spokesperson on Oxfam's work unpicking the role of the food industry as emitters of greenhouse gases. Follow her on Twitter @Winnie_Byanyima.

Heidi Cullen
Climatologist leading us through Years of Living Dangerously

Heidi Cullen is currently Chief Climatologist for Climate Central, a US-based nonprofit news organisation that analyses and reports on climate science. With a PhD in climatology and postdoctoral experience in scientific research, Cullen went on to be the Weather Channel's first on-air climate expert. She is one of the many women working to make climate science communications part of mainstream media and most recently has acted as Chief Science Advisor for the influential Years of Living Dangerously series. You can follow Cullen on Twitter @HeidiCullen.

Judith Curry
Blogger and scientist favoured by sceptics

Judith Curry is fast becoming the go-to scientist favoured by the more sceptical ends of the climate debate, though she is more than capable of making a name for herself in her own right. An established climate scientist, well known for her research on hurricanes and Arctic ice, Curry is currently Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology. Troubled by the way those who do not fit with scientific consensus are treated by the scientific community and broader environmental discourse, she regularly speaks up for the role of dissent and free speech in climate science. It is fair to say this doesn't always win her friends in either science or the green movement. Curry is an active blogger, reflecting her commitment to transparency of the debate within science, and can be found on Twitter @curryja.

Christiana Figueres
Most powerful woman in climate? Heads the UNFCCC

Christiana Figueres is possibly one of the most powerful woman in climate change, heading the United Nations Framework Convention on Climate Change (UNFCCC) and thus playing a key role in all the major global talks, including the ones in Paris in 2015. In defending the 2013 Warsaw talks as more than the disaster many wrote them off as, Figueres highlighted the role of women. She has a background in sustainable development and politics on a global level as well as in her native Costa Rica. She can be found on Twitter @CFigueres.

Tamsin Edwards

Scientist making a name for herself as a fearless communicator

A relatively junior climate scientist, at least compared to those who usually act as public voices for the profession, Edwards is making a name for herself as a prolific and fearless communicator, especially online. Currently a research associate at the University of Bristol exploring uncertainty in earth system modelling, Edwards initially trained in high energy physics. Happy to argue about power and the patriarchy along with the science, she is respected by many sceptics for the time she devotes to engagement with their communities. Although she's had her fair share of battles with other scientists especially on issues of advocacy, it is fair to say she is highly respected by this community too, as well environmentalists. You can follow her on Twitter @flimsin and read her blog – All Models are Wrong – hosted by the Public Library of Science.

Visit her blog ➜ http://blogs.plos.org/models/author/models/

Joanna Haigh

Solar expert, rare female Fellow of the Royal Society

Joanna Haigh was recently appointed co-director of the Grantham Institute for Climate Change and Environment at Imperial College and is expected to raise its profile along with her own. She is already well known for her work on solar viability and climate modelling, but this new post will give her a platform to engage in a broader set of issues. Haigh was elected a Fellow of the Royal Society in 2013 (part of a still very small number of women to hold such status) and has experience of offering clear rebuttals to politicians applying less-than-rigourous approach to climate change. You can listen to an interview with Haigh on her life in science – including experience of working with the IPCC – recorded by BBC Radio in summer 2013.

Katherine Hayhoe

Evangelical Christian climate scientist and communicator

Katherine Hayhoe is another example of a climate scientist who is increasingly devoting her time to public communications. What distinguishes her from many others is that she is also an evangelical Christian; both her parents were missionaries and her husband is a pastor. Hayhoe eschewed ideas of a necessary divide between Christianity in belief in global warming, winning many allies along the way. She played a key role in the recent Years of Living Dangerously series and you can listen to a recent NPR interview where she reflects on the connections between Christianity, conservatism and climate change. She can be found on Twitter @KHayhoe.

Connie Hedegaard
Danish politician, been leading EU work on climate

A Danish conservative politician with a background in journalism, Connie Hedegaard played a key role in the 2009 Copenhagen climate talks acting as Minister for Climate and Energy. In February 2010 she was appointed European Commissioner for Climate Action under the second Barroso Commission. She's a familiar face in global climate negations and an advocate for continued diplomatic work, even if it takes time. In arguing the 2012 talks in Doha were not a complete write-off, she concluded "Although frustration is a renewable source, it does not reduce emissions. To overcome frustration, one must remain intensely focused on the final goal that all parties have signed up a global climate deal by 2015". You can follow her on Twitter @CHedegaardEU.

Lesley Hughes
Scientist standing up to politicians' scepticism in Australia

Lesley Hughes is a globally recognised expert on the impacts of climate change on species and ecosystems, but she's also notable for her role in the Australian Climate Council. This is an independent non-profit organisation formed by former members of the Climate Commission, which had been a government organisation, after it was abolished following the election of Tony Abbott. The startup funding for this new Council was raised through crowdfunding, and Hughes is one of six expert Councillors at the organisation. Hughes therefore not only plays a key role in our recognition of how biodiversity loss intersects with global warming, but is also on the forefront of battles between scientists and sceptic politicians.

