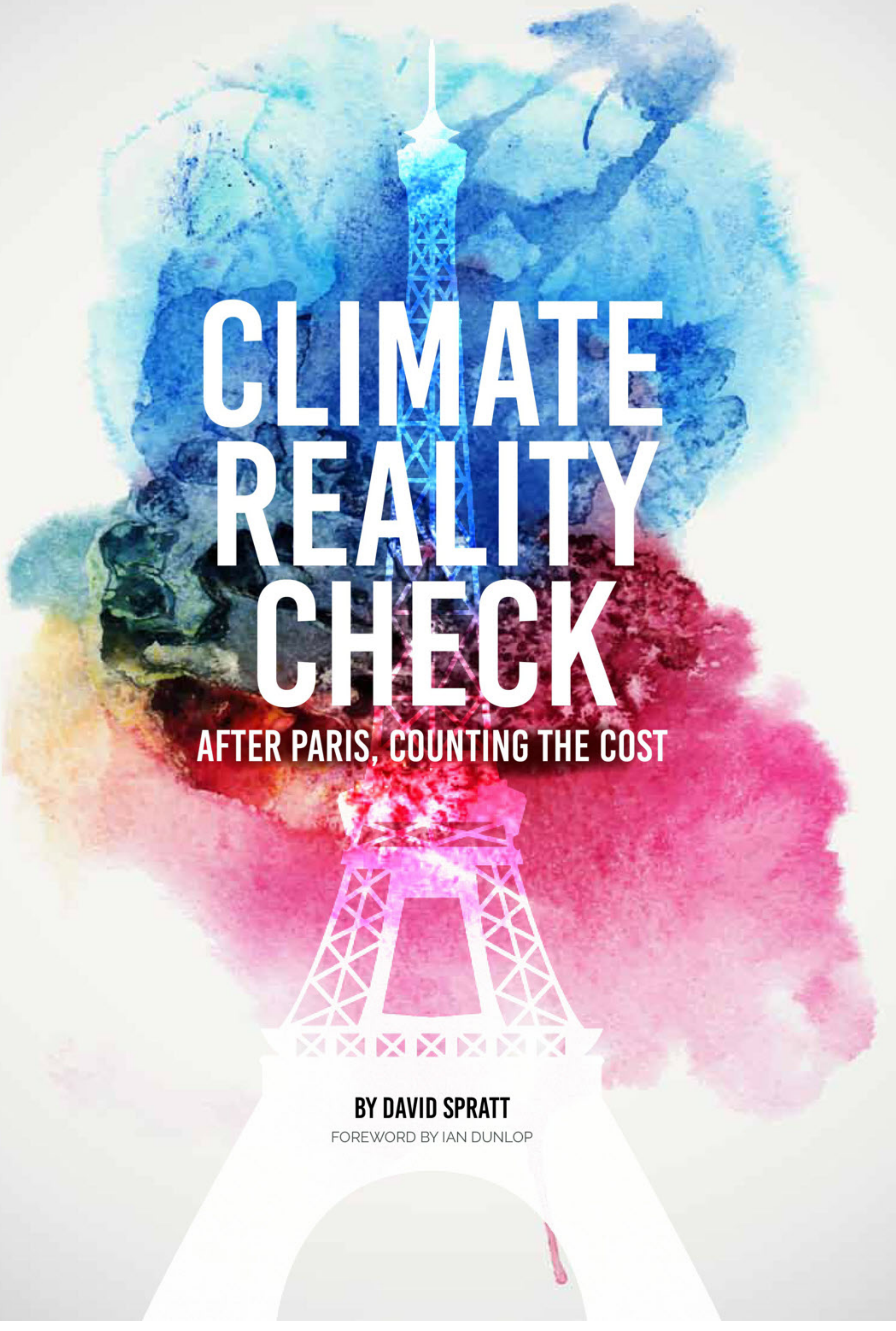


CLIMATE REALITY CHECK

AFTER PARIS, COUNTING THE COST

BY DAVID SPRATT

FOREWORD BY IAN DUNLOP

FOREWORD

"Recount", our Breakthrough report published in April 2015, emphasised the need for emergency action if the potentially catastrophic and irreversible impacts of climate change are to be avoided.

It explained why the international policy target of limiting warming to 2˚C above pre-industrial levels is too high, and why there is no remaining carbon budget if we are to have a realistic chance of holding warming to even the 2˚C level.

The Paris December 2015 climate summit in part acknowledged this, endorsing the goal "to hold the increase in global average temperature to well below 2˚C, and to pursue efforts to limit the temperature increase to 1.5˚C".

It is progress to have unanimous agreement from global and corporate leaders about the urgent need to meet these objectives. In political terms, the agreement was far more than expected, but in practical terms it is a disaster in which the chasm between rhetoric and scientific reality has dramatically widened. There is now an unjustified sense of complacency amongst many of the key players that the Paris objectives can be met by tweaking "business-as-usual" policies without radical change, as the glossy brochures and promises pouring forth since Paris from politicians, the corporate sector and international agencies demonstrate.

Ironically, climate change has accelerated rapidly over the last year, in part due to the unprecedented El Niño weather system generating record extreme events. But dangerous impacts from the underlying trend have also manifested far faster and more extensively than global leaders and negotiators are prepared to recognise.

The fundamental point being missed is that the "fat-tail" risks of climate change — the irreversible, positive-feedback tipping points which have long concerned scientists — are being triggered at today's warming of just 1˚C. This can be seen in the Arctic and the Antarctic, in our oceans, and not least with the destruction of the Great Barrier Reef. These are genuine, existential risks unlike anything previously experienced by humanity, which will result in a substantial reduction in global population unless rapidly addressed. They cannot be handled by existing risk-management techniques.

Given the latest evidence, it is almost impossible to now keep the temperature increase below 1.5˚C or even 2˚C with the current approaches. We have left it too late to solve the climate dilemma with a graduated response; emergency action, akin to placing economies on a war footing, remains essential.

This is not irrational alarmism, but an objective view of the latest science and evidence, as set out in this paper, which should be read and absorbed by every decision maker. New leadership, prepared to grasp and act on this reality, is essential.

IAN DUNLOP

Former Chair, Australian Coal Association & CEO, Australian Institute of Company Directors; Member, The Club of Rome.

AFTER PARIS, COUNTING THE COST

George Monbiot wrote of the December 2015 Paris climate conference: "By comparison to what it could have been, it's a miracle. By comparison to what it should have been, it's a disaster." Big flaws in the deal mean it gives the impression that global warming is now being properly addressed, when in fact the measures fall alarmingly short of what is needed to avoid escalating climate change, and set the world on course for well over 3˚C of warming.

Prof. Kevin Anderson of the UK Tyndall Centre for Climate Change is fond of quoting the twentieth century quantum physicist and Nobel laureate Richard P. Feynman: "For a successful technology, reality must take precedence over public relations, for Nature cannot be fooled."

We fool ourselves if we are not deeply alarmed by recent events. In 2015, atmospheric carbon dioxide (CO_2) concentrations jumped by 3.05 parts per million (ppm), the largest year-to-year increase in 56 years of research data. 2015 was the fourth consecutive year that CO_2 grew more than 2 ppm.[1] Methane levels also reached a new instrumental high, 254 per cent higher than the pre-industrial level.[2] And Arctic sea-ice extent hit a record winter low.

2015 was the hottest year on record by a significant margin. The UK Met Office says 2016 will be as hot or hotter, and observations support this forecast.[3] Scientists were stunned by NASA data that February 2016 was an "unprecedented" 1.65˚C warmer than the beginning of the twentieth century. That is 1.9˚C higher than the pre-industrial level.[4] The El Niño conditions contributed around 0.2˚C or more to the record figures[5] but, compared to previous big El Niños, we are experiencing blowout temperatures.

Prof. Michael Mann says, "We have no carbon budget left for the 1.5˚C target and the opportunity for holding to 2˚C is rapidly fading unless the world starts cutting emissions hard right now".[6] Other experts agree.

