commentary

Duality in climate science

Kevin Anderson

Delivery of palatable 2 °C mitigation scenarios depends on speculative negative emissions or changing the past. Scientists must make their assumptions transparent and defensible, however politically uncomfortable the conclusions.

In July, Paris hosted 'Our Common Future Under Climate Change', a key conference organized as a prelude to the political negotiations scheduled for December 2015, also in Paris. In the conference summary that immediately followed, the scientific committee noted that limiting "warming to less than 2 °C" is "economically feasible" and "cost effective"[1]. The statement chimed with the press release that accompanied the Synthesis Report published by the Intergovernmental Panel on Climate Change (IPCC) last November, in which IPCC representatives suggested that "to keep a good chance of staying below 2 °C, and at manageable costs, our emissions should drop by 40–70 per cent globally between 2010 and 2050, falling to zero or below by 2100"[2], and that mitigation costs would be so low that "global economic growth would not be strongly affected"[2].

If these up-beat — and largely uncontested — headlines are to be believed, reducing emissions in line with a reasonable-to-good chance of meeting the 2 °C target requires an accelerated evolution away from fossil fuels; it does not, however, necessitate a revolutionary transition in how we use and produce energy. Such conclusions are forthcoming from many Integrated Assessment Models, which are key tools for informing policy makers of alternative climate change futures. In these models, prices, markets and human behaviour are brought together with the physics of climate change to generate 'policy-relevant' and cost-optimized emission scenarios that typically offer highly optimistic views of the future. However, these positive outcomes are delivered through unrealistically early peaks in global emissions[3], or through the large-scale rollout of speculative technologies intended to remove CO_2 from the atmosphere[3,4], yielding so-called negative emissions.

In stark contrast, I conclude that the carbon budgets associated with a 2 °C threshold demand profound and immediate changes to the consumption and production of energy. According to the IPCC's Synthesis Report, no more than 1,000 billion tonnes (1,000 Gt) of CO_2 can be emitted between 2011 and 2100 for a 66% chance (or better) of remaining below 2 °C of warming (over preindustrial times)[5]. Without resorting to 'changing the past', or making the leap of faith that substantial amounts of CO_2 can be removed from the atmosphere in the coming decades, the IPCC's 1,000 Gt budget requires an end to all carbon emissions from the energy system by 2050 — five decades earlier than the IPCC headline suggests.

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Geo-engineering as systemic bias

In most Integrated Assessment Models, 2 °C carbon budgets are effectively increased through the adoption of negative-emission technologies. These technologies are currently at little more than a conceptual stage of development, yet are ubiquitous within 2 °C scenarios. Nowhere is this more evident than in the IPCC's scenario database[6]. Of the 400 scenarios that have a 50% or better chance of no more than 2 °C warming (with three scenarios removed due to incomplete data), 344 assume the successful and large-scale uptake of negative-emission technologies. Even more worryingly, in all 56 scenarios without negative emissions, global emissions peak around 2010, which is contrary to available emissions data[7].

In plain language, the complete set of 400 IPCC scenarios for a 50% or better chance of meeting the 2 °C target work on the basis of either an ability to change the past, or the successful and large-scale uptake of negative-emission technologies. A significant proportion of the scenarios are dependent on both.

Reality check

Building on the concept of carbon budgets[8–10], I present an alternative line of reasoning that suggests a radically different challenge to that dominating the current discourse on climate change.

As the IPCC reiterates (in section 2.1 of ref. 5), it is cumulative emissions of CO_2 that matter in determining the global mean surface warming out to 2100. Specifically, and as noted earlier, the IPCC's Synthesis Report concludes that no more than 1,000 Gt of CO_2 can be emitted between

2011 and 2100 for a 66% chance, or better, of remaining below a 2 °C rise[5].

However, between 2011 and 2014 CO_2 emissions from energy production alone amounted to about 140 Gt of CO_2 (ref. 7). To limit warming to no more than 2 °C, the remaining 860 Gt of CO_2 (out to 2100) must be apportioned between the three principal emission sources: energy, deforestation and cement production (for cement, I count process CO_2 only; energy-related cement emissions are accounted for in total energy CO_2).