Naomi Klein
Writer inviting us to consider ideological sides of climate debate

Environmental politics has always played a role in Naomi Klein's work and she has been active in the recent waves of divestment campaigns, including a critique of the green movement's own portfolio. Her new book, which focuses on climate politics, was released in September 2014, well timed to intervene in the debates surrounding the big UN talks in New York. Klein offers an alternative amongst the increasing vogue for capitalist-friendly climate discourse, though her 2011 article Capitalism vs the Climate may be showing its age. You can follow her on Twitter @NaomiAKlein.

Linkt to the article "Capitalism vs. the Climate ➜ http://bit.ly/1kyG7yc

Annie Leonard
New head of Greenpeace USA, community organiser

The head of Greenpeace USA, Annie Leonard is best known for her 2007 animated documentary, The Story of Stuff, which explores the lifecycle of material goods and offers a critical perspective on excessive consumerism. The film is credited with taking a networked approach to engagement, building a community around educational resources, materials for faith based groups and showings of the film itself. Similar approaches have been very successful in anti-fracking movement as well as the recent rise of 350.org, and it is expected that Leonard will take this focus on community organising to her new role at Greenpeace. She is less active on Twitter than some others in the field, but can be found @AnnieMLeonard.

Naomi Oreskes
Historian of science pointing out the 'merchants of doubt'

A historian of science with a background in geology, Naomi Oreskes' book 'Merchants of Doubt' – co-authored with Erik Conway – is one that has made the shift from standalone publication to a whole way of talking about a dimension of political debate. The book explores the ways uncertainties inherent in scientific work may be over-inflated – over climate change but with parallels in earlier controversies over tobacco, acid rain and the hole in the ozone layer – including the active lobbying that happens through aspects of the scientific community. Before Merchants of Doubt, Oreskes was already well known for her work on the scientific consensus on climate change, is a frequent contributor to the media and recently joined Twitter @NaomiOreskes.

Gina McCarthy
Head of the EPA, face of Obama's recent climate push

As head of the Environmental Protection Agency, Gina McCarthy fronted Obama's recent climate push, including the public health framing of the issue. A longtime civil servant and expert on environmental health and air quality, McCarthy's appointment was not a straightforward process. Indeed, it took almost five months to be confirmed by the U.S. Senate, the longest an EPA nominee has ever had to wait. As Time's Bryan Walsh wrote at the time, this may have well ended up being the easiest part of her job. You can follow her on Twitter @GinaEPA and read her Reddit Ask Me Anything. Link to her Reddit ➜ http://1.usa.gov/1WAsJWE

Corinne Le Quéré
Scientist highly respected in communications and policy

Originally from Canada with a PhD in oceanography, Le Quéré is one of the Directors of the Tyndall Centre for Climate Change Research and Professor of Climate Change Science and Policy at the University of East Anglia. Her research speciality is the interactions between climate change and the carbon cycle, but she is also highly respected as a passionate and thoughtful communicator who is active in policy. Le Quéré has been an author on the last three IPCC Assessments and wrote about her experience of the 2013 process.

Link to the story ➜ http://bit.ly/1l89WX1

Mary Robinson
First female President of Ireland, UN Special Envoy for Climate Change

Mary Robinson is best known as the first female President of Ireland, a post she held between 1990 to 1997. She then acted as United Nations High Commissioner for Human Rights (until 2002), and in recent years has become increasingly vocal on issues of climate change, setting up the Mary Robinson Foundation for Climate Justice in 2010 and, this month, being appointed UN Special Envoy for Climate Change. In the wake of Rio+20 in 2012 she wrote about the conference as an example of political failure but also found hope in young people, women, trade unions, grassroots communities, faith-based organisations, the private sector and other civil society organisations. Robinson also sits on the board of the European Climate Foundation and is part of the Elders.

Julia Slingo
Helping us understand climate and weather

Chief scientist at the Met Office – the United Kingdom's weather service – Julia Slingo made headlines with a call for climate scientists to reach out with poetry. With a career in climate modelling and research spanning several decades, she was awarded a Damehood in 2014 for her contribution to weather and climate science. She contributed to the highly influential Stern Review and was the first woman President of the Royal Meteorological Society. Before joining the Met Office she was the Director of Climate Research in NERC's National Centre for Atmospheric Science, at the University of Reading, where she is still a Professor of Meteorology. You can listen to a recent BBC Radio interview exploring her career and occasional interactions with climate sceptics.

Link to the interview ➜ http://www.bbc.co.uk/programmes/b03zr00k

Koko Warner
World authority on climate change and migration

Koko Warner works at the UN university and is a world authority on an issue which is gaining more and more attention: climate change and displacement. Warner has undertaken pioneering work on environmentally induced migration and was a lead author for the recent IPCC report on adaptation. Despite headlines describing a "prophecy of doom" with hundreds of millions of people displaced, as the Climate Change and Migration Coalition argued, the report suggested migration could provide ways for some people to escape the worst impacts of climate change, and expanding opportunities for mobility may reduce vulnerability for many populations. This marked some change from the last IPCC report, but is reflects current thinking on climate migration.