Prof. Stefan Rahmstorf of Germany's Potsdam University considers that we are now "in a kind of climate emergency"[7] and that at least 1.5˚C is "locked in".[8] More and more scientists agree.

Like the dramatic and unexpected Arctic "big melt" in 2007, these record temperatures confront us with the terrifying reality of global warming. Nature cannot be fooled. The recent data suggest it has taken just months for the Paris climate accord — with its escalating emissions to 2030 — to become a relic because of its gross inadequacy for the task the world now faces.

So what is the reality after Paris? What do recent research findings and observations teach us? And what does decisive leadership look like in the era of climate emergency?

1. CARBON EMISSIONS & TEMPERATURE

Human-caused carbon dioxide emissions increase the global average temperatures, such that the elevated temperatures remain roughly constant for many centuries.[9] One landmark research paper says that "any future anthropogenic emissions will commit the climate system to warming that is essentially irreversible on centennial timescales".[10]

In other words, we cannot, on human time scales and in the normal course of events, undo the elevated temperatures and damage done by CO2 emissions. The only exception to this understanding would be the deployment of incoming solar radiation management or very large-scale CO2 removal (negative-emission) technologies to cool the Earth. In the main, these technologies at present are at little more than a conceptual stage of development and not currently deployable at scale (see Section 15).[11]

2. "COMMITTED" WARMING

Accounting for inter-annual variability, global warming has now reached ~1˚C above the 1880-1920 level.[12] And warming is now ~1.2˚C above the 1750 pre-industrial level.[13]

If we were to cease burning fossil fuels today, the loss of aerosol cooling (see next section) would quickly add ~0.5˚C or more to temperatures, taking warming to ~1.7˚C above the pre-industrial level.[14] The more fossil fuels we burn, the higher this level of "committed" warming will become in the absence of yet unproven, large-scale, negative-emission and/or solar radiation technologies.

Each decade, human activity is adding ~20 ppm of CO2 to the atmosphere,[15] enough to cause an extra ~0.2˚C of warming. So if the emissions trajectory over the next 15 years follows the Paris path — in which annual emissions would be ~10% higher in 2030 than they are today[16] — then by 2030 "committed" warming will have risen by ~0.3˚C to ~2˚C.

Analyst Bill Hare of Climate Analytics says: "if the Paris meeting locks in present climate commitments for 2030, holding warming below 2˚C could essentially become infeasible."[17] In this sense, Paris has locked out a less-than-2˚C outcome, unless immediate and radical emission reductions occur across the high-polluting, developed economies.[18]

3. FAUSTIAN BARGAIN

A by-product of burning fossil fuels is a group of substances known as aerosols (including black-carbon soot, organic carbon, sulphates and nitrates) which have a short-term (~one week) cooling impact generally estimated to be in the range of ~0.5–0.8˚C. For now, these aerosols are ameliorating the warming impact of increasing levels of greenhouse gases, including carbon dioxide, methane and nitrous oxide.

Reducing the use of fossil fuels, however, will also reduce the production of aerosols, and the loss of their cooling effect will increase the global temperature. But not stopping fossil fuel use will eventually cause global warming sufficient to threaten human civilisation.

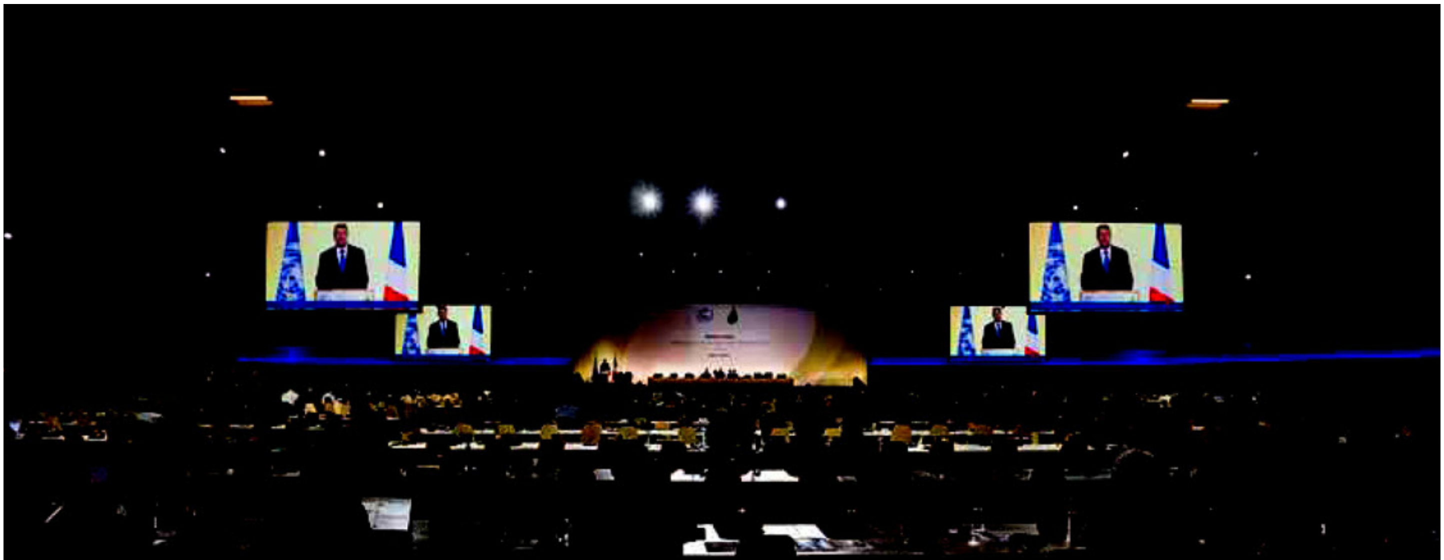
Former NASA climate science chief Prof. James Hansen keenly observed this dilemma to be our Faustian bargain, in which the "devil's payment" will be extracted from humanity via increased global warming as we end fossil fuel use: "As long-lived CO2 accumulates, continued balancing requires a greater and greater aerosol load. Such a solution… would be a Faustian bargain. Detrimental effects of aerosols, including acid rain and health impacts, will eventually limit the permissible atmospheric aerosol amount and thus expose latent greenhouse warming."[19]

4. PARIS COMMITMENTS

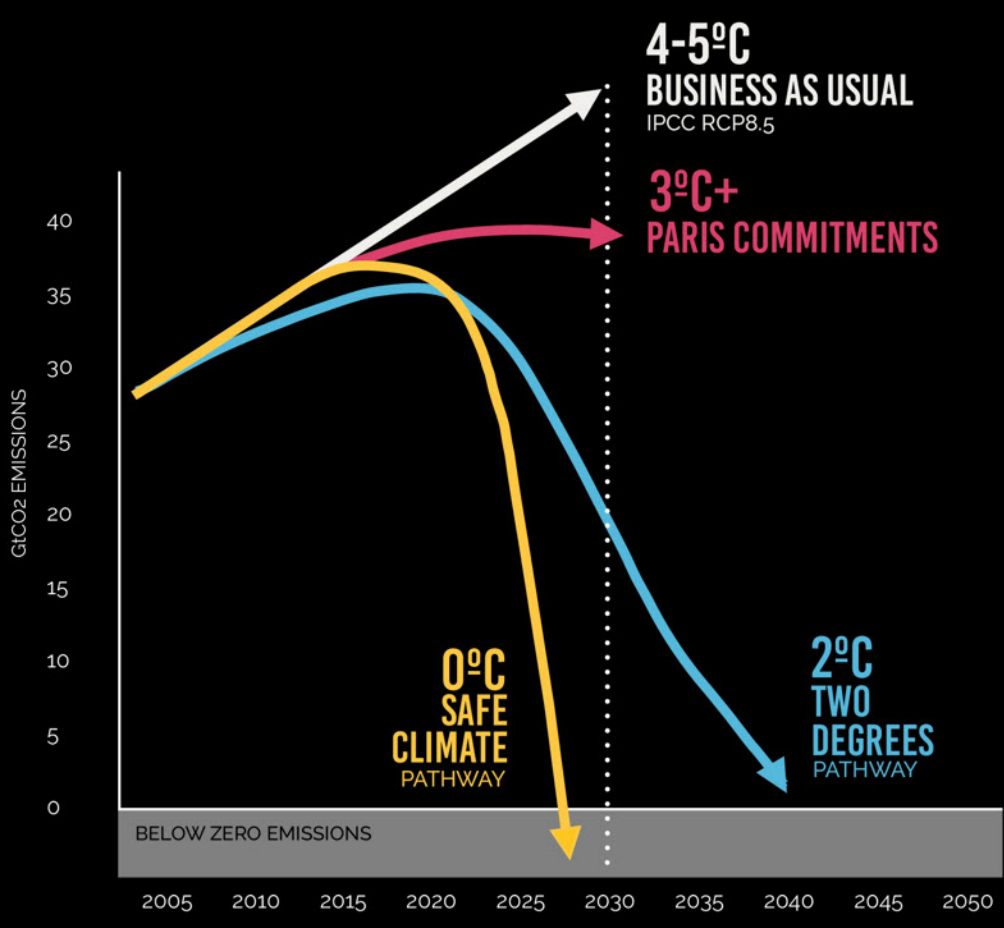
Although the Paris deal gives the impression that global warming is now being properly addressed, in fact the measures fall alarmingly short of what is needed to avoid escalating climate change.[20] Amongst its "deadly flaws" is the lack of any obligation on the parties to upgrade their existing pledges before 2030.