Assuming concerted efforts to reduce emissions from all three sources, I base deforestation and land-use change emissions for the period 2011–2100 on RCP4.5 (http://go.nature.com/dDeAWk), the IPCC's most ambitious deforestation pathway to exclude net-negative land-use emissions. I therefore adopt a highly optimistic total deforestation budget of about 60 Gt of CO_2.

Process emissions from cement production must be considered separately. Industrialization throughout poorer nations and the construction of low-carbon infrastructures within industrialized nations will continue to drive rapid growth in process emissions, which currently run at about 7% per year (R. Andrew, personal communication and ref. 11). Although lower-carbon alternatives such as carbon capture and storage and the prudent use of cement may reduce some of this early growth (R. Andrew, personal communication and ref. 11), in the longer term these emissions must be eliminated entirely. A provisional analysis, building on the latest process-emission trends (personal communications from both K. West and R. Andrew, and refs 11,12), suggests process emissions from cement production could be constrained to around 150 Gt of CO_2 from 2011 to their eradication later in the century.

Consequently, the remaining budget for energy-only emissions over the period 2015–2100, for a 'likely' chance of staying below 2 °C, is about 650 Gt of CO_2.

Unpalatable repercussions

A carbon budget this tight suggests a profoundly more challenging timeframe and rate of mitigation than that typically asserted by many within the scientific community. It demands a dramatic reversal of current trends in energy consumption and emissions growth: more than a fifth of the remaining budget has been emitted in just the past four years. To avoid exceeding 650 Gt, global mitigation rates must rapidly ratchet up to around 10% per year by 2025, continuing at such a rate towards the virtual elimination of CO_2 from the energy system by 2050.

The severity of such cuts would probably exclude the use of fossil fuels, even with carbon capture and storage (CCS), as a dominant post-2050 energy source. Only if the life cycle carbon emissions of CCS could be reduced by an order of magnitude from those postulated for an efficiently operating gas-CCS power station (typically around 80 g CO_2 per kilowatt-hour[13]), could fossil fuels play any significant role beyond 2050.

Delivering on such a 2 °C emission pathway cannot be reconciled with the repeated high-level claims that in transitioning to a low-carbon energy system "global economic growth would not be strongly affected"[2]. Certainly it would be inappropriate to sacrifice improvements in the welfare of the global poor, including those within wealthier nations, for the sake of reducing carbon emissions.

But this only puts greater pressure on the lifestyles of the relatively small proportion of the globe's population with higher emissions — pressure that cannot be massaged away through incremental escapism. With economic growth of 3% per year, the reduction in carbon intensity of global gross domestic product would need to be nearer 13% per year; higher still for wealthier industrialized nations, and higher yet again for those individuals with well above average carbon footprints (whether in industrial or industrializing nations).

A candid assessment

The IPCC's Synthesis Report and the scientific framing of the mitigation challenge in terms of carbon budgets are important steps forward. As scientists, we must now leverage the clarity gained by the budget concept to combat the almost global-scale cognitive dissonance in acknowledging its quantitative implications. Yet, so far, we simply have not been prepared to accept the revolutionary implications of our own findings, and even when we do we are reluctant to voice such thoughts openly.

Instead, my long-standing engagement with many colleagues in science leaves me in no doubt that although they work diligently, often against a backdrop of organized scepticism, many are ultimately choosing to censor their own research.

Explicit and quantitative carbon budgets provide a firm foundation on which policy makers and civil society can build a genuine low-carbon society. But the job of scientists remains pivotal. It is incumbent on our community to communicate our research clearly and candidly to those delivering on the climate goals established by civil society; to draw attention to inconsistencies, misunderstandings and deliberate abuse of the scientific research.

It is not our job to be politically expedient with our analysis or to curry favour with our funders. Whether our conclusions are liked or not is irrelevant. Yet, as we evoke a *deus ex machina* (such as speculative negative emissions or changing the past) to ensure our analyses conform with today's political and economic hegemony, we do society a grave disservice — the repercussions of which will be irreversible. ❐

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WORLD VIEW *A personal take on events*

Talks in the city of light generate more heat

Rather than relying on far-off negative-emissions technologies, Paris needed to deliver a low-carbon road map for today, argues **Kevin Anderson**.

The climate agreement delivered earlier this month in Paris is a genuine triumph of international diplomacy. It is a tribute to how France was able to bring a fractious world together. And it is testament to how assiduous and painstaking science can defeat the unremitting programme of misinformation that is perpetuated by powerful vested interests. It is the twenty-first century's equivalent to the victory of heliocentrism over the inquisition. Yet it risks being total fantasy.