Ailun Yang
Helping unpick low-carbon development in China and elsewhere

Ailun Yang leads the World Resources Institute's work on low-carbon development in major developing countries like China and India. She previously headed the climate and energy campaign at Greenpeace China, working closely with Chinese renewable energy industries. Her current work focuses on the global coal market and continues to explore China's power sector. Yang is an expert on China-US relations as they relate to climate and energy issues, and is an active Chinese non-governmental spokesperson on this issue in the media.

GERMANA CANZI

Laudato Si: Are we getting it all wrong on sustainable development?

Pope Francis' newly issued Encyclical – a sort of extended letter to Catholics, in this case also addressed to all human beings – is widely seen as a powerful intervention ahead of the three crucial United Nations meetings in July, September and December. This is when global leaders will decide on funding for development, future Sustainable Development Goals and a new global framework for climate change.

The document, named Laudato Si after a 13th century poem on nature by St Francis, is based on the idea that humans and nature are all part of the same common home. It starts with a comprehensive overview of the world's major environmental and social challenges, which are seen as far more deeply interconnected than people realise. It then praises people who are already working on fighting environmental degradation and on reducing the effects of that degradation on poor people.

"We cannot fail to praise the commitment of international agencies and civil society organizations which draw public attention to these issues and offer critical cooperation, employing legitimate means of pressure, to ensure that each government carries out its proper and inalienable responsibility to preserve its country's environment and natural resources, without capitulating to spurious local or international interests."

A new definition of progress

Laudato Si then invites individuals from all walks of life to enter into a dialogue about the moral and spiritual side of what is being done to the Earth and what the solutions are. Parts of the letter appear to be more specifically addressed to scientists, economists, politicians, architects and urban planners, inviting them to find a new definition of progress. More specifically, the letter encourages efforts to move away from fossil fuels and replace them with renewable energy.

"There is an urgent need to develop policies so that, in the next few years, the emission of carbon dioxide and other highly polluting gases can be drastically reduced, for example, substituting for fossil fuels and developing sources of renewable energy."

It singles out solar power as having huge potential to provide energy for the developing world, and the growth in clean energy cooperatives as a sign of hope:

"... while the existing world order proves powerless to assume its responsibilities, local individuals and groups can make a real difference."

The document is clear that we need to do more. More controversially, it argues that some solutions to climate change and international development are doing more harm that good, and we should move away from those. This is best understood against the background of Pope Francis' interdisciplinary approach to global problems.

The Encyclical explains that the climate crisis, global poverty and other major global challenges are a direct consequence of unequal economic, social and political systems including resistance to change by global elites in both developed and developing countries. Corruption, lack of transparency and a pursuit of national and individual interests over the common good are also a problem. In addition, humanity's impressive technological progress has brought benefits – which the Pope recognizes, including the beauty of airplanes for example – but this technological progress has not been matched by a corresponding level of moral and spiritual progress. The way people's interactions have changed – for better and for worse – with the use of the internet gets a mention.

Growth and consumerism

The Pope is particularly concerned about the predominance of techno-fixes, or the idea that problems can be solved by technology and markets, and that economic growth can be continued forever. This is a problem because it pushes humanity beyond the planet's environmental limits, but also because:

"These are signs that the growth of the past two centuries has not always led to an integral development and an improvement in the quality of life. Some of these signs are also symptomatic of real social decline, the silent rupture of the bonds of integration and social cohesion."

The constant push to consume has also brought extreme individualism, boredom and indifference to the plight of other human beings (particularly the poor and migrants) and the planet. Apart from causing environmental degradation, the growth of consumerism also stops politicians from taking the tough decisions needed to tackle the crisis.

"A politics concerned with immediate results, supported by consumerist sectors of the population, is driven to produce short-term growth. In response to electoral interests, governments are reluctant to upset the public with measures which could affect the level of consumption or create risks for foreign investment. The myopia of power politics delays the inclusion of a far-sighted environmental agenda within the overall agenda of governments."

Are we focusing on the wrong solutions?

Even the concept of sustainable growth is seen by the Pope as a concept that may not solve underlying problems as

"... it usually becomes a way of distracting attention and offering excuses."

More specifically, the Encyclical criticizes the concept of carbon trading:

"... it can lead to a new form of speculation which would not help reduce the emission of polluting gases worldwide" and "seems to provide a quick and easy solution under the guise of a certain commitment to the environment, but in no way does it allow for the radical change which present circumstances require."

This is in line with the position of a number of faith-based climate & development NGOs, which have also been pursuing the broader concepts of "climate justice" that are part of Laudato Si's narrative.

Elsewhere, the Pope stresses the need for small scale agriculture as a way to support food security in the coming years, as opposed to agriculture with large economies of scale that ends up

forcing smallholders to sell their land or to abandon their traditional crops: "Their attempts to move to other, more diversified, means of production prove fruitless because of the difficulty of linkage with regional and global markets, or because the infrastructure for sales and transport is geared to larger businesses. Civil authorities have the right and duty to adopt clear and firm measures in support of small producers and differentiated production."