Indeed, analysis reveals that the Paris voluntary commitments, with no further progress in the post-pledge period, would result in expected warming by 2100 of 3.5˚C (uncertainty range 2.0–4.6˚C).[21]

Claims that the Paris commitments represent a 2.7˚C path are dangerously overconfident as they are based on a highly uncertain assumption that countries will commit, in the future, to keep reducing emissions after 2030 at the rate they did before hand.[22]



PARIS COMMITMENTS COMPARED TO 2°C PATHWAY



SOURCES: WBGU special report 2009; Boyd, Stern & Ward (May 2015); IPCC 2014; Climate Action Tracker; Philip Sutton.

5. FEASIBILITY OF 1.5ºC GOAL

The Paris agreement's stated aims are to keep warming "well below 2˚C above pre-industrial levels" and to "pursue efforts to limit the temperature increase to 1.5˚C".

A goal far below 1.5˚C is highly desirable, because climate change is already dangerous.

"Committed" warming today is now 1.7˚C[23] and will be ~2˚C by 2030 if emissions proceed along the Paris pathway. So there is no carbon budget left for 1.5˚C: "And what about 1.5˚C stabilisation? We're already overdrawn", says Prof. Michael E Mann, one of the world's foremost climate scientists.[24]

Researchers say there are no model scenarios currently in the literature 'where global temperatures remain below 1.5˚C throughout this century". Current "overshoot" scenarios — exceeding 1.5˚C of warming and returning to below 1.5˚C by assuming the deployment of large-scale negative-emission technologies later in the century — impose challenging requirements, including "curtailing future energy demand... with only a slight increase over today's demand by 2100, despite rising populations and growing economies".[25]

The possibility of staying below 1.5˚C of warming for the whole of this century would require geo-engineering techniques such as the deployment of sulphate aerosols to reduce the amount of incoming solar radiation (see Section 15). Such approaches are not proven or safe technology, and are opposed by the large climate action NGOs, without exception. Likewise, the large-scale negative-emission technologies necessary to get warming back under 1.5˚C by 2100 in the "overshoot" scenarios are not presently deployable in an environmentally safe way and at manageable cost, and are strongly opposed by significant elements of the climate justice movement.

6. RELIANCE ON NEGATIVE EMISSIONS TECHNOLOGIES

Rather than requiring large emissions reductions in the short-to-medium term, the Paris agreement instead relies on being able to successfully suck the carbon pollution back from the atmosphere in the longer term, plumping for biomass energy with carbon capture and storage (BECCS) as the most promising negative-emissions technology.

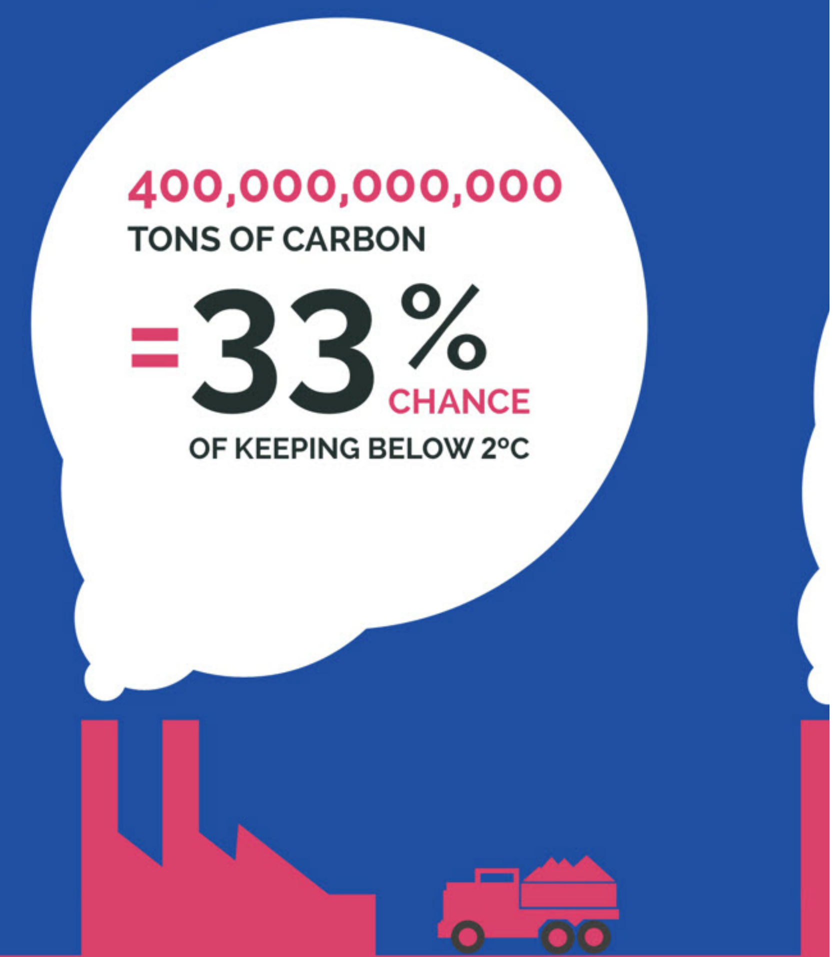
BECCS is an unproven technology at scale and "negative-emission technologies... are currently at little more than a conceptual stage of development", yet the framing of the 2˚C goal and, even more the 1.5˚C one, is premised on the massive uptake of BECCS some time in the latter half of the century.[26]

Potsdam Institute head Prof. John Schellnhuber warns against "the illusion you can just extract huge amounts of carbon from the air in order to restore the atmosphere".[27]

The land-use intensity of BECCS is quite high, with values of ~1-1.7 hectares per ton of carbon per year.[28] In other words, if ALL the world's land currently devoted to cropping (~3 billion hectares) were devoted to BECCS, the drawdown would be ~3 billion tonnes of carbon per year — still only about 30% of the world's current annual emissions. Whether the storage of the compressed carbon dioxide in expired oil and gas fields and other underground geological sites would be secure and stable over the long term is another question for which there is yet no satisfactory answer.

CHANCES OF KEEPING BELOW 2ºC

Releasing a further...