Let's be clear, the international community not only acknowledged the seriousness of climate change, it also demonstrated sufficient unanimity to define it quantitatively: to hold "the increase in … temperature to well below 2 °C … and to pursue efforts to limit the temperature increase to 1.5 °C".

To achieve such goals demands urgent and significant cuts in emissions. But rather than requiring that nations reduce emissions in the short-to-medium term, the Paris agreement instead rests on the assumption that the world will successfully suck the carbon pollution it produces back from the atmosphere in the longer term. A few years ago, these exotic Dr Strangelove options were discussed only as last-ditch contingencies. Now they are Plan A.

Governments, prompted by their advisers, have plumped for BECCS (biomass energy carbon capture and storage) as the most promising 'negative-emissions technology'.

What does BECCS entail? Apportioning huge swathes of the planet's landmass to the growing of bioenergy crops (from big trees to tall grasses) — which absorb carbon dioxide through photosynthesis as they grow. Periodically, these crops are harvested, processed for worldwide travel and shipped around the globe before finally being combusted in thermal power stations. The CO_2 is then stripped from the waste gases, compressed (almost to a liquid), pumped through large pipes over potentially very long distances and finally stored deep underground in various geological formations (from exhausted oil and gas reservoirs through to saline aquifers) for a millennium or so.

The unquestioned reliance on negative-emission technologies to deliver on the Paris goals is the greatest threat to the new agreement. Yet BECCS, or even negative-emission technologies, received no direct reference throughout the 32-page package. Despite this, the framing of the 2 °C goal and, even more, the 1.5 °C one, is premised on the massive uptake of BECCS some time in the latter half of the century. Disturbingly, this is also the case for most of the temperature estimates ascribed to the outcome of the voluntary emissions cuts made by nations before the Paris meeting.

The scale of the assumption is breathtaking. It would be the equivalent of decades of planting and harvesting of energy crops over an area of one to three times that of India. At the same time, the aviation industry envisages powering its planes with biofuel, the shipping industry is seriously considering biomass to propel its ships and the chemical sector sees biomass as a potential feedstock — and by then there will be 9 billion or so human mouths to feed. This crucial assumption deserves wider scrutiny.

Relying on the promise of industrial-scale negative-emissions technologies to balance the carbon budget was not the only option available in Paris — at least in relation to 2 °C.

Reducing emissions in line with 2 °C remains a viable goal — just. But rather than rely on post-2050 BECCS, deciding to pursue this alternative approach would have begged profound political, economic and social questions. Questions that undermine a decade of mathematically nebulous green-growth and win–win rhetoric, and questions that the politicians have decided cannot be asked.

Move away from the cosy tenets of contemporary economics and a suite of alternative measures comes into focus. Technologies, behaviours and habits that feed energy demand are all amenable to significant and rapid change. Combine this with an understanding that just 10% of the population is responsible for 50% of emissions, and the rate and scope of what is possible becomes evident.

The allying of deep and early reductions in energy demand with rapid substitution of fossil fuels by zero-carbon alternatives frames a 2 °C agenda that does not rely on negative emissions. So why was this real opportunity muscled out by the economic bouncers in Paris? No doubt there are many elaborate and nuanced explanations — but the headline reason is simple. In true Orwellian style, the political and economic dogma that has come to pervade all facets of society must not be questioned. For many years, green-growth oratory has quashed any voice with the audacity to suggest that the carbon budgets associated with 2 °C cannot be reconciled with the mantra of economic growth.

I was in Paris, and there was a real sense of unease among many scientists present. The almost euphoric atmosphere that accompanied the circulation of the various drafts could not be squared with their content. Desperate to maintain order, a club of senior figures and influential handlers briefed against those who dared to say so — just look at some of the Twitter discussions!

It is pantomime season and the world has just gambled its future on the appearance in a puff of smoke of a carbon-sucking fairy godmother. The Paris agreement is a road map to a better future? Oh no it's not. ■

THE ALMOST **EUPHORIC** ATMOSPHERE THAT ACCOMPANIED **THE DRAFTS** COULD NOT BE SQUARED WITH THE **CONTENT.**

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