According to a source, this is a criticism of some concepts of industrial agriculture being pursued by some large international institutions, including as a solution to concerns about climate related food security issues.

A change manifesto

Laudato Si does provide many ideas for solving the multiple crises the world is facing. Some are quite practical, such as those related to how we assess the social and environmental impacts of projects:

"Environmental impact assessment should not come after the drawing up of a business proposition or the proposal of a particular policy, plan or programme. It should be part of the process from the beginning, and be carried out in a way which is interdisciplinary, transparent and free of all economic or political pressure. It should be linked to a study of working conditions and possible effects on people's physical and mental health, on the local economy and on public safety. Economic returns can thus be forecast more realistically, taking into account potential scenarios and the eventual need for further investment to correct possible undesired effects. A consensus should always be reached between the different stakeholders, who can offer a variety of approaches, solutions and alternatives. The local population should have a special place at the table; they are concerned about their own future and that of their children, and can consider goals transcending immediate economic interest."

Other ideas relate more to morality and spirituality. The main concept is that of "integral ecology" and a move towards sobriety based on the philosophy of St Francis, and promoting ecological citizenship through education. According to Pope Francis, this conviction: "cannot be written off as naive romanticism, for it affects the choices which determine our behaviour. If we approach nature and the environment without this openness to awe and wonder, if we no longer speak the language of fraternity and beauty in our relationship with the world, our attitude will be that of masters, consumers, ruthless exploiters, unable to set limits on their immediate needs. By contrast, if we feel intimately united with all that exists, then sobriety and care will well up spontaneously. The poverty and austerity of Saint Francis were no mere veneer of asceticism, but something much more radical: a refusal to turn reality into an object simply to be used and controlled".

Germana Canzi (@germanacanzi)

Germana is a writer, analyst and consultant with extensive expertise in sustainable development. She started her career as a financial and energy reporter, including for Dow Jones Newswires where she also published on The Wall Street Journal Europe. She then spent three years working on energy issues for the WWF European Policy Office. As head of energy policy at Friends of the Earth in London, she later managed a comprehensive research project with major universities to support the establishment of the UK Climate Change Act. She has also worked in international development, including for REEEP – Investing in Clean Energy Markets, and is currently at the Energy & Climate Intelligence Unit, a London-based think tank.

The science of building a perfect world

LEIGH PHILLIPS

Science, technology and medicine are of course integral to the development of economies. Indeed, fundamentally, development is about wider access to precisely these things. But what does science have to tell us about the development process itself, about whether the objectives we choose are achievable, desirable? Is there a 'more scientific' approach to the goals we set ourselves?

The global leaders and stakeholders behind the forging of a new, universal set of goals that are to guide international development and transform the world into a single prosperous, modernized unit by 2030 certainly think so. Crafted by representatives from some 70 United Nations member states in consultation with civil society over the past two years, the UN's Sustainable Development Goals, or just SDGs, are the follow-up to the Millennium Development Goals that had been agreed by governments in 2000. This year, 2015, was the date by which the planet was supposed to have achieved the eight MDGs: eradication of extreme poverty and hunger; universal primary education; promotion of gender equality; reduction of child mortality, improvement of maternal health; combatting HIV/Aids, malaria and "other diseases"; ensuring environmental sustainability; and development of a global partnership for development.

But it is now February, 2015, and while development aid has risen over the last fifteen years, most of this has gone towards debt relief, disaster assistance and military spending. The greatest success has been with respect to the target aim of halving global poverty, a goal that was achieved five years early. This is largely down to rapid economic growth in the world's two most populous nations, India and China, thanks to a mixture of central planning and market-based efforts. And the People's Republic, which never endorsed the MDGs, is responsible for three-quarters of this feat. This is nothing to sneeze at. China's lifting of more than 700 million people out of poverty since 1978 is plainly one of the most humanitarian feats ever achieved, even if high inequality has accompanied this process.

> The fact that all nations gathered in the UN agree on the SDGs, some of which are quite concrete, is an achievement in itself
>
> *–Arnold Tukker, Leiden University*

The SDG process was vastly more open and democratic than the MDG process

–Marc Levy, Columbia University

But for much of the rest of the Global South, MDG success has been uneven. The sub-targets for extreme poverty reduction, access to safe drinking water and improving the lives of at least 100 million slum dwellers have been reached ahead of deadline, and gender equality in primary and secondary education and reduction in the incidence of malaria are projected to be met this year. But when it comes to access to improved sanitation, maternal mortality, infant mortality, under-five mortality, primary education completion and prevalence of undernourishment, a majority of countries are off target, in most cases significantly off target. Critics of the original process lamented the lack of specificity, analysis and measurement.