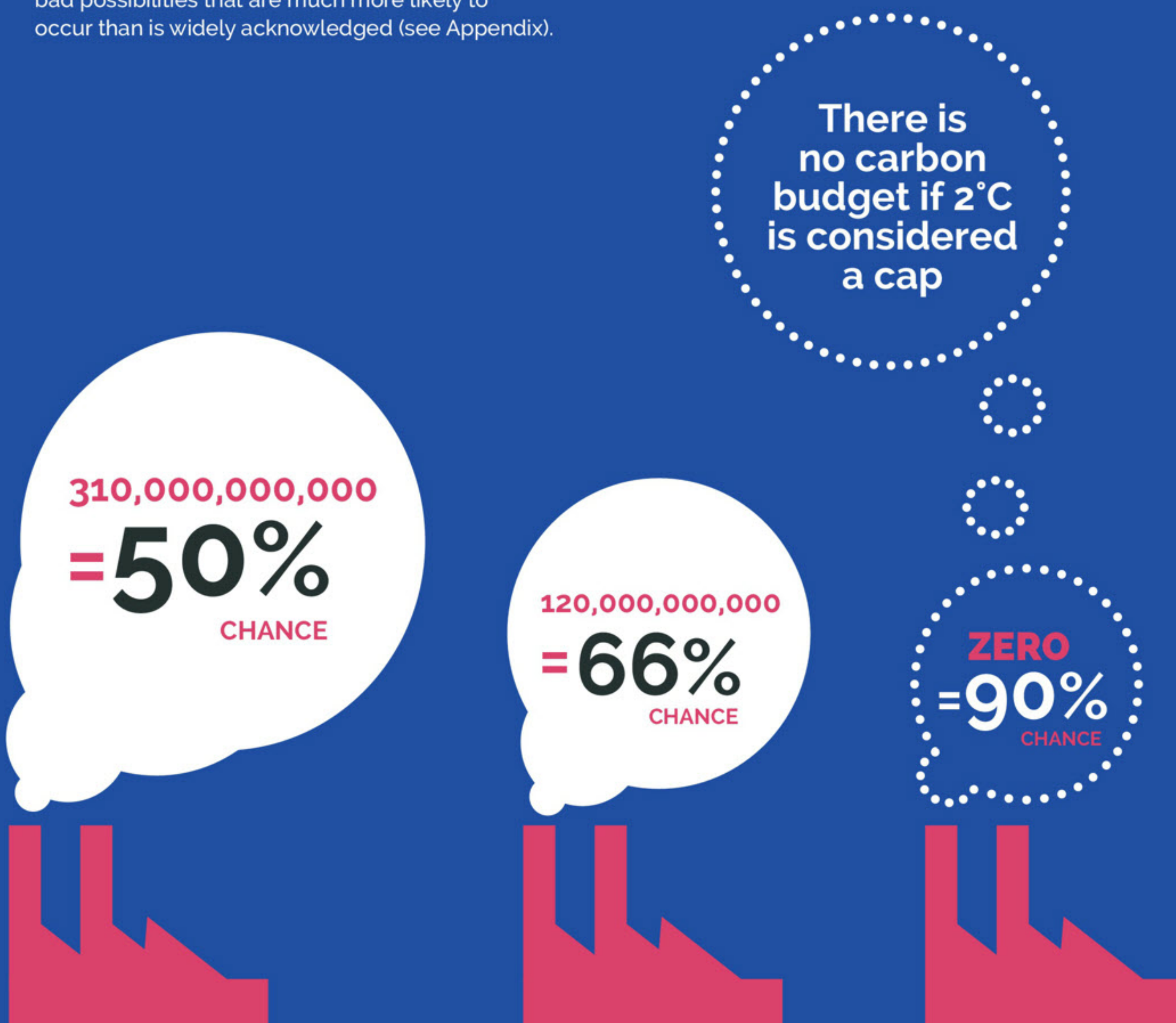
7. CARBON BUDGETS

Any temperature target only has practical meaning if the risk of exceeding it is known, and the scale of the impacts of exceeding the target are also known. A low-impact risk target for atmospheric greenhouse gases is very much less than the current level: the IPCC reported that "to provide a 93% mid-value probability of not exceeding 2˚C, the concentration (of atmospheric greenhouse gases) would need to be stabilised at or below 350 parts per million carbon dioxide equivalent (ppm CO_2e)" compared to the current level of ~485 ppm CO_2e.[29]

The catastrophic consequences caused by 2˚C of warming demand a strong risk-management approach of having a very low probability of exceeding the target, and fully accounting for the likelihood of changes in the carbon cycle. Yet policymakers focus on "middle of the road" outcomes, and turn a collective blind eye to the bad possibilities that are much more likely to occur than is widely acknowledged (see Appendix).

While policy-makers and advocates often talk about a carbon budget of allowable fossil fuel use that would limit warming to 2˚C, the evidence shows we have no such budget for a sensible risk-management, low-risk probability of exceeding that target.[30] There is no carbon budget if 2˚C is considered a cap (an upper boundary not to be exceeded) as per the Copenhagen Accord, rather than a target (an aspiration which can be significantly exceeded). And there is certainly no carbon budget for fossil fuel emissions after accounting for likely emissions resulting from future food production and deforestation.

Anderson and Bows have shown that even with a too-high goal of holding temperatures to 2˚C (with only a 66% probability of success), for developed economies to play a fair role they would have to cut their emissions by 40% delete reduction by 2018, 70% delete reduction by 2024, and 90% by 2030 from 1990 levels.[31]



2˚C is the boundary between dangerous & very dangerous climate change - how much can we chance?

8. CARBON CYCLE FEEDBACKS

There is an unacceptable risk that before 2˚C of warming is reached, significant "long-term" feedbacks will be triggered, in which warmer conditions make carbon sinks (stores) such as the oceans and forests less efficient at storing carbon, and polar warming triggers the large-scale release of greenhouse gases from melting terrestrial permafrost and frozen methane deposits on the ocean floor.

This escalating release of greenhouse gases generates even more warming in a cycle of reinforcing feedbacks that could make an effective human response extremely difficult.

It is conventionally considered that these feedbacks operate on millennial timescales. Yet the rate at which human activity is changing the Earth's energy balance is without precedent in the last 66 million years and about ten times faster than during the Palaeocene–Eocene Thermal Maximum, a period with one of the largest extinction events on record.[32] The rate of change in energy forcing is now so great that these "long-term" feedbacks have already begun to operate within short time frames.

A recent study makes use of projections from the most recent IPCC report to estimate that up to 200 billion tonnes of carbon could be released due to melting permafrost and cause up to 0.5˚C extra warming.[33] Some carbon stores have already reached a tipping point, and are now becoming carbon emitters rather than carbon sinks.

These include Arctic tundra.[34] One research paper concluded that: "the permafrost carbon feedback will change the Arctic from a carbon sink to a source after the mid-2020s and is strong enough to cancel 42–88% of the total global land sink." [35]

In February 2013, scientists using radiometric dating techniques on Russian cave formations to measure melting rates warned that a 1.5°C global rise in temperature compared to the pre-industrial level was enough to start a general permafrost melt. [36]

In the first half of 2015, new lines of evidence were published suggesting that more elements of the system may be heading towards tipping points or experiencing qualitative change. These include the slowing of the major sea current known as the Atlantic conveyor, likely as a result of climate change; accelerating ice mass loss from Antarctic ice shelves and the vulnerability of East Antarctica glaciers; declining carbon efficiency of the Amazon forests and other sinks; rapid thinning of Arctic sea-ice; and the vulnerability of Arctic permafrost, exemplified by the proliferation of Siberian methane craters. [37]

9. CRYOSPHERE THRESHOLDS

In late 2015, a chilling report on *Thresholds and closing windows: Risks of irreversible cryosphere climate change* [38] warned that the Paris commitments will not prevent the Earth "crossing into the zone of irreversible thresholds" in polar and mountain glacier regions, and that crossing these boundaries may result in processes that cannot be halted unless temperatures were returned to below the pre-industrial level.

It warns that: "These thresholds are drawing closer... some of these changes may close during the 2020–2030 (Paris) commitment period."