This time, ahead of an expected agreement by world leaders at a summit in New York in September, the United Nations hopes to get it right.* Where the MDGs were cobbled together by a small group of bureaucrats in the basement of the UN headquarters in Manhattan, the world body has engaged in reportedly one of the largest consultation processes in history, a global discussion whose granularity even involved knocking on doors around the world and asking people directly what they thought was most important. Marc Levy, a political scientist from Columbia University, feels that this effort is a major advance over previous efforts. Indeed, he feels that it is difficult to find similarly comprehensive endeavours in history: "The SDG process was vastly more open and democratic than the MDG process. There were good-faith efforts to consult people all over the world, including the first global survey about the future of the world. These efforts are without precedent."

A new, independent report, coordinated by the International Council for Science in partnership with the International Social Science Council, provides an independent assessment of these 17 goals. Over 40 leading researchers from across the natural and social sciences have critically analyzed the proposed targets beneath the goals, which cover everything from the elimination of poverty to the spread of advanced healthcare services and a transformation of the world's energy and transport infrastructure away from its dependence on fossil fuels. The report focuses on the 169 targets under the goals which are intended to operationalize the goals. It is the first independent review of the targets conducted by the scientific community, and authors found overall that the SDGs offer a "major improvement" over their predecessors, with a greater understanding of the interplay between the social, economic, environmental and governance dimensions. And where the MDGs only dealt with developing countries, the new set of goals cover all countries in the world.

But once the compliments are out of the way, the scientists feel obliged to point out problems of repetition, a lack of integration of the various topics, "weakly formulated targets" and, almost everywhere, far too much of a dependence on "vapid", "timid", "bland", qualitative language instead of hard, measurable, time-bound, quantitative targets. The word "vague" is actually used a full seven times in the report, while phrases such as "more specific", "more concrete" and "more focused" pepper the recommendations on how to improve it. The scientific review even uses quantitative language to describe how much more effort is needed to improve the SDGs: 71 percent of targets need work.

Relatedly, the researchers also stress that in order to be able to assess whether goals are being achieved, a gargantuan and possibly very expensive data-collection effort will be required, including in places where data-gathering is difficult, dangerous or just non-existent. Data-gathering isn't cheap or easy.

The goals tend to focus on what needs to be done by governments and NGOs, with little discussion of what action must be taken by the private sector. There is "a low level of integration" of the 17 different goals, which in a multiplicity of ways "overlap". "The goals are presented using a 'silo approach', that is, they are addressed as separate elements, mostly in isolation from each other," complain the researchers. Most importantly along these lines, without such interlinking, there is a danger of conflict amongst different targets, most notably, trade-offs between overcoming poverty and shifting toward sustainability. Climate diplomacy watchers will be very familiar with this conundrum: One of the easiest ways to counter poverty is cheap, coal-powered electrification, but this of course means we can wave goodbye to keeping below two degrees of global warming, and perhaps even three, four or five degrees.

As a result, the first SDG, the goal of ending poverty in all its forms everywhere, needs to be placed at the centre of all the other goals, "to avoid

*Since the original publication of this article in February 2015, the Sustainable Development Goals have been formally agreed in September 2015.

either an inequitable transformation to a low carbon future or the use of the poor as a trump card for preventing needed change towards a sustainable future."

Fundamentally though, the main problem with the process, say the scientists, is that the end-goal remains obscure. "[A] 'narrative of change' is missing, both in terms of how the pursuit of specific goals would lead to broader outcomes of

social change and in terms of how this change actually takes place," the report says. "There is no clear means-ends continuum or 'theory of change' underpinning the framework. The 'ultimate end' of the SDGs in combination is not clear, nor is how the proposed goals and targets would contribute to achieving that ultimate end." What would the world look like once all the goals are fully achieved? Policy makers need to "formulate an overarching goal", and how the 17 goals would contribute toward this end. They suggest that this meta-goal be "a prosperous, high quality of life that is equitably shared and sustainable".

But the researchers also say that if they weren't being rigorous, they wouldn't be doing their job. Levy, one of the authors and deputy director of Center for International Earth Science Information Network at Columbia University, told Road to Paris: "The toughness of our review should not be construed as a lack of appreciation for the draft goals. They are nothing short of remarkable. It is the first time since 1945 that the world's nations have come together to articulate a common, comprehensive vision for the future." "We are tough on it precisely because we take it very seriously and recognize its great potential–the same way a coach is toughest on her best athlete."

More specifically, elimination of poverty needs to focus more on concrete social policies—notably basic income schemes—with a universal approach to ensure society-wide buy-in. Uniform global metrics of poverty will also be required to ensure comparability and consistency. Targets relating to topics such as property, microfinance, inheritance, and access to basic services are "far too complicated and multi-faceted to be useful and measurable". Instead, this should be replaced with a simple target of equal access by all by 2030 to social, health, education services.

The researchers also note that the vexed and deeply political question of equitable wealth distribution also goes unaddressed, despite increasing evidence that equality and sustainability go hand in hand, with more equal countries tending to have stronger environmental legislation. With respect to the goal of ending hunger, the researchers note that the goal of sustainable agriculture is not the only important factor, but, crucially inequality, which is "essential but … not explicitly included". The targets here are not comprehensive, they warn, with only two directly addressing the hunger and malnutrition "and even for these the formulation is confusing and potentially contradictory." They recommend an extra focus on the first 1000 days of SDG implementation due to the irreversibility of undernutrition suffered at this stage. Further, policy makers need to understand that malnutrition is not simply undernutrition, but also obesity and the presence of micronutrient deficiencies.

In addition, care must be taken to simultaneously defeat hunger, increase agricultural productivity and avoid adverse impacts on the natural

resource base. And as another example of the interlinking of goals, the researchers note that defeating hunger cannot be addressed without ensuring universal access to safe drinking water and sanitation—which is goal number six. The biggest bang for the development buck here will come from a focus on small-scale producers, where there is the most acute vulnerability and greatest potential for productivity increases.

The health-focused SDG suffers from a lack of distinction between the wildly divergent starting points of different countries and makes no mention of inequalities within countries. The sub-target focus on HIV/Aids, tuberculosis, malaria, hepatitis and water-borne diseases "sounds like a catch-all for infectious disease", but neglects emerging infections such as Ebola and new strains of the flu. Researchers feel that the SDG related to access to water and sanitation does not recognize the need for a step change in water management governance, data collection and sharing. State-of-the-art remote-sensing and modelling will be necessary for global monitoring, yet few countries keep reliable records of wastewater, treatment and re-use.

The SDG also avoids discussion of what is required at the local level in terms of improved planning. Countries with different income levels should have different targets: low-income countries may wish to focus on controlling solid waste discharges, emerging countries may focus on wastewater treatment, and all countries may focus on recycling and reusing water. Instead, there should be three overarching themes: sanitation; reducing pollutants and untreated waste discharge; and reduction in water scarcity.

The seventh goal, access to energy, is "weak" and vulnerable to "loopholes" without a precise definition of the word access. Instead of an overall physical quantity of energy produced, the types and amounts of energy that every human should have access to should be explicitly mentioned. Furthermore, a new target should be added that aims to overcome indoor pollutants from cooking and heating using traditional biomass, currently responsible for millions of deaths of women and children.

The energy efficiency target is too vague and should instead piggy-back on the International Energy Agency's target of a doubling of global energy intensity improvement of 2.9 percent a year. With respect to the goal of economic growth and full employment, to avoid trade-offs with the environment, the researchers recommend new economic metrics beyond gross domestic product (GDP), and a focus on "radical" structural shifts to enable a decoupling of the economy from the environment through greater resource use efficiency. The analysts also worry that no mention is made of the millions of slum-dwellers and their participation in the informal economy.

The tenth goal, reducing inequality, has neither qualitative nor quantitative endpoints, say the researchers, and suffers from a danger of focus on social inequalities as the expense of economic inequalities. This imprecision can be addressed by targeting growth in the income share of the bottom 40 percent and a reduction in the share received by the top 10 percent. Inequality is not merely a question of reducing poverty, but the proportion of wealth allotted to elites. To achieve this, the researchers recommend inclusion of language seeking an improvement of regulation

of multinational corporations and the financial sector while boosting the democratic influence of citizens over policymaking and within the workplace. In place of an emphasis on foreign direct investment, the researchers recommend a focus on debt relief, shutting down illicit financial outflows and preventing tax evasion.

The goal of sustainable production and consumption is simply "too ambitious to be fulfilled" by 2030. How is this to be measured, wonder the scientists. A whole new set of metrics, with clearer quantification, will need to be developed before progress can be assessed. It is also left unmentioned how this can be achieved. Far better would be to establish specific, time-bound resource-use efficiency targets.

Action on climate change gets its own goal, but the drafters of the SDGs as well as the researchers recognize that the UNFCCC process is the primary vehicle for this challenge rather than the global development agenda. Similarly, the goal that concentrates on biodiversity, deforestation, and desertification have other venues whereby international action is to be mounted.

The assessment is not all bad. The targets relating to oceans and seas are largely cheered by scientists, who describe them as "ambitious, timely and backed by a significant body of natural and social science," although here too, researchers would be more comfortable with greater specificity and quantification. They also note that references to 'blue carbon'—CO_2 captured by oceans and marine ecosystems—and bioprospecting—the discovery of new products from biological resources—are absent, even though these areas are likely to increase in consequence in the future. Likewise, the goal could be enhanced by a target focusing on the impact of invasive alien species such as killer algae and the zebra mussel.

For the SDGs to avoid becoming a "wish list with little prospect of implementation", the framework governing the entire exercise is perhaps its most important aspect, the authors conclude. This will be difficult however, without specifics on financial resource mobilization to pay for this grand endeavour and more detail on how to engage citizens, civil society, scientists, the private sector and especially national and local governments. Geographer Susan Parnell of the African Centre for Cities with the University of Cape Town and one of the authors on goal 11 on sustainable cities, told Road to Paris that the process is likely to encounter criticism along these lines: "These non formal processes are likely to grow, but they are also going to be increasingly the object of criticism – precisely because they are not fully accountable and not everyone has access."