The consequences would include the loss of reliable water resources from mountain glaciers for millions of people; the melting of polar ice sheets that would set the world on a course to a sea-level rise of 4–10 metres or more; and fisheries and ecosystem loss from polar ocean acidification.

The report says it is not well understood outside the scientific community that cryosphere dynamics are slow to manifest but once triggered "inevitably forces the Earth's climate system into a new state, one that most scientists believe has not existed for 35–50 million years".

Observational estimates based on model simulations and the record of past climates make it appear very likely that "the loss of certain vulnerable parts of our planet's ice sheets will become unstoppable at temperatures and CO_2 concentrations at, or very close to those of today". The "best estimate" for "the threshold for Greenland melt to become irreversible" is 1.6˚C, a threshold beginning near today's levels and well below the 2.7–3.5˚C estimate from the Paris Accord.

10. ACCELERATING SEA-LEVEL RISE

Climate warming causes the ocean volume to expand. It melts polar and mountain glaciers. Both raise the sea level. The questions are how far, and how fast?

Most of sea-level rise for this century have been 0.5–2 metres, and centred around 1 metre, but this is only the tip of the iceberg. Prof. Kenneth Miller says: "The natural state of the Earth with present CO_2 levels is one with sea levels about 70 feet (21 metres) higher than now."[39] Other research scientists agree it is likely to be more than 20 metres.[40] The long-term sea-level rise associated with a 2˚C warming would submerge parts of Australia on which 25-50% of the population lives.[41]

Major recent studies show a number of polar ice sheets are unstable and heading toward collapse. As to how fast the seas will rise, one answer is "several metres" this century, according to Prof. James Hansen and 17 highly-regarded co-authors, who map a potential path to the "loss of all coastal cities" and the arrival of "super storms" not previously experienced by humans.[42] Superstorm Sandy and Cyclone Haiyan may be precursors of such a future.

This research surveys evidence from the previous warm Eemian interglacial period around 120,000 years ago. At that time there were of rapid fluctuations in sea level, and the research identifies a mechanism in the Earth's climate system not previously understood, which points to a much more rapid rise in sea levels than currently anticipated. Increasing ocean stratification occurs when cooler surface layers from melting ice sheets trap warmer waters underneath, accelerating their impact on the melting of ice shelves and outlet glaciers. This in turn increases ice sheet mass loss, and generates more cool surface melt water in a positive feedback.

The consequences include the slowing or shutting down of key ocean currents including the Gulf Stream System, which would increase temperature differentials between tropical and sub-polar waters, and drive "super storms" such that "All hell will break loose in the North Atlantic and neighbouring lands." [43]

The projected cooling pattern of waters around Antarctica and the north Atlantic waters from the injection of fresh ice-melt water is already visible in the observed data and is already contributing to a circulation decline of the Gulf Stream System and cooling of some European countries. [44]

Another significant new study [45] dovetails with the Hansen study and concludes that "Antarctica has the potential to contribute more than a metre of sea-level rise by 2100 and more than 15 metres by 2500", doubling previous forecasts for total sea level rise this century to 2 metres and more. "People should not look at this as a futuristic scenario of things that may or may not happen. They should look at it as the tragic story we are following right now," says Eric Rignot, an expert on Antarctica's ice sheet and an earth sciences professor at the University of California. [46]

Retreat of Jakobshavn Glacier, Greenland.

11. THE FATE OF CORAL REEFS

The Great Barrier Reef is home to 600 different types of corals. It has greater diversity than any other UNESCO World Heritage site. But it is dying.

Record high water temperatures in the Coral Sea in early 2016 caused unprecedented destruction of the Reef, when corals stressed by water more than 1°C hotter than normal expelled the zooxanthellae algae with which they live in a symbiotic relationship.

This "bleaching" — so named because algae give corals their colour and their loss leaves the coral structures white and lifeless — is the worst such event on record. Of 911 reefs included in an initial survey, 500 were severely bleached. Of the 522 reefs surveyed in the pristine and isolated northern sector, 81% were severely bleached. Scientists found: "North of Port Douglas, we're already measuring an average of close to 50% mortality of bleached corals. At some reefs, the final death toll is likely to exceed 90%." Around Lizard Island there is almost no living coral left. Before this mass bleaching started, the Great Barrier Reef had lost 50% of its coral cover. It takes several months for the full mortality to take effect, but the final death rate in the northern sector will be much higher than 50%.[47]

This means that significantly more than 60% of the Reef's coral cover has been lost in just three decades due to the effects of tropical cyclones, crown-of-thorns starfishes and reduced water quality, as well as climate change.

Moderately bleached corals can recover, but with severe bleaching mortality is high. Colonies may start to re-grow after healthy upstream reefs spawn; but it takes 10–15 years for reefs to regain health and that only happens if there is no further bleaching over that time. An adequate recovery time is crucial, somewhat like forests after a fire.

The global average land and sea surface temperature for January–March 2016 rose to 1.5°C above the 1880-1900 baseline, compared to the average warming of 1°C over recent years.

Researchers at the University of Melbourne say that for the Coral Sea there is "at least a 175 times increase in likelihood of hot (water temperature) March months because of the human influence on the climate", and that whilst the decaying 2015 El Niño event may have affected the likelihood of bleaching events, there was "no substantial influence for the Coral Sea region as a whole", which can be warmer than normal for different reasons.

They also found that: "March 2016 was clearly extreme in the observed weather record, but using climate models we estimate that by 2034 temperature anomalies like March 2016 will be normal". [48] In this scenario, reefs simply will not have the 10–15 years' recovery time they need, and will fall into a death spiral of more frequent bleaching events followed by increasingly inadequate recovery periods.

In 2009, Australian scientists contributed to an important research paper which found that preserving more than 10% of coral reefs worldwide would require limiting warming to below 1.5˚C.[49]

This year we have learned that, in fact, just 1˚C of average global warming is deadly for the Reef. Pioneer coral researcher Charlie Veron told the Royal Society in 2009: "The safe level of atmospheric carbon dioxide for coral reefs is ~320 ppm (and) sets the safe limit for a healthy planet during a time of abrupt greenhouse-driven climate change."[50] Today's level is 400 ppm and rising.

Corals' calcium carbonate structures are vulnerable to higher levels of carbonic acid, a consequence of the draw-down of increasing amounts of carbon dioxide from the atmosphere into the world's oceans. The last time oceans became acidic as fast as they are today, 96% of marine life became extinct. Parts of the Southern Ocean have already become acidic enough to dissolve sea snails' shells.

Coral reefs provide food and resources for over 500 million people along tropical coastlines, as well as coastal protection against storm surges.[51] If the world's coral systems are lost, coastal ecosystems will only be able to provide 20–50% of the fish protein that they do today for those half a billion people.

Australia's neighbours are particularly vulnerable. The Coral Triangle — encompassing Indonesia, Philippines, Malaysia, Papua New Guinea, the Solomon Islands and Timor Leste — contains 76% of the world's reef building corals and over 35% of the world's coral-reef fish species. It is the richest place on earth in terms of biodiversity.

The 100 million people who live along the coasts of these islands depend on healthy ecosystems such as coral reefs, mangroves and seagrass beds to provide food, building materials, coastal protection, and support industries such as fishing and tourism.[52]

The 2016 mass bleaching extended from Tanzania to French Polynesia, devastating reefs in Australia's Kimberley region, at India's Lakshadweep Archipelago, at Reunion Island in the western Indian Ocean, around the Seychelles, Christmas Island and in New Caledonia, as well as the Great Barrier Reef. This climate catastrophe is truly global.