For her part, sociologist Asun St Clair, a former research director of the International Centre for Climate and Environmental Research-Oslo (CICERO), wants the process to deepen its democratic undertakings: "We need more citizen participation in issues that are not only solved by science, such as climate, sustainability or biodiversity. We need to enhance local democratic processes and participatory forums. Governance is an evolving term."

And finally, the elephant in the room that the researchers hint at is related to a sub-target within goal 17: "enhance global macroeconomic stability". In plain language, this target aims to avoid the sort of economic crisis that has ravaged the world for the past seven years. Somewhat understatedly, the scientists merely say about this ambition that it is "potentially important" but "unlikely to happen."

In the end, the recommendations come from researchers who remain full of hope that despite their limitations, the SDGs will be a significant advance on what has gone before. Arnold Tukker, an industrial ecologist at Leiden University in the Netherlands, said of the effort: "We know that international policy processes are by definition agonizingly slow. The fact that all nations gathered in the UN agree on the SDGs, some of which are quite concrete, is an achievement in itself." And right now, we must work to move humanity with the governance tools we have at our disposal and not wait for the democratic optimum before trying to change things, he believes: "There is no parliament for the globe, so by necessity agreements on climate change, biodiversity loss, and the SDGs have to be made in 'post democratic' negotiations between countries."

"A process of negotiations between diplomats with input of science and civil society groups is the only realistic way. "

> "The toughness of our review should not be construed as a lack of appreciation for the draft goals. They are nothing short of remarkable."
>
> *–Marc Levy, Columbia University*

Editor's note: The International Council for Science, sponsor of Road to Paris, is one of the sponsors of the report "Review of Targets for the Sustainable Development Goals: The Science Perspective."

Link to the report ➜ http://bit.ly/SDGsReport

CLAUDIA DELPERO

Climate change and SDGs – an arranged marriage

Most people agree that efforts on sustainable development and climate change need to be tackled together. You can't succeed on one without addressing the other. Whether it concerns energy, food security, water, cities or consumption patterns, almost all the Sustainable Development Goals (SDGs) adopted at the UN last week are linked to the ability to tackle global warming. So on the surface, the issues of climate change and sustainable development would appear to be 'friends'. But are they real friends or rather 'frenemies'?
A 'frenemy' is an enemy pretending to be a friend or a friend who is also a rival. This captures an uneasy truth that is implicitly acknowledged but rarely discussed in public. So here are 8 facts showing how these two get along in the corridors of the UN.

1. United by necessity

Arising from different traditions – human rights activism and humanitarian relief on one side, scientific research and environmental conservation on the other – the development and climate change movements came together out of necessity rather than choice. "For development professionals, it became clear that more frequent and severe humanitarian disasters were caused by extreme weather," says Ben Phillips, Campaigns and Policy director at ActionAid. "Climate change campaigners embraced inequality as they realized that who puts less carbon in the atmosphere will suffer the most from it."

2. Different time horizons

"Because of the emergency approach of humanitarian work, many anti-poverty campaigners tend to focus on immediate needs, more than on potential threats for the future," Phillips says. Some speculate that this could explain why the development goals – both MDGs and SDGs – have been on a 15-year schedule, while climate treaties have a longer time span. Martin Kaiser, Head of International Negotiations at Greenpeace, stresses that the sustainable development goals lack long-term direction and, especially for energy, a goal to guide investors up to 2050.

3. It all started in Rio

When was the word "sustainable" added to "development"? Although work begun in the early '70s, the current definition dates to the Bruntland Commission in 1987. The idea of development that meets the needs of the present without compromising future generations set the stage for the 1992 Earth Summit in Rio. This launched the Climate Change Convention (with the creation of the UNFCCC Secretariat) and Agenda 21, a short-lived precursor of the SDGs. Twenty years later the Rio+20 conference decided that SDGs were to follow the Millennium Development Goals of 2000. In between, there was the failure of the climate negotiations in Copenhagen.

4. Developing countries brought them together

While development has long been associated with aid from rich to poor countries, its connection to environmental sustainability was brought to the table by developing nations. "Long before we began to discuss climate change, local communities in India and globally had begun to recognize the impact of environmental damage, especially of deforestation, on their lives and livelihoods" says Bina Agarwal, Professor of Development Economics and Environment at the University of Manchester. The problem was also about locating responsibilities for environmental change and global warming. "Since the 1992 Rio Earth Summit, developing countries insisted that the West take historic responsibility for the consequences of global environmental problems and unsustainable consumption patterns," she adds. This fed into the concept of "common but differentiated responsibilities," which has been an enduring flash point in the climate talks.

5. Many cooks competing at the UN?

Climate change sits with the UNFCCC secretariat but other agencies such as UNEP and WMO have a mandate to contribute to the IPCC and other climate-related programmes at the UN. The UNDP (United Nations Development Programme) is responsible for funding on development. UNDESA, the Secretariat for the Economic and Social Commission, is in charge of implementing the SDGs. And numerous other agencies will provide inputs into the global goals (UNEP, UNESCO, FAO and more). Some hope that the global goals will provide an incentive for these agencies – which do not have a stellar track record on collaboration – to work better together. Others are less optimistic. "Overlaps and silos are not suitable for universal goals in a globalized context. We have to build agencies that work together horizontally," says Tom Burke, Chairman of environmental think tank E3G. He acknowledges,

however, that the UN only mirrors the lack of integration within governments. Ian Scoones, Director of STEPS, a policy research centre at the University of Sussex, wrote that the SDGs have to move away from development committees and run across government departments. Just like global warming cannot be confined to environment committees.