Coral bleaching at Lizard Island (XL Catlin Seaview Survey)

12. ONE-DEGREE IMPACTS

Evidence suggests tipping points for events, which may be irreversible on century time scales, are being crossed already. The Arctic is warming two-to-three times as fast as the global average.[53] Even before we reached 1°C of global warming, a dynamic had been established that will lead to sea-ice-free Arctic summer conditions, with severe consequences for the future stability of permafrost and frozen methane stores, and for sea-level rises, as well as for accelerated global warming as ice sheets retreat and the Earth's albedo (reflectivity) decreases.[54]

One of the most significant research findings in 2014 was that the "tipping point" has already been crossed for the Amundsen Sea sector of West Antarctica at under 1°C of warming. Scientists found that the retreat of ice was "unstoppable" (unless temperatures return to the level of the 1970s). The consequences include that: "sea levels will rise one metre worldwide… [the ice's] disappearance will likely trigger the collapse of the rest of the West Antarctic ice sheet, which comes with a sea level rise of between 3–5 metres. Such an event will displace millions of people worldwide."[55] (Note: "millions" would seem a significant understatement.)

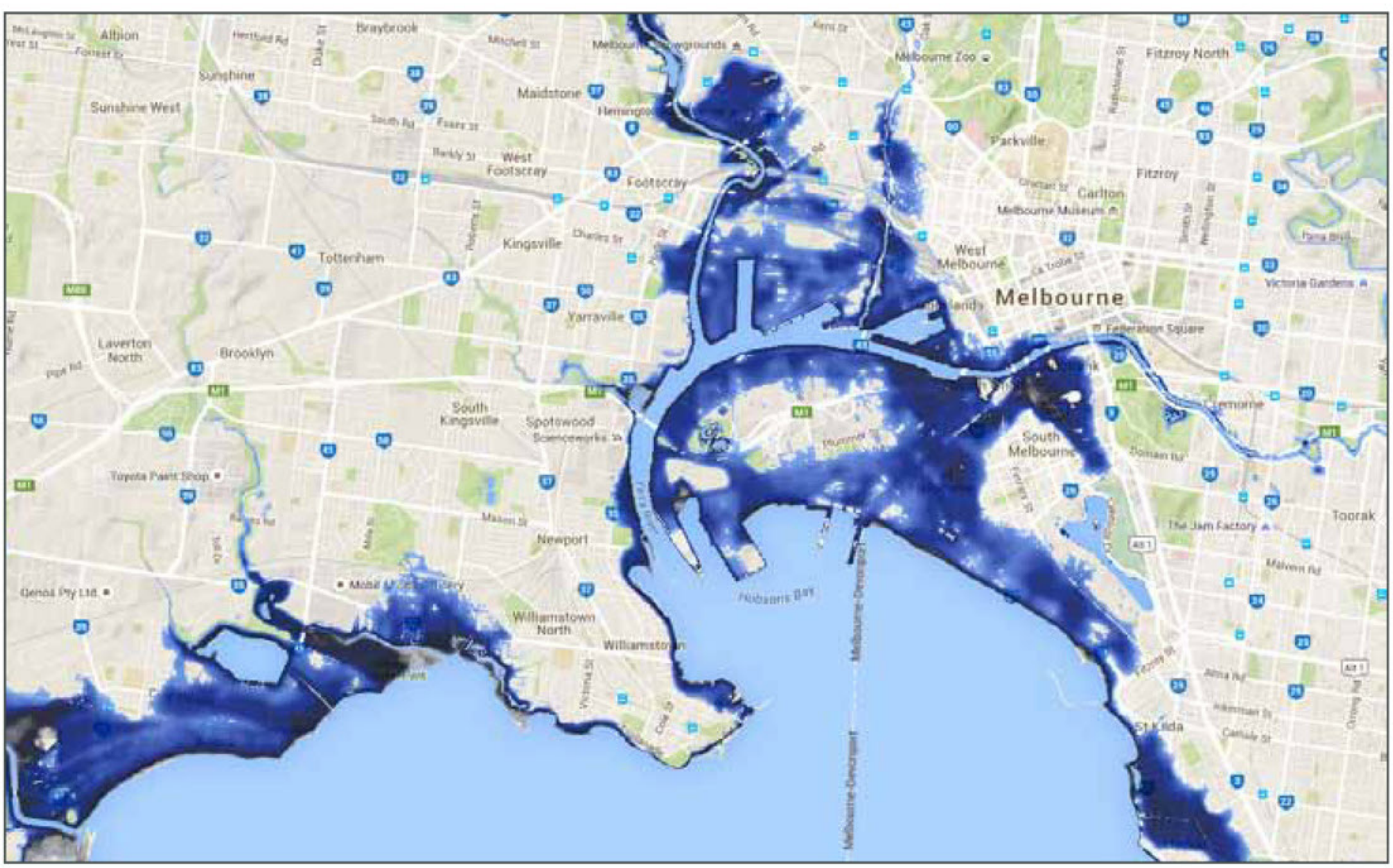
While a one-metre sea-level rise may sound manageable, it would destroy some nations, flood some of the world's richest river-delta agricultural lands or render them unusable due to salination, and likely create climate-change-driven failed states. In Bangladesh, a one-metre sea level rise would inundate 15-17% of the land and threaten more than a million hectares of agricultural land. The Mekong River Commission warns that a one-metre sea-level rise would wipe out nearly 40% of the Mekong Delta.[56] A one-metre rise would flood one-fourth of the Nile Delta, forcing more than 10% of Egypt's population from their homes. Nearly half of Egypt's crops, including wheat, bananas and rice, are grown in the delta.[57]

Current climate trends, if not arrested and reversed rapidly, will likely lead to a substantial displacement of, and reduction in, global population, with attendant mass social conflict and migration, early signs of which are already evident in the Middle East and North Africa.

The Syrian conflict was preceded by the worst long-term drought and crop failures since civilisation began in the region, resulting in 800,000 people losing their livelihoods by 2009, and 2–3 million being driven into extreme poverty.[58] The eastern Mediterranean has experienced significant decreases in winter rainfall over the past four decades.[59]

Central Melbourne & Bayside

2-metre sea-level rise plus 1-metre storm surge. (coastalrisk.com.au)



13. DAMAGE BEFORE 2°C

The damage that will eventually be caused by the current level of warming of just 1˚C is beyond adaptation for many nations and peoples, yet much higher temperature targets have been the goal of policy-makers. Prof. James Hansen maintains that it is "well understood by the scientific community" that goals to limit human-made warming to 2˚C are "prescriptions for disaster", because "we know that the prior interglacial period about 120,000 years ago was less than 2˚C warmer than pre-industrial conditions and sea level was at least five to nine metres higher, so it's crazy to think that 2˚C is a safe limit".[60]

The 2009 Copenhagen climate conference of governments agreed that there should be a scientific review of the 2˚C cap. It was completed in 2015 for the secretariat of the UN Framework Convention on Climate Change and concluded that that 2˚C is not a safe temperature cap and that a 1.5˚C cap, while causing less damage than the 2˚C cap, is also not safe.[61]

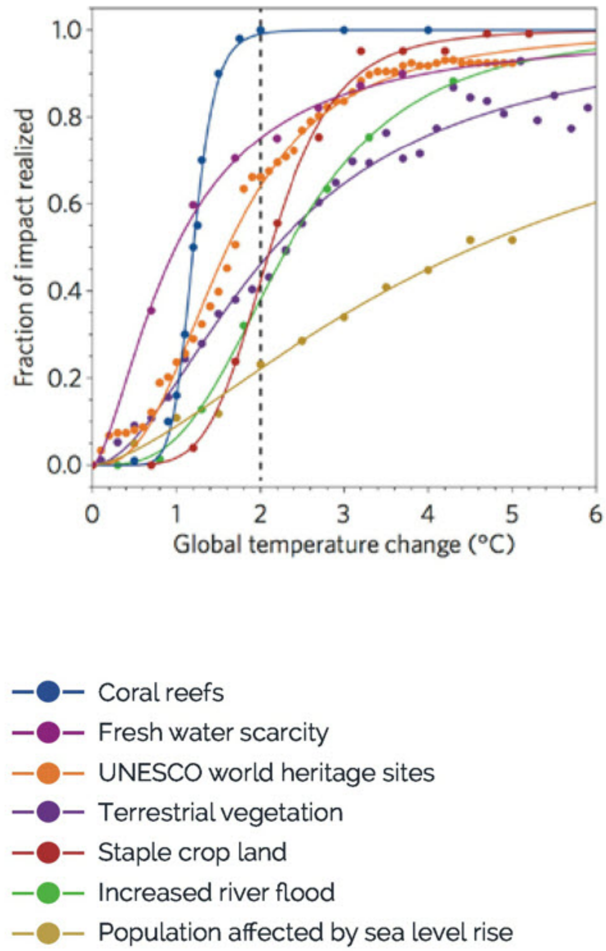
Scientists have found evidence of 41 cases of regional abrupt changes in the ocean, sea ice, snow cover, permafrost and terrestrial biospheres, many of which occur for global warming levels of less than 2˚C. Although most climate models predict one or more abrupt regional shifts, any specific occurrence typically appears in only a few models.[62]