6. Binding targets

Among the SDGs, the responsibility for the climate goal is handed over to the UNFCCC. This is the only body subject to binding targets. The SDGs themselves are not binding for anyone – it is up to the individual governments to decide how much, if anything, they want to implement.

7. Competition for money

Different agencies and silo approaches also mean separate funding streams with limited incentives to work together. This has been a major area of contention. The general understanding is that climate finance should come on top of development assistance (the principle of additionality). But no one knows where the money for all the goals will come from.

8. A data divide

Climate policies are supported by data collected over decades, if not centuries, and compiled in the assessment reports of the Intergovernmental Panel on Climate Change. In contrast, a study by the Overseas Development Institute revealed last year that there is a dramatic lack of information in relation to the sustainable development goals. In fact, a quarter more people may suffer from poverty than the current estimates. The "data revolution", an initiative to track the global goals, has been designed to cover the gap, but it will take time.

A mix of celebration and skepticism has welcomed the SDGs. Their ambition is vast and dispersed and the next steps will be a test of their ability to deliver. Connections with climate change have been much discussed at the institutional level but whether it will happen will be determined at the Paris climate conference in December. This will be a key moment to turn 'frenemies' into 'friends' and reveal for both the chances of success.

Claudia Delpero (@claudiacomms)

Claudia is a journalist with experience in public affairs across Europe, China and Africa. In the past she has been responsible for communications at the World Wide Fund for Nature (WWF) in Brussels and Beijing, where she focused on the European Union energy policy and on Chinese investment in Africa. Prior to WWF, she worked as a press officer at the European Parliament and as a freelance journalist in Italy.

ALICE BELL

Ten great writers to follow on Twitter for climate change news

Looking to quickly build climate change into your Twitter feed? Here's ten people you should follow. And of course, if you'd like to follow all of them quickly, we've built a Twitter list for you: www.twitter.com/road2paris/lists/climate-change-writers

Suzanne Goldenberg

@suzyji — The Guardian's award-winning US environment correspondent, based in Washington DC. There's a big environment team at the Guardian, see also: @fionaharvey, @john_vidal, @karlmathiesen, @adamvaughan_uk, @ArthurNeslen, @dpcarrington, @james_randerson and @georgemonbiot.

Brad Plumer

@bradplumer — Senior editor at Vox, and self-described reporter on the "apocalypse beat" he has a clear, sometimes stark take on climate issues. Also worth following at Vox is energy and climate specialist David Roberts, @drvox.

Brentin Mock

@brentinmock — Currently staff writer at City Lab, Mock's done some of the best work exploring the intersection of race and environmental politics in the US whilst at Grist.

Megan Darby

@climatemegan — News Editor at Climate Home. It's also worth following the site's Editor, Ed King, @edking_CH

Stella Paul

@stellasglobe — Award-winning Indian journalist who covers climate change and other environment topics, often focusing on women and indigenous people.

Roz Pidcock

@RozPidcock — Deputy Editor and Science Editor the Carbon Brief, her colleagues @leohickman, @DrSimEvans, @some_yeo, @rtmcswee and @_rospearce are worth following too.

Christine Ottery

@christineottery — Deputy Editor for Energy Desk. The site is embedded in Greenpeace, but Ottery shouldn't be confused as a spokesperson for the NGO, she's a journalist.

John Upton

@johnupton — Senior Science Writer at Climate Central. You can also follow Climate Central's chief scientist @heidicullen, and other writers @bobbymagill, @andreatweather and @blkahn.

Eric Holthaus

@EricHolthaus — Meteorologist perhaps most famous for breaking down in tears when boarding a flight in San Francisco, vowing never to fly again. Covers weather and climate for Slate.

Gaia Vince

@wanderinggaia — Freelance writer, editor and broadcaster. Former analysis and features editor for Nature Climate Change, she's also author of Adventures In The Anthropocene.

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In 2015, new political agreements on climate change, disaster risk reduction and sustainable development were imminent. At this watershed moment, ICSU's Road to Paris focused on the new and under-reported issues in this dynamic space where science, policy and economics intersect. This brochure assembles some of the most read and most shared stories from the site.

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Founded in 1931, the International Council for Science (ICSU) is a non-governmental organization representing a global membership that includes both national scientific bodies (122 National Members representing 142 countries) and International Scientific Unions (31 Members). Its mission is to strengthen international science for the benefit of society. As part of that mission, ICSU represents the voice of international science in UN policy processes, including the preparation of the 2015 World Conference on Disaster Risk Reduction and the Sustainable Development Goals. For decades, it has played a key role both in the establishment of research programmes that have provided the science base for the Intergovernmental Panel on Climate Change (IPCC).

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