Warming of 1.5˚C would set sea level rises in train sufficient to challenge significant components of human civilisation, besides reducing the world's coral ecosystems to remnant structures.[63]

Before or around +1.5˚C, more significant events are likely to occur, including a decline in the efficiency of terrestrial and ocean carbon stores, and the already-documented accelerating ice-mass loss from the Greenland ice sheet and West Antarctic glaciers. New research looks at the damage to system elements — including water security, staple crops land, coral reefs, vegetation and UNESCO World Heritage sites — as the temperature increases. The findings are sobering. Almost all the damage from climate change to vulnerable categories like coral reefs, freshwater availability and plant life could happen before 2˚C warming is reached, as the chart from this research results dramatically shows.[64]

Additionally, temperatures below 2˚C could trigger the release of CO2 and methane from natural carbon stores (eg. permafrost, ocean-floor methane deposits, forests and peat deposits) on such a scale that human efforts to contain the level of future warming to manageable levels could be rendered ineffective.

Maximum potential climate change impacts for various sectors as determined by the sigmoidal fit



14. HOLOCENE CONDITIONS

Human civilisation has flourished over the last 11,000 years under relatively stable climate conditions and sea levels in a period known as the Holocene, which provided a "safe operating space" for global societal development. [65] However, we have already left the Holocene temperature range. Reestablishing Holocene conditions of less than 325 ppm CO_2e would be safe for humanity, especially given that so much of human civilisation comprises coastal settlement and delta/flood plain agriculture.

If a significant proportion of coastal settlement were to be overwhelmed by rising sea levels and forced to retreat, what then would be "safe" for humanity?

Even a small global warming above the level of the Holocene begins to generate a disproportionate warming on the Antarctic and Greenland ice sheets.[66] Even a moderate sea level rise of 1–2 metres in less than a century would produce a change in coastlines that is unprecedented for human civilisation.

Current atmospheric greenhouse gas levels (~400ppm CO_2 and ~485 CO_2e) are likely to be the highest in the last 15 million years, and never previously experienced by humans. The current conditions, if maintained over centuries to millennia (that is, until the system reaches equilibrium), would likely produce temperatures 3–6°C warmer and sea level rises of 25 metres or more, based on evidence of past climates.[67] There is a widespread view amongst scientists that "a 4°C future is incompatible with an organised global community, is likely to be beyond 'adaptation', is devastating to the majority of ecosystems and has a high probability of not being stable".[68]

Given the current state of the atmosphere, getting back to Holocene-like greenhouse gas conditions would require a rapid end to human-caused emissions, and the deployment at massive scale of efficacious biological and other carbon dioxide drawdown measures to reduce the level of atmospheric greenhouse gases for many, many decades and perhaps a century or more.

Vietnam drought 2016 (Thanh Nien News)

15. CLIMATE INTERVENTIONS

For thirty years, efforts to tackle climate change have focused almost entirely on emissions reduction. But the modest scale and slow pace of action, plus better scientific understanding of what constitutes dangerous climate change, have led to the realisation that what is required is not just a slowing or stabilisation of the warming, but instead a cooling of the earth to below its current temperature.

To cool the earth requires two steps. The first is an end to human emissions, to stop making warming worse. The second is to remove excess CO_2 from the atmosphere and/or solar radiation management, which reflects a small amount of the incoming sunlight back to space.

Solar radiation management (SRM) and carbon dioxide removal (CDR) may be termed climate interventions or engineering: "purposeful actions intended to produce a targeted change in some aspects of the climate".[69] They could only make a practical contribution if they complement dramatic emissions reduction efforts, and their net benefit depends upon their technical effectiveness, cost, risk and governance.

SRM techniques are designed to produce immediate surface cooling by employing aerosol-cooling sulphates or similar into the lower stratosphere, or boosting the earth's reflectivity in some other way. The cooling effect would be almost immediate (within months) and substantial and the cost relatively low.[70]

SRM techniques have not demonstrated clear net benefits because of as yet not-fully-understood but damaging side effects.[71] They may not be able to simultaneously restore all features of the climate (e.g., temperature and rain/snow distribution) and do not address the issue of dangerous levels of ocean acidification. There are crucial unresolved ethical, political and governance issues. SRM could actually reduce the incentive to curb anthropogenic CO_2 emissions.

Some CDR techniques such as reforestation and afforestation are proven and safe, but limited in scale. Covering 3% of the world's surface with forests would be equivalent to negating just 10% of the world's current greenhouse gas emissions (a billion tonnes of carbon annually). Other CDR techniques include biochar, land management, accelerated weathering, bioenergy with carbon capture and sequestration (BECCS), direct capture and sequestration, ocean fertilization, and seaweed and algal farming.

Many of these are unproven, high cost at present, slow to implement, not currently deployable at the scale needed, and have implications for land use and the maintenance of food production and traditional land ownership, farming and biodiversity protection, because of the large spatial areas required (See section 6 above).

The impact of CDR would be slow and "will not have an appreciable effect on global climate for decades" and hence does not provide an opportunity for rapid reductions of global temperature. [72]

The use of carbon capture and storage technology to store liquid CO_2 either from power and industrial plants or direct capture from the atmosphere in disused oil and gas fields and other geological formations is being deployed and has substantial business-sector and policymakers' support in establishing a liquid CO_2 market perhaps larger than the existing oil industry. There is concern about the ethics and efficacy of such an approach, and the safety and stability of such storage, especially in geological formations other than disused oil and gas fields and in deep ocean sediments. At the moment, most CDR options are much more expensive than emissions reduction costs, so in the first instance emissions reduction is the better option in giving more "bang for the buck", though some deployment of carbon drawdown will help drive it down the cost curve. CDR becomes important when the marginal cost is less than that of reducing emissions, only then, "with declining costs and stronger regulatory commitment, atmospheric CO_2 removal could become a valuable component of the portfolio of long-term approaches to reducing CO_2". [73]

The bottom line remains a question of least-worst options. The US National Academy of Sciences poses a question most of us would hope does not materialize: "If, despite mitigation and adaptation, the impacts of climate change still become intolerable (e.g., massive crop failures throughout the tropics), society would face very tough choices regarding whether and how to deploy albedo modification until such time as mitigation, carbon dioxIde removal, and adaptation actions could significantly reduce the impacts of climate change." It concludes that despite the moral hazard risk that albedo modification research may distract from the mitigation effort, "the potential risks from climate change appear to outweigh the potential risks from the moral hazard associated with a suitably designed and governed research program". [74]

It must be emphasized that none of these technologies is currently viable at scale in terms of technical effectiveness, cost, risk and governance.

16. DISCUSSION

Over the medium-to-long term, living with 2˚C or more of warming will, in Prof. James Hansen's words, condemn "our biggest, most prosperous and populated cities to an underwater existence". [75] Climate change is already dangerous, especially for the world's most vulnerable people and species. Yet, there is no pathway to keeping warming below 1.5˚C without unproven solar radiation management. In light of the Paris commitments over the next 15 years, it is also very difficult to construct pathways that do not exceed 2˚C thresholds and prevent more significant tipping points from being crossed, unless large-scale climate interventions are also adopted.

Humanity faces an existential crisis. What can be done about the immediate challenges this poses?

HOW DO WE RESOLVE THESE CHALLENGES?

- **The immediate goal of any climate strategy must be to avoid passing further significant tipping points, including those related to the carbon cycle, ice sheets and sea levels.** We must seek actions that form the least-worse path for future emissions, greenhouse gas levels and temperatures.

- **No matter what we do, there will be severe and unavoidable consequences, especially for peoples and ecosystems most vulnerable to a hotter climate.** We must focus on preparing for and adapting to the changes that are now inevitable, while working to achieve negative emissions and reduce warming in a manner that causes the least damage.

- **The best path is one that includes emergency-scale action to get to zero emissions as fast as possible and by 2030.** After a natural disaster such as an earthquake or flood, we know that deploying maximum resources as quickly and efficiently as possible will produce the best result. We must respond to the climate disaster in the same way. This requires a whole-of-government effort based on conscious recognition that climate warming now represents a near-term threat to human civilisation. It requires a strong regulatory approach, because simply pushing and prodding the market within a neo-liberal framework cannot get the job done. A rescue plan must lay out the many steps to solving the problem: a plan to drive rapid emissions reductions; a plan for a just transition out of fossil fuels; a plan for the labour, skills and investment to do it; a plan for sustainable modes of work and leisure; and so on. The transition will be economically and socially disruptive because old, carbon-intensive industries must die, and current lifestyles in the high-income economies are not sustainable.

- **Innovation has astounded us.** Forty years ago when solar PV cells were ~$A100 a watt, who would have imagined that in 2015 they would be around 30 cents? We have many of the technologies we need, including battery storage rapidly falling in cost and new-generation electric vehicles that will make the petrol car obsolete. The obstacles are largely social and political, with a lack of commitment and poor regulatory systems slowing change for technologies that are already mature or rapidly sliding down the cost curve. Where technological challenges remain, we need a huge innovation and deployment effort on many fronts, including a search for efficacious climate interventions.

• **It is clear that a zero emissions strategy can't deliver, by itself, the degree of protection that would be desirable and that might be possible.** We need to set aside the reflex taboo that some people have begun to build up around CO_2 drawdown or solar radiation management and openly and rigorously assess if these interventions are able to contribute in strategically important ways to a least worst, or most beneficial, climate outcome for all people and species, especially the most vulnerable.

• **Some claim that climate intervention technologies can justify continuing high fossil fuel use and are unethical.** It is clear however that these technologies can only be effective over the longer term if allied to a zero-emissions plan. And surely not finding the path of least damage is not ethical in the face of intolerable future climate change impacts, such as massive crop failures throughout the tropics. We have a responsibility to investigate these through a large-scale research-and-development effort.

• **Radical emissions reductions can be driven more quickly by demand reduction than by replacing the energy supply system,** though of course both are essential. It is often said that the era of fossil fuels is coming to an end,[76] but it is not coming soon enough, however: the Paris path sees emissions increasing to 2030 and new coal power stations are still being planned and built. Energy-efficiency policies can reduce energy demand at a lower cost and more quickly than building new energy supply infrastructure.[77]

• **A great social mobilization is needed to transform society**. Technological innovation in the energy sector by itself is insufficient to bring about the necessary change in energy use and production. When people are educated and motivated and act in concert, great social transformation can be achieved.

IDEAS LEADERSHIP

The reasons for failing to do what is obviously in our collective best interest have been widely canvassed, but one striking element is the lack of public ideas leadership. Only a handful of public figures in Australia have ever canvassed the main issues discussed here. Timidity and a relentless bright-siding infuse the public conversation, as if people cannot bear to hear the truth.

But what if the public is more prepared for the conversation than are our public ideas leaders?

Melanie Randle and Richard Eckersley recently investigated the perceived probability of threats to humanity and different responses to them (nihilism, fundamentalism and activism) in the US, UK, Canada and Australia. They found that:

> Overall, a majority (54%) rated the risk of our way of life ending within the next 100 years at 50% or greater, and a quarter (24%) rated the risk of humans being wiped out at 50% or greater. The responses were relatively uniform across countries, age groups, gender and education level, although statistically significant differences exist. Almost 80% agreed "we need to transform our worldview and way of life if we are to create a better future for the world" (activism). About a half agreed that "the world's future looks grim so we have to focus on looking after ourselves and those we love" (nihilism), and over a third that "we are facing a final conflict between good and evil in the world" (fundamentalism). The findings offer insight into the willingness of humanity to respond to the challenges identified by scientists and warrant increased consideration in scientific and political debate.[78]

So here is the great irony: people have a fair, intuitive sense of what might be coming, but our ideas leaders cannot talk about it.

Now is the time to press those who aspire to leadership on climate issues and action to ask the questions that prompted this discussion paper. If the propositions are contentious, we must debate them. Repressing troubling thoughts does not resolve them — they will come back to haunt us with increasing intensity.

APPENDIX: BEWARE THE "FAT TAIL" CLIMATE

The question "How should we respond to climate change, avoid catastrophe and get back to safer conditions?" is often posed in "risk-management" terms. But what does this mean? We have tended to underestimate the rate of climate change impacts.[79] Scientists are not biased toward alarmism but rather the reverse of "erring on the side of least drama, whose causes may include adherence to the scientific norms of restraint, objectivity, skepticism, rationality, dispassion, and moderation".[80]

Too often, policy is based on least-drama, consensus scientific projections that downplay what Prof. Ross Garnaut called the "bad possibilities", that is, the relatively low-probability outcomes with very high impacts. But these events may be more likely than is often assumed, as Prof. Michael E. Mann explains:

> One of the most under-appreciated aspects of the climate change problem is the so-called "fat tail" of risk. In short, the likelihood of very large impacts is greater than we would expect under typical statistical assumptions... With additional warming comes the increased likelihood that we exceed certain "tipping points", such as the melting of large parts of the Greenland and Antarctic ice sheet and the associated massive rise in sea level that would produce.[81]

As one example of this "fat tail" risk, a greenhouse concentration may have a "most likely" outcome of ~3˚C of warming, but a greater than 10% risk of warming of greater than 6˚C! [82]

Prof. Garnaut suggests climate research had a conservative "systematic bias" due to "scholarly reticence".[83] Prof. Nicholas Stern wrote in similar vein about the IPCC Fifth Assessment Report: "Essentially it reported on a body of literature that had systematically and grossly underestimated the risks of unmanaged climate change".[84]

As far back as 2007, Prof. James Hansen said that scientific reticence hinders communication with the public about dangers of global warming and a potentially large sea level rise.[85] More recently Hansen wrote that: "the affliction is widespread and severe. Unless recognized, it may severely diminish our chances of averting dangerous climate change".[86]

Scientific reticence also facilitates criticism of the presentation of climate science that is not the middle-of-the-road version. Such charges were made against *Climate Code Red: The case for emergency action*.[87] But the evolution of climate warming since publication shows that book was not wide of the mark, because "the worst" it discussed on many key issues has already become our bitter harvest. The book's core proposition that we need an emergency-level response coincides with what many scientists are now saying.[88]

Two climate research scientists who reviewed the present report said it reflected most of the recent climate system insights correctly, and one said it leant toward the more "pessimistic perceptions". But that is exactly the distinction that has to be drawn between the science and the risks it implies. Waiting for catastrophe to happen before acting means that it is too late to act. It is precisely this scenario that proper risk management is designed to avoid.

As with a bushfire, a flood, a plane malfunction or any other potential disaster, it is prudent to plan for the worst that can happen, and be pleasantly surprised if it does not. To hope and plan only for "middle-of-the-road" outcomes, which characterises most climate policy-making, including in Australia, is foolish.

A prudent risk-management approach would consider the full range of real risks to which we are exposed, including those "fat tail" existential events whose consequences would be damaging beyond quantification, and which human civilization as we know it would be lucky to survive. If we focus on the "middle of the road" and ignore the worst possibilities, we may end up in a fatal crash.